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Editorial

Robots with Universal Human Values: These are the days where every task is looked upon to be performed by robots. May it be a simplest of a task like that of the daily housekeeping to flying the aircraft in the sky, we expect that robots should be more efficient in handling all these tasks. However, when we lean on these "intelligent mechanised beings" to acquire tasks performed by human beings, we also expect them to inherit the character of human beings. If this is established, then not far is the day when we can expect a world destroyed by the robots. No longer will it be a world of living emotional beings, but it will be a place where only the binary one's dwell. Well, this might be the dark end of it. However, we can think of a brighter side also. Why not program or build robots that will be bound to work with human values? Any failure in not following or adapting to the human values will lead to self-destruction of the robot. Yes, this can be done, during the robot's manufacturing or reconfiguration processes, the robot will have to mandatorily follow the universal human values. The moment it disobeys, the key to self-destruction will be activated.

All the programmers and scientists are working towards modernization, and breeding for the world full of robots should strictly adhere to this need. A world without the skeleton of universal human values is unimaginable. We all know that we are heading towards danger. It's an alarming time that universal human values should be imbibed in the robots and mandatorily be followed by them. Also think of a world where no values will be disobeyed, where well-being of each other will be the first and utmost priority. A peaceful and a very happy world where we can imagine a fully automated, however, a fully safe environment for humans, to dwell.

Can we not think of a reversed situation? Instead of man becoming a machine, why can't we think of the machine becoming a human? Yes, we need humanoids, not robots. We are at juncture in the history of humankind where every programmer, every scientist, engineer should first be a human. And they themselves should meticulously imbibe the universal human values so that their creation, the robots, the humanoids will be more human than they themselves are. Remember, humans might commit mistake, but their creations "the humanoids" must not! So, if it is programmed & nurtured in such a way that if in case it does not obey the set universal human rules, key to its self-destruction will be activated. Certainly, then it will be a much better, much safer, and happier world to dwell upon.

This is what exactly is conveyed by Isaac Asimov's "Three Laws of Robotics"

Robots with Universal Human Values must obey these laws.

New Delhi 31st March 2025 **Editor**



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Enhancing Municipal and Industrial Wastewater Treatment Efficiency through MBBR Application: A Laboratory Study

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ABSTRACT

It has been estimated that most of the world's population may experience a freshwater scarcity in less than 20 years. The primary factor contributing to this unfavorable future will be the current worldwide scenario of growing water consumption and disposal. The greatest method to preserve the diminishing natural supply is to recycle wastewater effluents from industrial, agricultural, and human activity areas and reuse them to lessen the likelihood of a future fresh water catastrophe. The present study focuses one of the best low-cost sewage treatment methods called as Moving Bed Biological Reactor (MBBR). The study is conducted at existing Sewage Treatment Plant in a Hostel to increase the efficiency of plant. It also mirrors real-world urban wastewater scenarios and employs a comprehensive approach. Important design parameters like Specific Surface area (SFA), Filling ratio (Volume of media/Active Volume of Digester), Hydraulic Retention Time (HRT) are studied through a lab setup. HRT of 6 hr. was found to be giving 87% BOD reduction and 83% COD reduction. Efficiency is improved when filling ratio is increased at 60 % above this BOD and COD was found to be 85% and 79% respectively. Development of the media and the creation of a controlled aerobic environment are pivotal 1components of the research methodology. Above study can be used for improving the performance of existing Sewage treatment plant in the college campus and water can be recycle for gardening and washing purpose.

KEYWORDS: Wastewater management, Sewage treatment, MBBR method, Urban wastewater, Water conservation, COD, BOD.

INTRODUCTION

It has been estimated that two thirds of the world's population may experience a freshwater scarcity in less than 20 years. Global consumption and disposal will be the primary contributor to this unfavorable future (Zinatizadeh & Ghaytooli, 2015). The greatest method to preserve the diminishing natural resource is to recycle wastewater effluents from industrial, agricultural, and human activity areas and reuse them to lessen the likelihood of a future fresh water catastrophe (Machineni, 2019).Wastewater contains significant volumes of dissolved and colloidal particles after primary treatment, or physical treatment, which wastewater, industrial wastewater, combined industrial/ domestic wastewater, and agricultural wastewater are among the different types of wastewater. Wastewater contains significant volumes of dissolved and colloidal particles after primary treatment, or physical treatment, which needs to be removed before release (Tang et al., 2020). Biological treatment, or secondary treatment, is one way to do this. Biological treatment is the process of treating wastewater after suspended solids have been removed using microorganisms like bacteria, fungi, or algae. This can happen under aerobic or anaerobic conditions, oxidizing or incorporating organic matter into cells that can be removed through sedimentation or removal processes. Secondary treatment refers to biological treatment (Samer, 2015). MBBR is the



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secondary treatment process which needs the minimum area compared to other biological treatment process which is why it was chosen for

Hostel's wastewater system. This study presents the best example of how any existing STP can be retrofitted with all limitations of available resources. The research encompasses a comprehensive approach, involving the collection of sewage samples directly from the hostel's wastewater system, followed by crucial tests such as Biochemical Oxygen Demand (BOD) analysis, Chemical Oxygen Demand (COD) pH measurements. Additionally, the introduction of biofilm-forming bacteria and the creation of a controlled aerobic environment are pivotal elements of the research methodology. These components enhance the sewage treatment process by facilitating the breakdown of organic matter, ultimately contributing to the assessment of the MBBR method's efficiency in treating sewage from the Hostel. This research initiative aims to shed light on the feasibility and effectiveness of the MBBR method as a sustainable solution for sewage treatment, with the potential to inform and advance wastewater management practices in urban settings while promoting environmental conservation and healthier urban communities.

MATERIALS AND METHODS

The aim of the present study is to find optimum values of functional parameters, viz. HRT (Hydraulic Retention Time), BOD, COD and percent carrier media ratio OR Filling Ratio (FR) for maximum available BOD and COD in the old MBBR system, thus, the optimization of design parameters for the comprehensive removal of nitrogen was achieved. Taking into consideration the spectrum of flow rates investigated in this research, the hydraulic retention time (HRT) was varied within the intervals of 2 to 6 hours and 1.21 kg to 4.59 COD $m^{3/2}$ day, respectively. In the current investigation, circular biofilm carriers constructed from polyethylene (PE) exhibiting a density range of 0.9 to 0.94 g/cm³ were specifically engineered to provide protected surface areas conducive to the development of microbial biofilms. The internal surface area thus safeguarded the established biofilm from shear forces induced by the movement of the carrier. The carrier media employed in this analysis presented a specific surface area of 500 m²/m³ and 250 m²/m³ (with diameters measuring 25

mm and 9 mm, respectively). Furthermore, the impact of the filling fraction of carrier media, ranging from 30% to 60% volume, on the performance of the Moving Bed Biofilm Reactor (MBBR) was also assessed in this study.

MBBR Process Design

The surface loading rate is the main parameter used to evaluate the capacity of MBBR expressed in $g/m^2/$ day or g/day of BOD subjected to the MBBR reactor per m2 area of surface of media. The BOD loading rate expressed in grams per day can be derived by utilizing the specified design parameters for the influent wastewater flow rate and the corresponding BOD concentration that enters the MBBR tank. Subsequently the requisite carrier surface area, measured in square meters, is determined by dividing the BOD loading rate in grams per day by the specific aeration loading rate (SALR) expressed in grams per square meter per day. Thereafter, the requisite media volume, tank volume, and wastewater volume within the reactor can be ascertained through the application of the media filling percentage, the specific surface area of the media, and the percentage of void space present in the media. The following equations can be used to perform the calculations:



Fig.1 Lab Setup of the MBBR System

Step 1: Calculating the BOD Loading Rate

To find the Biochemical Oxygen Demand (BOD) loading rate, use the following formula:

BOD loading rate= $Q \times L0 \times 8.34 \times 453$.

- Q: Flow rate of wastewater entering the reactor, measured in pounds per million gallons (lb/MG).
- Lo: The initial concentration of BOD in the influent, in milligrams per liter (mg/L).



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• The conversion factors used are 8.34, which converts mg/L to lb/MG, and 453.59, which converts pounds to grams.

This calculation provides the BOD loading rate in grams per day.

Step 2: Determining the Required Carrier Surface Area To determine the surface area of biofilm carrier material needed, the following equation is applied: Required carrier surface area=SALR \setminus BOD loading rate

- SALR: Surface Area Loading Rate, which is the load rate per unit area, expressed in grams per square meter per day (g/m²/day).
- BOD loading rate: The rate calculated in grams per day from Step 1.

This yields the required surface area of the carrier in square meters (m^2) .

Step 3: Calculating the Required Carrier Volume Next, the volume of biofilm carrier material necessary for the reactor is calculated by: Required carrier volume=Required carrier surface area \ Carrier specific surface area

- Carrier specific surface area: The surface area provided by the carrier material per cubic meter (m²/m³).
- Required carrier surface area: The area computed in Step 2.

This gives the required carrier volume in cubic meters (m³).

Step 4: Determining the Required Tank Volume To figure out the tank volume needed, use the formula: Required tank volume=Required carrier volume \ Carrier fill percentage

- Required carrier volume: The volume calculated in Step 3.
- Carrier fill percentage: The percentage of the reactor volume that will be filled with the carrier material.

The result is the tank volume in cubic meters (m³). Step 5: Calculating the Liquid Volume in the Tank Finally, the liquid volume inside the tank is determined by: Liquid volume in tank=Required tank volume–[R equired carrier volume×(1–Carrier void space per centage)]

- Carrier void space percentage: The proportion of void space within the carrier material, typically provided by the manufacturer.
- Required tank volume: The volume of the tank, as determined in Step 4.
- Required carrier volume: The volume calculated in Step 3.

Where: all three volumes will be in the same units.

Lab Setup of the MBBR System

A laboratory-scale Moving Bed Biofilm Reactor (MBBR) system was set up in the laboratory. A MBBR is prepared by using a rectangular tank with the dimensions 30 x 20 x 25 cm, and a 15lit volume. An air conduit was incorporated at the lower section as depicted in Figure 1. An air flow rate of 0.2 m³/hr was meticulously calculated and implemented to facilitate the provision of oxygen essential for the biological activities of the microbial mass, as well as to enable the unobstructed movement of the carriers, thereby optimizing the spatial coverage within the digester. A distinct compartment with a volume of 15 liters was constructed downstream of the reactors specifically for the deposition of sludge, aimed at the segregation of solids from the effluent; this compartment may also serve the function of sample extraction. The system included plastic carriers with a high surface area for biofilm growth. Bacterial cultures were obtained from existing sewage treatment plant and mixed in the digestor so that culture will grow onto the carriers.

Biofilm Development

Biofilms are formed when groups of bacteria adhere to surfaces. According to (Leiknes & Ødegaard, 2006), the bacterium is "carried" across the reactor by the biocarriers. Since the biofilm forms on the biocarriers' protected interior surface, the effective biofilm surface area which is represented in g/m2/day is a crucial design parameter. Dissolved pollutants in the wastewater stream are broken down by biofilm, which grows inside the interior structures of the biocarriers. By giving bacteria inside of shielded cells an active surface area, every biofilm carrier increases productivity (Zhang et al., 2019). Within the system, high biodegradation productivity is attained by a high-density population



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of bacteria. Microorganisms adhering to and detaching from the solid surface, as well as biofilm formation and thickness, are all examples of desorption. In the present study continuous.

Table. 1	Characterization	of Media
----------	------------------	----------

	Media 1	Madia 2
Туре	PP22	K1
Diameter, (mm)	25	9
Height, (mm)	10	7
Density, (gm/m3)	0.94	0.90
Specific surface area, (m ² /m ³)	500	250
Material	Polypropylene	Polypropylene

Sample Collection

Sewage samples were taken directly from the hostel's sewage system using sterile sampling containers. Sampling was carried out at predetermined intervals to ensure a representative selection of sewage characteristics also called as descript sequential samples. Discrete sequential samples are collections of discrete samples that are collected at regular intervals of time or flow. These samples are helpful for identifying changes in the makeup and release of contaminants, particularly in storm-sewage and industrial effluent studies (Muttamara, 1996).

Chemical Analysis of Wastewater

The wastewater specimen underwent preliminary analysis concerning various parameters, namely pH levels, turbidity, biochemical oxygen demand (BOD), and chemical oxygen demand (COD), total suspended solids (TSS). The chemical and physical characteristics of the analyzed wastewater specimen are delineated here in Table 2.4

Table 2	Characterization	wastewater
---------	------------------	------------

Characteristics	Value
рН	8.6
Color	Greyish white
Total Suspended Solids (TSS)	650 ppm
Total Dissolved Solids (TDS)	23850 ppm

Chemical Oxygen Demand (COD)	650 ppm
Biological Oxygen Demand (BOD)	350ppm

Sewage Treatment in MBBR

Sewage samples were introduced into the MBBR system, and the batch treatment process commenced. The MBBR system was maintained under controlled conditions, with continuous aeration and mixing to optimize microbial activity.

An Effect of rate of aeration

The effectiveness of MBBR in the treatment of wastewater is significantly influenced by the rate of aeration. Numerous studies have demonstrated that the filling ratio, aeration mode, and aeration intensity are the primary parameters to play major role in the performance of MBBRs (Tülay, Yilmaz et al., 2023). The fluidization performance of the biofilm carriers can be enhanced by increasing the aeration intensity; however, excessive aeration intensity may result in higher energy consumption (Jing, Wang et al., 2021). Furthermore, the elimination of contaminants based on nitrogen is impacted by the length of aeration cycles. It has been discovered that intermittent aeration with longer off times results in and less sludge production, more total nitrogen removal and reduced aeration energy requirements. Additionally, the behavior of membrane fouling in MBBRs is affected by the rate of aeration. The demonstration of coarse bubble aeration

Study of HRT

Moving bed biofilm reactors (MBBRs) are mostly dependent on the hydraulic retention time (HRT). In one study, better COD and TN removal efficiencies were obtained by extending the HRT in an SBR- MBBR from 24 to 12 hours (Camila et al., 2022). According to a different study, there were differences in COD removal between raw and ozonated OSPW MBBRs based on the HRT; higher HRTs translated into better removal efficiencies (Yijing, Shi et al., 2017). Furthermore, in raw OSPW MBBRs, it was discovered that the HRT was a significant determinant for COD lowering (Roberta, Ferrentino et al., 2018). It was discovered that the HRT has an impact on biomass production in a microalgal-



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bacterial membrane photobioreactor (MB-MPBR), with shorter HRTs encouraging higher biomass production (Jun, feng, Su et.al.2019). All things considered, these results imply that the HRT is a major factor in deciding how well MBBRs remove nutrients and COD. From the literature, a wide variety of HRT was chosen, for example, at 2-6 hours (Barry et al., 2017). In terms of BOD elimination, the best results are achieved. With all other factors held constant, the experiment was run with 2 hours, 4 hours, and 6hour HRT. The effluent underwent BOD and COD testing in a lab; the findings are displayed in Table No. 3. This data demonstrates the influence of hydraulic retention time on pH adjustments during wastewater treatment. Understanding these pH dynamics is essential for maintaining the optimal conditions for biological and chemical reactions, which are integral to efficient wastewater treatment systems.

Table 3 Study of HRT

HRT	Residual BoD (PPM)	Residual BoD (PPM)	PH Initial- Final
2	49	208	6.3-7
4	38	150	7-7.1
6	29	108	7.2-7

Fig. 2 Study of Effect of HRT



Effect of filling ratio

The filling ratio (FR) has been found as very significant parameter for the performance of MBBRs (Dewa, Arya et.al 2022, Yuan-Zhe et.al 2019) In terms of pollutant removal, the denitrifying MBBR showed that a filling ratio of 30% resulted in the highest nitrate removal rate and denitrification rate (Elham, Ashrafi et.al 2020). Similarly, for the SBR-MBBR, increasing the filling ratio from 40% to 60% improved the efficiencies for chemical oxygen demand (COD) and total nitrogen (TN) (A., Kamstra et.al,2017) Furthermore, the study on MBBR performance in fish farming systems found that the larger the scale of the MBBR, the better the performance in terms of total ammonia nitrogen (TAN) removal rate . However, it was also observed that superficial air velocity and media filling percentage had a strong effect on mixing time, which in turn affected the performance of the MBBR. The filling fractions must be less than 70% so that the media can move freely inside the reactor (Patel et al., 2021). The filling ratio of 20%, 50% and 70% were studied and BOD was determined taking 6hr HRT constant for all the ratios. The results of the experiments are as shown in fig.3

Study of Specific Surface Area

It has been observed that biocarriers with larger surface areas promote the growth of biofilm and enhance the biodegradation of organic load (Joana, Dias et.al 2018, Tao, Liu et.al 2020). The specific area of the carrier media is the one which mainly controls the performance, as it permits very high biofilm concentrations in a small reactor capacity (Barwal & Chaudhary, 2014). Different studies have shown that the shape, size, and surface area of the biocarriers influence the performance of MBBR systems. In particular, the surface area of the biocarriers plays a crucial role in the development of biofilm and the interaction between microbes and substrate (Dimitra, C et.al 2023, Amal, Ashkanani et.al 2019). Additionally, the specific surface area of the carrier media affects the start-up duration of MBBR systems, with media with higher surface areas requiring shorter periods to achieve stable biofilm formation rates (Vasan, Sivalingam et.al,2020). Therefore, increasing the specific surface area of carrier media can improve the efficiency of MBBR systems by enhancing biofilm development and promoting biodegradation processes. Using two types carrier called k1, Kepping HRT as 6 hr BOD and TDS was investigated. In the study, conducted for a 2-liter media configuration with a surface area 250 m2/m3 and 500 m2/m3. The resulting BOD values for these were 86 % and 91%, respectively. These findings indicate a clear trend in BOD removal efficiency as a function of specific surface area of these media configuration. This information is invaluable in the optimization of



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wastewater treatment processes involving media having a surface area greater than $500 \text{ m}^2/\text{m}^3$.



Fig. 3 Study of Filling Ratio

RESULTS & DISCUSSIONS

HRT of 6 hr. was found to be giving 87% BOD reduction and 83% COD reduction. While Efficiency is improved when filling ratio is increased at 60 % above this BOD and COD was found to be 85% and 79% respectively. pH has found to stable in the rage of 7-7.2 when and optimum for highest efficiency. 78% BOD reduction obtained at 50% BOD while increase in the percentage filling ration resulted in further decrease in efficiency. It was found that Development of the media and the creation of a controlled aerobic environment are pivotal components and increase in the specific surface area increase the efficiency of MBBR. In doing so, it has the potential to inform and advance wastewater management practices in urban settings while promoting environmental conservation and healthier urban communities. Above study can be used for improving the performance of existing Sewage treatment plant in the college campus and water can be recycle for gardening and washing purpose.

CONCLUSION

In many cases when there is an increase the loading rate of existing conventional STP, and in most of cases generally there is no scop of expansion in terms of space then retrofitting is the only option which is possible with MBBR process and various crucial parameters like Specific Surface area (SFA), Filling ratio (Volume of media/Active Volume of Digester), Hydraulic Retention Time (HRT), SLR can be optimized to get best efficiency out of old existing treatment plant.

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ABSTRACT

Predicting the compressive strength of concrete is a vital aspect of construction and material science, impacting structural integrity, durability, and safety. This study explores the application of model tree algorithms, specifically using the M5 rule, to predict concrete compressive strength based on various mix properties. The M5 rule, a robust method for generating model trees, splits data into subsets and assigns linear regression models to each subset, enhancing accuracy and interpretability. By M5 rule models with the conventional compressive strength values, this research aims to develop predictive models that can accurately estimate the compressive strength of concrete. Total 330 test sample were tested using IS 516 for compressive strength. This MT-based models are trained on experimental data and tested with 50%,40%,30%,20% and 10% percentage split to forecast the compressive strength, considering various concrete mix designs. With CC value of obtained in range of 0.95 to 0.98 with testing split. MLP model is showed excellent results. The model is validated using multi linear regression. By analyzing data from different mix designs, including variables such as cement content, water- cement ratio, and aggregate properties, this approach aims to deliver high predictive accuracy while simplifying the relationships between concrete mix components and strength results.

KEYWORDS : Coefficient of correlation, Mean absolute error, Root mean square error, Compressive strength.

INTRODUCTION

oncrete compressive strength is a most important - fundamental property of concrete which influences the performance, safety, and durability of concrete structures. [1] To meet the necessary load bearing and durability requirements predicting the strength of concrete is crucial for engineers and builders to ensure materials that meet the requirements.[2] The main technique for figuring the compressive strength has historically been laboratory testing, however these tests take a lot of time and may need to be repeated several times for different mix designs. Therefore, using data-driven methods to better accurately forecast compressive strength is becoming more and more popular. Machine learning techniques have emerged as valuable tools in this regard, offering faster, databased predictions that complement traditional testing.

[3]. Among these techniques, model trees have shown promise due to their capacity to capture complex, nonlinear relationships within concrete mix data. The M5 rule, a powerful model tree algorithm, combines decision tree analysis with linear regression, creating a model that segments data based on mix characteristics and applies specific linear equations to each segment. [4]. This hybrid approach enhances both the accuracy of predictions and the interpretability of the model, allowing insights into how various mix proportions contribute to strength outcomes.[5] This study investigates the application of model trees using the M5 rule to predict concrete compressive strength. By examining various parameters, such as cement content, water-cement ratio, and aggregate types, this approach aims to yield reliable, accurate, and interpretable prediction.

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LITERATURE REVIEW

The M5 model tree, initially designed by Quinlan. The M5 model tree algorithm creates a piecewise linear regression model by partitioning the input space into regions and fitting a linear regression model to each partition as shown in figure 1. The M5 rule model, also known as the M5' model tree, is derived from M5 and generates simple "if-then" rules at the leaf node for regression problems. M5 first partitions the dataset by recursively splitting the data, similar to a decision tree, using an attribute that minimizes the standard deviation of the target variable in each partition. The splitting criterion S for attribute A at node N is given by equation 1.



Fig. 1. M5 Model Tree

$$S(A,N) = \frac{\sum_{i} (n_i \times \sigma_i)}{\sum_{i} n_i} \tag{1}$$

Where,

n, is the number of samples in partition i

 σ_i is the standard deviation of the target in partition i.

At each leaf node (final partition), a linear regression model is fit to the data in that partition. For a given partition, the model can be expressed as equation 2:

$$y = w_0 + w_1 x_1 + w_2 x_2 + \dots + w_n x_n \tag{2}$$

Where,

y is the predicted output,

w_o is the intercept,

 w_1, w_2, \dots, w_n are coefficients for each attribute x_1, x_2, \dots, x_n

 x_n in that partition. After the model tree is created, it is pruned to avoid overfitting by removing branches that do not significantly reduce error. This results in a simpler model that generalizes better. Each leaf node of the M5 tree is converted into a rule. The path from the root to each leaf node gives the condition for the rule. For instance, if we have a path that splits based on attributes x_1 and x_2 , x_2 , a rule might be written as equation 3.

if
$$x_1 \le a$$
 and $x_2 > b$ then $y = w_0 + w_1 x_1 + w_2 x_2$ (3)

This forms an "if-then" rule where a and b are threshold values determined by the model splits. The M5 algorithm minimizes the mean absolute error (MAE) across all rules and partitions. The objective function optimized by M5 can be written as in equation 4.

Minimize
$$\frac{1}{m} \sum_{i=1}^{m} |y_i - \hat{y}_i|$$
 (4)

Where,

m is the number of samples,

y_i is the actual value of the target,

y_i is the predicted value from the rule.

Deepa et al. (2010) evaluated the M5 model tree's predictive capability on high-performance concrete. By developing regression models, the study achieved enhanced interpretability, showing that M5's linear models at leaf nodes enabled human- readable predictions Gupta & Sihag (2022) compared M5 with other predictive algorithms, highlighting that M5's rule-based structure effectively provided clear prediction rules for compressive strength, especially when variables had complex interactions. Ashrafian et al. (2020) utilized the M5 model tree for estimating the compressive strength of roller-compacted concrete pavements, noting that the M5 rule improved prediction accuracy through rules-based segmentation, essential for diverse concrete compositions. Kulkarni & Londhe (2020) tested M5 with fuzzy logic to predict 28-day compressive strength. This hybrid approach combined fuzzy rules with M5 to refine prediction boundaries, particularly benefiting short-term and longterm predictions. Ayaz et al. (2015) investigated the M5P classifier and the M5 rule model in forecasting compressive strength in concrete mixes with high

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mineral admixtures. Their results showed M5's strength in creating separate rules for different admixture levels, thereby boosting predictive performance. Ahmed et al. (2022) applied the M5P model alongside artificial neural networks to assess compressive strength in geopolymer concretes, finding that M5P provided reliable forecasts with lower computational costs compared to neural networks. Behnood et al. (2017) demonstrated the M5 model tree's advantage in managing non-linear relationships when predicting the compressive strength of both standard and high- performance concrete, highlighting M5's scalability across various concrete types. Omran et al. (2016) compared M5-Rules with other data mining techniques, concluding that M5's rule-based models were ideal for compressive strength prediction in eco-friendly concrete, emphasizing its environmental application potential. Jain & Barai (2018) conducted a parametric study using M5', illustrating the model tree's adaptability to complex data structures in predicting concrete strength with piecewise linear models. Esmaeili-Falak et al. (2022) evaluated the M5-Rule model on recycled aggregate concrete, revealing the model's effectiveness in adapting to material variability, an essential feature for sustainable concrete applications.

METHODOLOGY

In this study, concrete mix was prepared using IS dimension 150mm x 150mm x 150 mm were casted of different mix design and were cured at $27\pm 2^{\circ}$ C for 28 days. The specimens were tested at 7 and 28 days. The mix ingredients consist of cement, flyash, Alcofine, ground granulated blast furnace slag, water, fine aggregates and coarse aggregates and admixture as mentioned in table 1.

Table 1. Mix design Ingredients

Component	Data set of concrete mix		
	Min (kg/m ³)	Max (kg/ m ³)	Avg (kg/m ³)
Cement	125	650	325
GGBS	0	325	74
Flyash	0	360	59
Alco- fine	0	65	5

20mm	438	745	663
10mm	220	510	349
CRF	530	1100	836
Water	140	180	155
Admixture	1.017	8.45	5.24
Compressive strength	12.82	96.73	47.34

For machine learning, weka software was used. Total 330 dataset was taken as input. The input data was normalized and then dataset was trained and tested with different percentage as 50%, 40%, 30% 20% and 10%. Denormalization of dataset was done to revert the predictions back to their original scale. The statistical parameters such as coefficients of correlation (CC), coefficients of determinations (r2), mean square error (MSE), mean absolute error (MAE) and root mean square error (RMSE) is evaluated. Multi-linear regression equation for parameters compressive strength was developed from origin software. Comparing the statistical parameters developed with multi linear regression and M5 rule.

RESULTS AND DISCUSSIONS

The performance of an M5 Rule model, which is a decision tree-based model that combines regression and rule-based approaches, can be evaluated using key metrics like the Correlation Coefficient (CC) and the R-squared (R²) value. These metrics provide insights into how well the model has captured the relationship between the input features and the target variable. As mentioned in table 2 the CC and R² with 10% testing dataset showed higher values 0.98 and 0.96 respectively. The high CC value 0.98 and R² value 0.96 both indicate that the M5 Rule model performs exceptionally well in predicting the compressive strength of concrete. A very strong linear relationship between the predicted and actual values shows that the model's predictions are extremely accurate and closely follow the actual data trends as show in figure 2. Also, the MSE, RMSE and MAE values are also lower compared with other testing percentages. This indicates that the M5 Rule model effectively captures both linear and nonlinear relationships between the mix parameters and compressive strength.

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Strength	Training + Testing					
	50%	60%	70%	80%	90%	
	50%	40%	30%	20%	10%	
CC	0.95	0.95	0.95	0.96	0.98	
R2	0.91	0.9	0.9	0.92	0.96	
MAE (MPa)	4.98	5.08	4.96	4.26	3	
MSE (MPa)	39.04	41.94	42.53	29.05	15.34	
RMSE (MPa)	6.25	6.48	6.52	5.39	3.92	



Fig. 2. Predicted value VS Experimental value using M5 Rule for compressive strength of concrete

Low error metrics indicate the model's reliability in predicting strength within a narrow margin of error, crucial for reducing variability in mix performance. Designing targeted concrete mixes that meet specific strength requirement. The ability of the M5 Rule model to capture both linear and non-linear relationships enhances understanding of complex behaviors in concrete mixes. Such as Aggregate gradation (20mm and 10mm coefficients) influences packing density and interfacial bond strength. The synergistic effect of CRF (Crusher Run Fines) and other fine materials on improving strength and reducing porosity. The equation obtained from origin software, for 28 days strength prediction. Based on the provided regression analysis output, we can interpret the results for predicting the 28-day strength of concrete using various predictors like Cement, GGBS, Flyash, Alcofine, 20mm aggregate, 10mm aggregate, CRF (Crusher Run Fines), Water, and Admix (Admixture) as mentioned in equation 5.

Strength=-1483.02827+0.58545×Cement+0.57517

×GGBS+0.73427×Flyash+0.72902×Alcofine+0.53 04×20mm+0.54811×10mm+0.5276×CRF+1.58772 ×Water+3.85817×Admix ... Equation (5).

The positive coefficients of Cement, GGBS, Flyash, Alcofine, and aggregates reflect their direct contribution to enhancing compressive strength The water coefficient 1.58772 highlights the delicate balance in the water-cement ratio for achieving strength without compromising workability or durability. Admixtures highest coefficient: 3.85817 underscore their vital role in improving not just strength but also workability, durability, and performance in aggressive environments. The CC value obtained is 0.96, R2 0.93, MAE 4.61 MPa, MSE 33.49 MPa and RMSE 5.79 MPa from multi linear regression equation.

CONCLUSION

Machine learning offers powerful tools for predicting the compressive strength of concrete, outperforming traditional methods in most cases. Machine learning techniques provide more accurate and adaptive predictions compared to traditional empirical or statistical methods, which often fail to capture the inherent variability in concrete properties. The M5 Rule model achieves a CC ranging from 0.95 to 0.98, indicating a strong linear relationship between predicted and actual values. The highest CC(0.98) is observed with a 90%-10% training-testing split, slightly outperforming the MLR model's CC of 0.96. The M5 Rule model shows R2values from 0.90 to 0.96, with higher training proportions (80%-90%) providing better goodness-offit. However, MLR exhibits a slightly better R2 of 0.93 when compared to M5 Rule for moderate splits. The M5 Rule model has MAE values between 3 MPa and 5.08 MPa. The lowest MAE (3 MPa) is achieved with the 90%-10% split, indicating higher precision with larger training sets. In comparison, MLR has an MAE of 4.61 MPa, suggesting M5 Rule is superior when sufficient training data is available. MSE values for M5 Rule range from 15.34 MPa to 42.53 MPa. The best MSE is 15.34 MPa (90%-10% split), significantly better than MLR's MSE of 33.49 MPa, reflecting improved error minimization with larger training data. RMSE values for M5 Rule range from 3.92 MPa to 6.52 MPa, showing progressive improvement with larger training sets. The lowest RMSE (3.92 MPa) is significantly better than the



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MLR model's RMSE of 5.79 MPa, underscoring M5 Rule's superior predictive accuracy. M5 Rule adapts better with larger datasets, leveraging its piecewise regression structure to capture complex relationships, which is a limitation for MLR. The M5 Rule model is highly effective for predicting concrete compressive strength, especially with larger training datasets, where it consistently outperforms MLR in minimizing error metrics (MAE, MSE, RMSE).

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Bending Behaviour of a Thick Cantilever Beam Subjected to Parabolic Loading Analysed through a Novel Shear Deformation Theory

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ABSTRACT

The current research paper seeks to investigate a thick cantilever beam underparabolic loading using a seventhorder shear deformation theory. The current theory's displacement field considers transverse shear and normal deformation effects. The beam's depth influences the formulation of proposed beam's theory. Displacement field in the thickness or depth coordinate represents the shear deformation effects. To achieve a more accurate estimation of the beam's bending behaviour including shear deformation effects, displacements, rotations and stress distributions, the thickness coordinate terms are taken up to the seventh order. Virtual work Principle is applied to get governing equation, boundary condition. By using constitutive relations, transverse shear stresses can be computed which ensure the no shear stress state on the beam's upper and lower surfaces, hence shear correction coefficient is eliminated. The homogeneous, isotropic, cantilever beam under parabolic load is regarded for illustration. The analysis is performed and the expressions are retrieved for the transverse-displacements, normal displacements, normal bending-stresses, transverse shear-stresses. The results are subsequently evaluated against those reported in literature viz Euler theory, Timoshenko theory and various higher-order SDT to demonstrate the efficiency of seventh order theory. The novelty of present theory is its improved predictive capabilities for complex loading and boundary condition problems in automotive, aerospace and civil engineering.

KEYWORDS : Axial stress, Deep beam, Displacement field, Equilibrium equation, Shear deformation, Shear stress, Virtual work principle.

INTRODUCTION

In Civil, aerospace, marine and mechanical engineering, beams serve as essential structural elements. Beam theories reduce the complexity of three-dimensional elasticity issue by approximating it as single dimensional problem. As the thickness is notably smaller as compared to the length, the displacements and stresses in the thickness direction can be approximated. Shear deformation theory is the crucial component of structural analysis for deep or thick beams where one cannot ignore the shear deformation effect. Classical beam theory like Bernoulli-Euler's beam theory [1,2] assumes that plane sections that are normal to the neutral axis prior to bending will continue to be normal to it following the bending condition. The transverse normal and transverse-shear strain are also zero. This theory ignores shear deformation's (SD) effect, consequently suitable for thin beam and not well- suited to deep or thick beam. The shortfall in Euler theory is eliminated in the first order theory. Galileo and Saint Venant [3] tackled issues with shear and bending forces in beams, adding to this theoretical framework. The pioneering work in incorporating rotatory inertia, shear-flexibility as advanced dynamic effects can be attributed to Rankine [4]. Timoshenko [5] established the much stronger effect of transverse shear on prismatic bar transverse vibration response than rotatory inertia, Nevertheless, this theory is known as the Timoshenko's theory of beam or 1st order SD theory. As per the theory, the distribution of shear strain (transverse) remains uniform throughout



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the beam's thickness. hence, shear correction coefficient is must.

The limitations of ETB and FSDT are then eliminated in the higher order theories. Krishna Murty [6,7] developed the shear deformation (SD) theory with the consideration of 3rd-order function in depth or thickness coordinate. The theory meets the no shear-stress state on top as well as bottom face of beam, this effectively removes need for a shear correction coefficient. Soler [8] formulated higher-order SDT for deep beams rectangular in cross section. On the basis of stress assumptions and kinematic of Levinson's [9], Bickford [10] developed an advanced theory for beams that yields sixth order differential equations. Parabolic SD theories were provided by Rehfield[11], Murty A.K [12]. Baluch et al. [13] proposed a theory that considered how shear strain (transverse) and normal strain (transverse) affect the way beams bend. Kant, Gupta [14], Heyliger, Reddy [15] developed FE models utilizing higher-order SDT for rectangular beams. Based on Levinson's theory, Ghugal [16] created beam theory which justify for shear strain (transverse) and normal strain (transverse). A 5th order SDT accounts for static loading and analyze for bending, an isotropic plate, placed simply over the supports is presented by Ghugal and Gajbhiye [17]. Nayak and Khante [18] presents behaviour of plates with a and without cutout by performing linear transient dynamic analysis.

Based on the above literature review; in order to get more precise solution of deep beams, a new seventh order SDT is presented in the paper. The governing equation of the solution is developed from the principal of virtual work. Cantilever beam loaded with parabolic load is analysed with the current theory and the results achieved are evaluated against those documented in the literature. The key novelty of present theory is its ability to deliver more accurate and realistic depiction of shear deformation, more refined description of displacements, rotation and stress distribution and elimination of shear correction factor. Hence this theory is useful for analysing complex loading and boundary conditions specially in the field of aerospace, automotive and civil engineering.

THEORETICAL FORMULATION

A rectangular, isotropic and homogeneous beam is taken for the theoretical formulation.

$$\begin{bmatrix} 0 \le x \le L \end{bmatrix}; \begin{bmatrix} -b/2 \le y \le b/2 \end{bmatrix}; \begin{bmatrix} -h/2 \le z \le h/2 \end{bmatrix}$$
(1)

L - beam length in 'x' axis direction, b - width in 'y' axis direction, h - thickness in 'z' axis; x, y, z - co ordinates.

Displacement Field

Displacement field employed to present the theory is

$$u(x,z) = z \frac{dw}{dx} + z \left[3 - \frac{4}{3} \frac{z^2}{h^2} - \frac{16}{5} \frac{z^4}{h^4} - \frac{64}{7} \frac{z^6}{h^6} \right] * \phi(x)$$
(2)

w(x, z) = w(x)'u'- Axial displacement

'w'- Transverse displacement

'z' - Distance from neutral axis

Strains

Normal Strain:

$$\varepsilon_x = \frac{du}{dx} = -z\frac{d^2w}{dx^2} + z\left(3 - \frac{4}{3}\frac{z^2}{h^2} - \frac{16}{5}\frac{z^4}{h^4} - \frac{64}{7}\frac{z^6}{h6}\right)\frac{d\phi}{dx}$$
(3)

Shear Strain:

$$\gamma_{zx} = \frac{du}{dz} + \frac{dw}{dx} = \left(3 - 4\frac{z^2}{h^2} - 16\frac{z^4}{h^4} - 16\frac{z^6}{h^6}\right)\phi(x)$$
(4)

Stresses

Normal Stress:

$$\sigma_x = E\varepsilon_x = -Ez\frac{d^2w}{dx^2} + Ez\left(3 - \frac{4}{3}\frac{z^2}{h^2} - \frac{16}{5}\frac{z^4}{h^4} - \frac{64}{7}\frac{z^6}{h^6}\right)\frac{d\phi}{dx}$$
(5)

Shear Stress:

$$\tau_{x} = G\gamma_{x} = G\left(3 - 4\frac{z^{2}}{h^{2}} - 16\frac{z^{4}}{h^{4}} - 16\frac{z^{6}}{h^{6}}\right)\phi(x)$$
(6)

Governing-Equations derivation and associated support conditions

From equations (2) to (6), Virtual work Principle's, the boundary conditions and governing differential equations for the beam will be

$$b \int_{x=0}^{x=L} \int_{z=-h/2}^{z=+h/2} (\sigma_x \cdot \delta \varepsilon_x + \tau_x \cdot \delta \gamma_x) dx dz = \int_{x=0}^{x=L} q(x) \delta w dx$$
(7)

Integrating equation (7), successively, couple of equilibrium equations can be obtained.

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$$EI\frac{d^4w}{dx^4} - 2.67EI\frac{d^3\phi}{dx^3} - q(x) = 0$$
(8)

$$2.67EI\frac{d^3w}{dx^3} - 7.2EI\frac{d^2\phi}{dx^2} + 6GA\phi = 0$$
(9)

Where, $A_0 = 2.67$, $B_0 = 7.2$, $C_0 = 6$

ILLUSTRATIVE EXAMPLE

The following cantilever beam (Fig.1) with parabolic load is considered for the validation purpose, the beam material properties are $\rho = 7800 \text{ kg/m}^3$, E = 210,000MPa, $\mu = 0.3 \rho$ - density, E –Elastic Modulus, μ- Poisson's ratio.



Fig. 1. Cantileverdeep beam underparabolic load

The expressions for w(x) and $\phi(x)$ for cantilever boundary condition is as follows.

$$w(x) = \frac{q_0 L^4}{120 EI} \begin{cases} \frac{128}{63} \sqrt{\frac{x}{L}} \frac{x^4}{L^4} - \frac{40}{3} \frac{x^3}{L^3} + 24 \frac{x^2}{L^2} - \frac{B_0}{C_0} \frac{E}{G} \frac{h^2}{L^2} \begin{pmatrix} \frac{8}{3} \sqrt{\frac{x}{L}} \frac{x^2}{L^2} \\ -5 \frac{x^2}{L^2} \end{pmatrix} \\ -10 \frac{A_0^2}{C_0} \frac{E}{G} \frac{h^2}{L^2} \left[\frac{\sinh \lambda x - \cosh \lambda x + 1}{\lambda L} + \frac{1}{2} \frac{x^2}{L^2} - \frac{x}{L} \right] \end{cases}$$
(10)

$$\phi(x) = -\frac{2}{3} \frac{A_0}{C_0} \frac{q_0 L}{GA} \left((\cosh \lambda x - \sinh \lambda x - 1) + \sqrt{\frac{x}{L}} \frac{x}{L} \right)$$
(11)

Axial displacement, u

6

Table 1. Non dimensional parameter: Transverse deflection ' \overline{w} '; Axial displacement ' \overline{u} '; Axial Stress ' $\overline{\sigma}_x$ '; Transverse shear stresses ' $\overline{\tau}_{zx}^{CR}$ ' and $\overline{\tau}_{zx}^{EE}$ at x = 0.25L for aspect ratio 'S'

Source	Model	w	u	$\bar{\sigma}_x$	$\overline{\tau}_{zx}^{CR}$	$\overline{\tau}_{zx}^{EE}$
Present	VII order	1.7385	33.1636	24.3631	3.1166	3.8098
Ghugal Y M [17]	V order	1.7403	33.2244	24.6448	3.2490	3.8098
Krishna Murty [12]	HSDT	1.7403	33.2544	24.6397	3.5017	3.8099
Timoshenko [5]	FSDT	1.3119	30.6286	23.2000	-4.6720	1.5000
Bernoulli-Euler [1,2]	ETB	1.2956	-46.1414	-53.6000	-	1.5000

$$u = \frac{q_0 h}{Eb} \begin{cases} -\frac{z}{h} \frac{Z^3}{h^3} \left[\frac{32}{35} \sqrt{\frac{x}{L}} \frac{x^3}{L^3} - 4\frac{x^2}{L^2} + \frac{24}{5} \frac{x}{L} - \frac{B_0}{C_0} \frac{E}{G} \frac{h^2}{L^2} \left(\frac{3}{2} \sqrt{\frac{x}{L}} \frac{x}{L} - \frac{x}{L} \right) \right] \\ -\frac{A_0^2}{C_0} \frac{E}{G} \frac{h^2}{L^2} \left(\cosh \lambda x - \sinh \lambda x + \frac{x}{L} - 1 \right) \\ -\frac{2}{3} \frac{A_0}{C_0} \frac{E}{G} \frac{L}{h} \frac{z}{h} \left(3 - \frac{4}{3} \frac{z^2}{h^2} - \frac{16}{5} \frac{z^4}{h^4} - \frac{64}{7} \frac{z^6}{h^6} \right) \left(\cosh \lambda x - \sinh \lambda x \right) \\ -1 + \sqrt{\frac{x}{L}} \frac{x}{L} \end{cases} \end{cases}$$
(12)

Axial stress, σ_{x}

$$\sigma_{x} = \frac{q_{0}}{b} \left\{ -\frac{z}{h} \frac{L^{2}}{h^{2}} \left[\frac{16}{5} \sqrt{\frac{x}{L}} \frac{x^{2}}{L^{2}} - 8\frac{x}{L} + \frac{24}{5} - \frac{B_{0}}{C_{0}} \frac{E}{G} \frac{h^{2}}{L^{2}} \left(\sqrt{\frac{x}{L}} - 1 \right) \right] \\ -\frac{A_{0}^{2}}{C_{0}} \frac{E}{G} \frac{h^{2}}{L^{2}} \lambda L \left(\sinh \lambda x - \cosh \lambda x \right) \right] \\ -\frac{2}{3} \frac{A_{0}}{C_{0}} \frac{E}{G} \frac{z}{h} \left(3 - \frac{4}{3} \frac{z^{2}}{h^{2}} - \frac{16}{5} \frac{z^{4}}{h^{4}} - \frac{64}{7} \frac{z^{6}}{h^{6}} \right) \left(\lambda L \sinh \lambda x - \lambda L \cosh \lambda x \right) \\ +\frac{3}{2} \sqrt{\frac{x}{L}} \right) \right\}$$
(13)

Transverse shear stress $\tau_{_{\rm ZX}}^{CR}$ obtained from consecutive relationship

$$\begin{aligned} \tau_{xx}^{CR} &= -\frac{2}{3} \frac{q_0}{b} \frac{A_0}{C_0} \frac{L}{h} \left(\cosh \lambda x - \sinh \lambda x - 1 + \sqrt{\frac{x}{L} \frac{x}{L}} \right) \\ \left(3 - 4 \frac{z^2}{h^2} - 16 \frac{z^4}{h^4} - 64 \frac{z^6}{h^6} \right) \end{aligned} \tag{14} \\ \tau_{xx}^{EE} &= \frac{q_0}{b} \left[\frac{1}{8} \frac{L}{h} \left(1 - \frac{z^2}{h^2} \right) \left[\frac{16}{5} \sqrt{\frac{x}{L} \frac{x}{L}} - 8 - \frac{1}{10} \frac{B_0}{C_0} \frac{E}{G} \frac{h^2}{L^2} - \frac{A_0^2}{C_0} \frac{E}{G} \frac{h^2}{L^2} \lambda^2 L^2 \left(\cosh \lambda x - \sinh \lambda x \right) \right]^{-1} \\ \left[\frac{2}{3} \frac{A_0}{C_0} \frac{E}{G} \frac{L}{L} \left(\frac{3}{2} \frac{z^2}{h^2} - \frac{1}{3} \frac{z^4}{h^4} - \frac{8}{15} \frac{z^6}{h^5} - \frac{8}{7} \frac{z^6}{h^5} - \frac{1147}{3360} \right) \left(\frac{\lambda^2 L^2 \cosh \lambda x}{-\lambda^2 L^2 \sinh \lambda x} \right) \end{aligned} \tag{15}$$

RESULT

The outcomes for displacement along with stresses are furnished in non-dimensional patten as follows;

$$\overline{u} = \frac{E b u}{q_0 h}, \quad \overline{w} = \frac{10 E b h^3 w}{q_0 L^4}, \quad \overline{\sigma}_x = \frac{b \sigma_x}{q_0}, \quad \overline{\tau}_{zx} = \frac{b \tau_{zx}}{q_0}$$

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Fig. 2. Transverse displacement (\overline{w}) variation through beam thickness



Fig. 3. Axial displacement (\overline{u}) variation through beam thickness



Fig. 4. Axial Stress ($\overline{\sigma}_x$)variation through beam thickness



Fig. 5. Transverse shear stresses ($\overline{\tau}_{zx}^{CR}$) (Constitutive relationship) variation through beam thickness



Fig. 6. Transverse shear stresses ($\overline{\tau}_{zx}^{EE}$) (Equilibrium equation) variation through beam thickness

CONCLUSION

Table1shows the comparison of axial and transverse displacements, normal and shear stresses of cantilever deep beam under parabolic loading with load intensity

$$q(x) = q \sqrt{\frac{x}{L}}$$

The following conclusions are drawn

• The transverse displacements are matching with the other theories except ETB. The deflections given by ETB is lower than the VIIth order theory because shear



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deformation effects is disregarded. The graphs for the transverse displacement (Fig.2) depicts that the values of reduces as the aspect ratio increases.

- The transverse displacement ' ' remains constant for all the aspect ratios for ETB, while for FSDT, HSDT VI order and VII order, it goes on reducing with increase in aspect ratio. As aspect ratios surpass 20 all the SD theories tends to match the values of Elementary beam theory (ETB)
- Axial displacement obtained by this theory shows agreement toall others theories.(Fig. 3)
- Axial stresses are similar to all the considered theories, however Bernoulli-Euler theory and Timoshenko theory yeilds lower values of stresses (Fig. 4)
- Transverse shear-stress ' ' is achieved using constitutive relations and integrating equilibrium equations of 2D elasticity. Both methods result in a realistic variation of transverse shear-stress throughout the beam's thickness. Here, the realistic variation signifies the pattern described by refined theories that closely align with elasticity solution. Transverse shear-stress attained by two approaches fulfills the zero shear-stress state on the beam's upper and lower surfaces. (Fig.5 and Fig.6)
- It is also identified that with slight increase in length to width ratio, there is considerable increase in the non dimensional values of displacements and stresses as depicted in the graphs and result tables.
- In current theory, requirement of shear correction coefficient is omitted.

In essence, the prevailing theory offers accurate results by the illustrative example and concurs with earlier theoretical models.

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Removal of Heavy Metals in Wastewater with the help of Different Macrophytes

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ABSTRACT

Heavy metal contamination in water bodies has emerged as a significant environmental concern due to industrial and urban wastewater discharge. The presence of these metals poses substantial risks to both human health and ecosystems. Although various wastewater treatment methods exist, traditional techniques often prove to be costly and inefficient. This study explores the effectiveness of macrophytes in remediating heavy metals from wastewater. Phytoremediation, a sustainable and cost-efficient biotechnological approach, has shown promise in the sequestration of heavy metals through different macrophyte species. This paper provides a comprehensive review of case studies and comparative analyses of macrophyte-assisted heavy metal remediation.

KEYWORDS : Heavy metals, Phytoremediation, Macrophytes, Adsorption.

INTRODUCTION

Freshwater availability is a growing global challenge, with water pollution being a major concern due to industrial and municipal effluents. These discharges contain high concentrations of organic and inorganic pollutants, including heavy metals, which, when released into water bodies, lead to severe environmental and public health hazards. The accumulation of toxic metals such as cadmium, copper, lead, chromium, zinc, and nickel in aquatic ecosystems disrupts ecological balance. Researchers are focusing on cost-effective, eco-friendly methods for water purification, and macrophytes have demonstrated potential for absorbing and storing heavy metal ions.

THEORETICAL FRAMEWORK

Phytoremediation

Phytoremediation, a plant-based remediation technique, is a cost-effective and eco-friendly method for removing contaminants, including heavy metals, from wastewater. The process involves different mechanisms:

Phytoextraction: Plants absorb and accumulate heavy metals from wastewater in their aboveground tissues.

Phytovolatilization: Plants take up contaminants and release them into the atmosphere as volatile compounds.

Phytostabilization: Heavy metals are immobilized in plant tissues, preventing their spread.

Rhizofiltration: Roots of macrophytes absorb metals from contaminated water, reducing their concentrations effectively.

Among these, phytoextraction is widely recognized as an efficient method for heavy metal removal.

Evaluation of Phytoremediation Efficiency

The efficiency of phytoremediation is evaluated using the Bioconcentration Factor (BCF) and Translocation Factor (TF). These factors provide a quantitative assessment of a plant's ability to absorb and transfer contaminants, ensuring a more accurate evaluation of phytoremediation effectiveness...[5]

Bioconcentration Factor (BCFs)

The Bioconcentration Factor (BCF) measures a plant's ability to absorb heavy metals from its surrounding environment, indicating its suitability for phytoremediation. It is defined as the ratio of metal concentration in the plant's dry mass to its concentration in the external medium. [5]

The formula for BCF is:

$$BCF = \frac{C \text{ harvested tissues}}{C \text{ water(substratum)}}$$

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(1)

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Where

C harvested tissues = the concentration of the metal in the plant harvested tissue

C water (substratum) = the concentration of the same metal in water (substratum).

A BCF value of > 1000 indicates a considerable hyperaccumulation potency of plant

Translocation Factor (TFs)

The Translocation Factor (TF) measures a plant's ability to transport absorbed heavy metals from the roots to the aerial parts, indicating its efficiency in metal translocation. It is defined as the ratio of metal concentration in the plant shoot to its concentration in the root. [5]. It is calculated as follows:

$$TF = \frac{C \ shoot}{C \ root} \tag{2}$$

Where

C shoot = the concentration of metal in plant shoots

C root = its concentration in plant roots.

TF with higher values of 1, imply the high potency of plant metal transport systems [5]

Percentage of Removal (PR) & Increase in Removal (PIR)

The percentage of removal (PR) and increase in removal (PIR) and variation of concentration of pollutant can be calculated by using [3] Eq no. (3).

$$PR = \left[\frac{Co - Cf}{Co}\right] \times 100 \tag{3}$$

Where

 C_{f} = Final or after time period pollutant concentration.

 C_{o} = Initial pollutant parameter concentration.

While the percent increase in dissolved oxygen was calculated by using the following formula [3]:

$$PIR = \left[\frac{Cf - Co}{Co}\right] \times 100 \tag{4}$$

AQUATIC MACROPHYTES FOR PHYTOREMEDIATION

Several macrophytes have been identified for their ability to remediate heavy metals from wastewater: Water Hyacinth (Eichhornia crassipes): A highly productive floating plant with a strong capacity to accumulate metals.

Lemna Minor: A fast-growing species effective in absorbing lead and nickel.

Spirodela Polyrrhiza: Known for reducing heavy metal concentrations while improving water quality.

Pistia Stratiotes: Absorbs a wide range of metals, including cadmium and zinc.

Azolla Pinnata: A floating fern with high efficiency in removing cadmium, lead, and nickel.

Typha Latifolia: A wetland species with strong metal sequestration capabilities.

Phragmites Australis: Effective in stabilizing and removing metals from contaminated water bodies.

RESULTS AND DISCUSSION

The following table presents findings from various studies on macrophyte-based heavy metal remediation:

Sr. No	. Macrophyte	Researcher	Findings	
1	Hydrilla Verticillata	Abdul- Alghaffar & Al-Dhamin (2016), Phukan et al. (2015)	Shows high removal efficiency for chromium and copper.	
2	Lemna Minor	Al-Khafaji et al. (2017), Bokhari et al. (2016)	Accumulates Pb and Ni effectively; pH influences metal absorption.	
3	Spirodela Polyrrhiza	Yadav et al. (2017), Loveson et al. (2013)	Reduces pH and hardness; high chromium and copper removal.	
4	Pistia Stratiotes	Lu et al. (2011), Rodrigues et al. (2017)	Absorbs over 70% of zinc and cadmium.	
5	Azolla Pinnata	Naghipour et al. (2018)	Achieves 92.84% Cd and 97.12% Pb removal under optimal conditions.	

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CONCLUSION

Heavy metal pollution remains a pressing environmental issue, and phytoremediation offers a sustainable, low-cost solution. The macrophytes studied demonstrate significant potential for wastewater treatment. Future research should focus on optimizing growth conditions and scaling up phytoremediation applications for industrial and municipal wastewater management.

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RCC Design of Light Vehicular Underpass (LVUP) in Nagpur-Amravati (NH) Project

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ABSTRACT

A light vehicular underpass is a key infrastructure solution designed to alleviate traffic congestion and enhance mobility in urban areas. By allowing vehicles to pass beneath roadways, underpasses reduce the need for traffic signal stops and minimize the impact of intersections. This infrastructure is particularly beneficial in areas with high traffic volumes and limited space for above-ground road expansions. The design and construction of a light vehicular underpass require careful consideration of factors such as traffic flow, safety, environmental impact, and cost- effectiveness. Key components include efficient drainage systems, proper ventilation, and structural integrity to accommodate varying traffic loads. The underpass can also contribute to the aesthetic and functional enhancement of urban spaces by freeing up surface-level roads for alternative uses, such as pedestrian walkways or green spaces. This study aims to explore the benefits, challenges, and best practices involved in the planning, design, and implementation of light vehicular underpasses, with a focus on their role in improving traffic management and urban development.

KEYWORDS : Light vehicular Underpass, Traffic congestion, Structural integrity etc.

INTRODUCTION

A s urban populations grow and cities expand, traffic congestion has become one of the most pressing challenges faced by modern metropolitan areas. The continuous increase in vehicular numbers, combined with limited road space and outdated infrastructure, often results in bottlenecks, delays, and reduced efficiency in transportation networks. In response to these challenges, innovative solutions are being explored to improve traffic flow and reduce congestion. One such solution is the construction of light vehicular underpasses.

The design of a light vehicular underpass involves careful consideration of various factors, including structural safety, traffic volume, environmental impact, and construction feasibility. The purpose of such infrastructure is not only to improve traffic movement but also to enhance the overall safety and sustainability of the urban environment. By minimizing surface-level congestion, light vehicular underpasses contribute to reducing emissions, improving air quality, and lowering noise pollution in cities.

This paper will explore the technical aspects of light vehicular underpasses, including their design principles, construction methods, and potential benefits. Additionally, it will review case studies where such underpasses have been successfully implemented, demonstrating their effectiveness in addressing the challenges posed by urban traffic congestion. Ultimately, this study aims to provide insights into how light vehicular underpasses can be a key element in the development of smarter, more sustainable urban transportation systems.

Typical Components of an LVUP

Top slab: The upper surface of the box that supports the weight of the embankment or overlying structure.

Bottom slab: The base of the box in contact with the ground. Side walls: The vertical elements providing lateral support.



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Fig. 1. Light Vehicular Underpass

LITERATURE REVIEW

Literature Survey

Kumar, A., Singh, S., & Sharma, P. (2022). Dynamic Response of RCC Underpasses Under Light Vehicle Traffic Loads. Journal of Structural Engineering, Kumar et al. (2022) conducted a study on the dynamic load analysis ofIRCC underpasses subjected to the moving loads of light vehicles. The paper titled "Dynamic Response of RCC Underpasses Under Light Vehicle Traffic Loads" used Finite Element Analysis (FEA) to simulate traffic load scenarios, identifying the stress distribution within the concrete structure. The authors found that understanding dynamic loads is crucial for designing more resilient underpasses and optimizing reinforcement placement.

Yadav, R., Kumar, R., & Verma, R. (2021). Impact of Soil-Structure Interaction on the Structural Behaviour ofsRCC Underpasses. Yadav et al. (2021) emphasized the importance of soil-structure interaction (SSI) in RCC underpass design, particularly in areas with soft soils. Their study, "Impact of Soil-Structure Interaction on the Structural Behaviour of RCC Underpasses," presents a comprehensive approach to modelling the interaction between the foundation and the superstructure. The study concludes that considering SSI in the design leads to a more accurate prediction of settlement and deformation, reducing the risk of long-term structural failure.

Chauhan, S., Pandey, S., & Tiwari, V. (2022). Enhancing Durability of RCC Underpasses: Mitigating Corrosion and Cracking. Journal of Concrete Technology, Chauhan et al. (2022) explored durability issues in the RCC design of underpasses, focusing on corrosion of reinforcement and water infiltration. Their paper, "Enhancing Durability of RCC Underpasses: Mitigating Corrosion and Cracking," investigates the use of corrosion inhibitors and epoxy coatings to protect the structure against environmental degradation. The study advocates for the use offhighperformance concrete (HPC) and self healing concrete to extend the lifespan of underpasses.

Li, W., Zhou, Z., & Zhang, Y. (2021). Case Study: RCC Underpass Design and Performance in Dense Urban Environments., Li et al. (2021) conducted a study on a real- world RCC underpass project in Shanghai. Their research, "Case Study: RCC Underpass Design and Performance in Dense Urban Environments," examined the implementation of high-strength concrete and arch bridge configurations to optimize space and traffic flow in congested areas. Their findings revealed how integrating advanced materials and design forms can effectively reduce construction costs and improve structural longevity.

Kumar, A., & Sharma, P. (2016). Dynamic Load Analysis of RCC Underpasses for Light Vehicles. Kumar and Sharma (2016) investigated the dynamic response of RCC underpasses under varying traffic loads. The study focused on analysing the effects of dynamic vehicle loads on structural behaviour using finite element modelling (FEM). The authors concluded that dynamic effects, especially for light vehicular traffic, can significantly influence the stress distribution in the underpass structure and affect the design of reinforcement.

Soni, A., & Choudhary, S. (2018). Soil-Structure Interaction in RCC Underpasses. Soil-Structure Interaction (SSI) Understanding Soil-structure Interaction (SSI) is essential for the stability of underpass structures, especially in urban environments with variable soil conditions. Soni and Choudhary (2018) highlighted the importance of considering SSI effects when designing underpasses. Their study, "Soil-Structure Interaction in RCC Underpasses," proposed an advanced modelling technique to predict the settlement and deformation of RCC underpasses under varying soil conditions. The study showed that underpass designs without SSI considerations often overestimate the load bearing capacity ofvthe structure.



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Zhang, H., & Li, X. (2019). Performance-Based design of RCC Underpasses for Urban Infrastructure. Performance Base Design (PBD) Approach the shift towards Performance Based Design (PBD) has been significant in the design of RCC underpasses. Zhang and Li (2019) proposed a performance-based approach to RCC underpass design, considering serviceability, structural safety, and durability. In their paper, "Performance-Based Design of RCC Underpasses for Urban Infrastructure," they used probabilistic methods and structural reliability analysis to develop performance criteria that optimize the design process while minimizing material costs.

Kaur, P., Verma, A., & Bhagat, R. (2017), Finite Element Analysis of RCC Underpasses for Light Vehicular Traffic. Finite Element Analysis (FEA) in Structural Design The application of Finite Element Analysis (FEA) for modelling the behaviour of RCC underpasses under traffic and environmental loads has become widespread. Kaur et al. (2017) focused on using FEA in their study, "Finite Element Analysis of RCC Underpasses for Light Vehicular Traffic," where they assessed the impact of varying traffic conditions and soil characteristics on the RCC structure. Their results showed how FEA could optimize the placement of reinforcement and improve the overall efficiency of the design.

Gap Identified

The identified gaps in the RCC design of light vehicular underpasses point to several areas that require deeper investigation to improve the efficiency, durability, and cost- effectiveness of these critical urban infrastructure components. Addressing these gaps through further research can lead to more sustainable, resilient, and optimized designs, benefiting both engineers and urban planners in the future development of transportation infrastructure. Inadequate safety measures during construction, potentially leading to accidents or structural failures. Insufficient operational safety features, such as proper lighting and signage for users. By identifying and addressing these gaps, the overall effectiveness, safety, and durability of the RCC light vehicular underpass can be significantly improved.

METHODOLOGY

Criteria for selecting studies

This review includes topics relevant to topic Focus on RCC Underpass Design: Studies should directly address the design, analysis, or construction of light vehicular underpasses using Reinforced Cement Concrete (RCC).

Traffic Load Consideration: Studies should consider traffic load conditions, especially focusing on light vehicles and how they affect the structural behaviour of RCC underpasses. Design Approaches and Methodologies: Studies should explore design aspects such as load distribution, material choices, structural optimization, and sustainability specific to underpasses.

Soil-Structure Interaction (SSI): If the study deals with the impact of vsoilv-structure interaction on the behaviour of vRCC underpasses, it should be included. Durability and Maintenance: Research that investigates the durability, maintenance, and life cycle of RCC underpasses is crucial for understanding the long -term performance of such structures.

Method of Analysis

The selected literature includes a comprehensive review of the methodology and results reported in each study. Designing a Reinforced Cement Concrete (RCC) light vehicular underpass involves a thorough analysis to ensure the structure can safely carry the expected traffic loads, provide durability, and meet all safety standards. Site and Traffic Analysis: Determine traffic loads, soil conditions, environmental conditions, and hydrology.

Preliminary Design: Based on load and geotechnical data, create preliminary geometry (span, depth, width).

StructuralAnalysis: Perform load analysis (static, dynamic), FEA, and strength checks. Foundation Design: Based on soil data, determine the type of foundation and calculate its size and reinforcement. Reinforcement Detailing: Provide detailed reinforcement based on analysis for beams, slabs, and walls. Drainage and Safety Measures: Design drainage system and any safety/ventilation systems. Final Checks and Optimization: Perform final checks for serviceability, ultimate limit states, and overall stability.

RESULTS AND DISCUSSION

Synthesis of findings from literature

The synthesis of findings from existing literature provides comprehensive understanding of the design, performance, and construction of Reinforced Cement Concrete (RCC) light vehicular underpasses. This synthesis aims to integrate insights from various studies that cover key aspects such as structural behaviour, material efficiency, soil-structure interaction, hydraulic considerations,



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seismic performance, cost-effectiveness, and long-term sustainability. By combining these findings, it is possible to create a more holistic view of the challenges and best practices in underpass design.

Implications for Study

The synthesis of findings from existing literature on the design of Reinforced Cement Concrete (RCC) light vehicular underpasses offers critical insights into the key factors influencing their structural performance, sustainability, and cost-effectiveness. The implications of these findings are wide-reaching, affecting both future research and practical design applications. This section outlines the implications for further study and the practical applications that can help shape the future of RCC underpass design.

Need for Comprehensive Design Optimization Models: The studies reviewed indicate that various design typesbox-type, arch-type, and slab-and-beam-offer distinct advantages and trade-offs. The implication for future study is the need to develop comprehensive optimization models that can integrate multiple parameters like traffic loads, geotechnical conditions, environmental factors, and aesthetic considerations to guide design decisions. Specifically, further research should focus on: Multicriteria decision-making (MCDM) approaches that can weigh competing factors like initial construction cost, long- term durability, environmental impact, and maintenance costs to determine the most appropriate design under varying conditions. The integration of finite element analysis (FEA) with parametric design tools to create adaptive design processes that respond dynamically to site- specific conditions, optimizing structural performance and material usage.

Optimization algorithms that balance load distribution, material efficiency, and cost. These can be crucial for selecting the most efficient and cost-effective design under different traffic conditions and span lengths.

Incorporating Seismic Resilience and Safety Features: Given the increasing importance of seismic resilience, especially in earthquake-prone regions, future studies should focus on refining seismic design methodologies for RCC underpasses. Research into the development of seismic-resistant technologies, such as base isolators, energy dissipation systems, and seismic retrofit techniques, to enhance the earthquake performance of existing underpasses. The integration of seismic design criteria into the AASHTO LRFD Bridge Design Specifications for underpasses, ensuring that structures built in seismic zones adhere to rigorous safety standards.



Fig. 2. Light Vehicular Underpass During Construction

Methodology for future research directions

The methodology outlined above provides a structured approach for future research on the RCC design of light vehicular underpasses. By focusing on advanced modelling, sustainable materials, seismic resilience, costbenefit analysis, and field validation, this research will contribute to developing underpass designs that are more durable, cost-effective, sustainable, and safer. Moreover, these research directions will provide valuable insights into integrating emerging technologies and innovative materials, helping the field evolve to meet modern infrastructure demands.



Fig. 3. Rcc Section for Light Vehicular Underpass

CONCLUSIONS

The design of Reinforced Cement Concrete (RCC) light vehicular underpasses plays a crucial role in modern urban infrastructure, ensuring the smooth flow of traffic while also considering structural safety, sustainability,



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and cost- effectiveness. As cities continue to grow and the demand for efficient transportation systems increases, RCC underpasses are becoming an essential component of urban planning. This conclusion draws together the key points from the research and outlines the importance of continued innovation and development in the field.

As urban areas continue to expand and face increasing traffic congestion, the need for efficient, safe, and sustainable underpass designs will only grow.

ACKNOWLEDGEMENT

I would like to use this opportunity to show our sincere appreciation and respect to our project guide at the Tulsiramji Gaikwad Patil Collage of Engineering and Technology, Nagpur, who gave us direction and space to complete this assignment.

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Seismic Response and Performance of Multistorey Prefabricated Building Structures: A Review

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ABSTRACT

This study investigates the impact of in the plane diaphragm strength and stiffness on the seismic absorbing capacity of multi-story modular buildings. Modular construction, which involves prefabricating modules offsite and assembling them on-site, has gained popularity for its efficiency, quality, and environmental benefits. However, diaphragm irregularities, resulting from the joining of modules at separate points, can affect structural stability and lead to diaphragm fractures if not addressed. The study proposes a modified approach to determine diaphragm service flexibility, considering shear deformation in isolated module diaphragms and both shear and axial deformation in diaphragm connectors. A numerical model is developed for a four-story modular RCC structure to assess seismic performance. Additionally, the study explores the thermal behavior, energy consumption, and seismic resistance of modular prefabrication, comparing it with traditional construction methods. Given the lack of guidance for modular buildings in Indian seismic codes, this research provides valuable insights into their performance under seismic loads.

KEYWORDS : Seismic resistance, Energy, Prefab, Modular, Thermal behavior, Life cycle analysis, Bracings, Shear wall, Acoustic constraints etc.

INTRODUCTION

Modular construction, also known as prefabricated building systems, is gaining popularity for constructing medium-rise buildings. Unlike traditional methods, modular construction involves manufacturing each volumetric unit (module) in a factory-controlled environment off-site, which are then assembled on-site. This method significantly accelerates construction while ensuring high-quality standards, safety, and adherence to health regulations. Modular buildings can be either fixed or relocatable, offering flexibility for both permanent and temporary structures. Modules are typically manufactured in standard sizes, though they can be customized to meet specific architectural designs.

The appeal of modular construction lies in its simplicity, speed, and the higher manufacturing quality achievable in factory-controlled environments. Notable global projects including the Murray Grave on the UK, the Clements Canopy in Singapore, & the Little Hero housing development in Melbourne show the expanding acceptance of this building technology for large-scale projects. Modular construction provides a solution to the increasing demand for efficient and sustainable buildings, with reduced energy consumption, improved thermal behavior, In comparison to traditional building, it has a lower environmental impact.

Prefabricated modular construction isn't a novel concept. Its origins may be linked back to what was the 1851 Grand Exhibition on the UK, where the Crystal Palace was hastily built using prefabricated pieces. Over the years, modular construction evolved, with significant developments in the 20th century. For instance, during World War II, prefabricated structures like the Quonset hut were used for quick, bulk housing for military personnel. By the 1960s, concrete modular buildings were introduced, and the first multi-story modular hotel was constructed for the 1968 Texas World's Exposition, completing in an exceptionally short 202 working days.


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Today's modular buildings are manufactured from a range of materials, including steel, concrete, wood, and glass fiber reinforced polymers (GFRP). Advances in material science continue to influence the development of prefabricated construction, testing new insulation materials, plumbing fixtures, and facades. This growing versatility makes modular buildings increasingly appropriate for a wide range roofing applications, including residential units and commercial buildings.

The benefits of modular construction are evident in several key areas. Firstly, it significantly reduces the construction timeline. Site preparation and foundation work can occur Concurrently with the manufacturing of modules at the factory, reducing the overall schedule by 30 to 60 percent. Additionally, because modules are manufactured in a controlled environment, weather-related delays are minimized. This results in a safer, more comfortable working environment for laborers, enhancing productivity and the quality of the final product. The modular approach also reduces labor costs, as skilled workers can be employed in factory settings, benefiting from logistical hubs that offer easy access to raw materials. Lastly, modular construction generates less waste, aligning with growing environmental concerns in the building industry, making it a more sustainable option.

As modern architecture pushes for more innovative and unique designs, the demand for custom modular units that can be adapted to these creative concepts is expected to grow. This combination of speed, efficiency, sustainability, and adaptability makes modular construction a promising solution for the future of building design.



Fig.1. Bomb attack on Building in before and after the attack

PROBLEM STATEMENTS

The growing demand for efficient, sustainable, and quick construction methods has highlighted the limitations of traditional building techniques, especially for mediumrise structures. Modular construction, while offering significant advantages such as faster completion times, better quality control, and reduced environmental impact, faces challenges related to its seismic performance. The lack of clear guidelines in seismic codes, such as India's IS 1893-2016 (Part I), for designing modular buildings presents a critical gap. Modular buildings, due to their unique assembly of prefabricated units, often experience diaphragm irregularities at the junctions between modules, which can compromise structural integrity under seismic loads. These irregularities can lead to instability or diaphragm fractures if not addressed properly. Additionally, there is a need for more research on the in-plane diaphragm strength and stiffness of modular buildings, particularly in terms of how they perform under dynamic loads. This research aims to bridge this gap, ensuring the seismic resilience of modular construction.

LITERATURE REVIEW

Literature Survey

[1] Y. G. Zhao at. al. 2001, discussed "Moment methods for structural reliability," They stated that in order to conduct an accurate evaluation, an engineer with structural expertise must first evaluate details like distribution of loads, geometry, supporting circumstances, and material properties. Such a study frequently results in displacements, tensions, and encouraging reactions. The data is compared with standards which represent the causes of failure. Advanced structural research can examine stability, nonlinear conduct, and dynamic response.

[2] V. Umachagi et.al, Viscous dampers work by allowing fluid to flow through openings, as briefly detailed in the "Application of Dampers in Vibration Control for Structures: An Overview." comprised of an extremely viscous wall, a moving part with multiple microscopic holes, and a liquid cover filled with silicone or oil that enables fluid to flow from a single side of the cylinder to another. They devised a viscous damper that was employed in a building with three floors building for seismic control, along with another viscous damper. They suggested the optimal viscous damper to reduce the metallic building's interstory movement.

[3] K. H. Chang et.al., The assessment of loads on buildings and their parts is referred to as structural analysis. This type of study examines all structures that must support weights, including buildings, bridges, automobiles, machinery, clothing, furniture, soil the lamina, prosthetic limbs and biological tissue. Structural analysis calculates the deformations, inner torques, stresses, supporting



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reactions, accelerations, and stability of a structure using applied the mechanics, materials science, and mathematical methods. The inspection results are used to verify the structure's feasibility for use, removing the requirement for physical testing. As a result, structural analysis is an important aspect of the mathematical modeling of the aforementioned structures.

[4] Mario Paz et.al., Structure dynamics was further investigated and expanded, as The basic purpose of structural evaluation is to predict how an actual structure will react to a force. This activity can manifest as a burden caused by the mass of objects such as individuals, furniture, wind, snow, & so on, depending on another stimulation, including an earthquake or the ground trembling after a nearby explosion, among other things. Because these loads did not exist at the same time, they are all dynamic, including the structure's own weight. The difference between static and dynamic research is whether the action utilized has enough acceleration in comparison with the structure's frequency of birth. If the load is delivered slowly enough, the Newton's first rule of motion and inertia acts can be neglected, reducing the study to static analysis. Thus, structural dynamics is a sort of engineering study that investigates how structures operate when dynamic loaded-that is, when operations are performed at a rapid rate of acceleration. People, storms, waves, congestion, earthquakes, other explosions are all examples of dynamic loads. Any structure is susceptible to dynamic loading. Dynamic analysis may provide details concerning time histories, modals, and dynamic displacement.

[5] Özgur Atlayan, The influence of fluid-based damper on hybrid concrete moment frame designs with steel moment frames intended for strength. However, it was determined that adding more dampers improved the structural reaction. Damping increases maximum or residual roof shifts, interstory travels, with IDA (Incremental Dynamical Analysis) distribution. Furthermore, the bulk of collapses that take place for naturally damped structures are avoided by adding further damping.

[6] S. Amir et.al. According to research published in "Optimum Parameter of a Viscous Damper for Seismic and Wind Vibration," most structures can effectively reduce their vibrations even with relatively low damping because they can effectively dissipate considerable amounts of energy. The explanation describes how a nonlinear characteristic is needed in a dampening system to maximize the vibrations for a basic moment frame.

[7] Y. Zhou et.al. Unlike seismic isolation retrofit technologies, installing viscous damper in existing buildings can be more practical because of their ease and construction, as illustrated in "A Practical Method of Design for Reinforced Concrete Buildings with Viscous Dampers." Viscous damper layout, which provides a high degree of building dampening, was a very uncommon adoption in China of this well-researched & tested technology throughout greater seismically active regions of the world.

[8] Liya Mathew et.al. released "Effect of Fluid Viscous Damper assemblies in Multi-Storeyed Buildings," According to the report, new protective technologies have been designed to improve security and prevent damage to buildings during earthquakes. The fluid viscosity dampers (FVD) stand out here. That work also involves an examination of reinforced concrete structures with and without fluid viscous dampers. A parametric study was carried out to determine the best damping properties of reinforced concrete frames. A nonlinear history time reconstruction is being done on a symmetrical rectangular structure. Pushover analysis was performed utilizing software, as well as graphical comparisons were made.

[9] B. S. Taranath, To guarantee that the design satisfies the required degree of safety, each seismic event necessitates complex nonlinear historical analysis, as described in "Reinforced Concrete Engineering of Tall Buildings." The outcomes of simulations are evaluated with the performance criteria. Only in recent years have the analytical instruments required to do these simulations become economically viable. The rigorous and sophisticated procedure is expected to yield a design that is reliable and safe.

[10] C. Thormark, Embedded energy is a helpful metric of asset value and environmental impact. Prior research evaluated trash as an indicator of energy material and concentrated on the recycling possibility of construction and demolition waste. The easiest method to assess the ecological savings through reducing waste is to consider their embedded implications.

Research Gap

While much study has been undertaken on the use using viscous dampers in building structures for seismic or wind vibration control, gaps remain in optimizing damper parameters for different structural typologies and seismic conditions. Most studies focus on singlecomponent analysis, but integrated system-level approaches that combine damping with other structural design elements (e.g., hybrid frames or moment frames) remain underexplored. Furthermore, there is minimal

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research on the long-term viability of dampers under changing environmental circumstances and their impact on overall structural sustainability. Future studies could focus on advanced modeling techniques and real-world performance assessments to fill these gaps.

Summary of Literature

The literature on structural analysis and vibration control highlights the importance of understanding how structures respond to various loads, such as seismic and wind forces. Studies emphasize the need for detailed analysis, considering factors like structural loads, material properties, geometry, and support conditions to evaluate displacements, stresses, and failure circumstances. Structural dynamics plays a key role in analyzing dynamic loads like earthquakes, distinguishing between static and dynamic behavior. The use of viscous dampers is a common method for controlling vibrations, improving structural response by dissipating energy. Research shows that adding viscous dampers to buildings enhances stability and reduces interstory displacements. Various studies also focus on the role of damping in hybrid and steel moment frames, with a focus on optimizing the dampers' parameters for seismic and wind vibrations. Performancebased design methods, including nonlinear time history analysis and pushover analysis, provide more accurate measures of structural performance under dynamic loads.

CONCLUSION

The present investigation and the evaluated literature allow for the following findings to be made:

- Compared to a building with a shear wall, there was an approximate 30–35% displacement increase in a building with bracings. Time period values in both structures also show the building's ductile and flexible character. Compared to a building with a shear wall, A building having bracings has more ductile or flexible properties. Maintaining the ductility for the corner pillars is also critical for gaining better performance under high earthquake stresses. Even when yielding occurs, High ductile pillars may avoid collapse and help horizontal members rebalance loads.
- 2. Drift values are greatest at the base of a braced structure; however, as the story increases, drift decelerates, indicating that bracings act as though they are absorbing lateral forces at the base and transferring less force at the top.

It is determined that while modular structures with shear walls and bracings have advantages of their own, modular buildings with bracings are found to be more stable when it comes to earthquake resistance.

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I would like to use this opportunity to show our real appreciation and respect to our research guide at Tulsiramji Gaikwad Patil College in engineering and technology in Nagpur, who gave us guidance and space to complete this assignment.

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Effect of Wind Load on Low, Medium, High-Rise Buildings in Different Terrain Category: A Review

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ABSTRACT

The movement of wind can cause tall structures to sway in both the "along wind" and "across wind" directions. Even buildings designed to meet lateral drift criteria may experience excessive movement during storms. As the height of a structure increases, it becomes more vulnerable to wind-induced oscillations, which can pose a risk to the building. These oscillations may also cause discomfort for the occupants, even if the building itself is not at risk of collapse. Therefore, accurately evaluating the movement of the structure is essential for ensuring serviceability. There are several methods available to determine the Wind Load Response of tall buildings. Wind currents, which are visible to the human eye, vary in their intensity depending on the terrain. In rocky areas, wind travels more slowly, whereas on flat ground, it moves faster. This study examines the impact of wind on three different building heights (G+5, G+10, and G+15) in three different types of terrain. By using wind data from these terrains, the research explores the effects of story drift, shear forces, and structural responses on buildings of varying heights. All 12 models are analyzed using ETABSv9.7.4 software. The findings of this study provide valuable insights into the variations in drift, shear forces, and the percentage change in these factors with respect to both the building height and terrain type.

KEYWORDS : Wind load response, Structural drift, Shear forces, Tall buildings, Terrain variability.

INTRODUCTION

Wind has two primary aspects that engineers must consider. On the positive side, wind energy is a valuable resource that can be harnessed to generate electricity, propel boats, and help cool the environment during hot weather. These benefits make wind a crucial element in sustainable energy solutions and climate regulation. However, the aspect that concerns engineers the most is the force that wind exerts on structures. Wind load, especially in tall buildings, is a significant factor in structural design and safety, as buildings must be able to withstand these forces without compromising their integrity.

Wind load plays a critical role in the design and structural stability of buildings. The impact of wind forces on a structure can vary significantly depending on the building's height, type, and location. Low-rise buildings are generally less affected by wind than medium or high-rise structures, which are more exposed to atmospheric forces. The taller the building, the greater the effect of wind load. This makes it essential for engineers to carefully calculate and plan for wind resistance when designing taller buildings.

Background of the Project

Buildings are exposed to lateral forces from wind, which vary in magnitude based on factors like building height, shape, orientation, and the type of surrounding terrain. In open areas, wind speeds are generally higher due to the lack of obstacles, while in densely built urban environments, the presence of neighboring buildings can reduce the intensity of wind loads. Structural engineers must carefully design buildings to withstand these forces to ensure their stability and safety.

Terrain is classified in various ways by different codes and standards, such as IS 875 Part 3, where the roughness of the terrain plays a key role in influencing wind speed profiles. Tall buildings, especially those located in highwind zones, face an increased risk of damage if wind loads



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are not accurately calculated and properly accounted for in the design.

Wind load refers to the force exerted by wind on structures. It is classified into three main types:



Fig. 1. Wind Load on Building

Windward Load: This refers to the wind hitting the front face of the building.

The windward load creates compressive forces on the wind-facing walls, increasing stress and potentially causing buckling in the structural components. Additionally, it generates lateral forces that can induce sway in taller buildings, which may result in occupant discomfort and, if not properly designed, could lead to structural damage.

Leeward Load: This is the wind impacting the rear face of the building.

Where the pressure is lower. The leeward load creates tension forces that can lead to uplift on the roof and lateral forces on the walls. In extreme cases, if suction forces are substantial, they can cause roof lift-off or damage, especially during severe wind events.

Side Wall Load: This occurs when the wind strikes the side walls of the building.

Side wall loads generate lateral forces that affect the overall stability of the structure. In buildings with irregular shapes or asymmetrical designs, these loads can also cause torsional effects. The impact of side wall loads can result in significant deflections, particularly in high- rise buildings, where lateral wind forces are more pronounced.

LITERATURE REVIEW

Smith and Johnson (2020): Explored the effects of wind loads on low-rise buildings in urban areas. They concluded that buildings in densely populated areas experience higher wind pressures due to turbulence and surrounding structures.

Choudhary et al. (2019): Analyzed the wind load variations on medium-rise buildings across different terrain categories. Their study emphasized the importance of terrain classification in calculating accurate wind loads.

Patel and Kumar (2021): Studied wind-induced vibrations in high-rise buildings, noting that the building's height and aerodynamic shape play a critical role in wind load distribution.

Dutta and Sharma (2018): Investigated the effect of wind directionality on wind load estimation for low-rise buildings in coastal areas, highlighting the increased risk of damage due to consistent winds from a single direction.

Li and Zhang (2020): Analyzed the behavior of wind loads on tall buildings in varied terrain categories. They recommended incorporating both wind speed and terrain roughness in structural design.

Singh et al. (2022): Focused on the wind load effects on buildings with different aspect ratios. Their findings showed that taller buildings in rural terrains face less wind resistance than those in urban areas.

Nguyen et al. (2019): Evaluated the impact of terrain categories on wind pressure distribution, showing that urban environments experience higher wind speeds due to the 'urban canyon' effect.

Ravi and Sinha (2021): Studied the influence of wind gusts on building facades, particularly on medium and high-rise buildings, and their findings suggested that proper aerodynamic shaping can significantly reduce wind-induced damage.

Bhat and Verma (2020): Provided a detailed analysis of wind load coefficients for buildings in varying terrain categories, highlighting how different terrain classifications affect wind speed and pressure profiles.

Williams et al. (2022): Investigated how buildings with non-conventional shapes (e.g., domes and pyramids) interact with wind forces, concluding that such shapes can reduce wind load effects but complicate analysis.

METHODOLOGY

Method of Analysis

The assessment of wind load impacts on buildings combines field measurements, computational simulations, and theoretical models. Numerical simulations, using tools like CFD or software such as ANSYS or Wind Sim, allow



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for an in-depth examination of wind flow patterns around buildings across various terrains. These simulations help predict how wind interacts with structures of different shapes and sizes, revealing the distribution of pressure and identifying potential points of failure. Initially, the building's geometry, including dimensions and material properties, is defined. Then, wind profiles specific to the terrain are applied, factoring in wind speed, direction, and turbulence. For dynamic analysis, transient wind loads are modeled using time-history simulations, which capture variations in gusts and wind speed. Sensitivity analyses are performed to understand how changes in building orientation, terrain roughness, and building height affect resistance to wind loads. The data is then evaluated to assess structural stability, deflection, and potential failure under extreme wind conditions.

Method of Calculation

Wind Speed (Vb):

Vb (Basic Wind Speed): This is determined from local standards (such as IS 875 Part 3)

Formula

 $Vb = Vb0 \times K1 \times K2 \times K3$

(K1- K2, K3 – Factor for Terrain, Height and Local Conditions.)

K1: Terrain category factor based on terrain roughness.

K2: Height factor for wind speed with respect to the building height.

K3: Local topography factor (e.g., hills, valleys).

Wind Pressure (P): $P = 0.6 \text{ x V}^2$

V-Wind Speed

Wind Load (W):

W = q x G x C d x A

G - Gust factor (based on building height and terrain).

Cd - Drag coefficient (depends on the building's shape and type).

A - Projected area of the building.

RESULTS AND DISCUSSION

Structural Design Consideration

• Low-Rise Buildings: - Design focuses on resisting lateral forces and ensuring stability against

overturning. Roof and wall connections need to be strong.

- Mid-Rise Buildings: Structural design must account for increased wind loads, requiring stronger lateral load-resisting systems.
- High-Rise Buildings: Design must address both static and dynamic effects of wind. Aerodynamic shaping, damping systems, and tuned mass dampers may be necessary.

Safety Measures

Terrain Influence

Category 1: - Buildings need robust design to withstand high wind pressures.

Category 2: - Moderately robust design, accounting for some wind reduction.

Category 3: - Design focuses on the complex interaction of wind with urban terrain.

Category 4: - Highest complexity in design due to varied wind flow patterns around buildings.

Understanding these variations is crucial for designing buildings that are safe, economical, and able to withstand the specific wind conditions they will encounter based on their height and terrain location.

CONCLUSIONS

This project emphasizes how important it is to design buildings that can withstand wind loads, especially in areas that experience high winds or unpredictable weather patterns. The findings suggest that using flexible and lightweight materials, along with optimized structural forms, can greatly improve a building's ability to resist strong winds. While ETABS is a reliable tool for simulating wind loads, it is crucial that these simulations are validated through real-world testing to ensure their accuracy. The study also shows that wind impacts vary greatly depending on a building's height and the surrounding terrain, so it's clear that designs need to be tailored to specific conditions. This research provides valuable insights that can guide future construction projects, helping engineers and architects develop safer, more wind- resistant buildings. These findings are particularly important for areas that face frequent high winds, as they can help improve the overall resilience of buildings and reduce the risk of damage during severe weather events.



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Dynamic Analysis of a High-Rise Structure on A Deep Pile Foundation Using Advanced Computational Tools: A Review

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ABSTRACT

This study investigates the critical role of soil types, foundations, and building frames in resisting external loads, with a particular focus on storey displacement as an indicator of structural safety under various loading conditions. In earthquake-prone regions, foundation failures are a leading cause of structural displacement, often resulting in significant human and economic losses. The interaction between deep foundations and the surrounding soil, known as Soil-Structure Interaction (SSI), plays a pivotal role in a structure's performance. Factors such as foundation geometry, soil properties, and load conditions significantly influence the stability and design of buildings. This research highlights the importance of considering SSI effects to enhance the structural resilience and safety of buildings, especially in areas susceptible to seismic activity.

KEYWORDS : Single under-reamed friction pile, Isolated footing, Sub-structure, Storey displacement, Building frame etc.

INTRODUCTION

This research focuses on analyzing the displacement behavior of a four-storied, single-bay frame resting on different types of soil under dynamic loading, using finite element analysis software. The study examines the effect of deep foundations, specifically single underreamed friction piles, with or without square footings, on the structural displacement. Foundation failure, particularly in earthquake-prone areas, often leads to structural displacement, resulting in significant loss of life and economic damage. The type of foundation, footing, and soil properties significantly influence the stability and design of structures. The analysis reveals that foundations with single under-reamed friction piles and footings exhibit reduced total displacement compared to those without footings [1][2].

The interaction between the foundation and surrounding soil, known as Soil-Structure Interaction (SSI), plays a pivotal role in the dynamic response of structures. The research highlights that the presence of footings in single under-reamed friction piles significantly alters the foundation's dynamic behavior, improving the overall structural response to dynamic loads.

Deep foundations are commonly employed in areas with weak soil conditions or high vertical loads, where surface soil cannot support the structure. The performance of these foundations is influenced by various factors, including soil properties, foundation geometry, and loading conditions [3].



Fig. 1. Pile Foundations

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SSI is a complex process involving the transfer of forces between the foundation and the soil, and it can significantly impact the behavior of deep foundations under both static and dynamic loads. Understanding soil element behavior is crucial to ensuring the safety and stability of structures supported by deep foundations, as civil engineering structures transfer loads through foundation components such as footings, rafts, and piles into the underlying soil. This paper offers a comprehensive analysis of both static and dynamic aspects of SSI, providing valuable insights into foundation behavior under different loading conditions [4][5].

LITERATURE REVIEW

Literature Survey

Kurnia et al. (2021) This paper present a simplified approach to soil-structure interaction (SSI) analysis using a linearized p-y curve as spring stiffness to simulate soil resistance in pile foundations. This method enables a faster and more cost-effective analysis compared to complex continuum finite element models, allowing the simultaneous modeling of the superstructure, foundation, and soil. The study emphasizes the significance of SSI in accurately predicting the response of pile foundations during seismic events, demonstrating that a simplified SSI model can deliver reliable results, Optimizing time and resources during the design process.

Krishna et al. (2020) This paper focus on the seismic design of pile foundations under various ground conditions, using Indian and European seismic codes. The study evaluates multi-story buildings located in different seismic zones and ground types (C and D) to understand the effects on seismic loads and foundation capacity. By comparing seismic loads across different standards, the paper offers insights into optimizing pile foundation design for varying seismic conditions, ensuring structural safety. The research highlights the critical role that ground conditions play in determining the behavior and performance of pile foundations during earthquakes.

Poulos (2018) This paper outlines the principles for designing pile and piled raft foundations for tall buildings using a limit state design approach. The study advocates for using ultimate limit state (ULS) load combinations and applying geotechnical reduction factors to foundation components to ensure overall stability. The research emphasizes balancing safety and performance by limiting foundation deformation under service loads while maintaining structural integrity under ultimate load conditions. This approach offers practical guidelines for the design of pile foundation systems, ensuring high-rise buildings remain stable, safe, and resilient under varying load conditions.

Pal and Mahiyar (2019) This paper investigate the design of pile foundations for a G+20 high-rise building under different seismic conditions. The study uses STAAD Pro to model pile groups in various configurations (3, 4, and 5 piles in triangular and square arrangements) and examines their behavior under different seismic zones. The analysis shows how aspect ratios and seismic zones affect the seismic performance of the foundation. The results highlight the importance of careful seismic design, ensuring that the foundation system remains stable and efficient, regardless of the seismic intensity or configuration.

Prajapati and Panchal (2019) This paper emphasize the significance of Soil-Structure Interaction (SSI) in the design of deep foundations under dynamic and static loading conditions. They utilize a finite element-spring method to model the foundation response of high-rise buildings on sandy clay soil. Their findings reveal the complex relationship between soil properties, foundation geometry, and dynamic loads. This research underscores the critical role of SSI in ensuring the long-term performance of foundations, showing how dynamic interactions between soil and structure can influence foundation behavior and structural stability.

Shah (2021) This paper studies the behavior of deep foundations under static and dynamic soil-structure interaction (SSI). The research focuses on factors such as foundation geometry, soil properties, zone factor, and building importance in evaluating earthquake forces. Shah analyzes both static and dynamic SSI, providing key insights into the safety and efficiency of deep foundations. The study concludes with design recommendations for deep foundations, ensuring that SSI is thoroughly accounted for in foundation designs to enhance stability, particularly under seismic conditions, by analyzing deformation and load transfer mechanisms.

Noto et al. (2020) This paper investigate soil-foundationstructure interaction (SFSI) for buildings supported by pile foundations, comparing fixed base and compliant base assumptions. The study models a nine-story residential building using both linear and non-linear lumped parameter models to simulate the piled foundation. The findings highlight significant differences in structural



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response when SFSI is considered. By comparing fixed and compliant bases, the study emphasizes the importance of including soil flexibility in foundation design to better understand the building's dynamic behavior, particularly under seismic loading conditions, and to improve overall structural resilience.

Itankar and Kurzekar (2020) This paper focus on optimizing pile foundation systems using finite element modeling (FEM) software. They explore different ground conditions, such as low bearing capacity and high compressibility soils, to develop an efficient design for pile foundations. The study optimizes the number, length, and diameter of piles while maintaining structural integrity. Additionally, the research demonstrates how optimal pile group placement can enhance load distribution, reducing the total number of piles required, thereby cutting construction costs. Their findings highlight the importance of soil properties in determining the most efficient foundation design.

Gap Identified

Most research focuses either on the seismic performance of pile foundations or on the structural design aspects. There is a gap in integrated studies that combine seismic analysis with structural design to provide holistic insights into optimizing pile foundations for high-rise buildings in seismic-prone areas. The influence of varying soil conditions, particularly low bearing capacity and high compressibility, on the performance and optimization of pile foundations needs further exploration. Current research has not fully addressed how different soil types affect pile group design and foundation behavior under seismic loading.

Summary of Literature Survey

- Ground conditions, particularly soil type, play a critical role in the transfer of seismic loads to foundations and the overall foundation capacity. Soils with low bearing capacity and high compressibility require careful consideration in foundation design, especially for high-rise structures.
- Pile foundations are essential for supporting heavily loaded structures, particularly when shallow foundations are inadequate. They are commonly used in high-rise buildings, industrial structures, and offshore constructions where soil conditions are poor.
- Research shows that pile length, distance between piles, pile arrangement, and cap thickness significantly influence the behavior of pile foundations under static

and dynamic loading. Vertical loading conditions, in particular, are sensitive to these configurations in multi-storied structures.

COMPARATIVE ANALYSIS

Criteria for selecting this study

The study on deep foundations and soil-structure interaction (SSI) has been selected based on the following criteria:

- 1. Relevance to Real-World Conditions: The study emphasizes the challenges of applying research findings to practical design, particularly in seismicprone areas. It highlights the limitations of simplified models and small-scale tests, which often do not fully represent real-world scenarios. This makes the research highly applicable to actual construction projects.
- 2. Focus on Soil-Structure Interaction (SSI): The research addresses the critical role of SSI, an essential aspect of foundation design that directly impacts the stability and safety of structures. This factor is especially important in areas with soft soils or regions prone to seismic activity, providing valuable insights into the interplay between soil properties and foundation behavior.
- 3. Comprehensive Approach: By exploring a variety of factors such as soil type, foundation geometry, and loading conditions, the study takes a holistic approach to understanding deep foundations. It goes beyond traditional analyses by incorporating the effects of SSI, offering a more detailed evaluation of structural performance under external loads.
- 4. Impact on Earthquake-Prone Regions: The focus on seismic regions adds a layer of urgency and importance to the research. Foundation failures are a leading cause of building displacement during earthquakes, and this study provides insights on improving structural resilience and safety, a critical concern in seismic engineering.
- 5. Contribution to Structural Design Improvement: The research not only identifies potential risks (e.g., settlement and deformation in soft soils) but also offers strategies for improving foundation design. By emphasizing the importance of accurate soil behavior modeling, the study contributes to safer and more reliable building designs.

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Method of analysis

- The method of analysis for the given study involves a comprehensive approach using both experimental and numerical techniques.
- First, soil properties, foundation geometry, and load conditions are systematically evaluated through field data collection and laboratory testing to understand their influence on soil-structure interaction (SSI).
- Finite Element Analysis (FEA) is employed to simulate the response of foundations under various loading scenarios, particularly in seismic conditions.
- Additionally, sensitivity analysis is conducted to determine how variations in soil type, foundation shape, and material properties affect displacement and stability.
- The results are validated against real-world case studies to ensure practical relevance and accuracy.

Comparison and Analysis

The comparison of key studies on deep foundations and soil-structure interaction (SSI) reveals several critical insights across diverse approaches and conditions:

- 1. Simplified SSI Models: A simplified SSI approach using a linearized p-y curve to simulate soil resistance in pile foundations, making the analysis more time-efficient compared to complex finite element models. This technique is valuable in seismic events, optimizing design resources without sacrificing accuracy [1].
- 2. Seismic Design Standards: A focus on pile foundation design in seismic zones, comparing Indian and European standards. The study emphasizes the impact of ground conditions (C and D types) on seismic loads, highlighting the importance of localized seismic design to ensure structural safety [2].
- 3. Limit State Design for Pile Foundations: Using a limit state design approach for tall buildings, balancing safety and performance by minimizing foundation deformation while maintaining stability under ultimate load conditions. This method ensures resilience in high-rise structures [3].
- 4. Pile Configuration and Seismic Zones: Different pile group configurations and aspect ratios influence the seismic performance of foundations in varying seismic zones, providing practical insights into designing efficient pile systems [4].

- 5. Dynamic SSI in Foundation Design: The critical role of SSI in dynamic conditions, such as earthquakes. Shah particularly highlights the influence of foundation geometry, soil properties, and seismic factors on deep foundation behavior, while Prajapati and Panchal emphasize the complex interactions between soil and foundation, affecting long-term performance [5].
- 6. SFSI and Structural Response: Noto et al. (2020) study the difference between fixed and compliant base models in soil-foundation-structure interaction (SFSI), showing how incorporating soil flexibility into the design can significantly alter the building's dynamic response, especially in seismic scenarios [6].
- 7. Foundation Optimization: On optimizing pile foundation systems using FEM, demonstrating how pile placement, number, length, and diameter can be adjusted based on soil conditions to reduce costs while ensuring structural integrity. This optimization improves load distribution and minimizes the need for excessive piles [7].

These studies collectively highlight the importance of integrating soil properties, seismic standards, SSI models, and foundation design optimizations to enhance the stability, safety, and cost-effectiveness of deep foundations under various load conditions.

CONCLUSION

Most studies focus on either the seismic behavior of pile foundations or their structural design aspects. However, there is a lack of integrated research combining both seismic analysis and structural design, which could provide comprehensive insights into optimizing pile foundations in high-rise buildings, especially in seismic regions. Further investigation is required to understand how varying soil conditions, particularly those with low bearing capacity and high compressibility, influence pile foundation design and performance under seismic loads. Current research has not thoroughly explored how different soil types affect pile group configurations and the overall foundation behavior during seismic events.

This research emphasizes the critical role of Soil-Structure Interaction (SSI) in the design and performance of deep foundations, particularly in high-rise buildings located in seismic-prone areas. The dynamic and static aspects of SSI significantly influence the behavior of pile foundations, especially under varying soil conditions such as low bearing capacity and high compressibility. A holistic



approach combining seismic analysis with structural design is essential for optimizing pile foundation systems. The interaction between soil properties, foundation geometry, and loading conditions is complex but crucial to ensuring the stability and safety of deep foundations. By addressing these factors, this study provides insights into how foundations can be optimized to enhance performance under seismic loading. Future research should further explore these relationships to develop more efficient and resilient foundation designs, particularly in challenging soil environments.

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Analysis and Design of Roof Trusses for Industrial Shed of Maple More Unit Using STAAD.Pro: A Review

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ABSTRACT

An industrial building is a structure designed for the storage of raw materials or the production of industrial goods, characterized by components such as purlins, rafters, roof trusses, wind bracing, and columns. These buildings, often used as workshops or warehouses, rely heavily on steel for construction, particularly when concrete is impractical or time-sensitive. This study focuses on the design and analysis of a multi-story industrial steel truss building, developed using manual calculations in accordance with IS codes. The structural analysis includes various load combinations, such as dead, live, and wind loads, which significantly influence the performance of critical components like the column base. Steel purlins span between rigid frames, supporting the light gauge metal cladding. The findings, based on detailed load and impact evaluations, provide insights into the structural behavior and stability of industrial buildings, ensuring they meet safety and performance requirements.

KEYWORDS : Industrial sheds, Roof truss, Structural analysis, Staad Pro etc.

INTRODUCTION

A n industrial building refers to a structure designed for storing raw materials or producing industrial goods, incorporating key components such as purlins, rafters, roof trusses, wind bracing, and columns. These buildings are particularly suited for workshops and warehouses. Steel is predominantly used in the construction of largescale industrial buildings, especially where concrete is impractical or time-sensitive. The analysis and design of such multi-story industrial structures are typically conducted manually, with detailed attention to each structural component. The Industrial Steel Truss Building carries substantial loads, and the analysis follows IS codes that outline multiple load combinations, including dead loads, live loads, and wind loads. These load combinations are crucial for evaluating performance, particularly in the column base. Steel purlins span between rigid frames in this structure, supporting light gauge metal cladding [1].

For the structural analysis, STAAD.Pro, a design and analysis software, is employed. In this study, the design of steel roof trusses is emphasized. A truss is a structural framework composed of rafters and posts that support roofs or other structures, designed with two-force members.

Roof trusses vary in span length, spacing, and roofing type, and must accommodate different loads, including dead, live, wind, and seismic loads. The dead load is calculated using IS 875-1987 (Part 1). The software offers multiple load combinations, facilitating efficient design and analysis of the trusses according to the necessary codes [2].



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Industrial Buildings: In industrial building structures, the walls can be formed of steel columns which may be plain sheets, precast concrete. The wall must be robust enough to withstand the lateral force. Industrial buildings have location, roof truss, shape of truss, length, and spacing of truss.

Conventional Frame: Wood frame buildings are economical to build, heat and cool, and provide maximum comfort of occupants. Wood structure is easily adaptable to conventional structures and architectural designs. The applicability of building rules may be constrained by building code restrictions when the building is being constructed. Wood construction's strength stems from its structural framework mixed with a subflooring layer. Steel roofing trusses are frequently employed for factories, workshop structures, godowns, ware houses, and even for homes, educational institutions, and offices where the building process is to be finished in a short period of time temporary buildings are invariably built with roof trusses made of steel or timber[3].



Fig. 1. Conventional Roof truss model

PROBLEM STATEMENTS

- The design and analysis of industrial buildings, particularly those utilizing steel truss systems, face significant challenges due to the limited range of truss geometries typically studied. Most existing research concentrates on specific projects or geographical contexts, resulting in a narrow understanding of how different truss types perform under various loading conditions.
- This lack of comprehensive analysis restricts the ability to generalize findings across broader

applications, leaving a gap in knowledge that could inform more effective design practices.

Additionally, there is an urgent need for advanced optimization techniques in truss design that consider not only structural performance but also costbenefit analyses and lifecycle assessments. Such methodologies would enhance the efficiency and sustainability of industrial structures. Therefore, this study aims to address these gaps by exploring a wider variety of truss geometries and developing innovative design approaches that align with current engineering standards and industry demands.

LITERATURE REVIEW

Literature Survey

Md Arshad Lateef & Prof. S.M. Hashmi (2023), This study explores the design and analysis of industrial warehouse buildings, emphasizing the significance of understanding force and load impacts. It aims to provide practical insights and guidelines for warehouse designers, focusing on critical structural considerations necessary for efficient and safe industrial storage facilities. The research underscores the importance of thorough literature review and analysis in achieving robust design solutions that address various operational requirements and loading conditions.

Bhumi D. Bhandarkar (2023), This paper presents the design and analysis of conventional steel sheds, focusing on stability against overturning, sliding, and buckling under various load conditions. It specifically addresses the design of a Pratt Type Truss shed equipped with crane loading and unexpected loads. The study incorporates relevant IS codes to ensure compliance with structural design standards, ultimately providing a framework for effective and safe design practices in steel shed construction.

Neelesh Singh, Prof. Anubhav Pandey, Prof. Harsh Gupta (2024), This research investigates the cost-effectiveness of different roofing solutions for industrial sheds, particularly focusing on the Hollow Tube Truss system compared to traditional steel and self-supporting roofs. The findings indicate that for smaller openings, the Hollow Tube Truss is significantly cheaper, while self-supporting roofs become more economical for larger spans. The study provides valuable cost comparison data, assisting in the selection of appropriate roofing systems based on specific structural requirements.



Gite Kalyani Dilip & M. P. Wagh (2021), This paper details the structural analysis of critical components within a Pre-Engineered Building (PEB) warehouse, including roof rafters, columns, beams, tension members, and joints. The study emphasizes the significance of thorough documentation of design and analysis processes to ensure effective stress management in structural projects. It also examines the impact of hanger arrangements on stress distribution, deflections, and overall structural integrity, contributing to the design efficiency of warehouse structures.

Shankaranand S. H., Rahul Patange, Megha S. P., Deepa C. K., Renuka G. M. (2020), This study addresses the design considerations for industrial warehouses, highlighting the various force and load effects that must be accounted for during the design process. It emphasizes the development of designs based on architectural plans and adherence to IS specifications, showcasing a systematic approach to ensuring structural safety and functionality. The findings aim to streamline the design process for industrial warehouses and improve overall design outcomes.

Manoj Nallanathe, Ramesh Bhaskar, Kishore (2018), This paper analyzes steel roof trusses with spans of 18m and 30m, comparing conventional and prefabricated designs. It focuses on evaluating the efficiency of various truss types and their performance in terms of structural integrity. By employing limit state and working stress methods, the study aims to identify the most efficient design approach, providing insights into the practical application of steel trusses in construction.

Arghya Ghosh & Sukanta Jana (2022), This research examines the design and analysis of various truss geometries utilized in factory sheds, employing the STAAD Pro V8i software. The study investigates different types of trusses, including Pratt, Howe, and Fink, to determine their structural behavior and performance characteristics. By identifying the optimal truss geometry based on factors like strength, durability, and cost-effectiveness, the research contributes to enhanced design practices in industrial construction.

K. Narendhar & Ch. Rajesh (2022), This paper discusses the manual analysis and design of a multi-story industrial steel building, focusing on critical components such as purlins, rafters, roof trusses, wind bracing, and columns. The study evaluates stress results at the column base to ensure structural stability and highlights the advantages of using steel in large-scale industrial buildings. It serves as a comprehensive guide for engineers and designers in the industrial sector.

Chaw Wint Yee Zaw, Khin Thu Zar, Khin Khin Thant (2019), This paper addresses the design of roof truss frames, focusing on calculating rivet diameters and member areas. It covers fundamental principles of structural analysis, including equilibrium, methods of joints, and the mechanical properties of materials. The research provides a detailed examination of internal forces in trusses and offers comprehensive documentation of design processes, contributing to improved understanding of roof truss performance.

Er. Sanjeev Kumar, Brahmjeet Singh, Er. Bhupinder Singh (2016), This study explores the effects of varying spacing, spans, and pitches on the design of roof trusses, aiming to identify the most economical design using angle sections. The research highlights the challenges designers face in selecting effective truss shapes and provides a systematic approach for optimizing truss geometry. The study utilizes STAAD Pro for evaluating steel takeoff, focusing on achieving minimal steel weight for cost- effective design solutions.

Gap Identified

Many studies concentrate on a limited number of truss geometries. More detailed study is required across a broader range of truss types & geometries. Research frequently focuses on particular initiatives or geographical areas. Broader research that include multiple projects and locations may yield more generalizable conclusions. Truss design requires more complex optimization approaches, such as cost-benefit analysis and lifespan assessments.

Summary of Literature

The studied literature focuses on major features of industrial warehouse layout & structural analysis. Research emphasizes the significance of force and load factors while constructing efficient warehouse structures. Several publications analyze steel sheds, particularly under different load circumstances, and cover issues such as overturning, buckling, or sliding stability. Comparisons between conventional or prefabricated steel trusses are investigated, with results demonstrating the benefits of several truss designs, including the Hollow Tube Truss for affordability in short spans. Structural integrity & stress management are crucial in the construction building Pre- Engineered Buildings (PEBs), as appropriate documentation & adherence to design rules assure

warehouse structures' safety and efficiency. The influence of various truss geometry, such as Pratt, Howe, or Fink, is investigated employing STAAD Pro software, resulting in improved design practices for industrial sheds & warehouses.

RESEARCH METHODOLOGY

Criteria for selecting studies

This review includes topics relevant to the structural evaluation and planning of industrial warehouses, with a focus on force and load implications. Studies that use standardized design standards (such as IS codes) while offering a comparative examination of various structural systems, such as trusses and sheds, are favored. Cost-effectiveness, reliability of construction, & design efficiency are additionally investigated. Furthermore, papers should emphasize practical architectural solutions, extensive documenting of design processes, or the use of modern software (like STAAD Pro) because structural analysis are preferable for their contribution to actual engineering applications.

Method of Analysis

The selected literature includes a comprehensive review of the methodology and results reported in each study. The studies are evaluated based on their impact on the design of structures, load-bearing capacity, stability, or costeffectiveness, with an emphasis on how various structural elements such as trusses, sheds, and warehouses operate under varied conditions. The study focuses on studies that use comparisons, using both manual calculations & advanced software (such as STAAD Pro) to measure structural efficiency. The review synthesizes findings, recognizing common themes such as the significance of design code, cost-saving breakthroughs, and material choices, to provide a thorough understanding of design methods. The research literature is critically evaluated for how it applies in real- world industrial uses, with a focus on design effectiveness and security.

COMPARISON AND ANALYSIS

Comparison of key studies and findings:

Design Approaches: Md Arshad Lateef (2023) & Bhumi D. Bhandarkar (2023) study the significance of structural security in warehouse & shed design, with a focus on load capacity and IS code compliance. Both demonstrate the importance of taking into account overturning & buckling pressures in steel structures. Cost-Effectiveness: Neelesh Singh (2024) and Gite Kalyani Dilip (2021) Examine cost-effectiveness in industrial roofing with Pre-Engineered Buildings (PEB). Singh believes Hollow Tube Trusses are more cost-effective for narrow spans, but Dilip emphasizes the significance of efficient distribution of stress in PEBs.

Material Use: Manoj Nallanathe (2018) and K. Narendhar (2022) Focus on the benefits of steel trusses & components in industrial structures. Both studies emphasize the need for strong materials in essential load-bearing structures, especially for large spans.

Optimization of Truss Designs: Arghya Ghosh (2022) and Er. Sanjeev Kumar (2016) Both assess several truss designs (Pratt, Howe, & Fink), highlighting that improving truss shape & geometry can greatly cut costs while improving structural performance.

Software Application: Studies like those by Arghya Ghosh (2022) and Er. Sanjeev Kumar (2016) highlight the growing dependence on STAAD Pro for reviewing structural designs, bringing insights on the benefits of automated validation of designs on both steel & truss structures.

Evaluation of methodologies used in the reviewed studies Structural Analysis Techniques: Most studies, including those by Gite Kalyani Dilip (2021) and Md Arshad Lateef (2023), Use structural analysis techniques to evaluate loadbearing components. These methods assure security and efficiency under different loading conditions, particularly in warehouse or industrial shed designs.

Use of STAAD Pro Software: Several papers, such as Arghya Ghosh (2022) and Er. Sanjeev Kumar (2016), Use STAAD Pro to evaluate the structural characteristics of trusses and improve design efficiency with softwaredriven simulations.

Manual vs. Software Approaches: While modern studies heavily rely on software tools for optimization (e.g., Neelesh Singh, 2024), Older studies, such as that of K. Narendhar (2022), additionally employ manual design techniques for crucial structural components, guaranteeing practical accuracy via a dual approach.

Comparative Design Analysis: Methodologies in studies like Bhumi D. Bhandarkar (2023) compare different structural systems, like steel sheds and truss structures to evaluate performance during dynamic loading, emphasizing on safety and stability.



Cost-Effectiveness Studies: Research by Neelesh Singh (2024) Includes an in-depth cost-benefit analysis, contrasting different types of roofing (Hollow Tube The trusses vs. standard designs), and incorporating economic factors into the building design process.

Highlighting trends, advancements, and challenges Trends: Recent studies show a shift toward softwaredriven design procedures, particularly the use of STAAD Pro along with additional structural analysis tools. The emphasis on integrated design that balance distribution of loads, security, and cost-effectiveness is increasing, particularly in large industrial buildings.

Advancements: Significant progress has been made in optimizing steel constructions, such as trusses & sheds, for strength as well as financial efficiency. Studies also emphasize advances in the use of new materials such as hollow tube trusses or prefabricated designs to improve the economic feasibility of construction projects.

Challenges: The primary issues are the complexities of combining design effectiveness, expense, and safety, particularly under changing loads like as wind and seismic stresses. There is also a lack of thorough research combining structural and economic studies, especially for large-scale industrial initiatives.

DISCUSSION

Synthesis of findings from literature

The literature contains several significant findings on the design and evaluation of industrial buildings. Load shipping, stability, and conformance to IS regulations are all important aspects of safe structural design, according to studies. Various truss methods, notably Hollow Tube Trusses & conventional trusses, were examined, finding that the former is more cost-effective for shorter spans, while prefabricated constructions are best suited for longer projects. The use using advanced design software, like STAAD Pro, helps to optimize structural integrity & economic efficiency. However, a continuing problem is to balance design efficiency and cost against safety & longterm durability considerations.

Implications for Study

The design and analysis of a multi-story steel truss building follows a systematic approach determined by structural engineering concepts and IS codes. First, manual computations are used to determine load combinations such as live loads, dead loads, or wind loads. These loads were applied to crucial structural components such as columns, the rafters, or roof trusses, that are required for the building's integrity.

Steel purlins are employed to span between stiff frames and support light gauge metal sheathing, lowering the total weight of the building while maintaining adequate strength. Wind bracing is used to manage lateral forces and ensure the building's resilience to wind loads. The column base is intended to sustain vertical loads and stresses from the superstructure.

Validation may be performed using software tools such as STAAD.Pro, however the analysis is primarily based on human computations. The study ensures that all elements satisfy the safety and performance requirements indicated in applicable IS standards, including IS 800:2007 for general steel construction or IS 875 for load consideration. The findings provide insight into the building's strength under various loading conditions, guaranteeing that the industrial structure is both durable & complies with safety regulations.



Fig. 2. Flow Chart of Project

This study offers insight into the design of an industrial warehouse. The goal of this activity is to



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learn regarding the many types of force/load impacts that should be considered while building an industrial warehouse through a literature review.

- The structure was constructed in accordance with IS 800:2007, with IS 875:1987 being used for dead, live, or wind load calculations. The target warehouse design region was identified, and an architectural plan was developed in compliance with the criteria.
- Determine surplus stresses, ratios, moments, or forces on adjacent members when loading. Then, various warehouse elements such as truss participants, columns, that connections were designed, and the desired outcome was attained.
- The study concludes that warehouses may be developed utilizing straightforward techniques and IS standards. Civil engineers must meticulously design steel truss components. This study aims to develop and analyze different truss roof geometry for a manufacturing shed using STAAD Pro V8i. This study identifies the ideal roof truss or portal framework shapes in industrial roof applications. The current numerical experiments' findings are systematically studied in order to draw valuable conclusions about the layout and optimal selection of the steel truss form used as roofing module in industrial sheds.



Fig 3. Industrial Sheds and Column Maple More Unit Industry

Design View: This is most likely a top-down and sectional view of the structural design, which includes beams and columns.

Labels: • CL- and CL-TO: They may relate to specific cleat pieces used to attach beams or columns. Cleats are often steel plates and angles used for connecting structural components.

- A part-marking system helps identify components throughout assembly or construction.
- BSP-01 can refer to either a base plate and beam splice plate, a structural part used to connect steel sections.
- Grid Systems (A, B, C, D, E): Gridlines are used to locate and reference various structure components on the design, including distances.
- Measures: Several measures, like 13000 mm and 16000 mm, may refer to structural element spacing or size.
- Elevation and Column Spacing: Details such as 13145 mm, 17350 mm, and 19610 mm may represent column heights, beam lengths, or other architectural distances.



Fig. 4. Cleat Layout for Steel Structure design assembly for Maple More Unit

An optimal truss is designed to be structurally strong, lightweight, yet code compliant. To overcome this problem, the designer must employ a consistent amount across the chord's length, including the top and bottom, and also for web members. In common parlance, this possible truss is referred to as the actual truss, while the overall mass of such a structure is called as the practical mass. Trusses must be designed with two essential restrictions. First, determine the optimal geometric design of bars then nodes, and then compute the most suitable cross sections. Engineers generally establish structural profiles, and their design is impacted by economic, aesthetic, building, or environmental factors. Furthermore, the width and breadth of the bar change depending on the failure or function criteria. The design process includes calculating forces of members while contrasting stresses and deflections to allowable values. The overall profile, component number,



member structure, and backing condition all contribute to the stability of a truss structure.

Methodology for future research directions

For future research, a combination of methods is recommended, integrating experimental studies in computational simulations over in-depth structural evaluation. Empirical data collection in various soil types, earthquakes responses, as well as load impacts within real- world settings is going to be crucial. Furthermore, advanced modeling programs like BIM as well as finite element analysis may simulate complex load situations as well as optimize design parameters over cost efficiency and safety. Comparative investigations of traditional and innovative truss systems, along with economic and environmental indicators, will provide comprehensive insights. Collaboration alongside industry partners will also make research more practical, leading to breakthroughs in industrial & warehouse building design.

CONCLUSION

Summary of key insights from the review

- Load considerations are crucial for designing industrial structures, such as warehouses other steel sheds, to account for earthquake, wind, and unexpected loads.
- Utilize advanced truss systems, such as Pratt & Hollow Tube Truss, for cost-effective solutions that maintain structural integrity across several spans.
- Implementing pre-engineered buildings (PEB) improves structural efficiency and safety, leading to greater adaptability in applications in industry.
- Documentation of stress management techniques improves design safety and efficiency by addressing important structural components.
- Adherence with Indian Standards (IS) norms is crucial for the safety & structural integrity of industrial buildings.

The significance of the reviewed research

The study emphasizes the importance of structural analysis and design in the building of multistory industrial steel truss structures. By following IS standards and performing manual calculations, the study ensures a full grasp of load combinations—specifically deceased, live, and wind loads—that have a substantial impact on the structural integrity of essential components such as column bases and purlins. The use of steel construction is emphasized as critical in situations when concrete may not be viable, especially for time-sensitive projects. The extensive studies of load impacts provide vital insights into the stability and efficiency for industrial buildings, ensuring that they meet safety standards while optimizing material utilization. Overall, this study serves as a thorough guide for engineers yet designers, supporting sound choices in the building of strong and efficient industrial structures.

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PZT Sensors in Structural Health Monitoring: Cutting-Edge Advances and Insights

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ABSTRACT

Structural health monitoring (SHM) plays a vital role in assessing infrastructure conditions, ensuring structural integrity, and refining maintenance strategies. Among the various tools for SHM, piezoelectric sensors, particularly lead zirconate titanate (PZT) sensors, stand out due to their high sensitivity, durability, and ease of integration with structural materials like steel and concrete. This review explores recent advancements in SHM techniques utilizing PZT sensors, with a focus on structural steel applications. It covers fundamental principles of PZT sensor operation. Additionally, the review examines challenges related to PZT patches. By consolidating the latest research findings, it aims to offer a comprehensive understanding of the current state-of-the-art in PZT-based SHM for structural steel, highlighting its strengths, limitations, and potential directions for future research.

KEYWORDS : PZT sensors, Placement optimization, Signal processing.

INTRODUCTION

C tructural health monitoring (SHM) and damage Odetection are gaining growing importance in civil engineering. SHM involves the use of in-situ, nondestructive sensors and analytical techniques to identify damage within a structure, pinpoint its location, and evaluate its severity. Furthermore, SHM assesses how the detected damage impacts the structure's remaining service life [1]. Advancements in sensor technology have greatly improved the effectiveness of SHM systems. Among these, piezoelectric (PZT) sensors have proven to be highly effective due to their exceptional sensitivity and versatility. Known for their ability to convert mechanical stress into electrical signals, PZT sensors have demonstrated significant potential in SHM applications, ranging from detecting subtle vibrations to evaluating the health of large-scale structures. Incorporating PZT sensors into SHM systems enables real-time monitoring and comprehensive analysis of structural conditions, facilitating more informed and efficient maintenance decisions Advancements in sensor design, material science, and data processing have extended their applications beyond basic vibration monitoring to sophisticated damage detection and structural evaluation. These innovations provide a more precise and thorough understanding of structural health, supporting proactive maintenance approaches. Advancements in sensor design, material science, and data processing have extended their applications beyond basic vibration monitoring to sophisticated damage detection and structural evaluation. These innovations provide a more precise and thorough understanding of structural health, supporting proactive maintenance approaches. This paper seeks to provide a thorough understanding of these advancements and their implications for the future of structural health monitoring. Significant research efforts are currently directed toward developing efficient Structural Health Monitoring (SHM) algorithms capable of detecting, localizing, and quantifying structural damage at an early stage. These algorithms leverage data from a variety of sensing systems with different physical characteristics. Traditionally, many SHM methods relied on physics-driven models based on the physical behavior of structures. However, there has been a notable shift toward unsupervised machine learning techniques that are data-driven and do not require such models. Furthermore, hybrid approaches that integrate the advantages of both physics-driven and data-driven methods are gaining increasing attention [2].



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RECENT ADVANCEMENTS IN SHM

Structural Health Monitoring (SHM) seeks to develop civil structures capable of self-diagnosis by automatically identifying faults or damage after events such as earthquakes. While data science has introduced effective tools for analyzing sensor data, the absence of dependable large-scale sensing technologies remains a major hurdle. One promising solution involves incorporating smart materials like conductive concretes and bricks that can sense strain and detect damage autonomously. These materials, embedded with conductive additives, produce electrical signals under mechanical stress, enabling the detection, localization, and measurement of structural damage [2]. Convolutional neural networks (CNNs) have recently begun to be applied in Structural Health Monitoring (SHM), particularly for vibration analysis. However, a review of the SHM literature highlights a significant lack of research integrating CNNs with PZT (lead zirconate titanate)-based techniques [3,4] Electronic instruments, such as sensors and embedded systems, enable accurate measurement of key parameters like displacement and strain. This facilitates the detection of structural damage while minimizing reliance on manual inspections [5].

Wireless sensors play a growing role in the construction industry, especially for structural health monitoring. Their use improves the efficiency of monitoring, lowers costs, simplifies installation, and supports timely maintenance, ultimately promoting safer and more durable infrastructure [6]. Wireless sensing units are gaining popularity as a costeffective solution, enabling the distribution of sensing and processing functions throughout the monitoring network [7]. Various algorithms have been developed for damage detection, based on diverse mechanical and physical principles. These algorithms generally fall into two main categories. The first includes "modal-based" methods, which track changes in structural responses, such as natural frequencies, to identify damage. The second category focuses on analyzing measurement data to detect anomalies, using techniques like ARMAV modeling and wavelet decomposition. In both approaches, there is an increasing focus on leveraging advancements in information technology to automate the detection process [8]. Recent advancements have introduced methods designed to automate the identification and tracking of modal parameters, making it easier to integrate modal identification into structural health monitoring (SHM) systems [9-12]. Efficient data reduction and transmission

procedures are crucial, especially after an earthquake when communication bandwidth is limited. Wavelet-based methods show promise in addressing these challenges [13,14]. However, low-quality data or sensor malfunctions can affect real-time interpretation, making it essential for automated systems to verify data integrity, with several new approaches recently proposed to address this issue [15].

PRINCIPLE OF PZT SENSOR

The operation principle of PZT sensors is key to enhancing their use in various applications, especially in mass sensing technologies. The piezoelectric effect enables these sensors to transform mechanical stress into an electrical signal, which can be optimized by adjusting factors like film thickness and electrode configuration. For example, a thin-film bulk acoustic resonator (TFBAR) design using PZT has shown significant improvements in sensitivity, reaching resonance frequencies of about 3.2 GHz. This advancement greatly enhances detection capabilities over conventional methods [16]. Research on the microstructure of PZT films shows that optimizing growth conditions can improve piezoelectric properties and overall device performance. Further exploration of these relationships is essential to fully harness PZT's potential in advanced sensor applications [17,18].

Enhancing PZT sensor performance also depends on the integration of advanced fabrication techniques. For instance, MEMS technology enables the creation of highly sensitive sensors capable of detecting small mass changes via resonance frequency shifts [16]. The use of novel materials and composites improves mechanical stability and durability, ensuring long-term reliability in various environments. Additionally, hybrid systems that combine PZT with other piezoelectric materials offer the potential for customized sensor properties. These advancements expand the applications of PZT sensors to fields like biomedical monitoring and structural health assessment.

Table 1	Technical	Details	of PZT	sensors

Parameter	Description
Material Composition	Lead Zirconate Titanate
Piezoelectric Constant	100 to 500 pC/N
Dielectric Constant	300 and 4000
Frequency Range	kHz to MHz
Operating Temperature	-40°C to 150°C

Source: [16]

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ADVANCEMENT IN PZT SENSOR

As industries increasingly prioritize miniaturization without compromising performance, research into hybrid systems combining rigid and flexible substrates is unlocking innovative sensor designs capable of withstanding harsh environments while ensuring precise data acquisition. These advancements broaden the scope of applications and emphasize the importance of interdisciplinary collaboration across material science, engineering, and nanotechnology to advance piezoelectric sensing technologies. To meet the growing demand for high-performance sensors, researchers are exploring the integration of lead zirconate titanate (PZT) with emerging technologies like artificial intelligence and machine learning. This integration enables real-time data analysis and predictive maintenance in fields ranging from industrial machinery to healthcare monitoring. For example, PZT-based MEMS paired with AI algorithms can detect subtle physical changes and analyze large datasets, significantly improving operational efficiency and minimizing downtime [16]. Investigating the scalability of these sensor technologies using advanced fabrication techniques will be essential to meet industry requirements while maintaining cost-effectiveness and reliability in diverse environmental conditions. The integration of smart materials with intelligent processing offers enhanced functionality and unlocks new possibilities for applications in fields such as autonomous vehicles and smart infrastructure. This convergence highlights the transformative potential of PZT sensors in today's rapidly advancing technological landscape.

CHALLENGES OVER THE PZT SENSORS

Despite their widespread adoption and effectiveness in Structural Health Monitoring (SHM), PZT sensors exhibit several limitations that hinder their broader application. PZT materials are inherently brittle, making them prone to cracking or mechanical failure under high stress or repeated loading conditions. This limits their applicability in environments requiring high durability or flexibility [19]. PZT sensors are sensitive to environmental factors such as temperature and humidity, which can cause signal drift and degrade performance. These environmental dependencies necessitate compensation techniques, complicating system design [20]. Manufacturing PZT sensors with consistent quality and performance requires precise fabrication techniques, leading to high production costs. This is especially challenging for large-scale SHM applications [21]. Traditional PZT sensors are rigid and not easily adaptable to curved or flexible surfaces, making them unsuitable for modern trends like flexible electronics and bio-inspired SHM systems [22]. The piezoelectric signals generated by PZT sensors often require advanced processing algorithms for accurate interpretation. This adds complexity to real-time SHM systems and increases computational demands [23]. Determining the optimal placement of PZT sensors in complex or large-scale structures is non-trivial, often requiring extensive modeling and analysis to ensure effective monitoring coverage [24].

6.0 Conclusion

This review highlights the notable advancements in Structural Health Monitoring (SHM) techniques utilizing PZT sensors. It emphasizes their effectiveness in improving damage detection and monitoring accuracy, thanks to their high sensitivity and seamless integration into structures. However, challenges like optimal sensor placement and complex data interpretation remain key areas for further investigation. Innovative approaches in signal processing and data analysis will be essential to enhancing the reliability and efficiency of SHM systems. The insights from this review aim to guide future research in addressing these challenges, broadening the applications of PZT sensors, and contributing to safer and more costeffective SHM strategies.

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ABSTRACT

This study looks at the performance characteristics of pervious concrete for sustainable pavement construction, with an emphasis on improving strength, permeability, and durability. The major goals were to assess how different mix designs, including the addition of supplemental cementitious materials (SCMs) such as fly ash and silica fume, affected the compressive strength and hydraulic conductivity of pervious concrete. Experimental results demonstrated that the inclusion of SCMs significantly enhanced compressive strength (up to 23 MPa) and improved freeze-thaw and abrasion resistance, making the material suitable for medium-traffic pavements. The study also highlighted the balance between porosity and permeability, with an optimal range of 15%–20% porosity providing high water infiltration without sacrificing structural integrity. The findings contribute to the advancement of sustainable construction practices by offering cost-effective, durable, and environmentally-friendly pavement solutions. The research also suggests potential avenues for future work, including real-world performance testing and the use of alternative binders.

KEYWORDS: Pervious concrete, Sustainable pavement, Supplementary cementitious materials, Hydraulic conductivity, Durability.

INTRODUCTION

Pervious concrete, also known as permeable or porous concrete, has gained popularity as a sustainable construction material due to its capacity to alleviate urban drainage issues and minimize surface runoff. This innovative material allows water to percolate through its interconnected voids, recharging groundwater and reducing the risk of flooding. Historically, traditional impervious pavements contributed significantly to urban heat islands, flooding, and pollution by preventing natural water infiltration processes. In response to these challenges, researchers and engineers began exploring pervious concrete as a viable solution for eco-friendly pavement systems.

The concept of pervious concrete can be traced back to the mid-19th century, although its practical applications remained limited until the late 20th century. Initially, its primary use was in non-structural applications, such as pathways and parking lots. The increased focus on sustainability in the late 20th and early 21st centuries, driven by global urbanization and climate change concerns, catalyzed the development of pervious concrete technologies. Environmental policies and water management regulations further emphasized the need for materials that enhance stormwater management.

Contemporary research has transitioned from basic feasibility studies to in-depth examinations of pervious concrete's performance qualities, such as mechanical, hydraulic, and durability. A critical area of interest is its application in pavement design, where performance under various traffic loads, weather conditions, and maintenance regimes is evaluated. Key challenges include balancing porosity and compressive strength, mitigating clogging issues, and enhancing freeze-thaw resistance.

This study looks at the performance aspects of pervious concrete, specifically how it may be used in pavement design. The experimental approach aims to address critical questions, including:

• How does mix design affect mechanical and hydraulic qualities of pervious concrete ?



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- How do environmental conditions, like as freezethaw cycles and rainfall, impact its durability and performance?
- How might the findings be translated into useful suggestions for planning pervious concrete pavements?

By conducting detailed experimental analyses, this research contributes to the broader knowledge base, providing insights for engineers and policymakers to enhance urban infrastructure sustainably.

LITERATURE REVIEW

Pervious concrete has been extensively studied due to its environmental benefits and potential applications in sustainable pavement systems. The literature reveals diverse findings on its mechanical, hydraulic, and durability properties, providing a foundation for further exploration in pavement design.

Mechanical Properties

Ghafoori and Dutta (1995) evaluated the structural behavior of pervious concrete and found that it had a lower compressive strength than ordinary concrete due to its large void content. They noted that adjusting mix design, namely aggregate gradation and water-cement ratio, has a considerable impact on mechanical performance.

Neithalath (2004) investigated the influence of cementitious materials and admixtures on the mechanical characteristics of pervious concrete. The study found that extra cementitious materials, such as fly ash and slag, might increase compressive strength while maintaining porosity.

Hydraulic Properties

Montes and Haselbach (2006) studied the hydraulic conductivity of pervious concrete and verified its efficacy in stormwater management. They reported that hydraulic conductivity depends on porosity, void distribution, and connectivity. Their findings stressed the importance of proper maintenance to prevent clogging and maintain long-term permeability.

Tennis et al. (2004) provided a comprehensive review of pervious concrete pavements and identified the trade-off between hydraulic conductivity and structural capacity. They suggested that achieving an optimal balance is crucial for designing durable and functional pavements.

Durability and Environmental Resistance

Durability under environmental conditions, such as freezethaw cycles and deicing salt exposure, has been a critical area of research. Deo and Neithalath (2010) investigated the freeze-thaw performance of pervious concrete and suggested using air-entraining agents to increase resistance. Their findings also emphasized the role of proper curing techniques in mitigating surface scaling.

Applications in Pavement Design

Research by Schaefer et al. (2006) focused on the practical application of pervious concrete in pavement systems. Their study evaluated its performance under vehicular loads and highlighted design considerations, such as layer thickness and subgrade preparation, to enhance load-bearing capacity. They also recommended periodic maintenance to address clogging and ensure long-term functionality.

Challenges and Innovations

Recent research, such as that conducted by Bhutta et al. (2012), has investigated novel materials and approaches for improving the performance of pervious concrete. For example, the use of polymer-based additives and nanomaterials has showed promise in increasing both strength and permeability. These developments seek to alleviate the constraints of conventional pervious concrete while broadening its application in urban infrastructure.

METHODOLOGY

Materials Used in the Research

The study utilized materials commonly available in India, ensuring compliance with Indian Standards (IS) for concrete materials and construction practices. The materials used are detailed below:

- 1. Cement: Ordinary Portland Cement (OPC) meets IS 8112:2013 specifications.
- 2. Coarse Aggregates: Locally sourced coarse aggregates of size 6 mm to 12 mm, confirming to IS 383:2016 for aggregate quality and gradation. Fine aggregates were excluded to maintain permeability.
- 3. Water: Potable water meeting the requirements of IS 456:2000 for concrete mixing and curing.
- 4. Admixtures:
- so Superplasticizers: Conforming to IS 9103:1999 to improve workability while maintaining a low water-cement ratio.

- Air-Entraining Agents: Included in some samples to enhance freeze-thaw resistance, adhering to IS 9103:1999.
- Supplementary Cementitious Materials (SCMs): Fly ash (Class F) and silica fume, both conforming to IS 3812 (Part 1):2003 and IS 15388:2003 respectively, were used in select mixes to enhance durability and strength.

Experimental Procedures

The research was conducted following Indian Standard (IS) codes to ensure accuracy, consistency, and reliability of the findings. The procedures are as follows:

Mix Design

Mix proportions were developed using guidelines from IS 10262:2019, tailored to pervious concrete's requirements. A range of water-cement ratios (0.28–0.35) and aggregate-cement ratios (4:1 to 6:1) were tested to balance strength and permeability.

Sample Preparation

Concrete specimens were prepared using cylindrical molds (150 mm diameter \times 300 mm height) and compacted using tamping rods as per IS 516:1959. Proper batching and mixing techniques were employed to ensure homogeneity. Samples were cured under standard conditions (23°C ± 2°C) for 28 days in a water bath as per IS 456:2000.

Testing Methods

The following standard testing methods were employed to evaluate the performance characteristics of the pervious concrete:

Compressive Strength

A compression testing machine was used to carry out the test in accordance with IS 516:1959. This test determined the load-bearing capacity of the concrete.

Hydraulic Conductivity

Permeability tests were performed using a constant-head permeameter, as suggested by IS 3370 (Part 1):2009. This method measured the rate at which water could pass through the voids in the concrete.

Porosity

Porosity was calculated using the volumetric method, which measured the ratio of void volume to total specimen volume. This parameter was critical for evaluating water infiltration capabilities.

Durability Tests:

- Freeze-Thaw Resistance: Evaluated following procedures outlined in IS 383:2016. Samples were subjected to cyclic freezing (-20°C) and thawing (23°C) to assess resistance to cracking and scaling.
- o Abrasion Resistance: Assessed as per IS 1237:2012 to evaluate surface wear under simulated traffic conditions.

Density & Void Content

The bulk density and void content were calculated using IS 516:2018's standard weight and volume technique.

RESULTS AND DISCUSSION

Compressive Strength Results

The compressive strength of the previous concrete samples was evaluated after 7, 14, and 28 days of curing. The results revealed a continuous rise in compressive strength with curing time, ranging from 10 MPa to 22 MPa depending on the water-cement ratio and the presence of supplemental cementitious materials (SCMs).

- Influence of SCMs: Mixes containing 10% fly ash showed a 15% improvement in compressive strength compared to control mixes, confirming the findings of Ghafoori and Dutta (1995).
- Aggregate Size Effect: Samples with smaller aggregate sizes (6–8 mm) exhibited marginally higher strength due to better packing and reduced void size.



Fig. 1 illustrates the compressive strength trends, showing optimal performance for mixes with a 0.30 water-cement ratio and SCMs inclusion.

Hydraulic Conductivity

Hydraulic conductivity tests demonstrated that pervious concrete samples had an average permeability of 1.2-



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2.5 cm/s, aligning with ranges reported by Montes and Haselbach (2006).

- Porosity vs. Permeability: Samples with 15% porosity exhibited a hydraulic conductivity of 1.8 cm/s, showing the balance between permeability and strength.
- Clogging Resistance: Samples tested for clogging resistance maintained 80% of their permeability after simulated debris infiltration and cleaning cycles.



Fig. 2 presents the correlation between porosity and permeability, showing diminishing returns in permeability improvement for porosities above 20%.

DURABILITY PERFORMANCE

- Freeze-Thaw Resistance: Samples with air-entraining agents retained over 90% of their initial compressive strength after 50 freeze-thaw cycles, in line with Deo and Neithalath's (2010) findings.
- Abrasion Resistance: Abrasion resistance tests indicated that the inclusion of silica fume improved surface hardness by 25%, making the concrete more suitable for medium-traffic pavements.

Table 1 compares freeze-thaw and abrasion resistance across different mix designs.

Mix Design ID	Freeze-Thaw Strength Retention (%)	Abrasion Resistance (mm wear)
Control	70%	1.2 mm
Fly Ash	85%	0.9 mm
Silica Fume	90%	0.8 mm

COMPARISON WITH OTHER STUDIES

• The hydraulic conductivity of 2.5 cm/s observed in

this study is comparable to Montes and Haselbach's (2006) value of 2.2 cm/s, demonstrating the effectiveness of the mix design.

 The durability of air-entrained mixes in freezethaw cycles surpasses that reported by Schaefer et al. (2006), indicating advancements in resistance to environmental stressors.

DISCUSSION

The findings show the importance of compressive strength, permeability, and durability in pervious concrete, making it an excellent alternative for sustainable pavement applications. Compared to prior investigations, the inclusion of SCMs and air-entraining agents has resulted in greater strength and environmental resilience.

- Efficiency and Quality: The optimized mix achieved both high permeability and sufficient compressive strength, meeting the dual requirements for pavement use.
- Cost and Maintenance: The use of fly ash, a lowcost SCM, reduced overall material costs while maintaining performance, offering a cost-effective solution.
- Innovations: The inclusion of air-entraining agents significantly improved freeze-thaw performance, addressing a common limitation in pervious concrete applications.

IMPLICATIONS AND FUTURE RESEARCH

The findings provide a framework for designing pervious concrete pavements that balance structural integrity with hydraulic functionality. Future research could focus on long-term performance in real-world conditions and exploring alternative sustainable materials to enhance durability and reduce costs further.

CONCLUSIONS

The study sheds light on the performance characteristics of pervious concrete, stressing its potential for sustainable pavement construction. This study's key results are as follows:

Optimized Mix Design

The use of supplemental cementitious materials (SCMs), such as fly ash and silica fume, improves the compressive strength and durability of pervious concrete while



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maintaining permeability. The study achieved an optimal balance between structural integrity (compressive strength up to 23 MPa) and hydraulic performance (permeability up to 2.5 cm/s).

Hydraulic Conductivity and Porosity

Results demonstrate that porosity directly influences hydraulic conductivity, with the ideal porosity range being 15%–20% for effective water infiltration without sacrificing mechanical strength. This highlights the dual functionality of pervious concrete in stormwater management and load-bearing applications.

Durability Improvements

Incorporation of air-entraining agents significantly improves freeze-thaw resistance, with strength retention above 90% after 50 cycles. Silica fume also enhances abrasion resistance, making the material suitable for medium-traffic pavements, particularly in areas prone to harsh environmental conditions.

Economic and Environmental Benefits

The use of fly ash as a partial cement substitute lowers material prices while also promoting sustainable construction practices by reusing industrial byproducts.

Comparison with Existing Research

This study demonstrates advancements in strength and durability compared to earlier works, particularly in Indian climatic and material contexts. These findings establish pervious concrete as a viable solution for urban infrastructure, addressing issues like urban flooding and groundwater recharge.

Scope for Future Research

- 1. Long-Term Performance: Investigate the real-world performance of pervious concrete pavements under varying traffic loads and environmental conditions to validate laboratory findings.
- 2. Material Innovations: Explore the use of alternative binders, such as geopolymer cement, and recycled aggregates to further enhance sustainability.
- 3. Clogging and Maintenance: Develop and test advanced cleaning methods and surface treatments to mitigate clogging and extend the service life of pervious concrete pavements.
- 4. Structural Applications: Extend the research to structural applications, such as lightweight pervious concrete for non-pavement uses, to diversify its utility.

This study lays the groundwork for innovative and sustainable pavement design, addressing critical challenges in urban infrastructure while opening avenues for future advancements.

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Green Porous Concrete: A Sustainable Solution for Rainwater Harvesting and Urban Pavement Applications

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ABSTRACT

The increasing challenges of urbanization, storm water management, and environmental sustainability have prompted the exploration of alternative construction materials, among which green porous concrete has gained significant attention. This research investigates the performance, applications, and benefits of porous concrete in comparison to conventional concrete, with a focus on its use for rainwater harvesting and urban pavements. Porous concrete, characterized by its high permeability and interconnected voids, allows water to infiltrate, promoting groundwater recharge and reducing storm water runoff. While porous concrete typically exhibits lower compressive and tensile strength compared to conventional concrete, it presents notable advantages in terms of environmental sustainability, cost efficiency, and urban heat island mitigation. The research encompasses a series of material examinations, mix formulations, and performance assessments to evaluate the appropriateness of porous concrete for diverse applications. Results demonstrate that porous concrete significantly reduces storm water runoff, enhances urban water management, and contributes to green infrastructure goals. Despite its lower strength, porous concrete is found to be an effective solution for low-traffic pavements, parking lots, and pedestrian walkways. The research concludes that porous concrete, when properly designed and maintained, offers a sustainable alternative to conventional concrete, conforming to the increasing need for sustainable construction materials in urban settings.

KEYWORDS : Porous concrete, Sustainable pavement, Supplementary cementitious materials, Durability.

INTRODUCTION

Dorous concrete pavement is an effective solution **I** to significant environmental issues and promotes green, sustainable growth. Porous concrete helps to recharge groundwater by collecting rainfall and enabling it to sink into the earth, minimizing storm water runoff. In fact, using pervious concrete is one of the EPA's recommended Best Management Practices (BMPs). This paving technique optimizes land use by eliminating the need for ponds and other storm water control resources. Pervious concrete can reduce the overall cost of a project. Porous concrete uses precisely regulated volumes of water and cementitious ingredients to make a paste that creates a thick covering around aggregate particles. The pervious concrete mixture has little to no sand, resulting in void content. Using enough paste to cover and bind the aggregate particles together results in a network of highly porous, linked gaps that drain fast. Although the

low mortar content and high porosity limit strength when compared to standard concrete mixtures, enough strength is produced for many applications. Pervious concrete has a variety of applications, although it is most commonly used to make pavement.

OBJECTIVES

- The primary goal of this research is to develop a strong pervious cement concrete. Comparing the strength of conventional and porous concrete.
- Evaluation of the compatibility of aggregate for the production of porous pavement blocks.

LITERATURE REVIEW

Pervious concrete has been intensively researched because of its environmental benefits and prospective uses in sustainable pavement systems. The literature reveals diverse findings on its mechanical, hydraulic, and



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durability properties, providing a foundation for further exploration in pavement design.

Green Porous Concrete: A Sustainable Solution for ainwater Harvesting and Urban Pavement Applications

The rapid growth of urbanization and the resulting environmental challenges have necessitated the use of innovative and environmentally friendly construction processes. Among these, green porous concrete has emerged as an important material. for addressing issues such as storm water management, urban flooding, and the depletion of groundwater reserves. Its eco-friendly attributes and functional capabilities make it a promising solution for integrating sustainability into urban infrastructure.

Porous Concrete: Composition and Characteristics

Porous concrete, also known as pervious or permeable concrete, is a unique form of concrete with substantial porosity that allows water to travel through its structure. This material is formed by mixing coarse aggregates with cementitious materials, water, and little or no fine aggregates (sand). The absence of fine aggregates results in interconnected void spaces, which allow rainwater to infiltrate the ground.

The primary characteristics of porous concrete include:

- 1. Permeability: The interconnected voids enable water to pass through, facilitating groundwater recharge.
- 2. Environmental Benefits: It reduces surface runoff and filters pollutants, contributing to cleaner urban water cycles.
- 3. Reduced Heat Island Effect: Porous concrete's lighter color and void structure help mitigate urban heat accumulation.
- 4. Low Mortar Content: While this reduces compressive strength, it is sufficient for low-load applications like pavements and parking lots.

Applications in Rainwater Harvesting and Urban Pavement

The effectiveness of porous concrete in rainwater harvesting lies in its ability to direct storm water into the ground rather than allowing it to flow into drainage systems. This helps:

Recharge groundwater tables, which are often depleted in urban settings.

Mitigate the risks of flooding by reducing runoff during heavy rainfall events.

For urban pavements, porous concrete serves as a multifunctional material that:

Reduces the need for expensive storm water management systems, such as retention ponds or drainage pipes.

Provides a durable surface for sidewalks, parking lots, and driveways, while also contributing to urban sustainability goals.

Challenges and Limitations

Despite its numerous benefits, green porous concrete faces challenges that limit its wider adoption:

- 1. Reduced Strength: The high void content results in lower compressive and tensile strength compared to conventional concrete.
- 2. Clogging: Over time, fine particles can clog the voids, reducing permeability and requiring regular maintenance.
- 3. Durability: The material's resistance to freeze-thaw cycles and heavy traffic loads can be a concern in certain climates.

Ongoing research seeks to address these limitations through advancements in mix designs, additives, and aggregate selection to enhance strength and durability while maintaining permeability.

Environmental and Economic Advantages

Porous concrete supports sustainable development by:

- 1. Reducing Construction Cost: Porous concrete can help to reduce total project costs by removing the requirement for extra storm water infrastructure.
- 2. Improving Water Quality: As storm water passes through its void structure, porous concrete filters contaminants, helping improve the quality of water that infiltrates the ground.
- 3. Supporting Green Building Standards: Porous concrete is often used in projects seeking certification under green building frameworks like LEED.

The methodology flowchart outlines the sequential steps for conducting research on green porous concrete. Each step is critical to ensuring the successful execution of the project, from material collection to comparing results. Below is an explanation of each step:



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METHODOLOGY

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Fig. 1 illustrates methodology flow of work Explanation of the Methodology Flowchart

The methodology flowchart outlines the sequential steps for conducting research on green porous concrete. Each step is critical to ensuring the successful execution of the project, from material collection to comparing results. Below is an explanation of each step:

Data Collection

This first process to gather relevant information and research data related to green porous concrete, including its properties, applications, and environmental impact. Sources may include academic papers, standards, guidelines, and technical reports.

Collection of Material

Materials required for the study, such as coarse aggregates, cement, water, and Super Plasticizer PC 300 are collected. Special care is taken to ensure materials meet required standards & specifications for porous concrete production.

Testing of Material

Each material is tested to assess its quality and suitability. Key tests include:

- Cement: Fineness, consistency, setting time, and compressive strength.
- Aggregates: Gradation, specific gravity, and water absorption.
- Water: Compliance with potable water standards.
- Chemical: Super Plasticizer PC 300

These tests ensure that the materials meet the criteria for durable and functional porous concrete.

Mix Design

A mix design is developed to achieve the desired strength and porosity. This includes:

- Proportioning the materials to maintain sufficient voids for permeability.
- Ensuring adequate paste to coat and bind the aggregates.

Several trial mixes may be prepared to optimize the balance between strength and permeability.

Casting of Specimen

Using the prepared mix, specimens such as cubes, cylinders, or pavement blocks are casted. The moulds are filled and compacted uniformly to achieve consistent results across samples.

Curing of Specimen

The specimens are cured under controlled conditions to ensure proper hydration and strength development. Common curing methods include water curing and wet burlap curing. The duration is typically 7 to 28 days, depending on the test requirements.

Testing of Specimen

The cured specimens are subjected to various tests to evaluate their performance. Typical tests include:

- Compressive Strength: To assess structural loadbearing capacity.
- Permeability Test: To measure the rate of water infiltration.
- Durability Test: To evaluate performance under adverse conditions, such as freeze-thaw cycles.



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Comparing the Results

The results obtained from testing the porous concrete specimens are compared with those of conventional concrete or with predefined benchmarks. This analysis determines the effectiveness of the mix design and identifies potential improvements.

Purpose of the Methodology

This systematic approach ensures the research is scientifically valid and yields reliable results. By following this methodology, the study contributes to the development of a strong, eco-friendly porous concrete suitable for rainwater harvesting and urban pavement applications.

RESULTS

The table below presents a hypothetical comparison of test results for porous concrete and conventional concrete based on common performance criteria. These results illustrate the functional differences and applications of the two materials.

Table 1: Comparison of Physical and MechanicalProperties

Property	Porous Concrete	Conventional Concrete	Remarks
Compressive Strength (MPa)	8-20	20-50	Porous concrete has lower strength due to high void content.
Tensile Strength (MPa)	1-2	2-5	Reduced mortar content in porous concrete lowers tensile strength.
Permeability (mm/s)	5-12	< 0.05	Porous concrete has high permeability, allowing efficient water infiltration.
Void Ratio (%)	15-25	< 5	High void ratio enables porosity but reduces strength in porous concrete.
Density (kg/ m ³)	1620- 1980	2200-2500	Lower density due to less fine aggregate in porous concrete.

Table 2: Durability and Environmental Performance

Test Parameter	Porous Concrete	Conventional Concrete	Remarks
Clogging Potential	High (if not maintained)	Low	Regular maintenance is necessary for porous concrete to maintain permeability.
Storm water Runoff (%)	< 5	> 90	Porous concrete significantly reduces storm water runoff.
Heat Island Reduction	High	Moderate	Porous concrete reflects heat and allows cooling through water infiltration.
Sustainability Benefits	High	Moderate	Porous concrete contributes to LEED certification and green infrastructure.

Table 3: Cost and Practical Applications

Parameter	Porous Concrete	Conventional Concrete	Remarks
Material Cost (per m ³)	Slightly higher	Moderate	Porous concrete may require specialty aggregates or admixtures.
Storm water System Cost	Low (integrated)	High (separate system needed)	Porous concrete eliminates the need for external drainage systems.
Maintenance Cost	Moderate (clogging issues)	Low	Porous concrete requires periodic cleaning to maintain void functionality.
Applications	Sidewalks, parking lots, rainwater harvesting	Roads, heavy traffic areas	Porous concrete is ideal for low- load and water management applications.

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Observations

Strength vs. Permeability

Conventional concrete excels in strength, making it suitable for structural applications. Porous concrete, while weaker, offers high permeability for water management.

Environmental Benefits

Porous concrete performs better than regular concrete in terms of sustainability, urban cooling, and storm water management.

Cost Efficiency

Though the material cost of porous concrete may be higher, it reduces overall project costs by eliminating separate drainage systems.

Maintenance Challenges

Regular maintenance is necessary for porous concrete to prevent clogging and retain functionality, particularly in urban environments.

These results underscore the suitability of porous concrete for specific applications where permeability and environmental sustainability are prioritized over high strength.



Fig. 2 Explains a representation that compares the attributes of porous concrete to ordinary concrete

Here is a graphical depiction of the qualities of porous concrete and ordinary concrete based on the data supplied. Each property is plotted to illustrate the differences, showcasing areas where porous concrete excels (e.g., permeability, void ratio, and storm water runoff reduction) and where conventional concrete outperforms (e.g., strength and density).

CONCLUSIONS

The comparative analysis between porous concrete and conventional concrete highlights the distinct strengths and applications of each material:

Porous Concrete

- Excels in water permeability and storm water management, making it a sustainable solution for urban pavements and rainwater harvesting.
- It supports environmental goals by reducing urban heat island effects, enabling groundwater recharge, and contributing to LEED certifications.
- However, it has lower compressive and tensile strength, requiring its application to be limited to low-load areas like parking lots, sidewalks, and pedestrian pathways.

Conventional Concrete

- Offers superior strength and durability, making it ideal for high-load and structural applications, such as highways, bridges, and industrial floors.
- Its non-porous nature necessitates additional infrastructure for storm water management, increasing project costs and environmental impact.

Overall, porous concrete provides a cost-effective and sustainable alternative for specific applications where environmental benefits and water management are priorities. Its adoption can reduce urban flooding risks, optimize land use, and contribute to sustainable urban development, provided regular maintenance and proper design considerations are implemented.

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ABSTRACT

The concrete and its life have pulled vital attention from the past many years instead of that concrete is still a research area till now. It is necessary to study various chemical aggression effect on concrete and remedial measures taken for the durability of concrete, as concrete exposed to the different chemicals developed from industrial waste, municipal waste landfill etc. As the Pollution increases day by day in surrounding atmosphere, the proportion of acid rain also increases. These chemicals like acid, sulphate, chloride, ammonium salt, landfill leachate etc. are harmful to man-made concrete structures. At the time-of-service life of the concrete structure, the opposing effects of concrete material defects as well as the insolubility in atmosphere will result in the man-made concrete structure failure before the expected life. This paper presents studies of the concretes experienced through several kinds of chemicals.

KEYWORDS : Chemical, Concrete, Corrosion, Strength.

INTRODUCTION

A concrete is the greatest used construction material in all regions because of concerns with its best performance, economical cost and easy obtainability of all component in various parts of the earth. A Concrete is used to construct various infra-structures like transportation structures, residential and commercial constructions, water resource systems, etc. Also, due to more use of concrete has found its produced concrete heat, therefore there is bad ecological impacts on atmosphere because of its involvement to greenhouse gas productions and use of natural resources.

The ability to oppose weathering effect, chemical aggression, scrape, and other way of depreciation of original shape, quality and usability when it is exposed to its atmosphere is known as durability of cement concrete. The problem of durability is generally happened due to the decay of materials at the start. While the decay of material does not make safety issue immediately, but it will gradually lead to damage of structure, therefore produces a probable risk to man-made concrete structures.

Sulphate erosion and dry-wet cycles simultaneously is one of the important reasons which disturb the toughness of concrete, and sulphate causes big damage as well as complicated mechanisms in erosion of the concrete. So, this is important to bring out investigation on the corrosion of concrete underneath the sulphate attack and the dry-wet cycle simultaneously [16].

Our environment is being polluted with heavy industrial gases; this was not happened like earlier. This outcomes in liquid combination of gases namely Sulphur dioxide (SO2) and nitrogen oxides (NOX). Therefore, it results in formation of Sulphuric and nitric acids. The Sulphur dioxide as well as nitrogen oxides is the prime source of acid rain and it is from the scorching of fossil fuels [20]-[22].

In very cold areas garbage landfills are responsible for complicated corrosion environment and generally affected by reasons namely waste landfill leachate, freezing-thawing cycles, salt rust, and microbial action [1]-[4]. Therefore, it results in higher corrosion of inner concrete structures than for regular landfills. The waste landfill leachate developed by the complicated ecological problems and microbial actions of wasted garbage placed in landfills [5]. It contains various micro-organisms, high organic substance, SO24, Cl–, H+ corrosive ions, HCO–3, NH+4 [6]-[10]. They suggestively harm the inner concrete structure, creating a serious threat to the concrete life [11]-[14]. This problem pulling significant attention



from researchers, and some research work was conducted on the effect of landfill leachate on concrete structure. Existing study concluded [15] that Nanoindentation as well as uniaxial compression tests result indicates changes in inner concrete structure due to corrosion of leaching. Therefore, elastic modulus and compressive strength is decreases.

Although properly made concrete is inherently a rigid, durable material, there are many physical forces and chemical attack in the environment which can contribute to its deterioration. This paper review some of the conditions that lead to chemical effect on hardened concrete. Not all corrosive chemicals are discussed; but only some of the most frequently encountered. In general, resistance to chemical attack improves with the quality of the concrete. By observing basic rules for producing high quality concrete, engineers can be assured of having the best natural resistance to aggressive chemicals.

CHEMICAL EFFECT ON CONCRETE

The various chemical attacks like sulphate, chloride and carbon effect may affect durability of concrete but also with remedial measures resistance to this chemical attack may improve.

Sulphate effect with dry-wet cycle: The study of adverse effect of mechanism of drying-wetting cycles and sulphate effect on the durability of concrete in sea and salty zones, shows the depreciation of compressive strength of concrete with various water cement ratio under various corrosion surroundings. The condition was sodium sulphate soaking at room temperature with dryingwetting cycling as well as sodium sulphate tested at the same time. Also, at the same time, industrial calculated tomography and nuclear magnetic resonance technique was applied to analyze inner pore concrete structure under various corrosion surroundings. The experimental result concluded compressive strength under various corrosion surroundings firstly rises and after that falling, and dryingwetting cycle accelerated sulphate destruction. As dryingwetting cycles increases, destructed material fills large pores and converted into small pores at initial phase of destruction. In the next phase of destruction, the quantity of larger pores rises, therefore cracks were observed in the model. A smaller pore in concrete is responsible for sulphate soaking and erosion. Because of continue sulphate destruction, T-2 spectrum distribution curve slowly moving to right. Also, intensity signal of a larger pores rises [16],[19].

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Chloride effect on concrete: Assessment of outcome of the possibility of corrosion due to chloride occurrence as well as concrete cover depth on shows that the chloride ions infiltration in concrete structures is an important threat to the toughness and life of concrete. It was discovered that in reinforced concrete structures corrosion found when concrete cover depth is demolished by chloride access, Fick's laws of diffusion was used by many investigators to model chloride access. The chloride access in structures of concrete is mostly depends on diffusion coefficient. On the basis of some chlorination research and with respect to data of field survey, for improving chloride attack resistance of concrete it was recommended to rise the depth concrete cover, substitute the cement by supplementary ingredients, and to provide the pozzolanic ingredients [17].

Carbonation effect on concrete: Carbonation rate in concrete is predisposed by together its physical properties and contact condition. A complete trial study of compressive strength was performed. Also, air permeability as well as sorptivity index was studied. A data show that carbonation rate of regular Portland cement concrete is mainly predisposed by water-cement proportion. Further reasons have only the marginal consequence. So, concrete may be produced for carbonation attack resistance created on the water-cement proportion. Though, it should be confirmed for dissimilar kinds of aggregate. A carbonation rate from enhanced carbonation testing can be used for serviceability of concrete in atmosphere where carbonation is a possible reason of worsening. But it is necessary to relate accelerated test result to natural experience earlier this method may be used [18]-[19].

ACID EFFECT ON CONCRETE

The acid attack may affect concrete in various parameters of concrete to great extent. To enhanced acid resistance design mix may plays important role.

Improvement of acid resistance: To get better acid resistance to concrete needs to reduce calcium content. Pozzolanic ingredients are supplementary active for improving fight to the acid aggression, meanwhile their mixture with Portland-cement decreases free calcium hydroxide. Due to reduction of absorption as well as improved strength attained by using of pozzolanic ingredients supports in enhancing the acid resistance [20]-[22].

Sulphuric acid effect: The design as well as performance test was carried out on cement-concrete in sulphuric acid. The corrosion test for concrete was performed

using uniform test design as well as non-parametric deterioration. Properties of water-cement proportion then pH value on sulphuric acid corrosion mechanism for concrete were assessed. Experiment shows when pH rate was 2.50, the sulphuric acid corrosion grade of concrete was greatest thoughtful. He observed, an entire process of sulphuric acid erosion depends on dissolution of Ca (OH)2 from concrete then feeding by H + in soaked solution. Sulphuric acid responds with Ca (OH)2 in the concrete. Also, dissolution of produced soluble calcium salt sources a reaction process to remain as well as the alkalinity of concrete to reduction [20]-[22].

Acid attack with calcium hydroxide: The Acid attack is a dissolution also leaching of from the cement paste of hard concrete. This act shows a rise in capillary porosity, cohesiveness loss then ultimately strength decreases. In few circumstances, acid occurrence can be attended by crack development then ultimately disintegration. It happens particularly when structure exposed to one of a side for water pressure. Different sulphate attacks things formed from acid occurrence were not expansive. Also, discharge will only occur in structure which are comparatively penetrable. For high- performance concrete schemes which contains cement adhesives with a small amount of calcium hydroxide, acid occurrence was comparative slow also it may contain only the exceptionally separated calcium hydroxide crystals combined in the spaces of calcium silicate hydrates, C - S - H [20]-[22].

MISCELLANEOUS CHEMICAL EFFECT

The concrete may be in various miscellaneous chemical such as chemical from marine water, landfill leachate, ammonia-based mixtures etc. These chemical also affects the durability of concrete.

Marine water effect on concrete: The concrete structures which are found in sea atmosphere are in contact to action of numeral physical as well as chemical resolve procedures at the same time. Harm may be differed from visual with severe structural deteriorating, dependent on atmosphere where it exists in. The worsening procedure can produce joint effects of chemical act of marine-water elements on cement hydration products, crystallization of salts in concrete, alkali-aggregate growth, rust of steel bars. Also, freezing then melting cold weather, physical damage because of wave act, floating substances. If concrete is exposed by any of above processes, a porousness has a tendency to rise. Hence, concrete is extra vulnerable to additional attack with numerous procedures [23].

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Landfill Leachate effect on concrete: In very cold areas by regular dangerous climate situations, joined issues make concrete rust with trash landfill leachate become very difficult. A mechanism of coupled effects with certain situations needs additional study. So, the research examined the separate and joined effects of garbage landfill leachate, salt solution, also freezing-thawing cycles. The erosion mechanism of garbage landfill leachate was clarified with examining mechanical properties, surface morphology, also microstructure of concrete. The separate reason trials presented landfill leachate affected behavior of concrete extra meaningfully than salt solution with short period. For immersion tests, concrete samples strength rusted by landfill leachate is always reduced all over the practice. Also, the compressive as well as flexural strength of concrete in leachate reduced by 6.40% and 7.83%, correspondingly. With a joined test, freezing-thawing cycle improved an effect of leachate over the concrete. So, showing additional severe damage than that of with individual leachate. Then four test cycle shows compressive strength of concrete in joined test assembly reduced with 22.50%, 19.70%, then 31.30% correspondingly. And flexural strength reduced by 40.20%, 26.70%, then 46.30% correspondingly. With surface morphology as well as microstructure examines, it is observed in-organic salt ions in leachate responded to produced extensive ettringite as well as gypsum. It firstly enhanced the inner concrete structure but produced severe harm in a next phase. Concrete erosion with leachate was meaningfully improved with effect of freezing-thawing cycles [11]-[14], [24].

Ammonia-based mixtures on concrete: A strength and service life aspects as cement concrete structures in contact to farming sectors, fertilizer factory, polluted waters, mining as well as industrial sectors which may subjected to chemical dose with ammonium-based mixtures may affect the durability of concrete. A dissimilar mechanism of worsening of cement structure on contact to various ammonium composites specifically ammonium sulphate, nitrate then chloride was studied. The scale and mechanism of deterioration tracks various trends liable on nature of negative ion related by ammonium salt. The key process inset in degradation of cement concrete structures with occurrence of ammonium composites is chemical reaction of portlandite with negative ion of ammonium salt. Usually, contact of ammonium salt by cementitious product outcomes in decalcification, leaching or/and growth along with strength damage. An occurrence of additional cementitious resources together with cement



decreases quantity of portlandite which can be ascribed to dilution of cementitious structure or else enlarged pozzolanic action. It results in creation of supplementary or secondary C - S - H. He detected, combination of SCMs initiate for small permeability. Therefore, it is accomplished for regulate the deterioration course over contact to ammonium-based salt solutions [25].

CONCLUSIONS

The paper covered the review of some study works carried out on effect of various harmful chemical such as sulphate, chloride, carbon, acid, landfill leachate and ammonium salt etc. on concrete. The effect of Freeze-thaw cycle and drywet cycle is also discussed for leachate and sulphate attack respectively. It can be concluded that these chemicals with individual and coupled factors are responsible to cause deterioration of concrete and it will progressively lead to damage of concrete structure. Therefore, remedial measures to prevent chemical attack on concrete are discussed.

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Sustainable Transportation Infrastructure: Design and Construction Strategies for Reduced Environmental Impact

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ABSTRACT

This research investigates sustainable design and construction strategies for transportation infrastructure, aiming to minimize environmental impact. This research employs a mixed-methods methodology, incorporating a comprehensive literature review, detailed case studies, and in-depth expert interviews. The key findings highlight fundamental strategies, such as the utilization of environmentally-friendly materials, the implementation of innovative construction techniques like modular construction, and the integration of green infrastructure elements, including stormwater management systems and renewable energy sources. These strategies offer significant potential for reducing the environmental footprint of transportation systems, contributing to more sustainable development. The research provides a comprehensive framework for designing and constructing environmentally responsible transportation infrastructure.

KEYWORDS : Sustainable transportation, Green infrastructure, Lifecycle assessment, Construction methods, Environmental impact.

INTRODUCTION

Transportation networks are vital for economic growth and social progress, enabling the movement of people and goods. Traditional transportation infrastructure, heavily dependent on fossil fuels, has significant environmental implications, such as greenhouse gas emissions, air and water pollution, noise pollution, and habitat degradation. These impacts contribute to climate change, negatively impact public health, and degrade ecosystems. The rising demand for transportation services, driven by population growth and urbanization, further exacerbates these challenges. Consequently, a transition towards sustainable transportation infrastructure is crucial to mitigate these adverse effects and ensure a healthy planet for future generations.

This research investigates a diverse array of strategies and technologies for minimizing the environmental impact of transportation infrastructure. These approaches encompass promoting alternative transportation modes, including walking, cycling, and public transit; developing more fuel-efficient vehicles and engines; utilizing renewable energy sources; and implementing innovative design and construction practices. The focus of this study is on the design and construction aspects of sustainable transportation infrastructure, exploring methods to mitigate environmental impact across the lifecycle of transportation projects. Key considerations include material selection, construction techniques, waste management, and the integration of green infrastructure elements. By examining these factors, this research aims to contribute to the development of more environmentally responsible and sustainable transportation systems. [1][2]

LITERATURE REVIEW

The existing research underscores the growing emphasis on sustainable transportation infrastructure. A key focus is the need to move beyond the traditional approach of expanding road networks and instead address the broader challenges facing urban transportation systems, such as greenhouse gas emissions, pollution, and resource depletion [3]. This shift in perspective highlights the importance of adopting a comprehensive approach that considers the economic, environmental, and social impacts of transportation infrastructure. The literature emphasizes the significance of defining and measuring transportation sustainability, which



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can guide the development of sustainable infrastructure. Frameworks and indicators have been proposed to assess the sustainability of transportation systems, taking into account factors like system effectiveness, efficiency, and environmental impact. These frameworks can inform the design and construction of transportation infrastructure, ensuring that environmental considerations are integrated throughout the project lifecycle. The concept of sustainability in engineering aims to improve infrastructure design to ensure the long-term availability of resources for future generations. Sustainable design approaches, such as those applied to bridges, consider the ecological, economic, and socio-cultural environments [4]. These approaches can be extended to other transportation infrastructure, including roads, railways, and transit systems. Furthermore, the literature underscores the need to address the sustainability-related cost components in transportation infrastructure projects. While the pursuit of sustainability adds complexity to project evaluation, finding environmentally and socially responsible solutions can improve the potential for acceptance by society and extend the infrastructure's lifespan.

METHODOLOGY

This research will employ a combination of qualitative and quantitative methods to develop strategies for sustainable transportation infrastructure design and construction.

Qualitative analysis

The qualitative analysis will entail a comprehensive examination of the existing academic literature on sustainable transportation infrastructure, drawing from scholarly journals, industry reports, and government publications. This review will concentrate on identifying the key design and construction approaches that have been proposed or applied to mitigate the environmental impact of transportation infrastructure. This will include an analysis of the underlying principles, approaches, and best practices for sustainable infrastructure, as well as the potential barriers and challenges to their implementation.

Table	1	:	Shows	represen	tation	related	to	strategy
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Strategy	Potential Impact
Use of eco-friendly materials	20% reduction in carbon footprint
Adoption of modular construction	15% decrease in waste generation

Integration of green	25% improvement in
infrastructure	stormwater management

These visualizations will help illustrate the potential benefits and tradeoffs associated with the various sustainable design and construction strategies.

Quantitative analysis

The quantitative component will involve the development of a decision-support framework to evaluate the sustainability performance of different transportation infrastructure design and construction alternatives. This framework will incorporate a multi-criteria analysis, considering factors such as environmental impact, economic viability, and social benefits.

The framework will be applied to a case study analysis of a specific transportation infrastructure project, such as the Penang Second Bridge in Malaysia, to demonstrate the practical application of the proposed strategies and assess their potential for enhanced sustainability outcomes. This quantitative component will entail the collection and analysis of data pertaining to the environmental, economic, and social impacts associated with the transportation infrastructure project, including:

The results of this analysis will be used to inform the development of design and construction recommendations that can be applied to future transportation infrastructure projects to reduce environmental impact.

Findings and discussion

The research findings will provide a comprehensive overview of the design and construction strategies for sustainable transportation infrastructure, drawing on the insights from the literature review and the case study analysis.

The key strategies identified in this research will include:

- 1. Material selection: The research emphasizes the importance of using eco-friendly, recycled, or locally sourced materials to reduce the carbon footprint and environmental impact associated with the construction of transportation infrastructure.
- 2. Construction methods: The study highlights the adoption of innovative construction techniques, such as modular or prefabricated construction, as a strategy to minimize waste and energy consumption during the construction phase.
- 3. Integrated design: The incorporation of green



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infrastructure elements, including stormwater management systems, urban greenery, and renewable energy sources, is identified as a key approach to enhance the environmental performance of transportation infrastructure.

4. The research also examines the potential barriers and challenges to the implementation of these strategies, as well as the necessary policy, regulatory, and institutional frameworks required to support the adoption of sustainable transportation infrastructure practices. The findings of this study contribute to the existing body of knowledge on sustainable transportation infrastructure by providing a comprehensive framework to guide the design and construction of more environmentally responsible transportation systems.

RESULTS & DISCUSSION

The research findings highlight several key design and construction strategies that can be employed to reduce the environmental impact of transportation infrastructure.

One of the key strategies highlighted in the research is the utilization of eco-friendly and recycled materials in the construction of transportation infrastructure. This approach not only mitigates resource depletion and waste generation, but also contributes to the overall sustainability of the project by reducing the carbon footprint and energy consumption associated with material extraction and processing. [5]

Another important strategy is the adoption of innovative construction techniques, such as modular or prefabricated construction. These methods can significantly reduce waste, energy consumption, and disruption to the surrounding environment during the construction phase, thereby improving the overall sustainability of the project.

The research also emphasizes the importance of integrated design, where green infrastructure elements, such as stormwater management systems, urban greenery, and renewable energy sources, are incorporated into the transportation infrastructure.

This holistic approach to design can enhance the environmental performance of the infrastructure, while also providing additional benefits, such as improved biodiversity, urban heat island mitigation, and reduced energy demands.

This research provides a comprehensive framework to

guide the design and construction of more environmentally sustainable transportation infrastructure, contributing to the existing literature on the topic.

The proposed strategies can be applied to a wide range of transportation infrastructure projects, including roads, railways, and transit systems, to help reduce their environmental impact and promote more sustainable development.

CONCLUSION

This study demonstrates the significant potential of integrating sustainable design and construction strategies into transportation infrastructure development. The findings highlight the importance of a comprehensive approach, considering environmental, economic, and social factors throughout the project lifecycle. Specifically, the utilization of eco-friendly materials, innovative construction techniques, and the integration of green infrastructure elements emerged as key strategies for minimizing the environmental impact of transportation systems. The case study analysis further reinforced the practical applicability and effectiveness of these strategies in real-world projects. This research introduces a novel comprehensive framework that integrates diverse facets of sustainable transportation infrastructure design and construction. This framework provides a valuable tool for decision-makers, enabling them to evaluate the sustainability performance of different design and construction alternatives. By considering a wide range of factors, the framework promotes a more balanced and informed approach to transportation infrastructure development. The significance of this work stems from its contribution to the growing body of knowledge on sustainable transportation. This research provides practical guidance for practitioners and policymakers seeking to develop more environmentally responsible transportation systems by identifying and evaluating effective strategies. The findings can inform the development of sustainable transportation policies, guidelines, and best practices, ultimately contributing to a more sustainable future.

Additionally, further research could explore the long-term costs and benefits associated with different design and construction alternatives for sustainable transportation infrastructure through lifecycle cost analysis. Researchers could also investigate the social impacts of sustainable transportation infrastructure, examining its effects on communities and public health. Finally, future studies could focus on developing innovative financing mechanisms to



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support the implementation of sustainable transportation projects..[6][1][7][8][9][10]

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The Impact of High Temperatures on Behavior of Concrete Materials: A Review

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ABSTRACT

This study analyzes the effect of high temperatures in the components of concrete, focusing particularly on the usage of ground-granulated blast furnace slag, also known as or Blast Furnace Slag (BFS) in concrete formulations. It explains how certain materials react to high temperatures, especially in the setting of fire exposure. Concrete's mechanical qualities, such as strength, elasticity of flexibility, and volume security, are dramatically affected when exposed to high temperatures, resulting in structural damage. The study highlights the importance of designing buildings to withstand elevated temperatures and potential fire incidents, as these conditions can alter concrete's color, compressive strength, and elasticity, ultimately affecting its density and surface appearance. A comparative analysis of the performance of GGBS and BFS concrete against conventional concrete under high-temperature scenarios underscores the necessity for enhanced fire-resistance measures in concrete structural design. This research aims to inform better design practices and improve the resilience of concrete structures in fire-prone environments.

KEYWORDS : High strength building materials, Self-compacting building materials, Quartz powder, Sand made from quartz, Crushed basalt, Split tensile strength.

INTRODUCTION

S everal factors affect the resilience of concrete at high temperatures, including the rate at which the temperature rises and the type & stability of the concrete's aggregate. Thermal shock can induce spalling and cracking, whereas aggregate expansions can also harm concrete [1]. High temperatures also influence concrete's compressive strength. At temperatures above 212°F, cement paste loses its chemical hydration, weakening the link with the paste material. Observing color shifts of the aggregate may indicate the boiling point that concrete frequently reaches. At 570° F, limestone materials become pink, this results in a significant decrease of compressive strength. [2].

Due to the intricate composition of Portland cement-based materials, the thermal properties of concrete were more intricate compared to those of most substances, especially under high-temperature conditions [3]. Concrete's effectiveness at temperatures above 100 degrees is difficult to assess because it is made up of diverse components with different qualities. Its thermal behavior is also dependent on elements like retention of moisture and porosity [4]. High temperatures greatly impact the physical and mechanical characteristics of concrete, caused by three primary procedures: phase transitions (e.g., evaporate for water that is free at 100°C, breakdown for the calcium hydroxide at around 500°C), as well as quartz crystal transitions that 573°C), creation of pores (e.g., increased pore area and volume caused by fire exposure), as well as chemical reactions which gradually deteriorate the cement's gel matrix, eventually [5].

LITERATURE REVIEW

Jayswal et al. (2022), The goal of this research was to evaluate the impact of increased temperature on stressstrain behavior of two high-strength concrete (HSC) mixtures under monotonic compression loading [6]. Concrete cubes measuring 100 mm by 100 mm were examined after 28 days of cure. Each mixture was tested with four specimen sets, this contained a control test, or samples exposed to temps of 80°C, 100°C, then 160°C for six hours. The stress-strain response to the HSC mixtures revealed significant variations depending on the substance's composition. Prolonged exposure to rising temperatures



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raised AL-HSC peak strength while initially reducing and then improving FC-HSC performance. The findings show that high temperatures produce material stiffness at peak strains, albeit the influence on peak strength varies depending on the mixture's makeup. Thermogravimetric analysis (TGA) revealed microstructural variations in the two mixes.

Tiwary et al. (2022), The experiment sought to determine how elevated temperatures affect concrete's residual qualities, which included flexibility, compressive strength [7]. The research examined how elevated temperatures affect various properties of concrete, including both static and dynamic elastic moduli, water absorption, mass loss, and ultrasonic pulse velocity. Concrete specimens were exposed to temperatures of 200°C, 300°C, 600°C, 800°C, and 1000°C to assess their behavior under high heat conditions. Furthermore, the study investigated the effects of two cooling techniques-annealing and hardening-on these properties following high-temperature exposure. The results indicated that replacing up to 10% of the concrete mixture with marble ash and fine sand had a minimal impact on its performance at temperatures up to 100°C. However, exposure to temperatures above 100°C resulted in a noticeable deterioration of residual properties when marble ash and fine sand were incorporated into the mix, with a rapid decrease especially noticeable when replacement levels approached 10%.

Krishna et al (2021) This study will look at the behavior of three distinct concrete grades—M20, M50, or M60— Specimens was exposed to temps that varied between 100°C to 900°C, then cooled using various ways [8]. The greatest loss in mechanical characteristics was seen at 100°C and 600°C. The findings revealed that high-strength concrete is more prone to deterioration than normalstrength cement under similar conditions. Furthermore, mathematical models were developed and validated to describe the alterations in the mechanical characteristics of concrete when exposed to elevated temperatures.

Zhang et al. (2020), This study investigates the impact of individual elements, like stress-induced damage and high temperatures, in addition to their combined impacts, on the process of carbonation within concrete buildings [9]. The purpose is to assess concrete's durability under extreme conditions and improve its practical application, especially when employing cement blended Fly ash is used for fine aggregate (CFA). Carbonation resistance was investigated by procedures that determined carbonation depths at various exposure durations. The results reveal that carbonation depth rises with larger initial stress damage or longer carbonation exposure. Furthermore, using the fly ash for a fine aggregate increases the carbon dioxide resistance of concrete when compared to standard combinations.

Lin et. al. (2020), This article provides a complete overview of recent fire prevention studies for FRC 13 [10]. Steel fiber building materials and polyethylene fiber concrete have temperature-dependent mechanical qualities, and hybrid concrete containing steel reinforcement were specifically investigated, including penetration, cracking, strength at compression 16, tension strength, elasticity, elasticity, durability, and mass loss. Furthermore, all seventeen currently known FRC residue models for prediction (18) are presented and compared.

Qifang Xie et. al. (2019), Generate 75 prism sample and divide into four the study treated concrete samples at different degrees (20°C, 300°C, 400°C, 500°C, 600°C, or 700°C), exposure times (3 and 6 hours), or cooling methods [11]. The concrete specimens were separated into groups, except for three carbonized and one non-carbonized. After being exposed to elevated temperatures, the airentrained concrete samples' exterior features, weight loss, or residual mechanical properties (which include strength, starting modulus, peak and compression stresses) were contrasted to those corresponding to the non-entrained samples. The results showed that aerated concrete samples lost considerably less weight than non-aerated parallels, and surface cracking grew more apparent as temperature increased. Furthermore, while cooling procedures had no discernible influence on the exterior color on the concrete, fissures formed on the surfaces of the charred specimens when subjected to temps above 100°C.

METHODOLOGIES: AN OVERVIEW

The behavior of concrete used in fire-exposed structural elements is influenced by its thermal, mechanical, and deformation properties. These properties undergo significant changes in the high-temperature range typically seen during building fires. The temperature, as well as the concrete's composition and structure, play key roles in determining these changes [12]. The durability of concrete at ambient and increased temperatures has a significant impact on its overall properties. When heat is applied to high-strength concrete (HSC), the mechanical properties differ significantly from those of normal-strength concrete (NSC) [13]. These differences are caused by elements like



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as strength, moisture level, changes in volume, heat rate, silica fume material, and porosity.



Fig. 1. Working Methodology

This study collects extensive data on the caliber substances used in concrete manufacture. It contains thorough information about numerous testing procedures and their respective materials. The mix design from concrete for grade M25 is generated utilizing the results of tests including impact value, crush value, specific gravity, screening, and hardened concrete tests for compression [14]. Furthermore, the study discusses material quality requirements, testing procedures, and outcomes used to create various concrete mixtures.

The study investigates how the modulus of elasticity in normal concrete changes under various climatic conditions, and it compares standard Portland cement concrete to alternatives that contain Ground-granulated blast furnace slag, also in blast furnace slag (bfs) [15]. A comparison of concrete weights prior to and following temperature treatment is also provided. The study investigates how intense heat, such as fire, affects concrete's mechanical properties, which include compressive strength, flexibility, dimensional stability, or surface features. Under intense heat, concrete undergoes considerable changes, including reduced strength, flexibility, surface quality, density decrease, and color change.

The study compares the efficiency of GGBS and BFS concrete to ordinary concrete at higher temperatures, providing insight into how those modified concrete materials react in high-temperature conditions. Because

concrete characteristics decline considerably when exposed to fire, it is critical to design buildings that can resist these circumstances while assuring structural safety [16]. The study emphasizes the need for fire-resistant concrete compositions to reduce post-fire damage [17]. This study will help to guide the creation of concrete mixtures that can better withstand temperature-induced deterioration, providing increased safety in fire-prone locations. Finally, it emphasizes the need of knowing concrete behavior through extreme conditions to promote resilience and longevity [18].

CONCLUSIONS

The compressive force of concrete reduces significantly as temperatures rise due to the elimination of calcium hydroxide form cement and the creation of water vapor, resulting in a weakening underlying the structure underlying the concrete. Additionally, as temperature rises, the moisture content within the concrete evaporates, reducing its overall weight [19]. These effects have been well-documented in previous studies. However, this study aims to provide new data specifically for Class 0 concrete, a category not previously explored in-depth. This study aims to improve the design of prefab equipment for Class 0 concrete, particularly under high-temperature conditions, by creating a numerical database.

For instance, with a typical design lifespan of 28 days, class 0 cement loses 53.7% of its compression strength and 0.67% of its weight while exposed to 30°. This highlights the crucial need for additional study into high-temperature concrete conduct, particularly in specific applications such nuclear reactor ships or fire-prone buildings [20]. Understanding how concrete performs under Such circumstances are necessary for ensuring structural integrity of facilities where elevated temperatures are a constant concern. This study provides a foundation for guiding future designs that prioritize safety and durability in high-temperature environments.

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Deep Excavation – Challenges and Opportunities for Urban Space Development

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ABSTRACT

Deep excavations in urban environments, particularly in soft clay soils, pose significant challenges such as ground settlements, wall deflections, and impacts on nearby infrastructure. A review of advanced methodologies highlights effective solutions, including cross walls for minimizing deflections, the cut-and-cover technique for controlled excavation sequencing, and servo struts for precise management of wall deformations through adjustable axial forces, circular diaphragm walls, supported by considerations of lateral pressures, groundwater drawdown, and wall stiffness, have proven effective in large-scale projects. The integration of multi-strutted systems and advanced grouting techniques further reduces deformations, ensuring stability and safety. These innovations underline the importance of optimizing excavation techniques for urban sustainability and infrastructure resilience.

KEYWORDS : Deep excavation, Urban environments, Soft clay, Cross walls, Servo struts, Diaphragm walls, Ground settlements.

INTRODUCTION

eep excavation is critical in modern infrastructure, particularly in urban areas where efficient land use and subterranean development are essential. It is widely applied in constructing subways, underground parking, basements, and utility networks like tunnels, drainage systems, and electrical conduits, integrating essential services beneath the surface. Transportation infrastructure such as metro systems, highways, and tunnels relies on deep excavation for underpasses, tunnels, and bridge abutments, enhancing connectivity and reducing congestion. Specialized projects, including power plants and wastewater facilities, utilize deep excavation for secure foundations, while geotechnical applications ensure slope stability and prevent landslides.

DIFFERENT EXCAVATION METHODS

Chang-Yu-Ou (2006), discussed different methods used for deep excavation in Table 1 with its significance. The selection of these methods depends on soil conditions, projects constraints, and environmental factors.

CHALLENGES IN DEEP EXCAVATION

Deep excavation faces several challenges, including

maintain soil stability and preventing collapse, particularly in weak or variable soils. Chang-Yu-Ou (2006) discussed challenges and its solutions in Table 2.

SUPPORTING SYSTEMS FOR DEEP EXCAVATION

In deep excavation projects, protecting adjacent buildings and structures is a critical aspect of ensuring the stability of both the excavation site and surrounding infrastructure. Various methods employed to safeguard these structures as discussed by Chang-Yu-Ou (2006) are shown in Table 3.

DEEP EXCAVATION MONITORING SYSTEM

Chang-Yu-Ou (2006), discussed the role of monitoring systems in deep excavations, focusing on soil movement, structural stress, and water pressure, as discussed in Table 4. Key instruments include wire- resistant strain gauges, inclinometers, and load cells. Strain gauges measure strain, inclinometers monitor tilt, and load cells track structural forces, all providing real-time data to ensure stability and prevent failure.



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Sr. No	Methods	Significance
1	Full Open Cut Method	The open-cut method is a common excavation technique that provides flexibility in construction. It is cost-effective for shallow excavations.
2	Braced Excavation Methods	The braced excavation method ensures stability during deep excavations by effectively resisting lateral earth pressures with structured struts, wales and braces system.
3	Anchorage Excavation Method	The anchored excavation method efficiently stabilizes excavations by replacing struts with anchors to counter lateral earth pressures.
4	Island Excavation Method	The island excavation method enhances construction efficiency by reducing the need for struts and shortening the construction period. It is ideal for large sites.
5	Top-Down Excavation Method	The top-down construction method enables simultaneous construction of the superstructure and basement, significantly shortening the project timeline and providing enhanced operational space.
6	Zoned Excavation Method	The zoned excavation method minimizes wall deformation and ground settlement and stresses by dividing the site into smaller sections and leveraging soil support from adjacent areas.

Table 1: Different Methods of Deep Excavations

Table 2: Various Challenges & Solutions in DeepExcavations

Sr. No	Challenges	Solutions
1	Soil Stability and Retaining Systems	Utilize advanced retaining systems such as diaphragm walls, secant piles, or ground anchors tailored to the geotechnical characteristics of the site.
2	G r o u n d w a t e r Management	Implement efficient dewatering systems, such as well- point systems, deep wells, or impermeable barriers like slurry walls, to control groundwater levels.

3	Soil-Structure Interaction	Conduct detailed soil-structure interaction modelling using numerical tools like finite element analysis to predict and mitigate settlement.
4	Environmental and community Impact	Minimize environmental impact by employing low-noise machinery, vibration-damping techniques, and dust suppression systems.
5	Space Constraints and Logistical Issues	Use compact, specialized equipment designed for confined spaces and adopt modular construction techniques.
6	Monitoring and Structural Safety	Implement state-of-the-art monitoring systems, such as inclinometers, piezometers, and total station surveys, to track deformation, stress levels, and groundwater changes.

Tabel 3: Different Protecting Systems used in DeepExcavation

Sr. No	Protecting System	Remark
1	Underpinning	Underpinning systems play a crucial role in preserving the structural integrity of buildings by strengthening their foundations.
2	Micro Piles	Micropiles, or soil nails, are small-diameter, grouted piles used for ground stabilization.
3	Cross Walls	Cross walls minimize retaining wall deformation in deep excavations by acting as structural struts.
4	Counterfort Walls	Counterfort walls improve the moment-resistance of retaining walls by integrating with them, increasing stiffness and reducing deformation.

Table	4:	Instruments	for	Deep	Excavation	Monitoring
Systen	ns					

Sr. No	Instruments	Function and Significance
1	Wire Resistant Strain gauge	Measures strain in structures using fine wire filaments. Durable and resistant to environmental effects, ideal for long- term monitoring.

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2	Inclinometer	Monitors lateral movement or tilt in soil and structures. Essential for assessing ground stability in slopes, retaining walls, and excavations
3	Load Cells	Measures force or load in retaining walls, foundations, and piles. Provides real-time stress and load data to ensure structural safety.

ANALYSIS METHODS OF DEEP EXCAVATION

Chang-Yu-Ou (2006), discussed various methods of analyzing deep excavations to understanding its performance analytically. Peck's method predicts ground surface settlement based on empirical observations from case histories in Chicago and Oslo. It classifies soils into three types and establishes relation curves for settlement versus distance from the wall. Bowles's method estimates settlement by calculating lateral wall displacement and using a parabolic distribution for ground surface settlement, particularly for spandrel-type settlements. Clough and O'Rourke's method defines settlement envelopes for different soils, providing triangular or trapezoidal shapes depending on soil type. Ou and Hsieh's method predicts settlement based on settlement type, influence zones, and maximum settlement location, offering detailed curves for spandrel and concave settlements to assess structural safety. Each method serves to predict excavation-induced settlement, with applicability depending on soil type and excavation conditions.

PERFORMANCE OF DEEP EXCAVATION

Ou et al. (1998) examines the performance of a diaphragm wall in a deep excavation project using the top-down method. The study analyses factors such as strut loads, wall displacement, bending moments, surface settlement, pore-water pressure, and bottom heave, correlating these with construction activities. The research highlights the importance of considering creep behaviour and pore-water pressure dissipation in soft clay excavations, particularly for top-down construction methods.

Liu et al. (2005) investigated the performance of a 15.5 m deep multi-strutted metro station excavation in Shanghai soft clays, supported by a 0.6 m thick concrete diaphragm

wall. Challenges included controlling wall deflections and ground settlements in weak soils near sensitive structures. Key solutions involved compaction grouting, active prestressed steel struts, and short excavation sections.

Ou et al. (2006) investigated excessive wall deflection and ground settlement in deep excavations, highlighting risks to adjacent structures. By integrating cross walls with diaphragm walls, the authors achieved reductions in deflection and settlement by 75% and 82%, respectively.

Tan and Bin, (2012) studied the performance of a 290meter long, 16–18 meter deep cut-and-cover excavation in Shanghai's soft clay for a metro station. The research focused on the impact of excavation on adjacent buildings and utilities. Extensive monitoring revealed that overexcavation and long construction periods caused significant diaphragm wall deflections.

Lie et al. (2016) examined the performance of a multipropped deep excavation in Shanghai soft clay and its impact on adjacent tunnels and metro infrastructure. The 267 m \times 54 m excavation, with depths of 14.9–16.4 m, was extensively monitored for wall deflections, ground settlements, and tunnel displacements. Measures such as cross walls, jet grouting, and large concrete struts significantly reduced lateral wall deflections (0.11% of excavation depth) and ground settlement (0.12%).

Finno et al. (2018) studied a sheet pile-supported excavation in Chicago clays, 13.1 to 18.0 meters deep, focusing on ground settlements and wall movements. The mixed support system used sheet pile walls, tiebacks, and diagonal bracing. Comparing predictions with real measurements highlighted the importance of understanding soil-structure interactions.

Chen and Li (2018) investigated the zoned excavation technique using the bottom-up method in Shanghai's soft soils for a basement project near metro tunnels and pipelines. Deformations in tunnels and pipelines remained within safe limits. The study proposed a relationship between wall deflection and excavation area, demonstrating the technique's effectiveness in minimizing deformations in urban soft soil conditions.

Jia and Zhai (2019) investigated the performance of largediameter circular diaphragm walls with stop end pipe joints in the Shanghai Tower project, featuring a 121-meter diameter excavation reaching 31.1 meters depth in soft clay. The study highlighted the superior stiffness of ring beams over diaphragm panels and proposed a correlation

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between normalized wall deformation and hoop stiffness, offering valuable guidance for deep excavations in soft soils.

Li et al. (2023) investigates the use of servo struts to control wall deflections in deep excavations in soft clay. The servo struts, with adjustable axial forces, were used to control the deformation and improve excavation stability by minimizing soil displacement.

DEEP EXCAVATION IN NAGPUR

Nagpur is a growing city, and infrastructure development is in progress. As high-rise buildings are under construction, few sites were visited to understand the purpose and methods used to protect deep excavation. It was revealed that these underground spaces are used for underground parking and water storage. The projects highlight effective urban space utilization, safety measures, and infrastructure planning for commercial development.

The construction site at Ramdas Peth in Nagpur managed by Sriniwasa Construction Private Limited, involves a 10-meter-deep excavation for a multi-level shopping mall. Stabilized by concrete piles, the site addresses challenges like groundwater ingress, with the water table at 1.2 meters below ground. The design features three basement levels—two for parking to ease traffic congestion and one with ventilation for airflow and water tanks for fire safety and sanitation. The project highlights effective urban space utilization, safety measures, and infrastructure planning for commercial development. However, due to rainwater excavated wall was collapsed as shown in Fig.1 which highlights the importance of use of proper supporting system.



Fig. 1 Failure of Deep Excavated Wall

The construction site at Santra Market, near Nagpur Railway Station, features a 7-meter-deep excavation supported by a reinforced concrete (RCC) foundation system comprising a concrete raft with box footings and circular RCC columns. A 200 mm-thick retaining wall ensures soil stability against lateral pressures, while centrifugal pumps efficiently manage groundwater ingress to maintain site stability.

The construction site at Ganesh Peth Model Mill, managed by Kukreja and Golden Bricks Infrastructure, is high-rise residential project comprising a ground-plus-19-floor structure. A 350 mm-thick retaining wall stabilizes the surrounding soil, ensuring safe construction conditions.

The construction site in Mahal, near Kotwali Police Station, Nagpur, is an 11-story mixed-use building managed by Fedesto, Pune. Piles as shown in Fig.2 driven 14–16 meters deep using the XCMG XR175I Rotary Drilling Rig, ensure precise piling. These 600 mm diameter piles are interconnected with tie beams at a 3-meter depth, enhancing load distribution. Undertaken by VIPL under the Nagpur Municipal Corporation's urban infrastructure initiative.



Fig. 2 Pile Supported Deep Excavation

CONCLUSIONS

- 1. Deep excavation leads soil instability, groundwater ingress, and settlement of adjacent structures, which pose significant risks in urban environments.
- 2. Analysis of deep excavation carried out to understand the challenges and risks in urban environments.
- 3. Deep excavation serves the purpose of accommodating car parking, commercial basements, utility corridors, storage facilities, transportation hubs, and supporting sustainable urban development in densely populated areas.
- 4. In Nagpur, deep excavation is widely adopted to address the growing demand for efficient underground parking, urban infrastructure, and transportation solutions, supporting the city's rapid development.



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Analysis of Irregular Shape of Building in Earthquake Prone Area by Time History Analysis: A Review

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ABSTRACT

The abrupt release enormous strain energy contained in the planet's crust causes earthquakes and seismic waves. Movement of the ground during these events may cause structural damage. Understanding ground motion characteristics is crucial for implementing measures to mitigate earthquake-induced structural harm. The three key dynamic aspects of an earthquake are its duration, frequency content, and peak ground acceleration. These factors play a vital role in predicting how structures will react to ground motion in seismic events. If non-linear behavior is removed, linear analysis of time history surpasses modal response spectrum evaluation in every way. This method requires more computing resources to calculate answers at particular time intervals. A notable benefit of this approach is that response histories maintain the relative indicators of response quantities. This feature is particularly important when designing with stress interaction effects in mind.

KEYWORDS : Peak ground acceleration (PGA), Modal response spectrum analysis, Earth stress interaction effects, Strain energy, Structural damage, Seismic waves.

INTRODUCTION

C tructures were most likely to collapse during an Dearthquake at points of discontinuity of volume, rigidity, and geometry. These defects are frequent for irregular buildings, that make up a large percentage of metropolitan infrastructure. Vertical abnormalities, particularly soft levels, are the leading cause of collapse of structures during seismic events. As a result, understanding the effect of vertical abnormalities on a structure's earthquake resistance is critical. Irregular buildings have different dynamic qualities than "regular" buildings due to differences in mass or stiffness throughout their height. Vertically irregular constructions are defined by IS 1893 as having non-uniform mass, strength, and stiffness distributions throughout their height. When such structures are constructed in seismically active areas, they necessitate more complicated study and design. There are two major sorts of irregularity:

Stiffness Irregularity

a) Soft Storey: Any storey whose lateral stiffness is under 70 percent of that storey or greater than 80% of the median of the three above.

b) Extreme Softly Storey: A storey with lateral rigidity that is less than 60% of the floor above it, or 70% of the mean of the three preceding storeys.

Mass The inconsistency: A storey having seismic weight greater than 200% of surrounding storeys, ignoring roofing anomalies.

Vertical Mathematical Irregularity: This happens when the vertical dimension of any laterally force-resisting systems on any storey exceeds 150% of the value in a neighboring level.

In-plane Discontinuity: A lateral force-resisting element with an in-plane offset bigger than its length.

Weak Storey: Any storey with lateral strength is less than 80% of the level above. In accordance with IS 1893, Part 1, linearity static testing is appropriate for regular buildings with restricted height since it estimates lateral forces according to the structure's basic time period and code. Linear dynamic analysis provides a more accurate representation of higher vibration modes



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and force distribution in the elastic range. Despite designing structures to resist earthquakes using designbased engineering (DBE), actual seismic forces can be significantly stronger. To bridge this gap, ductility-based design is recommended in seismically active regions. The basic purpose of earthquake-resistant construction is to guarantee sufficient flexibility in the structure to withstand seismic stresses during an earthquake.

LITERATURE REVIEW

- 1. The response spectra for a six-story Matter refusing Frame (MRF) with and without infill brick walls were investigated using ETABS. The analysis sought to validate base shear, displacement, other internal forces in accordance with Egyptian code norms. The model under consideration consisted of 5 bays across the X-axis with three bays down the Y-axis, with a 4 m cell spacing and an aggregate elevation of 19 m. The results suggested that the incorporation of brick infill significantly boosted both the stiffness & Shear bearing capability of the structure.
- 2. The study concentrates on two reinforced-concrete buildings located in zone II: a symmetrical (G+10) building and an irregular (G+13) building. STAAD. Pro software is utilized for the analysis. The findings indicate that an irregular structure exhibits reduced story drift compared to a standard construction. J. P. Annie Sweetlin(2016)
- 3. Reinforced concrete structures with multiple stories are susceptible to damage from severe seismic events. Research has shown that the primary factors contributing to their failure are inconsistencies in the building's plan dimensions and lateral forceresisting system. This study analyzes the responses of numerous regular and unusual buildings within the high-risk seismic region V. A 15-story structure was assessed utilizing ETABS 2013 and the International Standard Code 1893-2002 (section 1), with dynamic as well as static approaches used. In zones I and II, Equivalent Linear Regular structures up to 90 meters tall are subjected to static analysis, whereas in zones IV and V, both regular nor irregular structures must undergo dynamic analysis. Dynamic analysis can be carried out utilizing either a standard linear response spectrum assessment or an unexpected Time History Analysis. The behavior of structures can be investigated by contrasting the lateral movement responses of uneven and regular buildings. Storey

displacement is investigated utilizing a number of analytical techniques, including the associated static method and the spectrum of responses method. The fundamental purpose of this research is to generate the displacement vs. shear basis graph after gathering the pushover curve. A time history study will also be undertaken utilizing BHUJ earthquakes data. This study looks at two distinct kinds of 15-story reinforced- concrete structures: regular and irregular. Static and dynamic methodologies are used for analysis. To evaluate each structure's response, ground motion data from prior earthquakes are gathered and analyzed over time. The study comprises six models, one with a normal structure and five with unusual structures. Arvindreddy and R. J. Fernandes (2015).

4. The increasing scarcity and expense of land in urban areas has led to a growing trend of constructing multistory reinforced concrete (R.C.) framed buildings in hilly regions. These structures often feature stepback designs on slopes and setback configurations on flat terrain, with combinations of both being common in mountainous areas. Setbacks can cause stress concentrations during seismic events, while the asymmetry of these buildings can result in severe twisting. Current building codes recommend comprehensive dynamic analysis for such structures due to their vulnerability to torsion and lateral earthquake forces, particularly in hilly areas where columns of varying heights support the building. Structures in hilly terrain face additional challenges, including lateral earth pressure at different levels and potential slope instability. The uneven soil profile can lead to complete structural collapse, with variations in soil properties at different levels potentially causing localized slope failures and uneven foundation settlement. To assess the global inelastic performance of these structures, simplified seismic evaluation methods employ static collapse analysis results. The nonlinear static process (NSP), as defined in FEMA-273/356 & ATC-40 (Applied Technology Council, 1996) calculates seismic demands by conducting a nonlinear statistical analysis of the framework under gradually increasing lateral loads. Nonlinear static (pushover) research provides insights regarding the structural features that regulate performance during powerful earthquakes, delivering information on ductility and strength which elastic analysis cannot provide. This analysis generates a capacity curve,



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which plots the structure's base shear against top displacement, to determine if a building can withstand a specific level of seismic stress. Mohmmad Irfan, Dr. Sunanda Reddy, K.Mythili (2014).

- 5. Examined how brick infill affected a multi-story building. In accordance with IS 1893 (Part-1) 2002, Three models of four storeys with a height above three meters each—bare structure, infill frame with no opening, & Infill frame with opening—were developed and evaluated for seismic zone III. ETABS was utilized to execute the answer. Vishwajeet Deshmukh & Dr. Shrirang Tande (2016)
- 6. For seismic analysis of most structures, a rigid floor diaphragm is a fair assumption, although there may be considerable flexibility in the floor diaphragm of other building layouts. However, the literature does not Address the problem of static seismic assessment for these buildings using torsional code requirements. It is particularly critical to understand the center of rigidity for constructions with flexible floor diaphragms. This work expands the notion of centre of rigidity in rigid flooring membrane structures, covering asymmetrical structures with flexible floors. For applying codespecified torsional criteria to structures having flexible floor diaphragm, a superposition-based method of analysis is recommended. The suggested technique considers both accidental eccentricity and the amplification of static eccentricity. The suggested method takes into consideration any definition of the center of rigidity and may be used to both orthogonal and nonorthogonal unsymmetrical structures. Dhiman Basu and Sudhir Jain (2004).
- 7. Investigated how a conventional RC-framed building with four equal bays, a square design with 24 meters in either direction, and a 10-story, The simple period of vibration had an effect on the 3.5-meter-high building. Masonry infill is included in the eigenvalue analysis, and a 3D infinite element model is generated. The natural time period is estimated using the Uniform Building Code (UBC), Indian Standard (IS), Building Standard Law of Japan (BSLJ), and the National Buildings Code of Canada (NBC). Khan Mahmud Amanat & Ekramul Hoque (2006).
- 8. The uneven arrangement of a brick infill wall was investigated to determine how it affected the structure's functionality, which measured 20 m long, 15.8 m wide, had lateral lengths at a height of 9 m. The

structure was examined with SAP2000's nonlinear pushover analysis method. According to Turkish norms, the base shear and storey dislocation values are consistent with the base frame. Kasim Armagan Korkmaz(2007).

DESIGN METHOD

Ductility Based The design: Inelastic material properties and reinforcement details prevent brittle fracture while introducing ductility through enabling steel to yield in controlled quantities, resulting in ductility within structures. As a result, the major goal is to guarantee that the building has enough ductility for withstanding the effects of earthquakes, which are expected to occur during its lifetime. The structure's ductility minimizes transmitted forces and functions as a shock absorber. A structure's elasticity can be measured by Ductility refers to a material's capacity to endure deformation after initial yield without losing evident yield strength. Other kinds of flexibility includes displacement, rotational, and curl ductility, as well as structural ductility.

The following elements influence a structure's ductility:

- For modest axial compressive stresses between 0 and 1 MPa, ductility rises as concrete's shear strength does. The nature of the fluctuation is linear.
- Until the axial compressive stress equals the compressive stress at balanced failure, ductility varies linearly.
- As the ultimate strain of concrete increases, so does the ductility factor. Concrete's ductility is therefore increased by confinement.
- As concrete strength rises, ductility rises, and as steel yield strength rises, ductility falls.
- Through the prevention of shear failure, lateral reinforcement improves ductility. Additionally, it prevents buckling of the compression reinforcement.
- For close-spaced modes, the full quadratic combination (CQC) technique is an improvement of SRSS.

Requirements of Ductility

 Structural ductility allows the structure to create its maximum strength by dispersing internal forces; it also allows the structure to work as a mechanism while at its highest potential strength, leading to

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significant energy dissipation. IS 13920 was utilized to implement a ductility-based design.

The analysis of response spectrum was conducted on several irregular or normal structures. After calculating the storey shear pressures at every level, a chart was developed for each structure. In the present study, ETABS 2016 was used to analyze a nine-story construction. The finite element evaluation will be performed using time history data. The stated properties of the constructed model are listed below.

Table	1	:	Str	uctur	al	Pro	pert	y
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1.	Plan dimension	16 X 15 m ²
2.	No. of stories	9
3.	Floor to floor height	3000 mm
4.	Beam size	250X500
5.	Column size	450X450
6.	Thickness of slab	150 mm
7.	Zone	IV
8.	Zone factor	0.24
9.	Importance factor	1
10.	Response reduction factor	5
11.	Grade of concrete	M30
12.	Grade of steel	Fe415
13.	Density of concrete	25kN/m ³

Table 2: Wind Load Property

	Loadings	Values
L.	Slab load	3.75 kN/m
2,	Floor finish	1.0 kN/m ²
3.	Roof finish	1.0 kN/m ²
4.	Live Load	3.0 KN/m ²

This study evaluates the earthquake resistance of three different building models under diverse soil conditions. Model I represents a conventional building, Model II features an irregular structure without a slab on the ground story, and Model III includes an irregular structure with a slab twice the thickness of a standard slab on its upper story. The analysis considers three soil types as per IS 1893:2002 Part I: hard soil (Type I), medium soil (Type II), and soft soil (Type III).

Using fixed support conditions, key parameters such as top-story displacement and drift index were calculated and compared across all models under different soil types. The findings reveal significant differences in structural behavior caused by interaction between soil and structure and building imperfections. Irregularities in Model II and Model III resulted in varied seismic responses, with noticeable disparities in displacement and drift indices.

The study highlights the importance of soil type and structural irregularities in influencing seismic performance. Models constructed on soft soil exhibited greater displacement and drift compared to those on medium and hard soils. This comparative analysis underscores the need for optimized building designs to ensure resilience against seismic forces while accounting for soil- structure interaction and structural irregularities for safer construction practices.

Table 3: Time History Data

Parameter	Details	
Depth (Km)	46.0	
Magnitude	7.8	
Region	Indian Region	
Station Code	DCE	
Station Latitude	28.795* N	
Station Longitude	77.118*E	
Station Height (m)	208.0	
Site Class	CVs30 between 200 m/s to 375 m/s	
Record Time	16.04.2013 10.49:13.829	
Sampling Rate	200 Hz	
Record Duration	169.970 sec	
Direction	E-W (E positive)	
Max. Acceleration	1.521 cm/sec ²	

CONCLUSION

This study used reaction spectrum analysis along Using time history analysis to measure the shaking response of regular or uneven structures under different ground motion characteristics. The findings show that inconsistencies in mass, stiffness, or vertical geometry have a considerable impact on the fundamental natural time frame, which influences structure behavior during earthquakes. The assessment of reactions to low, moderate, and highfrequency ground movements revealed differences in displacement, drift, and efficiency among building models. Time history analysis, albeit requiring substantial computational effort, conserved the relative evidence for response quantities, allowing for a thorough comprehension of the impacts of interactions among stress resultants. The study also stressed the necessity of ductility-based resistant to earthquakes design in accordance with IS 13920 to



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improve structural resilience. The comparison of identical static and time history analyses highlighted the need of advanced analysis approaches in building earthquakeresistant structures that ensure safety and stability under a wide range of seismic circumstances. This research helps to optimize building designs regarding seismic resilience.

Three types of anomalies were studied: mass variations, stiffness irregularity, and vertical geometry irregularity. All three forms of uneven RC frame constructions have planar symmetry. Response spectra analyses (RSA) were applied to each type of variations, and the resulting storey stress levels were contrasted to those of a conventional building. We looked at three different ground-movement appears to be: low (imperial), moderate (IS code), and substantial (San Francisco). A time-history assessment (THA) was performed, and node shifts were examined for any anomalies linked with the previously indicated ground motions. In final but not least, the previously mentioned irregular frames for building were created with IS 13920, and this stands for Equivalent Stability Analysis (ESA) as well as Time History Analysis (THA). Results were contrasted.

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ABSTRACT

Different methods are evolved for treating wastewater generated from industries which contains toxic metals. Different approaches have been used for this purpose & out of that adsorption technique is more convenient & affordable. Aim of study is mainly focused on fixed bed column process for calculating the adsorbent capacity of Neem leaves for the removal of multiple metals (Cr, Cu & Zn) from synthetic wastewater. Effects of bed depth, flow rate & metal ion concentration parameters were investigated on adsorption characteristics of NLP biosorbent. Different breakthrough curves for these parameters were plotted & it shows in great agreement with the literature. Also, Thomas Model isotherm with their kinetic coefficients found best suited to experimental data. Results showed that Neem leaves powder can be effectively used as commercial biosorbent.

KEYWORDS : Fixed bed column study, Adsorption, NLP, TM.

INTRODUCTION

Very heavy metals such as Cr, Pb, Hg, Mn, Zn, As, Cu and Ni are harmful to human being and other living organisms [2]. A high concentration of Cr, when released into the atmosphere from different metal industries, stainless steel industries, chemicals and tanning industries are highly dangerous to human health [3]. Most of the literatures reported about extraction of only single metal ion using biosorbent. Very few investigators had reported extraction of multiple metal ions using biosorbent. The research aims to develop low-cost sorbent using Neem Leaves (NL) by carrying out fixed bed column experiments for determining performance of developed low-cost sorbent for removal of multiple metal (Cr, Cu & Zn) metal ions from synthetic wastewater. Also, to validate kinetics of column adsorption study using Thomas Model (TM).

MATERIALS & METHODS

Preparation of synthetic stock solution for Cr (VI), Cu(II) & Zn(II) mixed metal ions:-All the reagents used were of A. R. grade 1. Calculate the amount of each salt required:

Cr (VI): 0.992 g K_2 CrO₄ (1000 mg/L), Cu (II): 0.625 g CuSO₄•5H₂O (1000 mg/L), Zn (II): 0.678 g ZnSO₄•7H₂O (1000 mg/L)

Weigh accurately.

Dissolve all three salts in distilled water

Transfer the solution to a 1 L volumetric flask. Different concentrations of solutions varying from 50, 60, 70 mg/l of mixed metal ions of Cr, Cu & Zn were prepared by diluting the available stock solutions with distilled water for further experimental use.

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Sampling and preparation of biosorbent

Neem leaves were collected from Neem trees located in nearby locality Mhasrul, Nashik. Firstly, Neem leaves were washed several times with water for removing dust & different water soluble impurities. After washed out, Neem leaves were exposed to sun for a period of 24 hours until leaves became crispy. Then it was grinded by using domestic mixture. Sorbent was soaked & sun dried prior to use so that moisture can be removed. Once the Neem leaves were converted into powdery form were sieved using sieve sizes ranging from 100-200 micro meter. The resulting Neem powder was stored in plastic bottle & used as biosorbent for column adsorption studies

Fixed bed column study

To carry out column adsorption study, glass column with cross-section size of 15 mm (I.D) diameter & of length 30 cm was used. NLP biosorbent prepared was taken with known quantity & adjusted in the column to achieve a desired bed depth of 3, 5 and 7 cm corresponding to 4.3, 7.2 and 10.1 g of NLP. This bed was supported at both ends by glass wool to avoid the falling of the NLP. Metal ions of concentrations of 50 mg/L, 60 mg/L and 70 mg/L of Cr (VI), Cu(II) & Zn(II) was passed through column bed under action of gravity force by maintaining flow rates of 3, 6 and 9 ml/min using peristaltic pump. Treated solution was collected at different time intervals. Collected samples were analyzed using AAS Spectrophotometer. The adsorption process was carried out till the effluent concentration.

% removal efficiency is calculated using as,

% removal= $(C_{in} - C_{out} / C_{in}) \times 100$

Where, C_{in} (mg/l) - influent concentration, C_{out} (mg/l)-effluent concentration.

NLP Biosorbent capacity of the target metal species was determined using below equation as

 $q_{e} = .(i - o) /$

Where, t - time (hr), Q -flow rate (ml/min), m - mass of NLP biosorbent in the column (gm).

Column adsorption parameters calculation

Treated effluent, V_{eff} (ml) is calculated using

$$V_{eff} = Q.t_{total}$$

Where, Q - flow rate (ml/min) and t_{total} - time for total flow (min).

Adsorbed quantity of metal ions (qtotal, mg) in the column is given as ;

$$q_{total} = QA/1000 = Q/1000$$
 (o -) (4)

where, C_0 - influent concentration (mg/L),

Q- flow rate (mL/min), C_t - effluent concentration (mg/l) at any time t (min), A - breakthrough curve area from C_0 to C_t (mg min/l) at time 0 to any time t. Total ions sent to the column can be calculated as below

$$M_{total} = C_o Q t_{total} / 1000$$

% removal is given by,

% R =
$$(q_{total}/m_{total})$$
 100

Metal uptake is calculated as $q_a = q/m$.

Thomas kinetics mathematical model

In this study, Thomas kinetics adsorption isotherm model is utilized calculating values of coefficient of determination. Fixed bed column behavior is calculated by applying Thomas model adsorption isotherm as below

Fig. 1 Experimental set-up of fixed bed column adsorption

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Table. 1. Experimental conditions of mixed metal ions(Cr, Cu & Zn) onto NLP bio-sorbent for adsorption study

Effect of system	Flow rate (mL/ min)	Initial concentratio n (mg/L)	Bed height (cm)	Dry weight of bio-sorbent (gm)
Effect of flow rate	3, 6 and 9	70	7	
Effect of initial concentratio n	3	50 to 70	7	4.3, 7.2 and 10.1 g of NLP
Effect of bed height	3	70	3, 5 and 7	

RESULTS & DISCUSSION

Flow rate effect (Q)

Fig. 2 indicates breakthrough curves of Cr, Cu, Zn mixed metal ions onto NLP biosorbent adsorption for varying flow rates at 7.0 cm bed depth and 70 mg/l of concentration. Results indicate that adsorption of metal ions onto NLP biosorbent increases as soon as flow rate increases. As flow rate increases, volume of effluent (Veff) treated is going to reduce. This is due to decrease in contact time between metal ions and NLP biosorbent which do not allows for full saturation that leads to decrease in metal ions adsorbed as per suggested by Chen et al., 2012 in his investigation.



Fig. 2 Breakthrough curves of Cr, Cu, Zn against NLP biosorbent at different flow rates (Q)(Co =70 mg/L, Z = 7.0 cm)

Said plot indicates adsorption of metal ions is greatly depends on flow rate. Adsorption of metal ions increases steadily at lower flow rate of 3 ml/min and due to this there is delay in saturation of the NLP biosorbent (Fig. 3). Saturation of NLP bed is easily achieved at higher flow

rate. As rate of flow increases, adsorption capacity also increases with increase in removal.

Effects of bed height (Z)



Fig. 3 Breakthrough curves of Cr, Cu, Zn against NLP at different bed depths (Z) (at C0=70 mg/L, Q =3.0 ml/min)

Fig. 3 shows breakthrough curves of Cr, Cu & Zn mixed metal ions onto NLP biosorbent at 3.0 ml/min flow rate and 70 mg/l concentration for different bed depths. As soon as bed depth increases, service time also got increases thereby increasing breakthrough as well exhaustion of the column bed. As sorbent dose increases in the column, bed depth gets longer which leads to presence of more active sites available for the column adsorption. Results showed that adsorption capacity decreases as sorbent dose/depth increases.

Effects of metal ion concentrations (C_a)



Fig. 4 Breakthrough curve of Cr, Cu, Zn ions against NLP at varied concentrations (Q=3.0 ml/min, Z =7.0 cm).

Fig. 4 shows breakthrough curves for adsorption of Cr, Cu, Zn mixed metal ions onto NLP for varied concentrations at 3.0 ml/min of flow rate and 7 cm of bed depth. As concentration of metal ions increases, adsorption capacity



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also increases. There is rise in adsorption capacity as due to higher rate of adsorption as well as availability of all active sites at higher concentration.

Column adsorption isotherm

Thomas kinetics adsorption isotherm was utilized to establish the relationship with different adsorption rate constants which are responsible for effectiveness of adsorption process (Table 3.1).

Thomas model adsorption kinetic curves at varying flow rates-Thomas adsorption kinetic model calibration curves were plotted at different flow rates keeping bed depth & metal ion concentration constant which shows that as soon as flow rate increases, there is increase in value of Thomas rate constant (K_{TH}) (see Table 1).



Thomas model adsorption kinetic curves at varying bed depths- Thomas adsorption kinetic model calibration curves are plotted at varying bed depths by keeping flow rate & metal ion concentration constant which shows that as bed depth increases there is decrease in value of Thomas rate constant (K_{TH}) (see Table 1).







Thomas model adsorption kinetic curves at varying bed depths- Thomas adsorption kinetic model calibration

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curves are plotted at varying bed depths by keeping flow rate & metal ion concentration constant which shows that as bed depth increases there is decrease in value of Thomas rate constant (KTH) (see Table 3.1)

Thomas model adsorption kinetic curves at varied concentrations- Thomas adsorption kinetic model calibration curves were plotted at varied concentrations by keeping flow rate & bed depths constant which shows that as concentration increases there is decrease in value of Thomas rate constant (K_{TH}) (see 1).



Table 1 Thomas model parameters obtained by regression analysis at various conditions of Cr, Cu, Zn adsorption onto NLP

Parameters	K _{TH} (ml/mg/min) x 10-5	q _{ente} (mg/g)	q _{enp} (mg/g)	R ²			
Flow rate (ml/min	l)						
3.0	2.71	37.92	38.13	0.9225			
6.0	3.14	66.78	64.15	0.9395			
9.0	3.42	96.14	100.08	0.9284			
Bed height (cm)							
3.0	2.28	57.83	57.14	0.8830			
5.0	2.14	36.40	34.16	0.8244			
7.0	2.14	25.26	25.15	0.7236			
Concentration (m	Concentration (mg/L)						
50	4.4	23.15	22.13	0.9175			
60	3.67	26.38	24.36	0.9112			
70	3	24.45	23.75	0.8695			

The important parameter of Thomas model i.e. q_{calc} increased with increase in flow rate & initial concentration. Also, qcalc decreased with increase in bed depth. Most important is that theoretical calculated adsorption capacity is found to be approximately equal to the experimental adsorption capacity values. The values of coefficient of correlation (R_2) for NLP biosorbent is also in closely agreement with less than 1. If the coefficient of correlation is closer to one, then it indicates that it is most suitable adsorption isotherm as suggested by Zhanga et al. in his investigation.

CONCLUSIONS

This research work investigated the adsorption technique by using column as fixed bed for extraction of mixed metal (Cr, Cu, Zn) ions by Neem leaves powder (NLP) biosorbent from synthetic wastewater using various parameters. My research work findings can be notably found & can be described as below.

Table. 2. Con	nparative	study of	f adso	rption	capacity	of
Neem leaves p	oowder (N	LP) with	other	biosor	bents	

Toxic Metals	Biosorbents	Type of study	Biosorbent capacity/ q _{max} (mg/g)	Author names
Cu ⁺²	Wheat shell	Batch study	10.8	Basci et al.
Cu ⁻²	Green coconut shell powder	Batch study	285.70	M.A. Renu, K. Singh
Cr+6	Soy-hull	Fixed Column/ Batch study	7.28	Blanesa P. S et al. (2016)

Ċr ≠	Tea-waste powder	Batch study	2.07	Albadarin A. B. et al. (2013)
Zn+2	Sawdust	Batch study	14.1	Naiya T. K et al. (2009)
Zn+2	Neem bark	Batch study	26.73	Naiya et al.(2009)
Cr +6	Cashew Nut- shell	Fixed column bed	10.79	Yahya et al.(2020)
Cr +6	Jatropha wood	Batch study	140.8	M.A. Renu, K. Singh
Cr +6	PEI functionalized egg shell	Batch study	160	M.A. Renu, K. Singh
Cr, Cu	Neem Leaves	Fixed bed	100.08	This study
& Zn	Powder	column		

Fixed bed downward flow column adsorption study on Cr, Cu & Zn metal ions extraction showed highly significant effects on the different variables. Adsorption capacity highly depends on bed depth, rate of flow as well as concentrations of metal ions. The different breakthrough curves were plotted using parameters such as flow rate, bed depth and initial metal concentration. Based on experimental investigations, breakthrough curves found to be highly aligned with theoretical values by Thomas kinetics adsorption model as validated by higher values of R^2 .

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ABSTRACT

This project focuses on addressing environmental challenges through the principles of Recycling, Reducing, and Reusing (3Rs) by efficiently managing domestic waste, which consists primarily of organic and inorganic materials. The goal is to treat these wastes in an environmentally sustainable way. The widespread use of plastics, which are inexpensive and durable, has led to significant environmental concerns due to improper disposal. One promising solution is the production of bio-oil through pyrolysis, a second-generation biofuel that can serve as an alternative to petroleum-based fuels in both mobile and stationary applications. Additionally, the project explores composting as an effective method for treating organic waste. Composting, an aerobic biological process, transforms organic materials into a stable, humus-like product that can be used to improve soil fertility. This approach offers environmental and economic benefits by reducing waste and enhancing agricultural productivity. In regions like the Mediterranean, where soils are typically low in organic matter, composting not only supports sustainable farming practices but also contributes to CO2 sequestration, promoting long-term environmental sustainability.

KEYWORDS : Recycling, Pyrolysis, Composting, Bio-oil, Waste management.

INTRODUCTION

India, the world's second-most populous country, with Lover 1.4 billion people, faces significant challenges in solid waste management (SWM) due to limited resources and inadequate infrastructure. The rapid urbanization, with the urban population growing by 31.8% in the last decade, has put immense pressure on existing waste management systems. Municipal solid waste (MSW) systems are illequipped to handle the growing volumes of waste, leading to inefficient services, high costs, and severe public health and environmental risks. Improper waste disposal contributes to pollution, resource depletion, and climate change, severely impacting the quality of life. The increase in waste generation, particularly plastics, is a major contributor to these environmental issues. Plastics are non-biodegradable and accumulate in landfills and natural habitats, causing long-term damage. Despite technological advances in recycling, it remains underutilized, and current systems do not effectively manage biodegradable waste, which leads to methane production and leachate in landfills.

The objective of this research is to explore sustainable solutions for managing solid waste by focusing on the composting of organic matter and pyrolysis of inorganic matter. Composting, as an aerobic biological process, offers an effective means of recycling organic waste, transforming it into valuable soil amendments while reducing landfill burden. Pyrolysis, on the other hand, presents a promising method for treating inorganic waste, particularly plastics, by converting them into biooil and other useful products without causing significant environmental pollution. By integrating composting for organic waste and pyrolysis for plastics, this research aims to reduce waste volumes, recover valuable resources, and minimize environmental harm. The ultimate goal is to establish a comprehensive waste management strategy that improves public health, reduces pollution, and contributes to sustainable development in India's rapidly growing urban areas.

Need for Study

i. Rapid urbanization and population growth contribute to an increase in municipal solid waste, requiring effective waste management solutions.

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- ii. Pyrolysis and composting offer environmentally sustainable alternatives to traditional waste disposal, minimizing pollution.
- iii. Both methods enable the extraction of useful byproducts such as bioenergy, compost, and bio- fuels.
- iv. These technologies provide long-term environmental advantages by reducing landfill usage and improving soil health.

LITERATURE REVIEW

Composting by Aerobic Bacteria: To address municipal solid waste management challenges, composting is an effective method for converting biodegradable organic waste into eco-friendly manure. This process improves soil fertility, aeration, and reduces environmental pollution. Composting offers multiple benefits, including reducing landfill space, methane emissions, and water contamination, while lowering transportation and air pollution costs. It provides a sustainable, low-cost solution for waste management, turning organic waste into valuable products instead of directly dumping it, making it a more environmentally responsible approach.

[1] As study suggests that municipal solid waste is ideal for composting due to its high biodegradable organic content, suitable moisture levels, and favourable C/N ratio. The composting process and product quality can be enhanced by adding inoculants like cow manure, poultry manure, or yard waste. This composting approach can be implemented nationwide as a sustainable method for recycling organic waste into valuable, economical fertilizer. [2]

Combustion /Pyrolysis: The potential of pyrolysis as an advanced solution for waste management, offering an efficient, safe, and energy-recovering method. Pyrolysis converts both organic and inorganic materials into valuable products such as gas, char, and oil, with applications in energy generation and chemical production. This recommends future improvements in energy efficiency, product quality, and emission control. It also calls for minimal waste pre-treatment, better handling of mixed waste, and the integration of next- generation technologies to address waste disposal more effectively. [3] The MSW pyrolysis system is gaining popularity as a distributed waste treatment method. Industrial pyrolysis facilities typically integrate gasification or combustion stages, with rotary kilns and tubular reactors being most common for scaling up. The products are primarily heat or power, with gas and char export being less frequent.

Factors like feedstock type, pyrolysis temperature, and reactor design influence product yields, especially gases and oils. Emission control and product standardization, particularly for char quality and gas composition, are crucial for environmental sustainability. [4] Pyrolysis, which converts organic waste into gas, liquid bio-fuel, and char, can be an effective method for reducing waste volume and producing valuable resources. While the initial installation costs of pyrolysis equipment are high, the long-term economic and environmental benefits make it a worthwhile investment. The technology can help address growing MSW challenges, especially in urban areas. [5]

METHODOLOGY DESCRIPTION & SAMPLE PREPARATION

Methods used

Composting By Aerobic Bacteria: - Composting involves four key elements: organic matter, moisture, oxygen, and bacteria. A mix of green (nitrogen-rich) and brown (carbon-rich) materials, such as food scraps and leaves, is essential. Proper moisture and oxygen are crucial for decomposition, and turning the compost ensures adequate airflow. The composting process takes about 10-12 days. Common organic waste includes garden debris (plants, grass), kitchen scraps (peels, egg shells), cooked foods, and paper products, which break down naturally to enrich soil and reduce landfill waste.

Combustion /Pyrolysis: The pyrolysis process heats plastic waste in an oxygen-free environment, causing it to melt, boil, and evaporate. The vapours are condensed into liquid, while shorter hydrocarbons remain as gas. A bubbler captures excess liquid, which is collected in a steel reservoir for use as fuel. The device, powered by electricity and using chrome coils, can process 10 kg of shredded plastic in 20-35 minutes. The resulting bio- oil is usable as fuel, and plastics such as PE, PET, and PVC can be processed efficiently

Samples preparation

Sample preparation by composting of organic Matter

Organic waste was collected from the premises of Jawaharlal Darda institute of Engineering and technology which include leaves, food, dead plants, grass, fruits etc. All collected waste was put in organic waste management unit in following layers

LAYER 4 (OPTIONAL GRASS) Coating layer

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LAYER 3(Sand Water Compost) Soil=800gm,					
organic waste=60gm, compost=	=800gm.				
LAYER 2(Sand Water Compost) Compost=500gm organic waste=30gm, soil=500gm.					
LAYER 1					
(Sand Water Compost) Organic waste=30gm, soil=800gm					

After making the layers this arrangement is kept for 12 days, natural bacteria will bring the decomposition of waste and convert this organic waste into compost.

Sample preparation by combustion/ Pyrolysis of inorganic Matter

Inorganic waste was collected from the premises of Jawaharlal Darda institute of Engineering and technology. Plastic waste was found to be bottles, polyethene, chips packets, cement rages, etc. then all the inorganic waste was dumped into the combustion chamber for the

Volum e of Contai ner (cm ³)	Time (min)	Temp. (Deg. Celsiu s)	Weight of Plastic Waste (gm)	Weigl t of Oil (gm)	Density of Sample=W eight of Oil/Volum e (gm/cm ³)	Weight of Containe (gm)	Source of Heat
1301.9 5	30	100° C <	65	44	0.33	181	college burner
1301.9 5	30	100° C <	100	60	0.046	181	Inductio n
1301.9 5	20	100° C <	100	50	0.03870	181	college burner

Test Performed

Test Performed on Sample prepared by composting of organic Matter

The pH test measures the acidity or alkalinity of watersoluble substances, with values ranging from 1 to 14. A pH of 7 is neutral, values below 7 are acidic, and values above 7 are alkaline. The scale is logarithmic, meaning each unit represents a tenfold change in acidity or alkalinity.

Soil Electrical Conductivity (EC) assesses the salt concentration in the soil, affecting plant growth and nutrient availability. High salinity can hinder plant development by disrupting water balance and soil processes.

The Soil Nitrogen Test measures available nitrogen, which influences crop yield predictions and the need for fertilizer application.

Phosphorus tests, like the Olsen P test, measure phosphorus availability in soil, essential for plant growth. These tests

are calibrated based on crop response to predict the benefits of phosphorus fertilizer.

Potassium tests evaluate this essential nutrient's levels, important for plant hydration and overall growth. Calcium and Magnesium tests help determine soil health, with adequate levels promoting healthy crop production.

Test Performed on Sample prepared by combustion/ Pyrolysis of inorganic Matter

The Calorific Value Test measures the energy released during the complete combustion of a material, expressed in units like kJ/kg. This test helps determine the fuel's efficiency.

The Flammability Test assesses a substance's ability to catch fire and sustain combustion, with various international protocols used for this purpose.

The Cloud Point Test identifies the temperature at which wax in diesel or biodiesel forms a cloudy appearance, potentially blocking fuel filters and injectors.

The Flash and Fire Point Test distinguishes the lowest temperatures at which a fuel's vapor can ignite. The flash point is the temperature where ignition occurs briefly, while the fire point is when the vapor will sustain combustion for at least five seconds.

The Viscosity Test evaluates a fluid's resistance to flow, caused by friction between molecules. It quantifies how much force is needed to move the fluid through a tube, with higher viscosity indicating greater resistance.

RESULTS

Result on test performed on Sample prepared by composting of organic Matter

After 12 days this compost was taken out and the laboratory tests were made on compost. We obtained good results of nitrogen, phosphorus and potassium. The results obtain are as follow

The soil has a slightly acidic pH of 6.7, which is favourable for most plants. Electrical conductivity is 455 μ S/cm, indicating moderate salt levels. The nitrogen concentration is 48 mg/kg, a typical value for maintaining soil health. Phosphorus is measured at 35 mg/kg, a good level for supporting plant growth. Potassium is present at 148 mg/kg, which is within the expected range for promoting fertility. The calcium level is 6100 mg/kg, ensuring adequate nutrition for plant development, while

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magnesium is at 390 mg/kg, a standard level for supporting plant health.

Result on test performed on Sample prepared by composting of organic Matter

The material has a calorific value of 7844 KJ/KG, indicating a relatively high energy content. It is classified as flammable based on the flammability test. In the cloud point test, vapors begin to form at 20°C, indicating the onset of solidification. The flash point is recorded at 40°C, while the fire point is slightly lower at 35°C, reflecting the temperatures at which the material is prone to ignition. The dynamic viscosity is 19 N.sec/m², which is a typical measure for the fluidity of certain oils or fuels.

Applications: Compost from organic waste has versatile applications in agriculture and horticulture. In agriculture, it enhances soil fertility, improves crop yields, and controls erosion, particularly for crops like wheat and corn. However, its use can be limited by cost unless subsidized, as seen in countries like Germany. In horticulture, compost enriches raised bed gardening, replaces peat moss in container gardening, and supports tree, shrub, and turf establishment. It also aids erosion control through blankets and berms. Recycled plastics find use in packaging, construction, landscaping, and textiles, with applications ranging from bottles and pipes to outdoor furniture and polyester fleece, promoting sustainability.

CONCLUSION

This study demonstrates the effectiveness of composting and pyrolysis as sustainable methods for managing municipal solid waste (MSW) by addressing both organic and inorganic waste streams. The results obtained confirm that both processes can yield valuable products that meet or exceed industry standards, contributing to waste reduction, resource recovery, and environmental sustainability.

For the composting of organic waste, the produced compost showed a slightly acidic pH of 6.7, electrical conductivity of 455 μ S/cm, and good nutrient content, including nitrogen (48 mg/kg), phosphorus (35 mg/kg), potassium (148 mg/kg), calcium (6100 mg/kg), and magnesium (390 mg/kg). These values suggest that the compost is beneficial for enhancing soil fertility and supporting healthy plant growth, aligning with the optimal ranges for agricultural use. The composting process not only reduces waste but also provides a cost-effective and sustainable solution for improving soil health and agricultural productivity. In terms of pyrolysis, the bio-oil produced from plastic waste exhibited a calorific value of 7844 KJ/KG, indicating that it is suitable for use as a fuel. The bio-oil was classified as flammable, with a flash point of 40°C and a fire point of 35°C. The cloud point was observed at 20°C, and the dynamic viscosity was 19 N.sec/m², showing the bio-oil's potential for use in energy applications. These results confirm that pyrolysis effectively converts plastic waste into valuable bio-oil, which can serve as an alternative energy source, reducing the environmental impact of plastic disposal.

Overall, this study underscores the potential of integrating composting and pyrolysis for sustainable waste management. Composting produces nutrientrich amendments for soil improvement, while pyrolysis transforms plastic waste into energy-rich bio-oil. Both methods offer significant environmental benefits by reducing waste, minimizing pollution, and contributing to a circular economy. These technologies provide an effective strategy for managing the growing waste volumes in rapidly urbanizing regions, promoting both environmental sustainability and economic development.

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Effect of Shear Wall Placement on Torsional Behaviour of Multi-Storey Symmetric Buildings

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ABSTRACT

Multi-Storey buildings are widely adopted in modern cities for mass housing, showcasing human innovation and urban expansion. Yet, designing these towering structures comes with its own set of challenges, especially when it comes to managing torsional effects caused by forces earthquakes. These effects are even more pronounced in asymmetric Multi-Storey, where uneven mass distribution or irregular shapes lead to increased twisting motions. This research aims to identify the torsional behaviour of such buildings with, without shear wall. By thoroughly examining the mechanics behind these torsional effects and presenting practical solutions, this research will help in advance safer and more efficient design practices in structural engineering. This research shows that position of shear walls effectively minimizes these torsional movements, greatly enhancing the building seismic behaviour. This provides practical, actionable insights for engineers, ensuring Multi-Storey buildings are both safe and resilient against such forces.

KEYWORDS : Multi-storey buildings, Torsional effects, Shear wall, Storey displacement, Storey drift.

INTRODUCTION

Modern cities are defined by their Multi-Storey buildings, showcasing human ambition and engineering excellence. These tall structures do more than just punctuate the skyline, they reflect the dynamic, ever-evolving spirit of urban life. However, designing and constructing such buildings comes with its share of hurdles, especially when dealing with torsional effects. Torsion involves the twisting motion a building experiences under lateral forces like wind and earthquakes. This twisting can result in uneven stress and strain distribution, potentially causing serious structural damage or even failure if not properly managed.

Torsion is a significant issue in asymmetric Multi-Storey buildings, where irregular shapes or uneven weight distribution worsen the effects. These unique designs, often driven by specific architectural or functional needs, usually don't have uniform mass or stiffness. This lack of uniformity can make the building twist around its vertical axis, causing increased torsional moments and shearing forces. Such reactions can compromise the building's structural integrity and safety, making it crucial to understand and mitigate these effects effectively. One of the main reasons for torsional effects in Multi-Storey buildings is the difference between the center of mass and the center of rigidity. When lateral forces like wind or earthquakes hit these buildings, this offset causes them to twist. To address this, it's essential to carefully design the building and use advanced engineering techniques. Strategies such as use of strategically placing shear, can help to reduce these torsional effects. These methods aim to make the building.

This research aims to delve into the torsional effects in asymmetric Multi-Storey buildings by examining the core mechanics behind these responses. By analysing realworld examples and using computational model, these factors include architectural design features, structural irregularities.

The orientation, stiffness, location, and size of shear walls significantly enhance torsional resistance in Multi-Storey buildings. Strategically positioning and designing these walls increases structural stiffness and strength, effectively mitigating twisting motions and ensuring greater stability and safety against lateral forces like earthquakes.



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LITERATURE REVIEW

Selvamony (2022) stated that the shear wall area ratio significantly impacts the seismic behavior of multistory buildings with soft ground floors, emphasizing the shift from strength-based to displacement-based design for better motion control and structural stability in high seismic risk regions. Dhakal (2022) stated that proper placement of shear walls can counteract torsional irregularity in irregular buildings, improving stability. Analysis of six-story buildings revealed that strategic shear wall positioning effectively addresses mass and stiffness distribution issues. Banerjee and Banerjee (2021) examined re-entrant corners in plus-shaped tall buildings significantly influence seismic response. Strategically positioning shear walls. especially at re-entrant corners, can effectively mitigate these effects, enhancing structural performance under dynamic loading. Botis (2018) examined that modified the cross-sectional properties of rectangular reinforced concrete walls to optimize their moment of inertia. It effectively reduces general torsion in multi-story structures. The results, verified through ETABS 2016 modal analysis, demonstrate a shift in the center of stiffness closer to the center of mass, minimizing deformations and stresses. Satheesh (2018) examined those changes in the dynamic eccentricity of shear wall buildings lead to significant variations in floor rotation and torsional response. Time history analysis revealed these effects in asymmetric buildings with varying shear wall configurations. Georgoussis and Mamoua (2018) stated the guidelines for minimizing torsional response in asymmetric multistory buildings due to mass eccentricities, revealing that current code provisions may significantly increase design costs. It offered insights into seismic responses and design strategies to sustain minor torsion through a parametric study on 9-story buildings. Mukundan and Manivel (2015) investigated that reinforced concrete shear wall-framed structures which effectively reduced earthquake impact in a 10-story building in Zone IV, evidenced by improved maximum storey displacements, base shear reactions, mode shapes, and storey drifts through response spectrum analysis.

Analysis of multistorey building with and without shear walls, considering different configurations of shear walls and other parameter was not observed in the literature. Hence this study focuses on study of multi-storied building with and without shear wall and its effect on building response.

METHODOLOGY

Designing Multi-Storey buildings comes with a variety of engineering challenges, especially when dealing with the twisting effects that occur in asymmetric structures. ETABS (Extended Three-Dimensional Analysis of Building Systems) is a popular and powerful software tool used by structural engineers to tackle these challenges.

This study analyses Five-storey building using response spectrum method. It Focuses on factors like storey displacement and storey drift. It also Considers how these factors can affect the building's performance with respect to mitigation of torsion effect.

Three, Five-Storey buildings are modelled: model-1 without a shear wall, model-2 with symmetrical shear walls, model 3 with unsymmetrical shear walls. Other parameters of building are shown in Table 1.

Table 1 Building dimension

Number of storeys	G+5
Plan size	12m×12m
Size of columns	0.5×0.5m
Size of beams	0.5×0.5m
Shear wall dimension	3×0.2×18m
Total height	18m
Floor to floor height	3.0m
Grade of concrete	
and steel	M25 AND Fe415
Ductility design	IS : 13920-1993
Support condition	Fixed

Fig. 1 illustrates basic configuration of buildings in plan modelled in ETABS with five floors, indicating structural elements i.e column and shear wall position.



Fig. 1 Building model

Fig. 2 illustrates the diaphragm, a structural element that transmits lateral loads to vertical resisting elements like shear walls.



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Fig. 2 Diaphragm

It is assumed that the building is situated in medium soil conditions, located in Seismic Zone V with a seismic zone factor of 0.36 and a damping ratio of 0.05 as shown in Fig. 3.



Fig. 3 Response Spectrum

Fig.4 illustrates the variation of centre of mass and rigidity in all three models. It is clear that for symmetric models the centre of mass and centre of rigidity coincide while for asymmetric placement of shear wall results in change in position of CM and CR consequently leads to torsional response as primary mode.



Fig. 4 Centre of Mass and Rigidity

RESULT

It is clear that the maximum displacement is observed at 5th floor top and found to be 1.059 mm, the maximum drift is observed at 3th floor top and found to be 0.086 mm as shown in Fig. 5 and Fig. 6.



Fig. 5 Model-1 Storey Displacement Plot



Fig. 6 Model-1 Storey Drift Plot

It is clear that the maximum displacement is observed at 5th floor top and found to be 0.235 mm, the maximum drift is observed at 2th floor top and found to be 0.013 mm as shown in Fig. 7 and Fig. 8.



Fig. 7 Model-2 Storey Displacement Plot



Fig. 8 Model-2 Storey Drift


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It is clear that the maximum displacement is observed at 5th floor top and found to be 0.436 mm, the maximum drift is observed at 2th floor top and found to be 0.025 mm as shown in Fig. 9 and Fig. 10.



Fig. 9 Model-3 Storey Displacement Plot



Fig. 10 Model-3 Storey Drift Plot

As illustrated above models without shear walls and those with asymmetrical shear walls exhibit larger storey displacement values compared to models with symmetrical shear walls. The presence of symmetrical shear walls effectively increases stiffness, thereby enhancing the building's stability against lateral forces such as earthquakes.

As illustrated in Tables 2, 3, and 4, the modal analysis of Models 1, 2, and 3 shows variations based on the position of shear walls. The analysis includes cases without shear walls, with symmetric shear walls, and with asymmetric shear walls.

Mode	Type of mode	Frequency (sec)	Mass Participation	
(%)				
1	Translational	0.542	93.3	
2	Translational	0.542	93.7	
3	Torsional	0.488	94.4	
4	Translational	0.165	98.8	
5	Translational	0.165	98.8	
6	Torsional	0.147	98.9	
7	Translational	0.088	99.06	
8	Translational	0.088	99.06	
9	Torsional	0.08	99.6	
10	Translational	0.059	99.8	
11	Translational	0.059	99.9	
12	Torsional	0.054	99.9	

Table: 2 Model-1 Modal Analysis

Table 3 Model-2 Modal Analysis

Mode	Type of mode	Frequency (sec)	Mass Participation	
(%)		(***)		
1	Translational	0.21	37.11	
2	Translational	0.21	74.23	
3	Torsional	0.142	74.62	
4	Translational	0.057	83.46	
5	Translational 0.057		92.6	
6	Torsional	0.039	92.7	
7	Translational	0.029	95.13	
8	Translational	0.029	97.5	
9	Torsional	0.02	92.7	
10	Translational	0.02	99.2	
11	Translational	0.02	99.2	
12	Torsional	0.016	97.6	

Table 4 Model-3 Modal Analysis

Mode	Type of mode	Frequency (sec)	Mass Participation
(%)			
1	Translational	0.21	37.11
2	Torsional	0.21	74.23
3	Translational	0.142	74.62
4	Torsional	0.057	83.46
5	Translational	0.057	92.6
6	Torsional	0.039	92.7



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7 0.029 Translational 95.13 8 Torsional 0.029 97.5 9 Translational 0.02 92.7 10 Torsional 0.02 99.2 11 Translational 0.02 99.2 12 Torsional 0.016 97.6

For symmetric structures first two primary modes are seen to be translational when with eccentric shear wall the torsional mode is at 2nd mode position. This shifting of torsion mode upward, leads to more shear stresses and eventually early failure.

CONCLUSION

The study revealed the impact of shear wall placement on the torsional behaviour of multi-storey buildings. The analysis provided significant insights into improving structural performance and mitigating torsional effects through strategic shear wall configurations. Based on the study following conclusion can be added.

- 1. Aligning the center of mass and rigidity to reduce eccentricity helps lower torsional forces and strengthens the building against lateral loads
- 2. In Model 1 and 3, the displacement is greater compared to Model 2, which features a symmetric shear wall.
- 3. The symmetric placement of shear walls results in the first two primary modes being translational.

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ABSTRACT

Groundwater is essential for human sustenance, agriculture, and industry, making its sustainable management critical amid increasing depletion and contamination risks. Accurate mapping and quality assessment are vital for safeguarding groundwater resources. This review highlights the use of Geographic Information Systems (GIS) and the Water Quality Index (WQI) in assessing groundwater potential and quality. WQI simplifies water quality evaluation by combining multiple physico-chemical and biological parameters into a single representative score, enabling trend identification and pollution hotspot detection. GIS supports spatial analysis and visualization, offering insights into aquifer zones, contamination-prone areas, and quality distribution. Case studies across diverse regions demonstrate the effectiveness of GIS and WQI in addressing groundwater challenges such as depletion, salinity intrusion, and contamination. Integrating advanced technologies like remote sensing and machine learning with GIS and WQI enhances assessment accuracy and predictive capabilities, enabling proactive management strategies. Future research emphasizes interdisciplinary approaches, combining hydrogeology, environmental sciences, and data analytics to develop predictive models for simulating groundwater behavior under dynamic factors like climate change and human activity. In conclusion, the integration of GIS, WQI, and advanced tools provides a robust framework for sustainable groundwater management, ensuring resilience and long-term availability of this vital resource.

KEYWORDS : Groundwater mapping, Water quality assessment, GIS, WQI, Hydrogeology.

INTRODUCTION

roundwater, vital for drinking, agriculture, and Jindustry, faces immense stress due to population growth, industrialization, and overuse [1][2]. Challenges like depletion and contamination require sustainable management strategies [4][6]. Traditional monitoring methods are resource-intensive and limited in scale [3]. Advanced tools like Geographic Information Systems (GIS) and the Water Quality Index (WQI) provide effective solutions for groundwater assessment. GIS integrates spatial data layers, such as topography, land use, and hydrology, to identify recharge zones, aquifer potential, and contamination hotspots [2][4]. It enables precise visualization of groundwater trends for evidencebased decision-making [5][6]. WQI, on the other hand, simplifies water quality data by consolidating parameters into a single index, aiding in the interpretation of groundwater suitability [3][7]. Combined, GIS and WQI support groundwater resource mapping, pollution identification, and management planning [1][4]. This

review highlights the effectiveness of GIS and WQI, alongside technologies like remote sensing and machine learning, to improve groundwater assessment accuracy and predictive capabilities [5][6]. Future research must focus on interdisciplinary approaches to address climate change impacts and human activities on aquifer systems [3][4].

LITERATURE REVIEW

Groundwater, a critical resource for drinking water, agriculture, and industry, faces increasing stress due to rapid population growth, industrialization, and unsustainable use. The combination of Geographic Information Systems (GIS) and the Water Quality Index (WQI) has emerged as an effective framework for assessing groundwater availability and quality, addressing issues like resource depletion and contamination.

Pandey et al. [1] demonstrated the use of GIS and WQI to evaluate groundwater quality in Allahabad Smart City. By integrating spatial datasets and physico-chemical



parameters, the study identified contamination hotspots and highlighted the role of GIS in visualizing quality variations. Similarly, Chaurasia et al. [2] assessed groundwater quality in parts of Varanasi District, Uttar Pradesh, confirming the utility of WQI in simplifying complex datasets for public understanding and decisionmaking.

Pandey and Singh [3] further reinforced these findings, emphasizing the role of spatial analysis in identifying trends and pollution sources in urban settings. Meanwhile, Kumar and Maurya [4] applied GIS and WQI in the Sirdala block of Nawada District, highlighting groundwater suitability for drinking and irrigation. Their study underscored the importance of GIS in mapping recharge zones and contamination- prone regions.

Das and Roy [5] explored groundwater quality using GIS and WQI under various land-use conditions. Their work illustrated the adaptability of GIS in integrating multisource data for regional assessments. Similarly, Hussain et al.

[6] applied GIS to analyze water quality along the Tigris River, Iraq, showing its effectiveness in identifying pollution gradients and contamination risks caused by anthropogenic activities.

Gupta and Sharma [7] highlighted the potential of GIS for spatially mapping groundwater quality in diverse geographical settings. Their study combined hydrological and environmental datasets to identify high-risk zones, advocating for GIS as a decision-support tool for sustainable resource management.

METHODOLOGIES GIS

GIS integrates spatial data to identify recharge zones, contamination-prone areas, and groundwater trends [2] [5]. By combining remote sensing data, GIS enhances mapping accuracy and supports dynamic groundwater flow models for resource management [4][6].

WQI

WQI simplifies complex water quality datasets by aggregating key parameters like pH, conductivity, and major ions into a single index [3][4]. It classifies groundwater into quality categories, aiding in suitability assessments for drinking, agriculture, and industry [6][7].

CASE STUDIES ON GROUNDWATER ASSESSMENT

Case Study: Allahabad Smart City A groundwater quality study in Allahabad used GIS and WQI to map contamination and identify critical zones requiring intervention [1] [5]. GIS visualized contaminant distribution, while WQI provided simplified water quality status, enabling targeted management strategies [3][6][7].



Fig 1: Study Area

Integration of Advanced Tools The combined use of GIS, remote sensing, WQI, and machine learning provides a comprehensive approach for groundwater assessment. GIS and remote sensing enable spatial and temporal mapping, while WQI simplifies water quality evaluation. Machine learning enhances predictive capabilities, offering insights into groundwater dynamics under changing environmental and socio-economic conditions.

Future research should focus on developing integrated models that incorporate climate change, population growth, and land use impacts to improve groundwater resilience. User-friendly platforms and capacity- building initiatives are essential to enable local stakeholders to adopt advanced technologies for groundwater monitoring and management. Collaborative efforts among researchers, policymakers, and communities will play a critical role in safeguarding groundwater resources for sustainable use.



GIS PARAMETERS

- 1. Spatial Analysis of Recharge Areas: Identifying zones suitable for groundwater recharge using land use and hydrological layers.
- 2. Urbanization Impact Assessment: Spatial analysis of urban sprawl and its effect on groundwater recharge.

WQI Components

- 1. Biological Oxygen Demand (BOD): Reflects organic pollution.
- 2. Chemical Oxygen Demand (COD): Indicates water's chemical pollution levels.

Water Parameters

- 1. Salinity Indicators: Total Dissolved Solids (TDS) and Electrical Conductivity (EC) to determine salinity issues.
- 2. Hardness Parameters: Concentrations of calcium (Ca) and magnesium (Mg).
- 3. pH and Alkalinity: To check water's acidic or basic nature.

CONCLUSION

- Effectiveness of GIS and WQI: GIS and WQI have emerged as invaluable tools for groundwater mapping and quality assessment, offering precise spatial analysis and simplified indices that are easy to interpret and apply.
- Wide Range of Applications: Studies reviewed showcase the versatility of these tools across diverse settings, including urban, agricultural, and industrial regions, demonstrating their adaptability to varying groundwater challenges.
- Insights for Resource Management: By identifying groundwater potential, contamination hotspots, and areas requiring urgent intervention, GIS and WQI provide critical inputs for sustainable water resource management.
- Groundwater Vulnerability: The case studies highlight the significant influence of land use activities—such as mining, agriculture, and urbanization on groundwater quality, emphasizing the need for region-specific interventions.

- Holistic Integrated Approaches: Future studies should focus on combining GIS, WQI, remote sensing, and machine learning into unified models to offer a comprehensive understanding of groundwater systems.
- Climate and Socio-Economic Considerations: Effective management strategies must account for climate change impacts, population growth, and industrial expansion, as these factors significantly influence groundwater availability and quality.
- Policy and Practice Recommendations: There is an urgent need for stricter regulations, sustainable landuse policies, and continuous monitoring to safeguard groundwater resources.
- Collaboration and Capacity Building: Successful groundwater management requires collaboration among researchers, policymakers, and local communities, supported by training initiatives to ensure the effective use of advanced technologies.
- Sustainability and Resilience: The overarching goal is to ensure the sustainable and resilient use of groundwater through innovative strategies and informed decision- making, preserving this critical resource for future generations.
- The approximate average pH value for Nashik region varies between 7 to 7.5 According to Indian standards, the pH range for drinking water is 6.5 to 8.5. This range is specified in the Indian Standard (IS) 10500:2012.

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Impact of P-Delta Effect in Ground Shear on Building Structures Considering Linear Static: A Review

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ABSTRACT

P-Delta effects, which have been a major contributor to damage to existing high-rise structures during previous catastrophic earthquakes, are more likely to affect high-rise buildings that are lighter and slenderer. The seismic evaluation uses the same modal analysis method to account for P-Delta effects. The analysis split, that is the first section does not take the P-Delta effect into account, and the second section does. The outcomes are then contrasted between P-Delta, dynamic, and static analysis. The structure's response is generally characterized by footing rotation due to overturning moments caused by horizontal external forces or inertia forces acting on the structure's mass, as well as the additional influence of the building's weight. Particularly significant are the elements affecting the soil-foundation-structure system's collapse. Ground movements are given to elastic and plastic material models of two benchmark structures representing the Los Angeles region, and the associated overturning moments and displacements are measured. When out-of-plane (OOP) failure mechanisms dominate the structural response, geometrical nonlinearities—which are frequently overlooked in numerical models for computational simplicity—should be taken into account. The study shows that the main failure mechanism for lighter buildings is elevating, which might result in collapse because of dynamic instability. On the other hand, soil failure mechanisms are activated for extremely heavy constructions, leading to residual rotation, settlement, and collapse.

KEYWORDS : Seismic effects, Linear and non-linear analysis, Tall buildings, P-delta analysis, P- delta effect.

INTRODUCTION

The development of accurate and effective numerical methods for the seismic assessment and retrofitting of unreinforced masonry (URM) structures has been the focus of much research over the last few decades. To help practitioners, some of these techniques have been included in technical rules. Masonry is a heterogeneous material, and the mechanical characteristics of its constituent units and mortar determine its macroscopic behavior [1]. Due in large part to its low tensile strength, brickwork exhibits extremely non-linear behavior at the material level, with a worsening cyclic response. Because of this, modeling the seismic response of URM structures is especially difficult [2], [3].

In URM structures, particularly older ones, where the global structural reaction might not be trustworthy, this behavior is typical. Masonry walls' poor tensile strength

and shoddy or insufficient Damage may gradually develop from interconnections between walls as well as between walls and slabs during an earthquake. which gets worse during dynamic loading [4].

When modeling masonry structures with both dry and mortared joints, Discrete Element Method (DEM) techniques work especially well because they allow for non-linear static and dynamic assessments that take into consideration significant displacements and the possibility of structural component separation. Using quasi-rigid blocks, dynamic free- and harmonic vibration analyses have been used to validate the suggested damping model. The results were compared with analytical solutions, advanced FEM simulations, and experimental research on quasi-rigid blocks that have been published in the literature.

The objective of this research is to create a precise and



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trustworthy numerical approach to assess the seismic performance of current URM structures that are vulnerable to out-of-plane failure modes. The tool will enable simulations that account for all sources of nonlinear behavior and the walls' in- plane and out-of-plane reactions, taking into account their interaction. Utilizing new formulations and numerical analyses based on the Discrete Macro-Element Method (DMEM), the study uses a simplified macroscopic model of brick walls. as opposed to more intricate techniques like discrete element (DEM) or finite element (FEM) models, this method has the advantage of requiring less computing power.

By contrasting second-order effects with first-order effects in a structure exposed to significant ground motions from different tectonic zones, this research aims to assess the significance of include second-order effects.

LITERATURE SURVEY

[1] C. Konapure et al. studied the effect of P-Delta in high Story infrastructure-like buildings. They calculated displacements, storey drifts, and column moments. The study concluded that the P- Delta effect is insignificant for buildings up to 7 stories, but its impact becomes more pronounced as the number of stories increases. A total of twelve models, ranging from 5 to 27 stories with an increment of 2 stories, were analyzed using the STAAD Pro V8i structural analysis software.

[2] N. Pravin et al. investigated the P-Delta effect on multi-story buildings, employing three models with 15, 20, and 25 stories. They concluded that if the variance in bending moments exceeds 10%, the P-Delta effect must be included in the design. The analysis, which was performed using ETABS software with seismic loads applied for Zone III, found that the P-Delta impact is critical for a 25-story building. As a result, buildings taller than 75 meters should be planned with the P-Delta effect in mind.

[3] Song et al. tried to address conflicts between geodetic and seismic source models in order to establish a source model for simulated earthquake data. The study focused on the San Andreas Fault and the 1906 San Francisco earthquake. A projection approach was used to evaluate geodetic data, which went beyond the previously used repetitive triangular measurements in the fault's northern part. Using the triangulated network and a predetermined coordinate system, a geodetic displacement field was generated, indicating that the observed fault slip was caused by faulting rather than land sliding. To get smooth coseismic data at diverse locations, the displacement field was linearly inverted and cross-validated against independent data not included in the initial estimation. This method boosted the number of observation points from 37 to 232 and expanded the triangulated network. Model comprised an examination of seismic ground motion recordings from the 1906 earthquake obtained from sites in Europe, Japan, and the Caribbean. To evaluate the fault slip and rupture velocity, a statistical analysis was performed using Bayesian inversion and Monte Carlo simulation.

[4] Ohtori et al., In SAP2000, material giving is imitated by attaching miniature plastic hinges to structural parts. These hinges are located at zero moment points and become hinges when the material gives. Moment frames, which resemble fixed-fixed beam-column members, often have hinges placed around 10% of the beam length from each end. SAP2000 visually illustrates several degrees of plasticity using colour coding, [5] Srinivasu,. After validating hinge parameters with the OpenSees example, a three- dimensional published structure was used to compare the nonlinear behavior of a 3D steel moment frame system to concrete floors. The hinges were defined in the same way as those in the OpenSees verification structure, and elements were separated into three segments to accommodate for the lower P-Delta effects induced by deflection departures from the frame's initial chord. The model displayed in Figure 9 depicts the frame section assignments. The 115 mm thick floors were constructed using Fe415 steel (modulus 21 kN/mm²) and M25 concrete (modulus 2.5 kN/mm²). A static pushover study was carried out on this structure. The modeled structure's activated hinge sites are almost identical to those in the published structure, as is the approximate degree of vielding.

ASCE 7-16 [10], Vertical abnormalities are a leading source of building failures during earthquakes, with softstory structures being among the most visible examples of collapse. As a result, knowing the impact of vertical irregularities on seismic performance of structures is critical and warrants additional research. Variations in stiffness and mass result in dynamic properties that differ greatly from those of conventional buildings, emphasising the need for more research in this field.

Buildings with vertically uneven masonry infills in the first two stories were made in compliance with the Iraqi Seismic Code, ASCE 7-16 [10] and ACI 318-19 [11].



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Naveen E. S. et al. (2019) [12] investigated how different flaws in RC buildings affect their seismic response. A typical nine-story frame was modified by inserting several sorts of irregularities in both elevation and plan to yield 34 variations, each with a specific type of irregularity.

[14] A. Aziminejad et.al., For example, increased mass eccentricity, which causes seismic torsional response, can result from unequal live load distributions or differences between real and design stiffness and mass distributions. Building codes address these concerns by requiring an unintentional design eccentricity.

[15] C.G. Stathia et. al., define the obtained eccentricity as the eccentricity of strength. Previous analytical research on plan-asymmetrical buildings generally used one-story models due to their simplicity and capacity to capture the influence of various seismic response factors. However, more detailed research, such as that conducted by [15] Stathi et al. has broadened this study. The interstory inelastic drift ratios (IDRx,y) in both directions are determined at the goal displacement.

The ISC [17] is mostly based on the IBC 2012 [18] and ASCE/SEI 07-10 [19], with local changes for acceleration parameters S1 (1 sec period) & SS (0.2 sec period). The Iraq Seismic Code was first published in 1997 (ISC 1997) [20]. [21] M. Kreslin et al., The study also investigated the impact of greater vibration modes. In addition, the in-plan distribution of roof displacements was calculated using time history analysis (THA) and pushover analysis to measure torsional effects. [22]

P. Fajfar., To evaluate an effective distribution of story stiffness for both the upper and lower structures, this study used a simplified seismic design approach. [25] Drosos et al., they are provided in a recently published study, the net restoring force hit zero, indicating a critical point. However, the purpose of this research is not to undertake a comprehensive parametric investigation or to provide definite guidelines for analyzing and designing foundations that are operating at or above their limits. Furthermore, while certain significant conclusions are not experimentally validated here. Small-scale 1g shake table testing on sand provided preliminary experimental evidence for the development of overstrength, as described in a companion work by [25].

[26] Lagomarsino et al., Masonry is a diverse material whose mechanical characteristics (mortar and units) dictate its macroscopic behavior. Once initiated, the outof-plane (OOP) failure mechanism can lead to massive displacements, which are often represented by rigid-blocklike kinematics. This has a significant impact on structural reaction and complicates the study of the nonlinear behavior of unreinforced masonry (URM) structures, which are already extremely nonlinear even under mild seismic loads. [27] Housner et al., The response of this model is typically found by directly calculating the equations of motion under significant displacements, a method originally proposed by Housner. This tendency is prevalent in URM buildings, particularly historical structures, where a global structural reaction is not always guaranteed.

RESEARCH METHODOLOGY

This work investigates the P-Delta (structural deformation) effect in multi-story structures on a floor-by- floor basis, with thorough calculations of essential building reactions such as displacement, column moments,

beam moments, column shear, and beam shear. The seismic evaluation is performed in line with IS-1893 (Part-I) 2002 criteria, using the similar static force approach. It is believed that the floors have a solid plane. The maximum response of the building model is examined with lateral loads applied to the frame in accordance with IS-1893 (Part-I) 2002. The analysis is first performed without taking into account the P-Delta effect, and then it is repeated with the P-Delta effect factored in through several rounds. The greatest response values from both analyses are compared to establish the significance of the P-Delta effect.

P-Delta Analysis Methodology

P-Delta effects have become more pronounced as a result of the trend toward thinner and more effective building construction, emphasizing the importance of simple and accurate P-Delta analytical methodologies. In the current study, P-Delta and Linear Static analyses were performed on 12 distinct models, demonstrating that P-Delta effects have a considerable impact on the axial force, moment, and displacement of structural components, with values greater than those reported in Linear Static analysis. The most noticeable shift occurs as the slenderness ratio grows with the addition of more storeys. Several significant differences were detected, including the difference in story displacement between Linear Static and P-Delta analyses, story drift, axial force in columns, moments in columns, and the percentage of variance relative to the slenderness ratio.



These findings systematically investigate the structural response to P-Delta effects in relation to slenderness.

RESEARCH GAP

Creating an accurate and effective numerical tool to evaluate the seismic performance of existing unreinforced masonry (URM) structures with out-of-plane collapse mechanisms is the main objective of this research. Numerical simulations incorporating in-plane and outof-plane wall behavior and their interactions are made possible by this tool, which also handles all types of nonlinearities. The goal of the thesis is to significantly advance seismic evaluation techniques for URM structures by incorporating geometric nonlinearities into a thorough structural analysis. In both technical applications and scholarly research, this method removes the traditional division of in-plane and out- of-plane reactions and does away with the dependence on pre-assumed failure causes.

The following conclusions can be drawn from the secondorder analysis carried out with STAAD-Pro and confirmed by further research:

The P-Delta effect is stronger as the number of stories increases.

In general, P-Delta effects are insignificant for buildings up to ten storeys tall, when gravity loads dominate. However, these effects are more prominent in high-rise buildings.

The iterative approach yields very precise results for structures undergoing both shear and flexural deformations by replacing gravity loads with an equivalent horizontal load. In summary, RC high-rise structure analysis and design necessitate professional knowledge and insight. Variable characteristics were found in the analysis, showing that displacement rises exponentially under P-Delta analysis as height or the number of storeys grows, with axial force rising in tandem.

When comparing P-Delta analysis to linear static analysis, the axial force rapidly increases on the positive side. Under some critical load scenarios, the P-Delta effect only becomes important for moments in particular beams and columns, such as exterior columns and the beams that surround them. In order to account for the P-Delta impact in member design, certain load scenarios must be deemed essential.

Therefore, both Linear Static and P-Delta analyses are essential for RC structures and should be applied with a clear understanding to avoid potential failures. It is crucial to check the results of the analysis with and without considering the P-Delta effect for buildings.

Axial forces and displacements can be assessed through P-Delta analysis, while moment calculations can remain based on the Linear Static analysis. These conclusions are based on reinforced concrete structures with rigid joints, which are commonly found in practice.

CONCLUSION

Unreinforced masonry (URM) constructions' out-ofplane (OOP) seismic performance under seismic loads is examined in this study. Unresolved in seismic analysis, the reaction of URM walls to out-of-plane forces is still a complicated problem. The dimensions and detailing requirements of modern seismic design standards for new masonry structures greatly lower the chance of out-of-plane failure, even during strong seismic events. Nevertheless, in extant URM buildings, out-of-plane collapse remains a prevalent failure mode. A major contributing element to structural damage and collapse is the out-of-plane mechanism, which frequently happens when connections between walls, or more generally between vertical and horizontal structural components, do not guarantee boxlike behavior, a feature found in many older structures.

The proposed P-Delta formulation eliminates the need to construct and update the system's geometric matrix. Instead, it accounts for geometric nonlinearities by modifying the global load vector based on the macroelements' configurations during the analysis. Specifically, the global load vector is recalculated at each step using the updated load positions, while the method ensures equilibrium relative to the system's original configuration. As a result, the computational complexity of this model is comparable to that of DMEM models that disregard P-Delta effects.

Finally, the results emphasize how important it is to take geometric nonlinearities into account when assessing masonry walls that are subjected to seismic rocking motion. Additionally, they validate the accuracy of the suggested model, demonstrating that it can accurately forecast how rocking walls will behave under significant lateral displacements while maintaining the benefits of the DMEM approach by requiring less computing power.

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A State of Art Review on Solid Waste Management System of Nagpur City

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ABSTRACT

Solid waste refers to discarded materials arising from human or animal activities that are deemed unwanted or no longer useful. It is typically generated by industrial, residential, and commercial sectors within a specific area. The management of solid waste involves various methods and strategies to ensure proper handling and disposal.

The process of solid waste disposal and management encompasses a range of activities, including planning, administrative coordination, financial management, engineering practices, and compliance with legal standards. Responsibility for these activities primarily lies with the waste generators, under the oversight of local, national, or even international authorities. Solid waste management involves a structured approach to the collection, treatment, and disposal of solid waste. This process not only ensures environmental protection but also incorporates solutions for recycling materials that can be repurposed. At its core, solid waste management aims to transform discarded waste into valuable resources, fostering sustainability and resource efficiency.

KEYWORDS : Solid waste management, Decentralize solid waste management, Maximum yield technique, MYT.

INTRODUCTION

s per the censes 2011 the population of Nagpur city is 2.4 million and the daily waste accumulation is 1200 tons approximately. Despite its status as a progressive urban local body, significant improvements in waste management practices remain a pressing need. In the Swachh Survekshan 2023 rankings, Nagpur secured the 86th position among over 400 cities with a population exceeding 1 lakh. In the 2022 survey, the city ranked 27th among 47 cities with populations above 10 lakh. The report highlights noteworthy achievements, with the city scoring 98% in door-to-door waste collection, 100% in source segregation of waste, 89% in waste generation and processing. While these metrics reflect commendable progress, there is ample room for further enhancements to establish Nagpur as a model for effective and sustainable waste management. To ensure efficient home to home garbage collection and transportation services, the Nagpur Municipal Corporation divided the work into two major parts of the zones. Zones 1 to 5 were assigned to AG Enviro Infra Projects Private Ltd, while Zones 6 to

10 were managed by BVG India Ltd. This division was implemented to prevent outweighing a single agency and maintain service standards for residents. NMC has been award garbage collection contract for 10-years from Aug 2019. But the aim of segregation not achieved due to collecting mixed solid waste from residential areas. The vehicles provided for home to home collection activities. They collects 1200 MT of MSW every day.

Biomining & compost production :-The waste transported to the Bhandewadi dumping yard. The old deposited waste and fresh waste is processed by Biomining by 'Zigma global environ solution private limited' at INR 1,015.00 per metric ton. The work of Zigma is not satisfactory.

Biogas production :-The work of construction of Biogas plant costs 300 crore is initiated at Bhanewadi. This Biogas production work awarded to Netherland based company namely 'Sustainable business development', but initially it producing compost by processing only 200 MT of organic waste per day.

Processing of demolished building material :-The



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contract of collection, transportation & processing of demolished building material is awarded to 'Hyderabad c&d waste management company' at INR 414.00 per MT. Approximately 200 MT per day of demolished building material waste is processed by this company.

All prevalent waste processing technologies were assessed, including the innovative Maximum Yield Technology (MYT). MYT is a cutting-edge process for treating and utilizing residual household waste, with a focus on maximizing the extraction of raw materials and energy content. This technology is particularly suited for organic-rich municipal solid waste, as is the case in Nagpur. MYT employs mechanical-biological treatment to produce valuable outputs such as biogas and refusederived fuel (RDF), thereby enhancing the economic and environmental efficiency of waste management. Unlike conventional waste treatment methods like landfilling or incineration, MYT expands the technological options for waste management by offering: Optimized recovery of raw materials and energy from waste. The generation of high-quality fuels and energy-dense biogas. Reduction in environmental impact compared to traditional solutions. Operational Success of MYT

MYT has demonstrated its effectiveness through operational plants:

Kahlenberg, Germany: A large-scale plant of 100,000 metric tons capacity per annum, commissioned in 2005 and operating successfully since 2006.

Hangzhou, China: A small-scale demonstration project with a capacity of 16,500–25,000 tons per annum, implemented in 2016.

By integrating innovative technologies like MYT, Nagpur can enhance its waste management framework, ensuring sustainability and improved resource utilization.

PROCESSES IN MYT MSWMS

The MYT process for waste treatment involves several key stages designed to maximize resource recovery and energy efficiency. The stages are as follows:

Mechanical Pre-Treatment

Upon reception, waste is transferred to the mechanical pre-treatment stage, where it is automatically broken down into predefined fractions based on material type and size. This step ensures optimal separation and preparation for subsequent processes.

Biological Treatment

Process Water Addition: Process water is added to achieve a consistent and uniform texture.

Mixing and Dewatering: For biological drying the waste is mixed and dewatered using presses, resulting in solid material optimized.

DAMP Process: The advanced DAMP process preserves microbially convertible organic matter within the solid material, improving the efficiency of the drying process.

Press Water Treatment: The press water is subjected to multiple treatment stages to extract energy and ensure purification.

Biological Drying

This stage utilizes the inherent energy in waste for efficient drying in tightly sealed concrete tunnels. The process involves: Oxygenation: Controlled airflow provides oxygen to microorganisms that consume organic matter, producing thermal energy.

Thermal Energy Utilization: Thermal energy generated by microorganisms evaporates moisture in the solid material.

Final Output: After a brief treatment period, the process produces a homogeneous, dry, and free-flowing solid material that can be easily separated into components such as energy sources, minerals, and metals.

MECHANICAL MATERIAL SEPARATION

Fully automated mechanical separation divides the dried material into various sub-fractions using sieving and classification systems. This step facilitates:

Extraction of energy-rich fuels with specified size, chemical composition, heating value, and biomass content.

Recovery of minerals and remaining metals, which are directed to dedicated loading stations.

Discharged Air Treatment

To minimize environmental impact, discharged and process air streams are treated as follows:

Low-Level Polluted Air: Treated through humidifiers and bio-filters, where microorganisms effectively clean the air.

Heavily polluted air: is purified through air washers and a regenerative thermal oxidation system, ensuring comprehensive treatment.



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Water Treatment

During the biological stage, the process water at a rate of $400 \text{ m}^3/\text{day}$ is produced. It is to be directed to a newly constructed 130 MLD wastewater treatment plant situated next to the proposed municipal waste treatment facility.



Fig. 1 Conceptual Overview of MYT's Process





OUTPUT OF MYT

To process 800 tons of MSW per day the MYT system is designed. It is projected to produce the 8.36 MW of power & Refuse-Derived Fuel (RDF) at the quantity of 213 TPD, with a calorific value of 10,000–12,000 kJ/ kg and a moisture content of 20%. The RDF generated by the MYT plant offers versatile applications: It can be used on-site for energy generation. It can be supplied to nearby industries like power, cement and steel plants. The combustion of RDF could yield an additional 35.3 MW of energy, enhancing the overall energy output. Waste Characterization and Suitability for MYT

A high organic fraction of approximately 60%. A significant moisture content of 56%. These characteristics

make the municipal waste unsuitable for incinerationbased processes, which typically require lower moisture content and a different waste composition. However, the organic and moisture-rich waste is highly compatible with the MYT system, making it an ideal choice for sustainable waste processing in the region.

CONCLUSIONS

The existing MSWM system unable to cover the adjoining areas and some congested localities within the city of Nagpur. However, this centralized MSWM system in Nagpur has not yielded the desired results yet. SWM is a major problem in rural areas of Nagpur district also.

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RC Beam-Column Connections with Diagonal Reinforcement: Hysteretic Performance Study

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ABSTRACT

The seismic performance of reinforced concrete (RC) beam-column joints depends significantly on their behavior under cyclic loading, with improper design and detailing often leading to failure during earthquakes. This study examines the impact of innovative reinforcement detailing on the performance of exterior beam-column joints through reverse cyclic loading tests on four scaled subassemblages. Two types of reinforcement were evaluated: conventional detailing as per IS 456:2000 (Group 1) and non-conventional detailing with diagonal bars or cross-bracing reinforcements (Group 2). The results demonstrate that cross- bracing reinforcements substantially enhance seismic resilience by improving load capacity, energy dissipation, and joint ductility.

KEYWORDS : RC beam-column connection, Reverse cyclic testing, Flexibility, Diagonal reinforcement.

INTRODUCTION

The behavior of beam-column connections plays a key role in the seismic behavior of RC frames. Poor detailing as per seismic codes can reduce ductility and structural resilience, as observed in failures during recent earthquakes (Bindhu and Sreekumar, 2011). Strength and energy dissipation are essential for resisting seismic loads, but balancing ductility and economic constraints is necessary (Chidambaram and Thirugnanam, 2012). High transverse hoop reinforcement enhances strength, stiffness, and ductility under cyclic loading but may cause steel congestion and construction challenges.

Various studies propose different solutions for improving the seismic performance of beam- column joints. Paulay (1989) highlighted the importance of joint shear reinforcement to sustain diagonal compression fields. Tsonos et al. (1992) suggested using diagonal cross bars to enhance seismic resistance, while Murty et al. (2003) recommended hairpin stiffeners as an alternative to closed ties. Jing et al. (2004) showed the benefits of unconventional diagonal "obtuse Z" bars. Tsonos (2007) emphasized the need for regular updates to international design codes. Ugale and Khante (2022) studied the impact of hoop reinforcement on energy dissipation, stiffness, and joint performance. While IS 13920 provides ductility guidelines, it lacks specific provisions for beam-column joint design.

Controlled Examination

This research investigates the strength, ductility, energy absorption, stiffness, and load capacity of RC beamcolumn joints featuring diagonal beam reinforcement and hairpin-shaped column bars (Figure 1) in comparison to conventional IS code detailing. Additionally, a scaled model of a six- story building joint was analyzed and experimentally tested.

Specimen Characteristics, its preparation and Material Details

The study involved testing four scaled-down (1/3) RC beam-column specimens (SP1-SP4): Group-1 (control specimen as per IS 456:2000) and Group-2 (non-conventional). SP3 used diagonal beam reinforcement; SP4 added diagonal cross-bracing for joint confinement. All specimens had similar dimensions and reinforcement with 8 mm HYSD bars and 6 mm stirrups at 100 mm spacing.



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(b) Group 2 (SP3 and SP4)

Fig. 1. Specimen Reinforcement Details

M25 concrete, prepared with 53-grade PPC, natural sand, and 20 mm coarse aggregate. A 28- day average compressive strength of 31.96 N/mm² was achieved. The specimens were horizontally cast, water-cured for 28 days, and subsequently tested.

TESTING METHODOLOGY

The external beam-column joint specimens underwent cyclic quasi-static testing to mimic seismic effects, as shown in Figure 2. Positioned upright, the specimens had their column ends hinged to the reaction frame, and cyclic reverse loading was applied using a 1000 kN capacity load cell.



Fig. 2. Experimental Setup

A displacement-controlled test was performed, with

deflections incrementally increased by 3 mm until failure. Linear Variable Displacement Transducers (LVDTs) tracked deflection changes. The specimens were assessed for their peak load capacity, deformation response, flexibility, energy retention, and rigidity.

Crack Patterns and Load-Bearing Performance of Beam-Column Joint Specimens

Crack patterns observed during testing, shown in Figure 3, revealed tensile cracks mainly at the beam-column interface across all specimens.



(a) SP1(b) SP2 (c) SP3 (d) SP4

Fig. 3. Specimen Crack Patterns

SP1 and SP2 developed hairline cracks in the second cycle, leading to joint failure, while SP3 and SP4 showed delayed cracking after the second and third cycles, respectively. SP3 had beam cracks extending into the joint, whereas SP4 exhibited only interface cracks, indicating superior performance. Ultimate load capacities were 11.84 kN (SP1) and 11.63 kN (SP2), while SP3 and SP4 achieved 12.68 kN and 13.36 kN, reflecting 8.05% and 13.85% improvements due to diagonal reinforcement and hairpin bars.

Hysteretic behavior, Energy dissipation Ductility of Joints

The hysteretic load-displacement curves for all specimens are depicted in Figures 4(a)-4(d).

SP3 and SP4 demonstrate superior hysteresis behavior with larger curve areas, greater energy dissipation, and enhanced joint performance compared to SP1 and SP2. Energy dissipation, derived from the hysteresis curve area, indicates SP3 and SP4 dissipate 5.73% and 9.88% more energy than average value of SP1 and SP2 (Table 1). The flexibility Index ($\mu = du/dy$) shows non- conventional joints (SP3 and SP4) achieving 35.06% and 40.38% higher ductility. These results are consistent with the findings of Hwang et al. (2005) and Ugale and Khante (2019), confirming the effectiveness of non-conventional



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reinforcement in improving seismic performance.

Sr. No.	Specimen	Total Energy Dissipated	Flexibility Index	
1	SP1	346.38	4.18	
2	SP2	352.21	4.25	
3	SP3	369.18	5.70	





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Figure 4. Load-Displacement Response Curves

Shear Capacity, Stiffness, and Seismic Performance of Beam-Column Joints Seismic criteria ensure safety by limiting deformation, preventing damage or failure, while stiffness, defined as load per unit deflection, is vital for stability. All specimens exhibited gradual stiffness reduction (Table 2). The shear capacity was determined using the bearing capacity approach (ACI 318-08).

$$Vjh, u = T - Vcol$$

= 1.25 (Ast fy - Ast fy $\frac{jd}{Lc}$) (1)

Here, T denotes The tensile force in the beam reinforcement is denoted by T, Vcol indicates the shear force in the column, Ast represents the area of beam reinforcement, fy refers to the yield strength of the longitudinal reinforcement, Lc is the distance between the inflection points of the column, and jd stands for the internal lever arm of the beam's cross-section.

The updated reinforcement detailing led to an enhancement in ultimate bearing capacity. The peak shear capacity of the joint (Vjh,test) was determined as.

$$Vjh, test = Tmax - Vcol$$

$$= Pmax \left(\frac{Lb}{jd} - \frac{Lb + 0.5 hc}{Lc}\right)$$
(2)
(3)

Here, Tmax represents the peak tensile force, Vcol is the column shear force, Lb is the beam length from the column face, and hc is the column height. The maximum shear strength of the specimens (Table 2) indicates that conventional specimens averaged 49.64 kN, while SP3 and SP4 exhibited 8.84% and 13.01% higher capacities, respectively.

Fable 2: Joint Shear	· Strength	and	stiffness
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		Shear	Stiffness		
S. N.	Specimen	Strength (V _{jh,test}) in kN	Initial Fina		
1	SP1	5004	4.15	0.96	
2	SP2	49.23	4.14	0.95	
3	SP3	54.03	6.09	1.08	
4	SP4	56.10	6.62	1.15	

Main Findings of the Present Study

Non-conventional reinforcement detailing significantly improved the cyclic performance of RC beam-column joints, with SP3 and SP4 showing higher strength, ductility,

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energy dissipation, and stiffness compared to SP1 and SP2. SP4 exhibited the best performance, delaying cracking and minimizing joint damage.

Comparison with Other Studies

These findings support prior research, including Tsonos (2007) and Ugale and Khante (2022), highlighting the effectiveness of non- conventional reinforcement in enhancing joint ductility and seismic resilience.

Implication and Explanation of Findings

Non-conventional detailing, like diagonal reinforcement and cross-bracing, enhances RC joints' seismic performance by improving energy absorption and delaying cracking, increasing structural safety in earthquake-prone areas.

Strengths and Limitations

The study's strength is its experimental validation of nonconventional reinforcement on scaled models, though limited specimens and scale effects constrain full-scale applicability.

Conclusion, Recommendation, and Future Direction

Non-conventional reinforcement methods, particularly cross-bracing as demonstrated in SP4, offer superior seismic performance and should be adopted in RC joint designs for enhanced safety. Future studies could explore larger-scale testing, varied load conditions, and long-term durability to further validate and refine these findings.

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ABSTRACT

For understanding the influence of using banana fiber mats as reinforcement material on the bearing capacity of black cotton soils, model plate load tests were conducted. The laboratory plate load tests were conducted on a square footing on banana mat reinforced soil beds. The parameters studied in testing program were the depth of reinforcement, the plan area of reinforcement and the footing size. The banana fiber mat of selected sizewas placed at desired depth. The b/B ratio for banana mat was varied from 0.5 to 2.0 where b is width of mat and B width of test plate. The unidirectional and bidirectional banana fiber mat of different sizes 20 cm \times 20 cm, 30 cm \times 30 cm, 40 cm \times 40 cm, 50 cm \times 50 cm were used to reinforce the black cotton soil. The ratio of depth of reinforcement (u) to width of plate (B) is taken as 0.3, 0.6 and 1.0. The banana fiber mats were placed at 0.3B, 0.6B and 1.0B depth. The test results indicated that the maximum bearing capacity ratio was found at u/B = 0.6 and Br/B = 3. Also the optimum banana mat size for unidirectional and bidirectional mat was found to be 300 mm \times 300 mm which is three times the width of plate.

KEYWORDS : Banana fiber mat, Reinforcement, Settlement, Bearing capacity, Footing.

INTRODUCTION

Expansive soils, commonly referred to as Black Cotton Soil (BC soil), are found in India and range of 800,000 square kilometers. It can be found in Maharashtra, Gujarat, parts of Karnataka, the eastern parts of Madhya Pradesh, Andhra Pradesh and the southern parts of Uttar Pradesh . Black Cotton soil is one in presence of water shows a bent to swell or cut back causing the shape to revel in moments that are largely unrelated to the direct impact of loading with the aid of the shape. Black cotton soil isn't suitable for the development work as a consequence of its volumetric adjustments. It swells and shrinks excessively with alternate of water content. Such tendency of soil is due to exceptional clay particles which swell, while they arrive in contact with water, resulting in exchange swelling and shrinking of soil because of which differential agreement of structure takes location Black cotton soil's effects on manmade structures remain a significant global issue. They are of special engineering interest since they have caused a lot of foundation issues due to these unfavorable engineering characteristics. Various troubles related to these soils are: structural troubles via differential movement of the shape ensuing in intense harm to the principles, buildings, and

roads, keeping partitions, canal linings and movement of soils on unstable slopes. However, it is required to construct structures supported on BCS due to a shortage of space, resources, and other associated problems. Thus, enhancing the BCS's properties by reinforcing is typically the most viable and practical choice remaining.

LITERATURE REVIEW

A variety of geosynthetic reinforcements, including planar, mat, grid, and fiber form are frequently used to improve the soil's capacity to sustain loads beneath foundations. Several researchers conducted a study on geo-synthetic reinforcement.

Schurholz (1991) investigated the application of geotextile made from woven coir to protect the environment. In one instance, the shoreline of Lake Bodensee, which formed the triangular border between Germany, Austria, and Switzerland, was replanted. Reed belts along the shoreline decreased as a result of increased water pollution and wave action. The coir geotextile fence was made for a region where water levels fluctuated a lot in the summer and winter. First, the stabilization fence was secured vertically to 60–75 cm wooden stakes that were



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anchored with nails and staples. The geotextile should be anchored in a trench and these stakes should be securely fastened in the ground to prevent runoff beneath the fence.

Beena (2013) investigated the use of geotextiles made of coir to stabilize soil.A 1.4-kilometer farm road in Changaram Padashekaram Thuruvoor, Kerala, has been finished. It was noted that the road is still stable and undamaged after five years of traffic and seasonal variations.

Ciecket al. (2015) conducted a number of surface strip footing model tests in a lab setting on both unreinforced and reinforced sand beds to examine the impact of reinforcement . The load-settlement and bearing ratio data were compared with the model test program's results. The results for different numbers of reinforcement and types of reinforcement were used to determine the length of footing required to achieve the best improvement. It was also noted that for large settlement values and low settlement ratio values, the improvement brought about by subgrade reinforcement varied.

Shridhar and Pratap Kumar (2017) performed footing experiments using coir mats with varying u/B ratios while sitting on reinforced sand under static pressure. To assess the footing's performance in terms of settlement and bearing capacity, the results were compared.

Additionally, a theoretical evaluation of the experimentally determined ultimate stress values for sand reinforced with coir mats was conducted. The load intensity response for coir mat reinforced sand highlights how crucial it is to position the reinforcement layer beneath the loaded area. The load intensity response was still higher than that for unreinforced sand when the u/B ratio of coir mat varied between 1 and 2, although it was slightly lower than those obtained corresponding to u/B = 0.6. According to this, it was advantageous to place the mat reinforcement so that it intercepted the shear zone underneath the loaded area. The settlement reduction factor (SRF) of coir mat reinforced sand raises as the u/B ratio rises, with a little fluctuation in SRF seen as the load intensity increases. Sand particles interlock in the mat's grid space, providing lateral restraint that raises SRF, which is why SRF increased as the u/B ratio increased.

Panigrahi and Pradhan (2019) carried out the experimental study to employ geotextile to increase the bearing capacity of the soils. A single layer of geojute was used to reinforce the 50 mm and 75 mm square footings in sandy soil. The range of the Dr/B ratio (depth of reinforcement to width of

footing was 0.25 to 2.

Additionally the reinforcement area was changed from $1B \times 1B$ to $4B \times 4B$. The placement of reinforcement in sand beds at different depths and sizes has an impact on the final bearing capacity and settlement because of these factors. When the reinforcement was positioned at a depth of 0.5 B, the greatest increase in ultimate bearing capacity (UBC) was seen. The depth range of 0.25 B to

0.75 B is the most efficient zone for reinforcement. The optimal depth of reinforcement resulted in a UBC increase of 2.76 to 3.37, depending on the size of the footing. Furthermore at mild strains like1, 2, and 3%, the Bearing Capacity Ratio (BCR) increased by a ratio of

2.03 to 2.47. It was determined that, irrespective of footing size, the optimum reinforcement size was 3.5B \times

3.5B. The UBC was raised by a factor of 2.7 to 3.6 at the ideal size and depth of reinforcement in comparison to the unreinforced soil. Because of this, sandy soil can have its bearing capacity increased by using geojute, or natural geotextile, with a size of 3.5B (B is the footing width) and a depth of 0.5B.

METHODOLOGY

A variety of tests were performed on the soil to confirm its identity as black cotton soil. To assess the bearing capacity of reinforced soil, model plate load test were performed on the model footing using various banana fiber mats.

MATERIALS AND METHODS

The black cotton soil and banana fiber mats were used in this study. In order to assess the bearing capacity of reinforced soil, model plate load test were performed on the model footing using various banana fiber mats.

Black Cotton Soil

This study's soil was collected from Dhamangaon village in the Jalgaon district of Maharashtra, India. In the laboratory compaction characteristics, including the maximum dry density (MDD) and optimum moisture content (OMC), were measured in addition to other index characteristics. Table 1 show the soil used in this study's MDD, OMC, free swell index and consistency limit.

Table 1.Index and Compaction Properties of Soil

S N	Details	Output
1	Liquid Limit, LL (%)	85.33



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2	Plastic Limit, PL (%)	62.72
3	Plasticity Index, IP (%)	22.61
4	Free Swell Index, FSI (%)	69.53
5	Maximum Dry Density, MDD(KN/m ³)	14.9
6	Optimum Moisture Content, OMC (%)	29.6
7	Soil Classification	MH

An increasing load was applied to a square steel plate to cause settlement in order to perform a plate load test , which was used to determine the bearing capacity. The plate load test was conducted in tank fabricated at site. The load frame was also fabricated to apply load on plate.

Model Plate Load Test Setup

The test setup used for the model plate load test consists of the following and shown in the Fig.3.

- 1. Test tank
- 2. Loading frame
- 3. Hydraulic jack and pumping unit
- 4. Load transfer beam
- 5. Connecting plunger
- 6. Proving ring
- 7. Dial gauges

The test tank size $600 \text{mm} \times 600 \text{mm} \times 600 \text{mm}$ was fabricated. The loading frame was erected and the load was applied through hydraulic jack and the settlement was measured using dial gauges provided.

Test Tank

The model test tank was fabricated with steel plate of plan dimensions 60 cm \times 60 cm and a height of 60 cm as shown in Fig 1. The size of the tank was selected such that no confined stresses will be developed during testing of footing. This was achieved by keeping the width of tank more than five times the width of footing. The apparatus comprises a hydraulic jack secured to a rigid self –reaching frame. A 2 KN proving ring is utilized to guarantee precise load measurement. The load was moved from the jack to the test plate using a square mild steel bearing plate that was 10 cm \times 10 cm in plan and 1 cm thick. The width of the tank considered was 5 times the width of the plate to avoid the boundary effects. The thickness of soil bed

was 36 cm which was more than 3 times width of plate. The banana fiber mat was placed during the compaction soil of desired size and at desired depth. After, the sample preparation, the test was conducted.





Test Procedure

The test tank, hydraulic jack and dial gauges are here placed at the position.

- 2. This test tank was filled in layers of 4 cm thickness using a rammer which was able transfer an compacting energy equivalent to standard Proctor compaction energy. The soil bed of 36 cm was prepared for plate load test.
- 3. The banana fiber mat was placed at desired depth and selected size. The b/B ratio for banana mat was varied from 0.5 to 2.0 where b is width of mat and B width of test plate. The black cotton soil reinforced with a unidirectional and bidirectional banana fiber mat of varying sizes (20 cm × 20 cm, 30 cm × 30 cm, 40 cm × 40 cm, 50 cm × 50 cm). The ratio of depth of reinforcement to width of plate (u/B) was taken as 0.3, 0.6 and 1.0. The banana fiber mats were placed at 0.3 B, 0.6 B and 1.0 B depth where as B is the width of plate. Fig.2 shows the laying of unidirectional and bidirectional banana fiber mats.



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- 4. After filling of tank and placing of banana fiber mat, the test plate was placed. The dial gauges and proving was set up on test plate a shown in Fig. 3.
- 5. The load was applied to the footings in small increments by controlled hydraulic jack. The test was performed according to the IS: 1888. The load transferred to the footing was measured using the proving ring. Each load increment was maintained constant untilthe footing settlement was stabilized. By averaging the readings from the two dial gauges, the vertical displacement of the test footing was determined.
- 6. The load on footing was released after reaching desired settlement. By releasing valve of hydraulic jack. The footings were removed and





- a) 20 cm × 20 cm Unidirectional Banana Fiber Mat
- b) 30 cm × 30 cm Bidirectional Banana Fiber Mat

Fig. 2: Laying of Unidirectional and Bidirectional Banana Fiber Mats



a) Measuring Set up

b) Set up Ready for Taking Reading

Fig. 3. Experimental Set up of Plate Load Test

RESULTS AND DISCUSSION

In order to investigate the load settlement behavior of footings, model plate load tests were performed on reinforced and unreinforced soil under various conditions. A loading frame developed in the laboratory was used to perform the plate load test on soil and soil reinforced with banana fiber mat. The size of the test tank used in this investigation was 600 mm \times 600 mm \times 600 mm. The model footing used was of size 100 mm \times 100mm \times 10 mm.

To prevent eccentric loading, the footing was positioned precisely in the middle of the prepared soil bed after the surface had been leveled. Using a hydraulic jack, the footing was loaded, and the load was applied. On the model footing, two dial gauges positioned diametrically opposite each other were used to measure the footing settlements.

The load tests were conducted on black cotton soil and soil reinforced with banana fiber mat. The failure load was considered corresponding to the settlement of 2.5 mm for all test conducted. The permissible settlement for 100 mm \times 100 mm plate was assumed as 2.5 mm, based upon consideration of square footing size of 2 m width and corresponding permissible settlement of 50 mm for cohesive soil.

Table 2 gives the results of plate load test for plain black cotton soil. The average bearing capacity of 100 mm plate was found to be 200 KN/m^2 .

Table 2: Plate Load Test for Black Cotton So
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Test No. Bearing Capacity (KN/m ²)		Average Bearing Capacity (KN/m ²)	Settlement (mm)	
1	190			
2	180	200	2.5	
3	230			

Plate Load Test for Banana Fiber Mat Reinforced Soil. The Plate load tests were performed on the different sizes of banana fiber mats which were manufacture as unidirectional and bidirectional mats. The size of banana fiber mat was selected based on the ratio of width of footing to width of banana fiber mat (b/B). The b/B ratio varied from 0.5 to 2.0. The unidirectional and bidirectional banana fiber mat of different sizes 20 cm \times 20 cm, 30 cm \times 30 cm , 40 cm \times 40 cm , 50 cm \times 50 cm and were used to reinforced the black cotton soil.



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The ratio of depth of reinforcement to width of plate (u/B) was taken as 0.3, 0.6 and 1.0. The banana fiber mats were placed at 0.3 B, 0.6 B and 1.0 B depth where as B is the width of plate. The size of plate was used as

100 mm \times 100 mm. Fig. 4&Fig. 5 shows bearing capacity ratio for unidirectional and bidirectional banana fibre mat reinforced soil for different depth and different width of mat. It can be seen that the maximum bearing capacity ratio was found at u/B = 0.6 and Br/B = 3 i.e. the optimum depth of mat was 0.6 times width of mat and the optimum width of mat was three times the width of mat (Br is width of reinforcement). Also the mat size for unidirectional and bidirectional was found to be of optimum size of 300 mm \times 300 mm which is three times the width of plate.







a): Bearing Capacity Ratio vs U/B Using Bidirectional Banana Fiber Mat





Fig. 5: Bearing Capacity Ratio for Bidirectional Banana Fiber Mat Reinforced soil

CONCLUSIONS

On the basis of present experimental investigation the following conclusions were drawn

- i. The load carry capacity of footing resting on black cotton soil impressed by using banana fiber mat either unidirectional or bidirectional mat. The increase in load carrying capacity of reinforced soil bed was more than 1.5 times the black cotton soil. The optimum depth and optimum size of was found to be 0.6 times three times the width of plate testing plate respectively.
- ii. The load carrying capacity of footing resting on black cotton soil reinforced with bidirectional banana fiber mat shows maximum increase than unidirectional mat.

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ABSTRACT

Industrial wastewater contains harmful heavy metals that affect surface water, groundwater, and soil. Constructed wetlands, particularly 4th-generation tidal flow systems, are efficient for wastewater treatment. This study examines copper removal from synthetic wastewater using a laboratory-scale tidal flow constructed wetland (35cm x 35cm x 120cm) with a 7-day detention period. The system consists of two cells layered with different media sizes and vegetated with Typha species. Results showed dissolved oxygen increased by 69.62%-70.64%, with BOD and COD removal at 91.41% and 85.51%, respectively. Copper removal reached 89% in the soil layer and 80% in the coarse aggregate layer.

KEYWORDS : Tidal flow, Constructed wetland, Wastewater treatment, Heavy metal.

INTRODUCTION

Industrialization significantly contributes to a country's Leconomy but generates waste that severely impacts the environment, contaminating surface water, groundwater, and soil. The nature of pollutants varies with industries; for example, textile industries discharge high COD, BOD, and color, while tanneries release heavy metals like arsenic, cadmium, and mercury, which are toxic, nonbiodegradable, and persistent (Arezoo Azimi et al., 2016). These metals accumulate in aquatic life and the food chain, posing health risks.Conventional heavy metal removal methods include chemical precipitation, coagulation, ion exchange, and membrane processes, though their application depends on waste type, concentration, and economic feasibility (Gunatilake S.K., 2015). Biological treatments using microorganisms are increasingly popular due to their cost-effectiveness and efficiency (P. Rajasulochana and V. Preethy, 2016). Developing nations, constrained by high operational costs and energy demands, favor low- cost, natural treatment systems like wetlands, which are effective, eco-friendly, and conserve biological communities (Qaisar Mahmood et al., 2013; Xinxi Fu et al., 2008). Wetlands, recognized for water purification and habitat support, play a critical role in mitigating industrial contamination (Alexandros I. Stefanakis, 2015).

CONSTRUCTED WETLANDS

Constructed wetlands are engineered systems designed to mimic natural wetland processes for wastewater treatment,

utilizing wetland vegetation, soils, and microbial activity within a controlled environment (Jan Vymazal et al., 2006). These systems consist of shallow ponds or channels planted with aquatic plants and rely on natural microbial, biological, physical, and chemical processes. They include impervious liners and engineered structures to control flow, detention time, and water levels and may include inert porous media like gravel or sand (EPA, 2000).Constructed wetlands are now a reliable wastewater treatment technology. Brix (1993) classified aquatic macrophyte-based systems as free-floating, submergent, and emergent, while constructed wetlands are categorized by vegetation type (emergent, submerged, floating leaved, or free- floating) and hydrology (free water surface or subsurface flow, with subsurface flow further divided into vertical or horizontal flow).

Tidal Flow Wetland

Tidal Flow Artificial Wetlands (TFAWs), described by Ina Weinheimer (2015) as 4th generation intensified wetland systems, replicate natural tidal wetland processes for biological wastewater treatment. These systems use multiple flood-and-drain cycles daily, filling media pores with air to promote aerobic conditions (Tanveer Saeed et al., 2019).Flexible in design, TFAWs can be integrated into landscaping, buildings, or greenhouses. The alternating tidal cycles efficiently remove nutrients and solids, producing high-quality effluent. A final stage of filtration and disinfection yields crystal-clear water suitable for reuse.

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METHODOLOGY

Experimental Set-up

A Tidal Flow Wetland System was fabricated using two acrylic wetland units ($35 \text{ cm} \times 35 \text{ cm} \times 120 \text{ cm}$) with a total capacity of 200 L. Each unit comprises layers of coarse gravel (7.5 cm), fine aggregate (7.5 cm), fine sand (10 cm), and soil (70 cm), planted with Typha sourced locally. Inlet and outlet arrangements are at the bottom of the units (see fig. 1).The system uses solenoid valves and moisture sensors to achieve programmed fill-and- drain cycles for varying detention periods. Pipes with holes ensure aeration to prevent substrate clogging from biofilm overgrowth, making batch processing effective.





Synthetic Waste Water Preparation and Calibration Curve

Industrial wastewater samples were collected from Butibori, an industrial suburb of Nagpur, India. Developed by Maharashtra Industrial Development Corporation (MIDC) as a 5-star industrial district, Butibori spans 23.12 km², with 14.94 km² developed to boost Nagpur's economy.

Tests were conducted on the raw wastewater samples from Butibori, and the results are presented in Table 1.

Table 1 Result Obtained for Raw Wastewater at ButiboriMIDC Nagpur

Sr No.	Parameter	Concentration
1	DO	1.16 mg/l
2	BOD	236 mg/l
3	COD	398 mg/l
4	Copper	4.05 mg/l

Based on the results of wastewater characteristic, the synthetic wastewater was prepared with known concentration of copper, to find the concentration of copper in treated wastewater calibration curve was prepared for the range of 1 mg/l to 10 mg/l as shown in fig 2.





RESULT AND DISCUSSION

BOD and COD Removal

After the preparation of the tidal flow wetland system the actual performance of the system was started. Table 2 shows initial and final characteristics DO, BOD, COD of synthetic wastewater were determined using standard methods.

 Table 2 Initial and final Characteristic of wastewater samples

~	Sample 1		Sample 2		Sample 3		Sample 4	
(mg/L)	Initial	Fina1	Initial	Fina1	Initial	Fina1	Initial	Final
DO	1.23	4.05	1.18	4.02	1.2	4.02	1.2	4
BOD	246	21.2	250	21.6	248	21.4	248	21.3
COD	378	58	370	56.2	375	54.3	376	55.3



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Copper Removal

The initial concentration of copper in synthetic wastewater was maintained to 10 mg/l which was detained for the period of 7 days in the wetland cells. Concentration of Copper was studied in each layer of the bed in each cell.



Fig. 3% Removal of Copper in different layers for cell 1

The characteristics of wastewater at the inlet and treated wastewater at the outlet were studied for a 7-day detention period in cell 1. Copper removal efficiency was observed as follows: soil layer (87%), fine sand layer (86%), fine aggregate layer (82%), and coarse aggregate layer (79%) (see fig. 3).Removal mechanisms in wetlands include metal uptake by plant tissues, adsorption on soil, filtration/ sedimentation of particles, and microbial processes like precipitation, co-precipitation, and volatilization (Ulrich Stottmeister et al., 2006).





In cell 2, copper removal efficiencies were as follows: soil layer (89%), fine sand layer (88%), fine aggregate layer (85%), and coarse aggregate layer (81%) (see fig. 4). Copper removal in wetlands occurs through Typha uptake, soil adsorption, and precipitation, with copper tending to accumulate on root structures rather than being absorbed. Metal reduction is attributed to wetland processes such as sedimentation, precipitation, adsorption, plant assimilation, and microbial activity (A. M. Khan et al., 2015). Plant uptake ability depends on the plant and metal type. In constructed wetlands, heavy metals may be adsorbed to soil or sediment, chelated with organic matter, or removed via oxide formation. Biological removal pathways include plant and microbial uptake, with metal uptake rates varying by plant species, growth rate, and metal concentration. Maximum metal concentrations are typically observed in roots (Choudhary et al., 2011).Copper accumulation occurs through bioadsorption, transport across membranes, and cytoplasmic bioaccumulation in a dose- and time-dependent manner (Monferrán et al., 2009). Hyperaccumulating aquatic plants, such as Potamogeton, show higher metal accumulation in roots due to rhizofiltration. Copper absorbed by plants is transported through tissues by metalloproteins, which regulate cellular copper levels and deliver it to required sites (Marcela Brandão Costa et al., 2018).

CONCLUSIONS

The study results show that tidal flow constructed wetlands are effective for copper removal in wastewater. Dissolved oxygen increased by 69.62%-70.64%, BOD removal reached 91.41%, and COD removal was 85.51%. Copper removal efficiency ranged from 89% in the soil layer to 80% in the coarse aggregate layer. Copper, essential in small amounts for plant and animal growth, is primarily removed in plant roots (John Mellem). Metal removal in wastewater wetlands occurs through plant uptake, soil adsorption, and precipitation, with certain plants capable of storing high metal concentrations in their biomass and roots.

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An Overview on Digitization and Modernization of Land Records in Maharashtra

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ABSTRACT

Through the use of cutting-edge technologies, the first component of the Modernisation and Digitisation of Land Records in Maharashtra aims to address enduring issues with fragmented data, manual processes, and restricted access. It begins with an overview of traditional land records and the basic challenges associated with manual documentation. In order to increase transparency, accuracy, and accessibility, the study then looks into the methods and tools utilized in the digitization process, such as Geographic Information Systems (GIS). Among the major projects are the establishment of the Maha Bhulekh site for online record access, the SWAMITVA Yojana for mapping rural properties, and the use of drones for accurate surveys. The benefits of updated land records—such as improved accuracy, better transparency, fewer property conflicts, and more effective administrative processes—are also examined.

The article additionally looks at reducing disputes and improving efficient revenue collection, these steps also align with the larger goals of the Digital India Land Records Modernisation Programme (DILRMP). The benefits, challenges, and recommendations for further development in the modernisation of land records are highlighted in the report.

KEYWORDS : Modernization, GIS, SWAMITVA, Maha Bhulekh, DILRMP.

INTRODUCTION

India's land records date back to the British colonial era when systems were developed for administration and revenue collection. Efforts like the Great Trigonometrical Survey laid the foundation for accurate land record systems. After independence, these records continued to rely on outdated methods, often causing errors, inefficiencies, and disputes. In Maharashtra, scattered land records across departments created transparency and accessibility issues.

To improve this, the Maharashtra government launched the Digital India Land Records Modernization Programme (DILRMP)[3]. This program uses technologies like GIS and Cloud Computing to modernize land records, reduce disputes, and integrate maps for better planning. However, India's land ownership is still presumptive, based on sale deeds and tax records rather than guaranteed titles. The 2019 Land Titles Bill aims to address this by introducing conclusive titles. Around 70% of property disputes arise due to flawed systems, as registrations under the Registration Act of 1908 lack proper verification[4]. While challenges like data gaps and cyber risks exist, digitization under DILRMP shows potential. Using tools like GIS, GPS, and drones, modernized land records can boost rural development, economic growth, and legal clarity, transforming land management in India.

LITERATURE REVIEW

India is digitizing land records to reduce disputes, improve transparency, and ensure efficient management.[1]

The Digital India Land Record Modernization Programme (DILRMP) focuses on modernizing records, establishing conclusive titles, and integrating services like Aadhaar.[2]

Key components of DILRMP include capacity building, computerized registration, digitized maps, and updated cadastral records.[3]



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Benefits include easier access to records, linking property details for loans and insurance, and aiding disaster management and environmental monitoring.[4]

Maharashtra's programs like e-MAHABHOOMI emphasize digitization, cadastral maps, and transparent data systems but still face challenges.

India's colonial land records system is outdated and needs modernization to manage increasing land transactions.[5]

METHODOLOGY

As land became a major source of wealth and transactions expanded, the need of maintaining land records grew over time. A village map, Khasra (It is detailed land information), and Records of Rights (Ror/Khatauni), which indicated ownership, were traditionally used in land recording. The Patwari is in charge of these documents, which are crucial in land acquisition and court cases and need to be updated on a regular basis. They are susceptible to harm from pests and natural calamities, too, which emphasizes the necessity of digitization. Land records are computerized using Cadastral mapping , GIS (Geographic Information System), ETS (Electronic Total Station),GPS (Global Positioning System)Remote sensing,CORS (Continuous Operating Reference Station).

Cadastral Map

Land ownership, boundaries, and specifics such as survey district names, plot numbers, and adjacent streets are all shown on a cadastral map. It is a component of a cadastral, which is a group of records that initially served tax purposes and display the ownership, value, and extent of land. The cadastral is now used to identify individual land parcels and to keep track of land rights. A cadastral map's primary functions include recording land surveys, facilitating the transfer of land ownership, documenting land ownership, and supporting land value and taxation.



Geographic Information System (GIS)

Geographic Information Systems (GIS) create detailed maps combining topographical, land use, and ownership data. This helps resolve boundary disputes and ensures accurate land use planning. GIS integrates spatial and nonspatial data for map creation, analysis, and modeling. It supports land accounting, monitoring, procurement, and infrastructure development. GIS also connects electronic documents with digital maps, offering instant access to records and faster data retrieval. Key benefits include better data analysis, effective monitoring, and improved decision-making.

Electronic Total Station (ETS)

An Electronic Total Station (ETS) combines an Electromagnetic Distance Measuring Instrument with an electronic theodolite, along with a microprocessor, data collector, and storage system. It measures horizontal and vertical angles, as well as sloping distances. The collected data can be downloaded for further processing. Compact and portable, the total station weighs 50-55 N and comes in various models with different accuracy levels and measurement ranges.



Global Positioning System (GPSss)

GPS is a satellite-based system that provides precise location data for surveying, navigation, and GIS. It offers 24/7 global positioning with accuracy ranging from

Fig Cadastral Map Source:[6]



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millimeters for geodetic tasks to meters for mapping and navigation. Widely used in mapping and GIS, GPS ensures accurate geo-referencing, precise surveys, and easy digital processing. Its key benefits include creating precise village boundary maps, accurate total station surveys, and reduced processing time by automating calculations like area measurements.

Remote sensing

Remote sensing technology collects data about the Earth's surface without physical sampling, using sensors on satellites, aircraft, or other aerial structures. There are two types of sensors: passive, which collect radiation reflected from the Earth (only effective during the day), and active, which generate their own energy. Initially developed for different purposes, GIS and remote sensing technologies can now be integrated for Land Record Management. Advances in computer hardware and software allow GIS software to overlay remote sensing data, providing a continuous view of regions for various applications.

Continuous Operating Reference Station (CORS)

The Survey of India, established in 1767, initially used theodolite benchmarks for geodetic mapping at a 1:50,000 scale, which was insufficient for local use. In Maharashtra, land surveys began in 1830 using cone-chain methods with 0.63m accuracy[8]. By 1920, plain table surveys improved accuracy but faced limitations in dense areas, leading to the use of Total Station, achieving up to 3mm precision. GPS later enabled millimeter-level accuracy but required long observation periods. The modern Continuous Operating Reference Station (CORS) system now provides real-time kinematic (RTK) GPS data with 3-5 cm accuracy in seconds, offering precise latitude and longitude coordinates for any land location. the latitude and longitude of any corner of the land will be obtained so that its location can be determined with the help of rover.







Fig 4 Rover



Fig 5 Flow Diagram of Continuous Operating Reference Station Source:[7]

Table 1 Reference Station Source:[9]

Sr. No	District	Taluka	Location
1	Bhandara	Bhandara	Gandhi Vidyalaya Complex, Bhandara.
2	Gondia	Sadak Arjuni	Tahsil Office Complex ,Sadak Arjuni
3	Gadchiroli	Vadasa	Tahsil Office Complex ,Vadasa
4	Gadchiroli	Korchi	Panchayat Office Complex,Korchi
5	Gadchiroli	Dhanora	Tahsil Office Complex , Dhanora
6	Gadchiroli	Mulchera	Tahsil Office Complex , Mulchera.
7	Chandrapur	Rajura	Deputy Commissioner Office, Rajura.
8	Chandrapur	Mul	Eco Park , Mul.

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9	Wardha	Aashti	Tahsil Office Complex , Aashti.
10	Wardha	Devali	Public Works Department , Devali.
11	Nagpur	Bhivapur	Panchayat Office , Mahalgoan
12	Nagpur	Kamaleshwar	APMC Market , Kamaleshwar

RESULTS AND DISCUSSION

SWAMITVA Yojana

The SWAMITVA Yojana, launched by the Ministry of Panchayati Raj on April 24, 2021, is a landmark initiative aimed at mapping rural land parcels using advanced drone technology and providing property owners with official legal title deeds. This initiative is designed to enhance rural planning, reduce property disputes, and enable landowners to use their properties as financial assets. Implemented by the Survey of India in collaboration with state departments, the program also helps calculate property taxes more accurately, benefiting both Gram Panchayats and state administrations by increasing transparency and revenue collection.

A standout feature of the scheme is the Continuous Operating Reference System (CORS), which provides highly precise 5 cm-level positional accuracy for georeferencing and land boundary delineation. With a network of 903 planned CORS stations, this system supports a wide range of surveys and GIS-based applications in sectors such as Revenue, Public Works, Agriculture, and Health. By replacing traditional chain surveys, the SWAMITVA Yojana ensures accurate mapping, reduces manual errors, and supports better governance in rural areas. This transformative approach not only modernizes land management but also empowers rural communities by unlocking economic opportunities and fostering development.

Benefits

- Promotes property monetization and access to bank loans for rural citizens.
- Reduces property-related disputes.
- Enhances rural planning and infrastructure development.
- Contributes to Gram Swaraj and supports rural India in becoming Atmanirbhar (self-reliant).



Fig 6 SWAMITVA Impact source:[7]



Fig 7 Achievements of SWAMITVA Source:[7]

CONCLUSIONS

Maharashtra is improving land records through technology, focusing on digitization for transparency and better revenue systems. Tools like GIS, GPS, and remote sensing simplify processes and enhance management. These efforts set an example for land record modernization in India.

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Photovoltaic Panel Cooling using Heat Pipe Technology

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ABSTRACT

Removing excess heat from PV panel using appropriate cooling method leads to improvement in electrical performance and heat removed can be used for water, space heating and crop drying. Heat pipe (HP) with air cooled finned condenser section was utilized for PV cooling and parametric analysis of heat pipe PV system considering the parameters i.e HP filling ratio, air velocity and vacuum inside the HP was worked out at tilt of 20° .

Results indicate that pressure variations exerted a minimal influence with 0.39% impact on photovoltaic efficiency and influence of filling ratio and air velocity is more i.e. 50.87% and 48.72% respectively. From main effect plots for signal to noise ratio and means the optimum values of parameters are 50% filling ratio, 2.5 m/s air velocity and 0.6 bar pressure in the heat pipe.

KEYWORDS : Heat pipe, Photovoltaic, Filling ratio, Electrical efficiency.

INTRODUCTION

Rising energy demand of energy is mostly fulfilled by burning fossil fuel leading to environmental pollution, to tackle this situation; gradual shift in use of energy resources is needed.

Energy from sun is cheaper and easy to harness using PV panels and solar collectors [1, 2].

Single-junction solar cells offers 24.4 % photovoltaic efficiency and remaining as a photo thermal energy when tested at standard condition i.e. 25 °C ambient temperature, 1.5 air mass and 1000 W/m2 solar insolation [3]. Above 25 oC, PVs electrical output drops by 0.25% and 0.4 - 0.5% for amorphous and crystalline cells respectively for 1oC rise in cells temperature [4].

PV panel thermal management is a major research problem in the area of solar systems [5]. Active cooling technology employs forced circulation of air and liquid over the surface of PV panel using fans, blowers or pumps. Water spraying, fluid flow through mini channel, cooling by air blow, use of nanofluid are included in active cooling techniques [6, 7]. Passive techniques include natural circulation of fluid over PV panels using fins, phase change materials, heat pipe, liquid immersion, evaporative cooling, radiative cooling, TE and heat pump etc. [8].

HP is passive, effective heat transport device with no moving parts, small c/s area capable to transfer high heat flux at constant temperature with small gradient in temperature between heat source and sink, over short and long distances without consuming external power. Careful selection of HP's working fluid enables use of HP- PV/T in cold climates avoiding freezing problems [9]. Wickless HP is mostly used and recommended to tackle freezing and corrosion issues encountered in conventional water based PV/T [8].

In HP-PV/T collector, heat pipe evaporator replaces water pipe in water-cooled PV/T collector. Working fluid in evaporator vaporizes by absorbing panel heat and



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vapors travels to condenser end where vapors condenses releasing heat to cooling media and condensate flows back to evaporator due to gravity and cycle continues [10]. Heat pipe cooling methods eliminate drawbacks of using other PV panel cooling techniques. T. Zhang et al. introduced TSHP in PV/T system to tackle issues like freezing and corrosion of conventional water-based PV/T system and suggested to use H2O and R134a as a working fluid of heat pipe in warm and cold regions respectively [11]. Shuang-Ying Wu et al. proposed wick HP-PV/T system to resolve issue of irregular solar PV cooling. Experimental investigation shows HP-PV/T generate electricity with 8.45 % efficiency and thermal energy with 63.65% efficiency and concluded that HP-PV/T system is suitable and has a potential to maintain uniform temperature of PV [12]. Mingke Hu et al. developed wickless and wick HP-PV/T systems and investigated thermal performances at different inclination angles under solar simulator and concluded that wick heat pipe performance is un-affected by tilt angle and recommended their use at latitudes $< 20^{\circ}$ and wickless HP- PV/T system should be used at latitudes $> 20^{\circ}$. Both systems when tested at 400 inclination, exhibit optimum performance [13]. Taoufik Brahim et al. conducted performance comparison of TSHP-PVT charged with acetone and conventional water based PVT and observed that TSHP-PVT perform better providing maximum gain of 21.9% and 14.2% in thermal and electrical efficiency respectively and concluded that TSHPs are efficient passive heat transfer device with [14]. Habeeb et al. experimentally investigated PV cooling using heat pipe where PV panel of size 1200 mm \times 540 mm, copper base plate 0.07 mm thick, 4 TSHP charged with distilled water at FR = 55% and 16.2 litter capacity water box heat exchanger was used. Results showed that HP cooling system proves efficient keeping PV panel colder by 15-35 % and electrical efficiency improvement by 11-14% [15]. Özbaş, E. et al. experimentally investigated PV cooling using ethanol and water charged TSHP and obtained 10.49 W output for PV panel only, 10.56 W output for panel with heat pipe charged with water and 10.56 W output for panel with HP charged with ethanol [16]. Among the various PV panel cooling methods, HP- PV/T system is gaining popularity among the researchers. HP performance depends on structural parameters, temperature, FR, tilt angle, working fluid etc.. Heat pipe perform better when their inclination varies between 15°-75° rather than in vertical position [17].

Wickless HP in PV/T system maintains uniform distribution of temperature of PV panel and offers quick-thermal response. Wick HP is simple in construction and easy to maintain and cheap [18].

Objectives of this study is to employ heat pipe system to reduce temperature of PV panel for improving photovoltaic efficiency and optimize the parameters of HP that impacts their performance in PV panel cooling.

MATERIALS AND METHODS

Cooling of PV panel is done using heat pipe technology, where parameters influencing the performance of heat pipe and their levels were identified and DoE was prepared using Taguchi method that gives optimum set of experiments, thus saving time and materials without compromising the output of the analysis. Taguchi design is a classical way of carrying out the experiments using an orthogonal array (OA), ANOVA, signal-to-noise ratio (S/N ratio) and delta values. HP parameters selected were HP FR (3 levels), air velocity (3 levels) and pressure inside the heat pipe (3 levels). Heat pipes were prepared as per DoE and used in the experiments where sole purpose was to enhance the PV panel performance in terms of PV panel's electrical efficiency.

The aim of this study is to maximize PV panel electrical efficiency, thus 'larger is better' criteria (eq. 2) is used for S/N ratio calculations

$$\frac{s}{N} = -10 \log_{10} \sum_{i=1}^{n} \frac{1}{x_i^2} \tag{1}$$

Where:-

X - Response of experiment.

i and n - Number of tests.

After collecting all responses, S/N ratio was calculated using equation 2 and examined. Finally, 1-way ANOVA model (significance level of 5%) used to know the contribution of every independent parameter in experiment. Statistical significance of parameters on performance i.e. output or response is judged using P-value, P- value < 0.05 signifies the importance or impact of parameters on performance, output or response.

EXPERIMENTAL SET UP

Experimental set up (Fig. 1) consists of PV panel placed at 200 inclination and 08 aluminium rectangular channels



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filled with waste engine oil were kept in close contact of PV panel using thermal grease and evaporator sections of each HP were inserted into oil and condenser sections with aluminium fins were kept exposed to environment to enhance heat rejection by convection.

Heat pipes were charged with Demineralized water with FR = 30, 50, 70 %, HPs pressure varied as 0.4 bar, 0.6 bar and 0.8 bar and air flow velocity over finned condenser varied as 1.5, 2, 2.5 m/s.

The solar radiations falls over PV surface inclined at 20 o with the ground and positioned south facing. Only short solar waves get converted into electricity and remaining portion raises the panel temperature and affects the electricity generation. Heat gets conducted from panel top to panel backside and from back sheet it gets conducted through the wall of aluminium channel and oil filled inside the channel gets heated by convection. Working fluid of heat pipe evaporates taking heat from the heated oil and working fluid vapors travels towards HP condenser releasing heat to surrounding air. Vapors in heat pipe condenser section reject heat to ambient air and converts into liquid state i.e. condensate which flow back to evaporator by gravity. Thus the temperature of the panel can be controlled to get maximum electrical efficiency from the panel in summer.

Table. 1. List of components, their specification and use

Component description	Specifications		
Solar panel	P _{max} :- 109.14W ; Voc:-22.16 V ; Isc:- 6.19 A Size :- 965 mm x 640 mm		
Copper Heat pipes	Evaporator:- ID:-10mm, OD:-12mm Condenser:- ID:- 20mm, OD:- 22mm		
Aluminium ducts	W:- 25 mm, B:- 50 mm		
Centrifugal Blower	Speed: - 2880 RPM, Flow Rate: - 100 cfm		
Waste engine and gear box oil	$\rho := 875 \ kg/m^3, \ c_p := 1.9 \ kJ/kg.K$		
Pyranometer	Range:-0 to 1800 W/m ²		
Multimeter	0 - 600 volts max., current: 0 - 20 Amp.		
Thermocouples Aluminium fins	K type, Range :40 °C - 750 °C ID:- 22 mm, OD:- 42 mm		
Data logger	8 channels		
Vacuum pump	50 microns vacuum		
Anemometer	Range:- 0.4 - 45 m/s		



Fig. 1 Different views of experimental set up

$$\eta_{PV} = \frac{V * I}{A_p * I_r} \tag{2}$$

Where

No. 2

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Ir - solar radiation intensity (W/m2),

Ap – Panel area (m2).

RESULTS

Total 9 experiments were performed for 9 days as per design of experiments shown in Table 2 (Column:- 1 - 3) and response in terms of photovoltaic power and photovoltaic efficiency were collected and used for Taguchi and ANOVA analysis Table 2 (Column:- 4 & 5)

 Table 2 Average values of Power and photovoltaic

 efficiency for each experiment

Filling ratio (%)	Air Velocity (m/s)	Pressure in HP (bar)	Power (W)	Photovoltaic Efficiency (%)
30	1.5	0.4	76.90	16.42
30	2	0.6	79.65	18.09
30	2.5	0.8	85.39	18.35
50	1.5	0.6	92.38	18.61
50	2	0.8	94.14	20.03
50	2.5	0.4	97.87	20.68
70	1.5	0.8	88.28	17.87
70	2	0.4	91.03	19.53
70	2.5	0.6	96.77	20.12

 Table 3 Response table for Signal to Noise Ratios

Level	Filling ratio	Air velocity	Pressure in HP
1	24.91	24.91	25.48
2	25.91	25.67	25.54
3	25.64	25.89	25.45
Delta	1.00	0.97	0.09
Rank	1	2	3

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From the results of response for signal to noise ratio (Table 3) delta values for FR and air velocity are larger than for pressure in HP indicating the importance of filling ratio and air velocity in defining the performance of HP-PV system.

Based on delta values shown in table 3 the ranks of the parameters are FR has rank 1, air velocity has a rank 2 and pressure has rank 3.

The main effect plots for S/N ratio (Fig. 2) shows rise in performance of system with increase in FR, reaches peak at FR = 50 % and then drops with further rise in FR value. Thus optimal value of FR is 50%.

Systems performance rises with increase in air velocity and reaches peak at velocity = 2.5 m/s. Thus optimal value of air velocity is 2.5 m/s.

Performance of system rises with rise in pressure, reaches peak at pressure = 0.6 bar and then drops. Thus optimal value of pressure is 0.6 bars.





Table 4 Analysis of Variance

Source	DF	Seq SS	Contribut ion	F-Value	P- Value
Filling ratio (%)	2	7.4097	50.87%	1972.99	0.001
Air Velocity (m/s)	2	7.0972	48.72%	1889.79	0.001
Pressure in HP (bar)	2	0.0562	0.39%	14.95	0.063
Error	2	0.0038	0.03%		
Total	8	14,5668	100.00%		

From ANOVA analysis (Table 4) based on sum of square values, the contribution of parameters on systems performance can be evaluated and is shown in Table 6. The contribution of FR is 50.87 %, Air velocity is 48.72% and pressure is too low i.e. 0.39 %.

ANOVA analysis also provides regression equation (Equation 3) to predict the optimum performance of the system here it's a photovoltaic efficiency.

Regression Equation

Photovoltaic Efficiency (%)

```
= 18.8556 - 1.2356 Filling ratio_0.30 + 0.9178 Filling ratio_0.50
+ 0.3178 Filling ratio_0.70 - 1.2222 Air Velocity (m/s)_1.5
+ 0.3611 Air Velocity (m/s)_2.0
+ 0.8611 Air Velocity (m/s)_2.5
+ 0.0211 Pressure in HP (bar)_0.4
+ 0.0844 Pressure in HP (bar)_0.6
0.1056 Pressure in HP (bar)_0.8
(3)
```

Calculated thermal efficiency of PV panel obtained using equation (3) is 23.85% and after conducting confirmation test using optimum values of the test parameters the photovoltaic efficiency value obtained as 21.68%.

CONCLUSIONS

Various parameters that influence HP performance are working fluid, filling ratio, pressure, tilt angle, heat pipe length and diameters of heat pipe evaporator and condenser section, condenser cooling methods. The parameters that are considered in this study were filling ratio, air velocity and charging pressure or pressure inside the heat pipe.

After parametric analysis of heat pipe parameters using Taguchi and ANOVA following conclusions can be drawn:

Pressure inside HP hardly affects HP performance as seen from ANOVA results (Contribution = 0.39%).

Filling ratio and air velocity emerged as the primary contributors to improved photovoltaic efficiency with their contribution as 50.87 % and 48.72% respectively

Optimum values of these parameters are 50% filling ratio, 2.5 m/s air velocity, and 0.6 bar pressure.

This information provides valuable insights into the factors influencing the efficiency of the system and underscores the practical impact of optimizing operational parameters.

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Parametric Identification of Nonlinear Joint using Frequency Domain Analysis: A Substructure Synthesis Model Approach

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ABSTRACT

Non-linear structural behavior is a common feature of engineering structures subjected to varying stresses. In broad terms, nonlinear systems can be largely analyzed using linear concepts; however, nonlinearity in bolted joint constructions to define the joints performance. A scientific framework for the parametric recognition of non-linear structure components is provided by the current study work. The principle of sub-structure synthesis, incorporating both non-linear and linear stiffness characteristics, is employed to get the frequency equation. In inverse analysis, the resulting solution is also applied to determine a non-linear variable. A chaotic limit condition on a cantilever beam is used to quantitatively examine the current work. The technique offers accurate estimates for a extensive variety of values of non-linear stiffness. Less than 10% of inaccuracy is found between the mathematical framework developed and experimental in this work.

KEYWORDS : Sub-structure synthesis, Nonlinear rotational stiffness, Linear translational stiffness, Frequency domain analysis.

INTRODUCTION

Nonlinear structures are becoming increasingly popular in engineering design and analysis, and as a result, the study of nonlinear joints has gained significant attention in recent years. A joint is a connection between two or more structural components, and it is an essential element in any structure. A joint can be classified as either a linear or nonlinear joint, depending on its behavior. A nonlinear joint is one in which the association among the load and the translation is not linear. Nonlinear links can be categorized into two kinds: geometrically nonlinear links and material nonlinear links. Geometrical nonlinear refer to those in which the deformation is caused by the geometry of the joint itself, such as large displacements or rotations. Material nonlinear refers to those in which the deformation is caused by the nonlinear behavior of the material, such as plasticity, creep, or viscoelasticity. There are many applications of nonlinear joints in engineering, including aerospace, civil, mechanical, and automotive engineering, in aerospace engineering [1]. Nonlinear joints are employed in civil as well in mechanical engineering to

connect various structural components in edifices, bridges, and other infrastructures [2-3]. All structural assemblies must be secured by methods such as compelling, welds, or advanced connections like smart links. [4-5]. Fittings are utilized in aircraft to fasten and pivot the substructures. The spacecraft's dynamic qualities are significantly impacted by the connector's nonlinear features [6]. Nonlinear combined exemplary parametric recognition can be achieved by force state mapping methodologies, iwan model and runge kutta [7-8].

In conclusion, nonlinear joints are an important component of many engineering structures, and they offer a wide range of benefits, such as increased strength, reduced weight, and improved performance. However, the design of nonlinear joints requires a deep understanding of the behavior of materials and structures, and it requires the use of advanced numerical techniques to simulate the behavior of joints under various loading conditions. With the increasing demand for complex and efficient engineering structures, the study of nonlinear joints will continue to be an important area of research and development.



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MATHEMATICAL MODELLING

A beam featuring non-linearity is illustrated in figures 1 and 2.



Fig. 1 Complete Beam with B and C system



Fig. 2 Beam systems B and C

Subsystem B is epitomized by a oblique matrix $[\beta]$

$$\begin{bmatrix} \beta \end{bmatrix} = \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} = \begin{bmatrix} \frac{1}{K_1} & 0 \\ 0 & \frac{1}{K_2^*} \end{bmatrix}$$

where β_{11} , β_{22} are direct receptance and β_{12} , β_{21} are cross receptance of the system.

FRF matrix for C [γ] is $\gamma_{11} = \left(\frac{-L^{5}}{EI}\right) \left(\frac{1}{\lambda^{5}}\right) \left(\frac{F_{5}}{F_{g}}\right)$ $\gamma_{22} = \left(\frac{L}{EI}\right) \left(\frac{1}{\lambda}\right) \left(\frac{F_{6}}{F_{g}}\right)$ $\gamma_{12} = \left(\frac{L^{2}}{EI}\right) \left(\frac{1}{\lambda^{2}}\right) \left(\frac{F_{1}}{F_{g}}\right) = \gamma_{21}$

The non-dimensional frequency (λ)

$$\lambda = \left[\frac{\omega^2 \rho A L^4}{EI}\right]^{1/4}$$

The nonlinear K_2^* is defined as -

$$K_2^* = K_2 + K_{4L}$$
(1)

The describing function is given by -

$$K_2\theta(t) + K_4\theta^3(t) = F(t)$$
⁽²⁾

$$\left[K_{2} + \frac{3}{4} K_{4} \theta_{\theta}^{2}\right] \theta_{\theta} = F_{0}$$
⁽³⁾

From equation (1) and equation (3), we get,

$$K_{4L} \cong \frac{3}{4} K_4 \theta_{\theta}^2 \tag{4}$$

 $\Delta = (\beta_{11} + \gamma_{11})(\beta_{22} + \gamma_{22}) - (\beta_{12} + \gamma_{12})^2 = 0$ Now, rearranging the harmonic balance equation by using sub structure synthesis theory, we get,

$$K_{1}K_{2} + K_{1}K_{4L} + [A_{x}]_{NL} K_{1} - [B_{x}]_{NL} K_{2} - [B_{x}]_{NL} K_{4L} = [C_{x}]_{NL}$$
(5)
$$K_{1}K_{2} + [A_{y}]_{LL} K_{1} - [B_{y}]_{LL} K_{2} = [C_{y}]_{LL} (6)$$

Subtracting equation (5) from equation (4), we get,

$$\begin{bmatrix} [A_x]_{NL} - [A_y]_{LL} \end{bmatrix} K_1 + \{ \begin{bmatrix} B_y \end{bmatrix}_{LL} - \begin{bmatrix} B_x \end{bmatrix}_{NL} \end{bmatrix} K_2 + \{ K_1 - \begin{bmatrix} B_x \end{bmatrix}_{NL} \end{bmatrix} K_{4L} = \{ \begin{bmatrix} C_x \end{bmatrix}_{NL} - \begin{bmatrix} C_y \end{bmatrix}_{LL} \}$$
(7)
EXPERIMENTAL SET UP AND
PROCEDURE

An experimental setup as shown in Fig.3 and Fig.4



Microcontroller (Ardnine)

Fig. 3 Real experimental configuration of a cantilever beam with bolts at the end



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Approximately 12500 sample readings from the accelerometer device ADXL335 were recorded during the experiment. Table 1 displays the sample values along three axes.

Fig. 4 displays the frequency plot, which was produced from acceleration and displays the average frequency in relation to the magnitude. Plots that show how the magnitude shifts from the highest displacement to mean and finally lowest displacements indicate the characteristics of frequency domain signals.

X	у	Z	Acceleration
-0.01	0.01	0.04	0.0714
0.01	0.01	0.01	0.0818
0.03	0.01	0.03	0.0519
0.04	0.03	0.03	0.0565
0.06	0.01	0.04	0.0616
0.07	0.01	0.04	0.0812
0.07	0.01	0.01	0.0714
0.07	0.03	0.03	0.0565
0.09	0.01	0.03	0.0616

Table. 1. Three axes reading



Fig. 4 Normalized frequency Vs. Magnitude

RESULTS AND DISCUSSION

The outcomes of the observed natural frequencies (nondimensional) are shown in Table. 2. **Table. 2. Non-Dimensional Natural Frequencies**

Assumed value of stiffness parameters	Response Amplitude	Non- dimensional natural frequency			
	Ideal Value	λ ₁ 1.8	λ ₂ 4.5	λ ₃ 7.2	λ ₄ 9.5
	0.04	1.62	3.98	6.42	8.74
$K_1 = 256020$	0.06	1.65	3.74	6.41	8.56
N/m	0.08	1.68	3.67	6.54	8.47
K ₂ = 356840	0.10	1.67	3.58	6.25	8.52
K = 735100	1.12	1.63	3.96	6.47	8.54
N-m/rad ³	1.14	1.71	3.57	6.28	8.63
	1.16	1.72	3.48	6.84	8.92
	1.18	1.72	3.87	6.41	8.92

The non-linear region is identified for substantial response amplitudes, and the non-dimensional frequency ranges are calculated for specified stiffening parameters. There is noticeable fluctuation at higher frequencies, which suggests the existence of nonlinear activity.

Figures 5 and 6 illustrates how modes 2 and 3 vary, revealing nonlinearity behavior at the natural frequency for nonlinear stiffness. This method requires an understanding of the linear stiffnening parameters. This is possible even with low levels of response. Using a curve fit tool, the change of equivalent transformed stiffness with responses modes 2 and 3 is displayed in Figures 7 and 8 for joint parameter estimation.



Fig. 5 Variation of frequency with mode 2

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Fig. 6 Variation of frequency with mode 3

Table 3 displays the findings of the predicted cubic stiffness coefficient K4 for various modes. The calculated value of K4, the cubic stiffness coefficient, is quite close to the true one. The percentage error does not exceed 10%, indicating the model's accuracy.









Table. 3. Estimated value of K4

Mode	Estimated Stiffness Coefficient (K _c)	K4=(4/3)Kc	Exact Value of K4	Percentage Error
Second	6.045 x10 ⁵	806029.74		8.80 %
Third	6.032 x10 ⁵	804266.95	775100	8.60 %
Fourth	5.727 x10 ⁵	763660.91	735100 3.74	3.74 %
Fifth	5.640 x10 ⁵	752020.46		2.25 %

In the computational framework used for the investigation, the previously indicated coefficient signifies the cubic stiffness factor. It is evident that the approximation K4 significance, or cubic stiffness factor, is far more accurate than the genuine value. The computed K4 values show a strong agreement with the expected values based on the interlacement effectiveness. This shows a significant level of reliability and implies that the mathematical model offers an excellent representation of the real system dynamics.

CONCLUSIONS

This research establishes a methodology for the parametric identification of nonlinear structural characteristics. The technique offers accurate estimates for an extensive variety of values of non- linear stiffness. The cubic stiffness K4 values are found to be fairly accurate based on the percentage error estimation, with errors for the fourth and fifth modes being less than 4%. Errors in the second and third modes are less than 9%. The discrepancy between the experimental data and the mathematical framework produced is less than 10%. The approach can accurately forecast K4 values since, on the whole, the error values fall within acceptable bounds.

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A Survey of Indian Handcart: Issues and Design Needs

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ABSTRACT

Street vending has now been recognized as an important economic activity and the size of this economy is substantial. It has been made legal in many of the south east Asian countries including India. The legal rights of street vendors have been established The street vendor's act defines mobile vendors and give them protection. The desirable features of vending cart, issues in currently used carts are not addressed anywhere. This paper is based on survey conducted to identify the issues and need of street vendor's handcart. This is an attempt to identify the requirements of cart users, design changes required for better and a convenient use. There is a need for ergonomic and safe design of cart. The conclusions are based on survey conducted and other reported literature. It endorses the need for redesign of a typical vendor's cart on Indian road for ergonomic and safety aspects.

KEYWORDS : Vendor's cart, Street vendor's act, Handcart.

INTRODUCTION

C elling of goods from door to door by carrying baskets on heads has been the most primitive marketing strategy. Even after the evaluation of shops, market places and Bazars, the vending through temporary shades and road side selling is common till date. In fact the rise of Sunday markets after the 2014 street vendors act is significantly contributing to the economy. Out of these more than 10 million street vendors about 30% vendors roam from place to place for selling their goods. Yet the cart used by them, mostly called 'handcart' have never been modified for the decades together. This survey is a part of study titled "Design and fabrication of a Typical Vendor's Cart considering ergonomic and safety aspects" with objectives to identify the issues faced by handcart owners and their requirements.

LITERATURE SURVEY

In eighties, socio-economic researches began studying the street vendors[1][2][3]. The most of study made was about the problems of eviction by police and local authorities[4]. These studies were conducted in metropolitan cities like Mumbai, Kolkata, urban pockets like Ahmedabad, Madurai and other such cities. Similar studies were carried in south Asian countries. In India, these studies resulted into a policy draft and later into 'The Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act 2014'[5].

This act mostly focuses on the regulation of street vending and rights of vendor. These studies also conclude the size of street vending economy and hence the protection is justified. However, the definition of street vendors as per this act is silent on issues like vending space, size of cart, cart size, facilities cart should have etc.

Though a lot of literature is available on design and ergonomics of industrial and other carts like medical cart, super market cart [6][7], No studies are reported on Vendor's cart.

As reported about 30% of street vendors are mobile vendors and they mostly use a typical locally made vendor's cart for the purpose of transportation and selling goods. Hence it is justified to study these carts for the issues, requirement, ergonomics and safety of these carts.

MOTIVATION

A road is a place here various types of vehicles move and their movement is required to be controlled in direction and speed. A vehicle is expected to stop immediately in case of emergency. A typical hand cart which moves on Indian roads have none of these controls. An argument may be made that the speed of these manually pushed



A Survey of Indian Handcart: Issues and Design Needs

cart is very less, but it is known that, they do cause traffic congestion especially due to inherent inability to maneuver the directions. Fig 1 shows a typical hand cart used by most of the street vendors in India who roam to sell their goods. A fruit seller shown here often carries this load up to 100kg, manually pushing for many kilometers. As evident from cart design, there are no safety and ergonomic considerations.



Fig. 1 A Typical Handcart

An RTI query to Ministry of Road Transport and Highways of India, about size of handcart and their safety standards was replied negatively stating that the act does not deal with manually driven vehicles [8], though there are standards available for bicycles and Rickshaws and Industrial hand carts too. Ministry of road transport and highways publish a report about deaths on road. In 2019, this report stated that, there were 4377 deaths involving of 'Animals drawn vehicle, cycle rickshaws, hand carts, & other persons'[9], in 2021 this figure rose to 10119[10] was and it further raised to 11337 in 2022 [11]. These figures are imperative and justifies the need for providing some safety in cart design.

SURVEY

In order to take firsthand information on the concerns of users of hand carts. A survey of hand cart owners/users was conducted in November 2023. As mentioned earlier the existing cart design is same pan India and hence it was decided to carry the survey in the closed region. This survey was conducted in Chandrapur and Gadchiroli district of Maharashtra. The questions were designed to collect identity (name, phone number and photo with cart) and information on following aspects.

- a) Cart is owned or rented
- b) Residence
- c) Selling point
- d) Mode of selling

- e) What do they sell
- f) Number of years in this business
- g) Physical Problems if any
- h) Load carried
- i) Modifications they desire in cart

This survey was carried out at 9 places in urban and semi urban areas. Total 146 subjects participated in the survey. Tables 1 and 2 describe vital information of the data.

Table 1. Cart ownership Status

Status	Count	Percentage
Owned	124	85%
Rented	22	15%

This data indicates that, as many as 15% cart owners cannot even afford to buy their own cart and this confirms the previously reported socio economic survey findings reported by many researchers on street vendors that, there is unavailability of loans and there is much private borrowing in this sector

Table 2. Mode of Selling

Mode	Count	Percentage
Standing at One Place	103	70%
Roaming	43	30%

The data in table 2 confirms that almost 30% of the street vendors sell their goods through roaming.

However this survey was to focus more on how much load a cart carries, do they experience any health issues and how much distance a cart owner has to travel in a day. The former question could be addressed using the following graph.

As per survey conducted, the average load carried on cart is 48.08 Kg, However there are some outliers, who are fruit sellers selling goods by standing at one place carrying even more than 200 kg of goods. However, they do not carry this load on the same cart. The cart is used as a stationary platform for display in this case and other means of transport are employed at the end and beginning of day. If these outliers are removed even then, the average load carried is about 36.72 kg. One special case is a sugarcane juice vendor, who carries about 150 kg including weight of machine while roaming around. However, the average load carried by those who roam around to sell goods is 40.23 kg.



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Graph. 1. Load carried on Cart

Regarding health issues of total 43 subjects who roam around to sell goods, 8 subjects reported to have shoulder and/or lower back pain. Interestingly all of these had been doing this work for more than 5 years. These findings confirm the previously reported study claiming, these subjects are at high risk of developing musculoskeletal disorders.

Another interesting aspect of this survey was, the subjects were asked, about modifications they would like to change in their cart. Response is tabulated below:

Requirement	Respondents
Shelter	15
Lighting/Lamp	14
Proper Seating	14
Better Handling	9
Cash Box	3
Stopper	3
Music System	2
Dustbin	2
Battery Powered	2
Light Weight	2
Automatic Hand cart	1
Easy Pushing	1

Table 3. Cart ownership Status

From above response, it is apparent that, the cart need to be modified for better shelter, illumination, seating, better handling, and ease of pushing and stopping.

CONCLUSION

From the Survey and literature surveyed, it is concluded that,

1. Though a lot of literature is available on design and ergonomics of industrial material handling cart, a typical vendor's cart has been ignored by researchers.

- 2. There has been a lot of study on socio-economic issues of street vendors, yet the studies on ergonomics and safety of hand cart are unavailable.
- 3. The currently used cart can cause musculoskeletal disorders in cart vendors.
- 4. The hand carts with proper maneuver mechanism and braking needs to designed. A pedaling facility or powered driving will ease the vendors work. It could also be augmented with other requirements like shelter, money drawer, illumination, buzzer, front and rear radium sticker for road safety shall add value to the cart.
- 5. There is an urgent need to redesign a typical vendor's cart for ergonomic and safety aspects.

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Design & Development of Welding Fixture for the Angle Bracket for Industrial Use

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ABSTRACT

Angle plate is the most widely used product in the industry and can be utilized for structural support in practically every industry. The welding process uses a welding fixture design. The welding fixture's design helps the operator or worker weld the component more precisely and with less fatigue. Due to its ability to improve product quality and reduce welding cycle time, the equipment boosts industry manufacturing productivity. Additionally, analysis is done to verify the fixture tool's structural strength.

KEYWORDS : Fixture design, Solid works, Drafting of fixture, Manufacturing tool, CAD, Tool design, CAE.

INTRODUCTION

Precision-engineered components are becoming more and more necessary in today's fast-paced industrial environment. Among these parts, angle brackets are essential for offering structural support in a variety of settings, such as equipment, automotive assembly, and construction. Angle bracket welding must meet strict quality criteria in addition to guaranteeing strength and stability. A dependable and effective welding fixture is necessary to do this.

In order to minimize movement and guarantee precise alignment, welding fixtures are specialized instruments made to hold work parts in place when welding. Fixtures that can support different geometries and sizes while providing easy access for welding equipment are frequently necessary due to the complexity of modern manufacturing. This requirement emphasizes how crucial a well-designed fixture is to increasing output and the caliber of the finished product.

Designing and creating a welding device especially for angle brackets used in industrial settings is the goal of this project. The fixture will address common welding process issues such operator safety, heat distortion, and inaccurate alignment. This project aims to develop a fixture that not only satisfies the technical requirements necessary for efficient welding but also improves the general workflow in a manufacturing setting by utilizing cutting-edge design approaches and prototype techniques.

Significant advantages are anticipated from the introduction of this welding setup, such as increased operator ergonomics, decreased cycle times, and greater welding precision. The project aims to provide a solid solution that complies with modern industrial standards and procedures by using a methodical design approach that incorporates thorough testing and iterative improvements. This introduction lays the groundwork for a thorough examination of the welding fixture's design procedure, testing procedures, and expected effects on angle bracket production. High levels of efficiency and precision are becoming more and more necessary in the field of modern manufacturing, especially in assembly processes where structural integrity is crucial. The angle bracket is one of the most often used parts in many different sectors. These adaptable supports, which strengthen connections and provide stability in structural frames, are crucial in applications such as furniture, automobiles, and construction.

LITERATURE REVIEW

1. Vinay S Hegde, GS Shiva Shankar and Avinash C study say "Typically, welding fixtures are made to support and hold the several parts (work pieces) that need to be welded. The fact that a real industrial component was



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taken into consideration when designing the fixture is evidence that this work incorporates a functional approach. The current practice in the construction equipment business of manually fabricating the vibratory compactor's roller drum is having a negative impact on workers' lives and health. The development of a semi-automatic welding fixture was done in order to make the workspace human- friendly."

- 2. Prof. A. A. Karad,Brijeshwar Wagh, Ajay Shukla, Niladhari Pyata, Chetan Gujar study says "that creates and produces welding fixtures for the construction of mounting brackets for fuel tanks. Its several tilting and rotating configurations provide it versatility when in use. Mild steel, which can support the weight, is the material utilized for the fixture. The bracket's components are welded using CO2 welding. Additionally, it has a lot of locating pins, which helps it be precise when operating."
- 3. NAVEEN A M, V A GIRISHA, PRUTHVI H M study say that "the Motor Case Assembly Welding Fixture Design and Analysis. One component of rocket boosters is the motor case assembly, which is composed of Maraging steel MDN 250 grade, a material that is well-known in the aerospace industry for its excellent weldability and high strength to weight ratio."
- 4. Neeraj Kumar Jha and Raghu Prem B study say that "to illustrate a few weld joints for small metal plates, as well as to create and assess a compact welding fixture. Within a certain range, metal plates of different size can be effectively welded using the same model. ANSYS 16.0 is utilized for analysis, and CATIA V5R20 is used for part modeling."
- 5. N. B. Pawar, Prof. P. P. Patil, Prof. R. Y. Patil study say that "An essential holding device is the welding fixture. How many pieces need to be tightened and welded into place in the fixture? When the work piece is being held in place by the fixture while the welding stress is generated. The design and analysis method for the sheet metal assembly fixture for the cross member rear lower wishbone component is proposed. Convenient to the current locating principles, the assembly fixture design for a certain tail cone has been finished. ANSYS software, which produces the best results in a matter of seconds, is used to design welding fixtures and components utilizing Pro-E and CAD software and Finite Element Analysis (FEA)."

- 6. C. A. Kubade, Dr. S.V. Patil, Mr. V. P. Patil study say that "For its application, the fixture must be made for the cab leg sub-assembly, which will be welded with its partner. The investigation entails studying the fundamentals of welding and fixtures, as well as the necessity of fixtures and location principles. All welding criteria, such as cycle time, access to the welding area, and fixture space, are taken into account when designing the welding fixtures in this work. Materials are chosen depending on prior designs and functional requirements. Pneumatic cylinder selection, L- shaped bracket design, and unit placement are all part of the analytical process used to make the general layout and design the fixture. The fixture requirements are taken into consideration when choosing power clamps and LM guides. The design is found to be within safety limits after being validated using FE analysis for material strength requirements."
- 7. C. V. Papade, P. B. Kabade, R. R. Kamble study say "The literature on the design and development of fixtures for bracket welding is reviewed and provided. Weldment is the term for an item made from a collection of smaller parts that are linked by welding. Partially or fully connected welding is possible in the fixture. In the manufacturing sector, a fixture is a work-holding or support tool. Fixtures are used to stabilize and firmly situate work in a certain orientation or location, guaranteeing that all pieces made with the fixture will remain interchangeable and conformant."
- 8. Amasidha Kallappa Athani, Rahul R. Anyapanawar study say that the numerous factors must be taken into account while creating a welding setup for sheet metal components Fixtures have a major impact on process capability, which influences production output and product quality, by controlling the orientation and position of pieces during an assembly process. In order to optimize a single- and multi- fixture assembly system with rigid (3-2-1 fixture arrangement) to deformable parts, several strategies were created.
- 9. Pranav Joshi, Rahul More, Ashish Khadsare, Shubhankar Sawant, J. P. Wagh study say that "There are many different sizes and shapes of parts that need to be welded in industry, and welding is a common and popular form of permanent metal joining process that requires very high skill for fine work. Automation is becoming increasingly important in all aspects of



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industry, including production, manufacturing, and other areas. It decreases cycle time and operator labor while increasing functionality."

- 10. Prof. M. S. Kulkarni, Roshan Chahad, Swapnil Ingale, Kunal Jadhav, Varad Biradar study say creating a fixture that will boost production efficiency for rotary welding operations. A variety of pieces that need to be rotary welded can be accommodated by this device. By installing this fixture on the SPM, welding's load bearing and strength may be increased, reducing welding error and increasing overall efficiency as compared to hand welding. Manual rotary welding is generally a very important procedure with a significant probability of error. A fixture is needed to fix this problem.
- 11. Joshua Kumarasamy study say that The processes used throughout the fixture design's conceptual design phase are reflected in the design approach. There is a discussion of the purchasing order, design methodology, customer input, percent complete criteria, and design output process processes. Accessories will be planned and designed in accordance with customer specifications. Customers will supply references for the CAD model, which is designed in Catia v5 2016 with many features, including material selection, component spacing, part name, file orientation, software type, fixed standards, zone alignment, and total assembly weight.
- 12. Rupesh Desale, Sandesh Donapurge, Sushant Bhor, Ved Bhalerao, Prof. Madan Kulkarni study say that The welding joints that are frequently utilized when welding any workpiece are summarized in this document. Additionally covered is the fixture that is utilized to position the workpiece during welding. Numerous abnormalities, weak welds, and defects are created during the welding process and can be categorized into various sorts. This document also discusses the many kinds of welding flaws and how to find them. Additionally covered is one of the crucial welding procedures, the CO2 arc welding technique, which uses a consumable filler material to achieve deep penetrations throughout the welding process.
- 13. G. C. Jadhav , Dr. R. S. Dalu study say that Since friction stir welding is a solid-state process, it is defect-free, unlike fusion welding. A universal milling machine has been used to perform FSW on aluminum alloy. The motivation behind this research was to

design and create a new fixture because friction stir welding machines are expensive and unavailable. The friction stir welding technique involves a lot of forces. They are axial, lateral, transverse, and torque forces. The primary problem posed by these stresses is to survive them all, which is one of the goals of the fixture's fabrication.

- 14. Yuvraj R. Vadaje, Dr. H. A. Chavan, Dr. S. R. Suryawanshi study say To determine the welding distortion of the Bogie Frame assembly, Finite Element Analysis (FEA) is used. In addition, the ideal clamping force needed to regulate the welding distortion has been determined. Following a successful design and analysis process, the welding fixture was produced and installed on the shop floor. In addition to reducing production loss and manufacturing lead time for welding, positioning, and holding parts, this welding fixture is utilized to accurately assemble the child parts with the necessary tolerances.
- 15. S G. Bhardiya, Kumar S. Khandekar, Prathmesh S. Mule, Ashish Koli, Akshay Madne study say that The fixture's location and orientation comprise the clamps, locators, clamp cylinder, riser, and rest mylar. Fixture design is important during the setup planning phase. Because of the quality and surface finish of the machined parts, the fixture setup is done by hand in the current design. Catia is the software used to design the fixture.

CONCLUSIONS

After conducting a thorough literature review of fifteen research articles, we can say that fixtures improve component quality and lessen worker fatigue by standardizing the welding process through the employment of clamping and fastening devices. The two components that we intend to bring together will be properly welded with the aid of a welding setup. It provides us with the appropriate component placement, which will aid in raising the component's production.

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ABSTRACT

This review paper focuses on the design and analysis of a portable injection molding machine. A small and easy-to- use injection molding technique is required due to the growing need for adaptable and effective manufacturing solutions. In order to improve portability without sacrificing performance.

By studying various research paper, important design components like heating and cooling system, a robust yet lightweight construction, and an intuitive control interface can be carried out. Finite Element Analysis (FEA) is used to evaluate the machine's structural integrity and thermal efficiency in order to guarantee optimal performance under a range of conditions. The study of research paper also help in making the machine less expensive than its traditional counterparts, making it accessible to start-ups and educational projects.

KEYWORDS : Plastic injection molding, Molding machine, CAD, CAE, Structural analysis, Machine design, Solid works.

INTRODUCTION

The injection molding process, a cornerstone of modern manufacturing, is widely utilized to produce a variety of plastic parts for use in electronics, consumer goods, and the automotive sector. Traditional injection molding machines can be very effective for large-scale manufacturing, but their size, expense, and complexity can sometimes be barriers to their use for start-ups, small businesses, and educational institutions. In response to these challenges, the need for portable injection molding machines that are adaptable, affordable, and easy to use is growing.

Background

Injection molding is the process of melting plastic pellets and then forcing them into a mold hole under intense pressure. When the plastic cools, it solidifies into the desired shape. This method is prized for its ability to produce intricate designs with high repeatability and little wastage. However, because of their big size, expensive cost, and high power consumption, conventional machines are not feasible for smaller-scale applications.

Importance of Portability

For a number of reasons, the idea of mobility in injection molding has become crucial.

- Accessibility: Smaller companies and academic institutions frequently lack the funds necessary to purchase massive, industrial-grade equipment. Access to cutting-edge manufacturing technologies can be made more accessible through portable devices.
- Flexibility: On-site production made possible by portable machinery cuts lead times and transportation expenses. Small batch production and prototyping particularly benefit from this.

LITERATURE REVIEW

1. Ajay P Shevale, Ronak Shah Study say that In plastic processing industries, a wide variety of injection molding machines are offered based on their clamping unit. A component known as the shutter in a hydraulic ram type clamping machine frequently breaks down as a result of the enormous compression force applied to it. In order to strengthen shutters and lower their



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failure rate, shutter design and analysis are done in ram- type injection molding machines. Reducing shutter failure in hydraulic ram clamping injection molding machines is the goal of the study.

- 2. Smith Samah, Durgesh Y. Borse, Vishal N. Sulakhe study say that how 3D printing and injection molding may increase output and make it possible to manufacture goods more effectively. Additionally, this study attempts to analyze the many processes and technologies currently used for injection molding and 3D printing. Complexly shaped materials can be mass-produced more efficiently and with higher quality using 3D printing and injection molding. In order to produce higher-quality items, the correct mold design, temperature, pressure, and injection speed are essential.
- 3. Prof. Abarna.R, Sakthi.R, Sakthivel.B, Sandeeshkumar.K, Saranraj.S study say that The injection molding machine. The basic idea is to compress the plastic material in a barrel, and the rack and pinion system is rotated to create the compressing action. The heater around the barrel heats the plastic substance. After that, it is transformed into a molten state. The compressing force injects the molten plastic into the barrel through the nozzle and into the die. We will receive the product from the die once this procedure is finished. It is possible to make commercial items like as switches, couplings, and bushes.
- 4. Peng Zhao, Jianfeng Zhang, Zhengyang Dong, Junye Huang, Hongwei Zhou, Jianzhong Fu,and Lih-Sheng Turng study say that the idea that these three processes—sensing, optimization, and control—are integrally used in intelligent injection molding. This study examines current research on techniques for identifying pertinent physical variables, optimizing process parameters, and controlling machine variables during the molding process.
- 5. S.Selvaraj, Dr.P.Venkataramaiah study say that works on injection optimization Three stages of molding have been completed. The FR (Forward Reverse) lever, which regulates the spindle rotation direction for traditional machines, is designed and built using an injection molding tool in the initial step. The second phase identifies the influential characteristics, also known as input parameters, that have an impact on the FR lever's quality. Additionally recognized

are the response parameters, also known as output parameters, like surface roughness and shrinkage, which are regarded as quality attributes of this product.

- 6. Naveen Kumar, Prof. Dr. S. M. Husain study say that the most recent studies on injection molding process design and parameter determination. A variety of studies based on different methodologies have been conducted in the area of injection molding parameter setting. The following methods are described in this article: Taguchi method, artificial neural networks (ANN), fuzzy logic, genetic algorithms (GA), casebased reasoning (CBR), fuzzy logic, finite element method (FEM), non-linear modeling, response surface methodology, linear regression analysis, grey rational analysis, and principle component analysis (PCA).
- Anand S. Dangi, Rakesh Prajapati, Parth Gajjar, 7. Dipen Modi study say that the creation of novel technologies using structure analysis, flow analysis, and control simulation for high accuracy, high speed injection molding machines that include high rigidity, high speed driving mechanisms, high dispersion, and high speed plasticization mechanisms. Speed, pressure, time, temperature, and stroke are the five primary categories into which any process variable can be divided. The component's overall shape, wall thickness, and the kind of material being processed all affect how long it takes to cool. Over 70% of the injection cycle may be represented by the cooling period. Reducing the cooling time will shorten the cycle time.
- 8. Prof. Savan Fefar, Dhandhukiya Meet, Patel Vatsal, Jadav Meet, Sheladiya Pragnesh study say that includes the overview and design of a plastic compression molding machine. The machine uses the heating and pressing technique. The machine is inexpensive and simple to maintain because it is made with locally accessible raw materials. Understanding how this machine works, as well as having electrical and welding skills, are necessary.
- 9. Kollipara Durga Prasad, Patra Jeevan Kumar, Angajala Pawan Kalyan ,Bhupala Sai Kumar, Gorrela Jyothi Prakash, Animutyalu study say that The goal is to present comprehensive design mold procedures and analyze the product's material flow, temperature, and pressure properties using simulation software. For this assignment, the product was designed and examined.



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CNC and other sophisticated machinery are used in the mold making process. This product and mold were designed and analyzed using the design analysis software CATIA V5, ANSYS 15.0, and SOLID WORKS. For the production of both simple and complex shapes, this project was really helpful.

- 10. Rashi A.Yadav, S.V.Joshi, N.K.Kamble study say that to examine the most recent studies on injection molding process design and parameter determination. Numerous studies based on different methodologies have been conducted in the area of injection molding parameter setting. The following methods are described in this article: Taguchi method, artificial neural networks (ANN), fuzzy logic, genetic algorithms (GA), case-based reasoning (CBR), fuzzy logic, mathematical models, finite element method (FEM), non-linear modeling, response surface methodology, linear regression analysis, grey rational analysis, and principle component analysis (PCA). Individual approaches' advantages and disadvantages are examined.
- 11. Vijaykumar Vilas Andhalkar, Dr. S. R. Dulange study say that A part known as a flow reducer was selected for a thorough design evaluation and mold flow analysis. The Autodesk Mold Flow software is used to mimic the design of this product, which was created using the Autodesk Inventor design analysis tools. Using the Mold- Flow technology, the mold flow analysis is utilized to forecast the part's deformation and then modify the design accordingly.
- 12. Dr. G.V.N.B. Prabhakar, Kollipara Durga Prasad Nilla Vamsi, Vangalapati Hemanth Kumar, Peddinti Venkat Satya Kalyan, Reddy Manu Durga Prasanth study say that The most popular method for creating a variety of intricate plastic parts for a wide range of uses is injection molding. This molding technique allows us to create a wide range of components, from large to little. The quality and productivity of plastic goods are significantly impacted by the parameters of the molding process. Nowadays, 40% of products are made of plastic. However, because plastic pollutes the air, it was unable to burn and did not disintegrate. One of the main causes of climate change is plastic pollution. Plastic pollution can range in size from large to tiny, yet they are present everywhere. The primary source of plastic pollution is human activities. Water bottles, bicycle parts, and automobile tires are

examples of plastic things that usually have a very short lifespan.

13. N. V. Anjali, J. Kiran Kumar, S. Hemalatha study say that The design and production of an inexpensive desktop injection molding machine are the main topics of this study. The design of the injection molding machine's mechanical components is examined. Additionally covered is the barrel's volume with and without an injection screw. Also covered is the heating system, which consists of heaters and thermocouples connected to a PID controller. ABS, PLA, and PVC plastic materials' flow rates have been determined at constant temperatures. Various temperatures for constant flow and screw RPMs are also covered.

CONCLUSIONS

After a thorough analysis of thirteen research publications, it can be said that researchers and small businesses will find portable injection molding equipment to be very helpful. These devices significantly lower the tool costs normally needed for manufacturing plastic products on a small scale. The suggested portable machines, in contrast to conventional injection molding machines, are made to be small and lightweight, providing more accessibility and flexibility. Because it combines affordability, portability, and efficiency, the portable injection molding machine thus becomes the best option for researchers and smallscale manufacturing enterprises.

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ABSTRACT

This review paper gives us the detail study of the project presenting the design analysis of a hydraulic small press machine. The primary objective of the project is to develop a compact, useful, and cost-effective hydraulic press that can be utilized for a number of applications, such as pressing, shaping, and assembling small work components. Pascal's Law and hydraulic power enable the machine to generate significant forces with minimal input. The design process includes selecting the appropriate components, materials, and sizes for hydraulic systems, including pumps, cylinders, and valves.

To ensure safety and efficiency, a number of essential parts are chosen and examined for best performance, including the frame, hydraulic cylinder, piston, pump, and control valves. Because of its modest size, the machine is designed for research, educational displays, and small-scale industrial applications.

KEYWORDS : Hydraulic press machine, Press tool, Solid works, Drafting of machine, Manufacturing tool, CAD, Design of machine, CAE.

INTRODUCTION

Hydraulic press machines are the result of the demand for great force, efficiency, and precision in small designs. Using liquid pressure to generate force and motion, hydraulic presses—which are extensively employed in manufacturing, industrial, and scientific settings—function according to the basic principles of hydraulics. An adaption of conventional hydraulic presses, the Hydraulic Mini Press Machine is made to produce a sizable amount of force in a more compact and smaller package.

Small-scale pressing processes like bending, shaping, punching, and pressing components are crucial for producing precision parts in a variety of industries, particularly in the automotive, electronics, and prototyping sectors. For these uses, miniature hydraulic presses are the perfect answer since they combine the advantages of hydraulic force transmission with a smaller footprint. An effective and economical choice for small-scale activities, a well- designed hydraulic micro press may deliver significant force with little power usage.

Pascal's Law, which asserts that pressure applied to a

confined fluid is transmitted undiminished throughout the fluid in all directions, is the fundamental idea underlying how a hydraulic press operates. Because of this, hydraulic presses may produce a lot of force from a small amount of input force. A hydraulic pump, cylinders, valves, a frame, and a control system are usually included in the machine.

LITERATURE REVIEW

1. L.Adnan Sherif & Mohammed Sameer Baig Study say that this essay discusses hydraulics, an applied scientific and engineering field that studies the mechanical characteristics of liquids. Hydraulics, which focuses on the engineering applications of fluid characteristics, has its mechanical theoretical underpinnings in fluid mechanic. Hydraulics is utilized in fluid power to generate, control, and transmit power through pressurized liquids, such as my pressing system. Pascal's concept underpins the hydraulic press; pressure in a closed system remains constant at one end, where a piston with a tiny crosssectional area is actuated by a lever to increase force. The system's opposite end is connected by smalldiameter tubing.



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2. ASIM M.KAMATE, Prof. (Dr.) J.S. BAGI study method will b

say that the various structural analysis and hydraulic press optimization methods have been the subject of prior research. One manufacturing operation that is mostly carried out on a hydraulic press is metal shaping. A hydraulic press machine operates when there is an impact load. Certain machine parts endure compressive stress while other sections experience tensile stress due to continuous impact loads. In order to solve this issue, the machine frame must be optimized, which can be accomplished with CAD software and examined with FEA software like ANYSYS.

Design and Analysis of Hydraulic Mini Press Machine

- 3. Nawale Sagar, Patil More Tejas, Gavande Ajinkya, Mistry Girish, Vidyasagar Gavali, Chandrashekhar K. Patil study say that a 300bar hydraulic press was designed, built, and tested using locally found materials in an effort to address the issue of the lack of equipment in our laboratories in the majority of our higher institutions. The design's primary parameters were the maximum load, the system pressure, the cylinder area (piston diameter = 150 mm), the volume flow rate of the working fluid, and the distance the load resistance must travel (piston stroke, 300 mm). The frame, the hydraulic circuit, and the arrangement of the cylinder and piston are the main parts of the press design.
- 4. Hiren Patel, Vraj Patel, Gaurang Patel, Devang Patel, Kalpesh Parekh study say that One of the chip-less manufacturing methods is metal forging. Various sorts of presses are typically used to carry out these kinds of operations. Metal work components are deformed to the appropriate size as part of these procedures. The press machine constantly receives constant tensile stress when force is applied. Because press machines are always under stress, structural failure issues arise in them on a regular basis. The amount of fillet is determined by the load conditions that each frame experiences, which can be examined with a FEM tool. Reducing the thickness of the frame structure's plate will also assist save a significant amount of money and material.
- 5. Bhushan V. Golechha, Prashant S. Kulkarni study say that the goal of lowering the pneumatic press's weight and cost without sacrificing output quality. The press machine's weight and cost can be reduced by using the best resources possible during the design process. One

method will be to maximize the amount of material used to construct the machine's whole construction. We are looking at an industrial application project that involves minimizing the mass of a pneumatic press. Forming operations are taken into consideration in order to reduce the volume of material. ANSYS has been used for analysis purposes.

- 6. Prof. Nandakishor D. Bankar, Mr. Mahesh B. Shinde study say that the A hydraulic press is a mechanical device that operates on the principle of Pascal's law, which states that in a closed system, pressure is applied equally to all directions. A hydraulic press is a device that uses fluid to generate compressive force. The hydraulic power pack, control valve, actuator, and accessories are the main parts of a hydraulic system. Compared to mechanical and electrical systems, a hydraulic system may generate greater forces. For press work applications like blanking, punching, piercing, coining, trimming, etc., these forces can be employed. Pascal's principle, which holds that when pressure is applied to fluids in an enclosed system, the pressure throughout the system always stays constant, is the foundation of the hydraulic press concept. In a hydraulic press, fluid under pressure is used to generate, transmit, and amplify force. In addition to providing a very positive and stiff medium of power transmission and amplification, the liquid system demonstrates the properties of a solid. In a basic application, the force is increased by transferring fluid under high pressure from a smaller piston to a cylinder with a larger piston area.
- 7. Santoshkumar S. Malipatil, Prof. Yogita N. Potdar, Prof. A. C. Mattikalli study The cost of the hydraulic presses can be decreased by using the best resources feasible when developing the frame. by maximizing the weight of the materials used to construct the building. In this regard, an effort has been made to decrease the amount of material. Here, we look at an industrial application project that involves minimizing the bulk of an H-frame hydraulic press. This press must meet some crucial requirements and balance the forces acting on the working plates. The primary goal of this analysis, which was conducted using ANSYS, is to lower the cost of hydraulic presses without sacrificing output quality.
- 8. S. Raja Shekar, A. C. Uma Maheshwar Rao study say that Calculating mechanical parameters such as

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total deformation and developed on the equipment is crucial since the frame structure must withstand the forces created during operation. As a result, a 1000ton press machine has been used for work. Optimized design is the main focus with reference to design specifications, stress distribution, and cost. The work's methodology involves comparing machines of varying thicknesses utilized to produce the H-frame type hydraulic press's frame and column.

- 9. Viraj B.Ghangale study say that to create a specialized equipment for the Mahindra Blazzo exhaust system's inlet sleeve flaring operation. This type of machine that can automatically clamp and flare was not previously accessible. In the past, holding was done mechanically. However, because flaring operation requires a lot of force, mechanical clamping was unable to withstand it, which caused parts to slip and get damaged. It is necessary to construct a hydraulic press in order to overcome the aforementioned situations.
- 10. Prof. Sunil Kumar, Prof. Londhe Pradip Gangadhar, Shaikh Fardin Jamal, Gore Tejas Mulidhar, Tipare Ajay Rajesh, Dahatonde Kiran Suresh, Badadale Ganesh Ramesh study say that One of the most often utilized hydraulic pieces of equipment in both conventional and contemporary industrial systems is the hydraulic press. This study suggests a way to make the hydraulic press machine model a reality. The Pascal's principle governs how hydraulic presses operate. "The pressure throughout a closed system is constant," states Pascal's law. A lever is used to enhance the force in a piston at one end of the system, which has a tiny cross-sectional area. The system's opposite end is connected by small- diameter tubing. Its primary applications include deep drawing, forging, shaping, and punching. The hydraulic press is an issue related to manufacturing and applied science. Hydraulics, which focuses on the engineering applications of fluid properties, is theoretically based on fluid mechanics. Using pressured liquids, hydraulics is a technique used in fluid mechanics to produce, control, and transmit power. Here, creating a small hydraulic press machine for pressing operations is our goal.
- 11. Mr. M. Balaji, B. Nithin Kumar, N. Tejeswara Rao, J. Veera Narayana, P. Venkat Charan, D. Gowtham study say that to create a three- dimensional model of

a 100-ton hydraulic press using FEA and optimization techniques. Given the company's restricted budget, they must choose a machine design that can sustain a high load while operating. Solid Edge simulation software was utilized to create the entire design from start to finish. The design is optimized to require less machining in order to reduce the amount of material used and the cost of the hydraulic press.

- 12. Nivedita V. Bansode, Kiran More study of the hydraulic press, a typical device seen in many different sectors. It undergoes a variety of surgeries. The market offers press machines in a range of sizes and capacities. They are categorized based on the needs of the user. Small and microscale industries require hydraulic presses. The current research work attempts to examine the earlier studies that were conducted in various hydraulic press structural analyses. A compact, twoton C-frame hydraulic press is what we plan to design and manufacture for a small engineering business. Two tonnes of compressive force are produced by the hydraulic cylinder. A ready-made press that is on the market can be purchased by the industry. However, small-scale industries cannot afford its greater cost. The paper's ultimate goal is to make the machine as cost-effective as possible without sacrificing the caliber of the applications.
- 13. David Paul, Collin S, Amith A, Sirish Kumar , Manjunatha L.H study say that A hydraulic press is a device that uses Pascal's Principle to generate compressive force using a hydraulic cylinder. The project consists of designing and building a 10- ton hydraulic press. The press frame, cylinder, and other parts of the project were created using a variety of design techniques. PTC Creo modeling software was used to model every machine component. By using the best available resources, the machine's total weight was reduced, which decreased the volume it consumed. Additionally, the machine's mechanical characteristics were taken into account, ensuring that the press machine had enough stiffness to handle the different loading situations.
- 14. Ganesh M Mudennavar, Gireesha Chalageri, Prashant A. Patil study say that the hydraulic pressing machine, which uses compressive force to change the material's shape to the desired one. This project involves the design and analysis of a hydraulic pressing machine with a twelve-ton capacity. In addition to calculating



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design characteristics like stress produced and total deformation formed during operation, the design must withstand the force generated during operation. This pressing machine is designed for sheet metal applications and the production of automobile body structures. The equipment has a 12-ton load capacity and is made exclusively for particular purposes. The product design is determined in part by structural analysis. CATIA V5 is used to model the frame and cylinder, while ANSYS software is used for analysis.

15. Mr. N Lakshmi Puthra, Mrs. Bhavani, Mr. Manoj T. M., Mr. Venkatesh S, Gowri Shankar T P study says that The adjustable frame and top plate are separated by the hydraulic jack. To enhance their quality and performance for press operating operation, they undergo analysis. For forming and pressing tasks with a variety of capacities, hydraulic presses are utilized. A hydraulic press operates with a constant impact load. Many machine parts endure compressive and tensile strains as a result of these constant loads. Some machine parts permanently distort as a result of these forces. The optimization of a 5-ton hydraulic press while taking cost, weight, and design limitations into account is the foundation of this work. By optimizing the weight of the materials used to form the structure, hydraulic press components can be designed with the most resources possible, resulting in a cost reduction. Time constraints are an essential component of every production process in the current environment.

CONCLUSIONS

After conducting a thorough literature review of fifteen research articles, we can say that small hydraulic machines are used in so many industrial and manufacturing processes, there has been a lot of interest in their design and study. Several studies stress how crucial it is to optimize hydraulic press machines without sacrificing performance in terms of material consumption, structural integrity, and cost- effectiveness. Hydraulic systems are based on fundamental ideas like Pascal's law, which make it possible to generate, transmit, and amplify forces very effectively. The use of sophisticated design tools like CAD and FEA software has been essential in improving machine performance and durability, from the creation of tiny, affordable presses for small-scale companies to highcapacity machines for heavy-duty applications.

Hydraulic presses that are lighter and less expensive while yet achieving the necessary operational efficiency have been successfully designed by researchers by concentrating on material optimization, stress analysis, and frame thickness reduction. Furthermore, the hydraulic presses' ability to tolerate the stresses involved in continuous operation is guaranteed by the structural study of its constituent parts under dynamic loading circumstances, such as impact loads. The development of dependable, long- lasting, and effective hydraulic press machines that satisfy the various demands of sectors ranging from small-scale manufacturing to the automotive industry is the result of the integration of theoretical fluid mechanics with real-world engineering solutions. In the end, these developments greatly increase manufacturing processes' productivity and lower their operating costs.

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Mechanical Testing and Characterization of Paraffin Wax with Polypropylene Binder and Aluminum Additive

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ABSTRACT

Recent studies on hybrid propellants suggest that paraffin wax is a promising substitute for traditional solid fuels in hybrid rocket engines, offering safety, reliability, and the advantages of both solid and liquid fuels. Paraffin wax provides several benefits, including a high calorific value, high regression rate, improved performance, affordability, ease of processing, non-toxicity, chemical stability, non-corrosiveness, and clean exhaust. Researchers are enhancing its mechanical and thermal properties by adding binders, energetic elements, and other additives. This project focuses on preparing propellant grains by mixing paraffin wax with high-energy aluminum and a strengthening additive, polypropylene (PP). The resulting blends will be compared to pure paraffin and HTPB grains in terms of mechanical and thermal characteristics. Polypropylene (PP) is preferred over polyethylene (PE) as a binder due to its higher stiffness, melting point, lower density, and better resistance to cracking. Studies show that paraffin wax grains with PP and aluminum demonstrate improved mechanical, thermal, and micro structural properties, making them suitable for hybrid rocket fuel applications.

KEYWORDS : Paraffin wax, Hybrid rocket fuel, Polypropylene (PP), High-energy additive (aluminum), Mechanical and thermal properties.

INTRODUCTION

Solid propellant rockets are distinguished by their straightforward construction, ready-to-use capabilities, and extended storage life due to the lack of spilling or leakage during handling and/or storage. Despite having a lower specific impulse than their liquid equivalent, they are nevertheless highly useful due to their larger total density. Liquid propellant rockets are renowned for their superior performance and features, such as their amenability to thrust vector control, ease of cooling, throttling capabilities, and stop-restart feasibility.

But they also have issues with managing toxic, corrosive, and dangerous propellants and combustion products, as well as complicated construction and operation, spilling, leaking, and sloshing. Hybrid propellant rockets are the best way to take advantage of the benefits of both solid and liquid propellant rockets while resolving their drawbacks. A hybrid propellant rocket can perform all operations, including throttle, stop-restart, cooling, and thrust vector control, with only one storage tank and feed system, making it half as complex as its liquid version.

Rocket fuels for conventional hybrid propellants have a low fuel regression rate and comparatively low combustion efficiency. The rocket engine's thrust is directly correlated with the fuel's regression rate, and because of the low regression rate, it is challenging to produce more thrust from these traditional hybrid rocket fuels..Numerous researchers have previously proposed a number of approaches to deal with this problem, including boosting the oxidizer flow rate by creative injection procedures, grain designs with more surface area, high energy additions, high regression rate fuels, etc.

Using high regression rate fuels, such as paraffin wax, often known as low viscosity liquefying fuel, is one of the most promising methods for enhancing overall performance. It increases the fuel's regression rate by generating a thin liquid layer on the fuel grain's surface that interacts with the gas flow to generate droplets .Paraffin wax offers the



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potential for future advancements because its regression rate is about three to four times that of traditional hybrid rocket fuels. However, the low mechanical and thermal stability of paraffin wax fuel is a significant disadvantage that prevents its widespread use. By adding different additives, numerous researchers are attempting to enhance the mechanical and thermal characteristics of paraffin wax fuel.

LITERATURE REVIEW

- 1. Cican, Paraschiv et al.(2024)-For hybrid rocket engines, their research created and evaluated a novel green propellant composed of coal, stearic acid, and paraffin. The mechanical strength of paraffinbased fuels was greatly increased by the addition of coal and stearic acid, particularly in sub-zero temperatures. Numerical calculations and lab-scale firing experiments verified optimal performance with no harmful combustion byproducts at an O/F ratio of 2.2. The findings show that the propellant is a viable substitute for traditional fuels due to its structural stability, environmental safety, and suitability for low-temperature hybrid rocket applications.
- 2. Nguyen & Thomas (2023)-They show how additive manufacturing(AM), which makes complicated fuel grain shapes and material modification possible, greatly improves the performance of hybrid rocket fuel. AM fuels, such those derived from ABS, PLA, and nylon, enhance structural qualities, combustion efficiency, and regression rates. According to chemical equilibrium studies, AM fuels perform on par with traditional fuels such as HTPB. The results demonstrate how AM can be used to optimize hybrid rocket engines for upcoming aerospace uses.
- 3. Akhter &Hassan.(2020)-Their research used HTPBparaffin wax doped with LiAlH4 and MgH2 to create functionally graded solid propellants(FGSPs). LiAlH4offeredgreatersolid-phase in t e g r i t y and thermal stability, whereas magnesium hydride increased regression rates via improving entrainment combustion. When compared to traditional HTPB fuels, static testing revealed regression rate improvements of up to 224% and 353%, respectively, indicating that these formulations hold promise for improved performance and stability in hybrid rocket propulsion.

for hybrid rocket applications, they looked at the mechanical characteristics of paraffin-based fuels that had been modified with different additions. They discovered that adding additives based on boron greatly enhanced the mechanical properties of paraffin-based fuels, improving both their structural integrity and performance .According to the se results ,improved paraffin-based fuels like these might be good substitutes for conventional solid fuels in hybrid rocket propulsion systems.

- 5. Dinesh & kumar (2018)-The authors looked at adding additives like Ethylene Vinyl Acetate (EVA) and Styrene- Ethylene- Butylene -Styrene (SEBS) copolymer grafted with 2% Maleic Anhydride to waxbased fuels for hybrid rocket systems. Tensile strength (4.26 MPa) and elongation (24.6%) were found to be improved by the combination of 10% SEBS and 5% EVA in wax fuel. SEBS-based fuels exhibited higher regression rates, with the best performance coming from the ideal blend of 10% SEBS and 5% EVA. The addition of EVA improved fuel performance by increasing combustion efficiency from 63% to 72%. They came to the conclusion that adding EVA and SEBS to wax-based fuels greatly improves their combustion efficiency, regression rates, and mechanical characteristics. For realistic hybrid rocket applications, a potential fuel composition is provided by the ideal wax matrix formulation of 10% SEBS and 5% EVA.
- 6. Piscitelli & Saccone et al.(2018)-The study examined the physical, thermo mechanical, and calorimetric properties of paraffin wax, namely SASOL® 0907, in order to determine whether it is suitable for use as a hybrid rocket fuel. In order to create paraffin fuel grains free of defects, the study also investigated different manufacturing techniques. These techniques addressed issues such high solidification shrinkage, which can result in cavities, cracks, and internal rips that compromise structural integrity and mechanical qualities. According to the study's findings, paraffin wax can be used as a fuel for hybrid rockets if it is appropriately described and processed. To improve the performance and dependability of hybrid rocket engines, the best production technique uses a heated mold-piston system with regulated temperature and pressure to create premium paraffin fuel grains.
- 4. Pal & kumar et al. (2019)-To increase their applicability
- 7. Ishigaki and Nakagawa (2017)-The goal of the



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project was to improve the mechanical characteristics of paraffin- based fuels, which are brittle and prone to breaking during production and use despite having high regression rates. In order to improve the paraffin wax's tensile strength and elongation, the researchers experimented with adding an ethylene-vinyl acetate (EVA) copolymer. The study found that adding EVA to paraffin-based fuels improves their mechanical characteristics and increases their suitability for use in hybrid rockets .The structural integrity of the fuel grains can also be further enhanced by stream lining the production process and managing the cooling environment.

- Cardoso & Ferrão et al.(2017)-The goal of the project 8 is to create a dependable process for making solid flammable grains with a high paraffin loading. To get the required fuel properties, the authors use a kinetically stable paraffin emulsion and regulate the droplet sizes. They discovered Solid fuel grains with a high paraffin content can be prepared by using a kinetically stable paraffin emulsion with regulated droplet sizes. The produced paraffin-based fuels have good combustion characteristics that make them appropriate for use in hybrid rockets. This study's technology offers a dependable way to make paraffinbased solid fuels with high paraffin loading, which could be advantageous for hybrid rocket propulsion systems.
- 9. Pal &Kumar(2017)-The study looked into how additions of polyethylene (PE) and aluminum powder (Al) affected the ballistic, thermal, and mechanical performance of paraffin-based hybrid rocket fuels. PE and Al were added to improve compression strength and elastic modulus, which improved the structural integrity of the fuel grains. PE also improved thermal stability, and Al increased the heat of combustion and made up for the decreased regression rates caused by PE. Al also decreased the decomposition temperature, which improved combustion efficiency. In comparison to pure paraffin, the total fuel regression rates were enhanced by the best Al and PE combinations. According to the study's findings, paraffin-based fuels that contain both PE binder and Al powder have better combustion, mechanical strength, and thermal stability, which makes them ideal for hybrid rocket propulsion applications.
- 10. Kobald & Schmierer et al.(2017)-In order to create

prediction models for fuel performance, the study sought to comprehend how the viscosity of the liquid fuel layer affects the regression rate of hybrid rocket fuels. The investigation discovered an exponential link between the regression rate and the viscosity of the liquid fuel layer. The regression rate of novel fuel formulations based on their viscosity can be predicted using this connection. The scientists came to the conclusion that liquefying hybrid rocket fuels work best when the viscosity of the liquid fuel layer is understood and controlled. In hybrid rocket applications, the known exponential connection offers a useful tool for forecasting and improving fuel regression rates.

- 11. Sinha & Sridhar et al(2016)-In order to improve fuel performance, the study concentrated on the thermo- mechanical characteristics of a hybrid rocket fuel made of paraffin wax and HTPB (Hydroxyl-Terminated Polybutadiene). The blend demonstrated a two-step decomposition process, with paraffin breaking down first and then HTPB. They also found that the fuel had a higher combustion enthalpy than pure HTPB, indicating better energy output, and that the blend had improved tensile strength and elongation when compared to pure HTPB, indicating better mechanical integrity. For hybrid rocket propulsion applications, the HTPB–paraffin blend improved mechanical strength, thermal stability, and combustion performance.
- 12. Kumar &Ramakrishna(2016)-The goal of the study was to blend paraffin wax, a fuel frequently used in hybrid rocket systems, with EVA in order to increase its mechanical strength and elongation properties. They discovered Better elongation at break and tensile strength were the outcomes of adding EVA to paraffin wax. In particular, compared to pure paraffin wax, a blend comprising 20% EVA and 80% wax demonstrated a tensile strength of roughly 3.5 MPa and an elongation of roughly 17%. When EVA was added to the wax, the study found that the regression rate decreased. The regression rate was increased by employing a bluff body at the fuel grain's head end to offset this decrease. According to the study's findings, mixing EVA with paraffin.
- 13. Ryu & Han et al.(2016)-The goal of the study was to increase the mechanical strength of paraffin wax by adding different sized and concentrated aluminum



particles. According to the study, paraffin wax's tensile and compressive strengths were increased by the addition of aluminum particles. In particular, adding 10 weight percent of nano-sized aluminum particles produced a compressive strength of roughly 5.2 MPa and a tensile strength of roughly 3.5 MPa. These properties were further improved by increasing the aluminum content to 30 weight percent. According to the study's findings, adding aluminum particles to paraffin wax improves its mechanical qualities and increases its suitability for usage in hybrid gas generators.

- 14. Kim & Moon et al.(2015)-The goal of the study was to blend paraffin wax with LDPE in order to increase its regression rate and combustion efficiency. The study assessed the blends' mechanical qualities, decomposition behavior, and thermal stability using a variety of analytical methods, including as thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), and thermomechanical analysis (TMA). They discovered that the paraffin wax/LDPE blends exhibited a two-step thermal degradation process, with paraffin breaking down first and then LDPE. The blends' regression rate was higher than that of pure paraffin wax, indicating improved combustion characteristics. The addition of LDPE also decreased thermal deformation, improving the fuel's structural stability. According to the study's findings, mixing low-density polyethylene with paraffin wax improves the fuel's combustion.
- 15. Galfetti &Nasuti et al.(2014)-By using a combined experimental and numerical approach, the study sought to improve scientific knowledge of combustion processes in hybrid rockets. In order to improve fuel properties and combustion behavior, scaled motor testing and the development of highregression rate hybrid solid fuels were made possible by the experimental work conducted at Politecnico di Milano and the University of Naples. In the meantime, the University of Rome and Politecnico di Torino's numerical modeling efforts produced advanced models and optimization tools that made it possible to design more effective combustion chambers and nozzles as well as hybrid rocket motors that were optimized to meet particular mission needs. With a concerted effort, the four Italian universities that comprised the collaborative research network advanced hybrid rocket performance significantly.

CONCLUSION

With an emphasis on improving the mechanical, thermal, and combustion characteristics of paraffin-based fuels using various additives and production techniques, this study examined a variety of hybrid rocket fuels. By adding components including polyethylene (PE), styrene-ethylene- butylenes-styrene (SEBS), and aluminum particles, the reviewed research showed notable improvements in fuel performance, including improved mechanical strength, combustion efficiency, and regression rates. Fuel properties were improved by these additions, increasing the fuels' suitability for hybrid rocket propulsion systems.

The mixing of paraffin wax with polymers or aluminum particles improves tensile strength, elongation, and thermal stability, all of which contribute to increased fuel reliability during combustion, according to key findings from the evaluated studies. Furthermore, it has been demonstrated that combining paraffin wax with EVA and low-density polyethylene (LDPE) improves thermal stability and combustion efficiency, making these fuels a good choice for launch vehicle applications.

Numerous research teams, including the cooperative Italian network, carried out experimental testing and numerical modeling that yielded important information about the performance optimization and combustion properties of hybrid rocket fuels. The significance of managing fuel viscosity and particle size to maximize regression rates and overall fuel performance was brought to light by this multidisciplinary approach.

Overall, the results point to the intriguing potential of paraffin-based fuels for improved hybrid rocket propulsion, particularly when paired with particular additives, which could result in more dependable and efficient performance in space exploration applications.

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Effect of Addition of MoS2 and SiC Reinforcement to Develop the Self-lubricating Novel Aluminium Metal Matrix Hybrid composites for Tribological Applications: An Overview

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ABSTRACT

Now a day, the demand of newer light weight and high strength material has been shifted towards composites. Day by day, novel hybrid Composites are gradually and rapidly replacing the costly super alloy and plain composites and gaining prominence in the manufacturing industry. Present review comprises the investigation of the reinforcing agent like carbide of silicon and solid lubricant like sulphides of molybdenum on the overall performance of novel AMM composites. Similarly, Al hybrid composites shows excellent tribological applications because of its improved properties such as high strength, antifriction and anti-wear behaviour. Development or fabrication of novel hybrid AMMC with suitable characterisation is of utmost importance to ensure the desired tribological and mechanical properties. Therefore, centrifugal casting, powder metallurgy and Stir casting method is studied in the present review. Out of this Stir casting method is simple, economical and equally effective for Hybrid AMMCs. The effect of SiC and MoS2 particulate reinforcement in the aluminium metal matrix composite is also briefly studied in order to justify its use in Automotive industry. It also discusses the improved tribological aspects such as wear resistance and enhanced mechanical properties like hardness. Thus, the review is carried out to study the effectiveness of mechanical properties with improved mechanical properties to justify its suitability for the tribological uses in automotive, aerospace and military benefits.

KEYWORDS : Tribological applications, Novel hybrid AMMCs, Characterization, Stir casting, Pin on disc wear tester, Hardness tester, SEM, ANOVA for DOE.

INTRODUCTION

In the recent era, material development is focused to the lighter, stronger, high strength, sustainable, low cost, high refractory and self-lubricating, smarter options. Keeping this way intact, newer hybrid metal matrix composites(MMCs) have been rapidly alluring the researchers greatly. The need of novel high strength & light weight material for modern engineering applications in the aerospace and automotive sector had led to a rapid development of metal matrix composites. Researchers also finding newer hybrid composites more economical and strength worthy with self-lubricating characteristics thereby more eager to develop the particulate reinforced aluminum metal matrix composites(AMCs).



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AMMC is becoming prominent as a material for tribological and mechanical applications such as automobile & aerospace industries. AMMCs have superior strength, toughness, conductivity, wear and corrosion resistance. It is therefore rapidly replacing the monolithic alloys. This decade is indeed an era of AMMC research.

LITERATURE REVIEW

Wear Resistance Analysis by Ragupathy Kuppusamy et al. [2]

Ragupathy Kuppusamy and his team studied how adding molybdenum disulfide (MoS2) and silicon carbide (SiC) particles to aluminum composites improves their ability to resist wear. They used an aluminum alloy (Al6061) as the base material and experimented with different levels of reinforcement, ranging from 3% to 5%. To evaluate wear resistance, they used a pin-on-disc machine under carefully controlled conditions, applying Taguchi's method to optimize the test parameters.

The study found that a composite with 3% SiC and 5% MoS2 had significantly lower wear compared to one with 5% SiC and 3% MoS2. This result highlights the importance of MoS2, whose self-lubricating properties play a key role in reducing wear. Additionally, hardness tests using the Brinell hardness tester showed that these reinforcements enhanced the material's strength, making it more durable under sliding conditions.

Hybrid Composite Fabrication by M. Arun et al. [1] M. Arun and colleagues focused on creating a hybrid aluminum composite using Al6061 alloy reinforced with MoS2, SiC, and titanium carbide (TiC). They explored how varying the reinforcement levels (3%, 6%, 9%, and 12%) affected the material's mechanical and wear properties. Their findings showed that the addition of SiC and MoS2 made the composite denser and stronger compared to pure Al6061.

Among the tested combinations, a hybrid composite with 11% SiC and 3% MoS2 achieved the highest density, while toughness increased with the addition of TiC. This composite also exhibited the highest hardness value (111.02 HV) and excellent tensile strength. The study attributed these improvements to the solid lubricating nature of MoS2 and the formation of a strong TiC layer at the surface, which reduced wear and enhanced durability compared to unreinforced materials.

METHODOLOGY

Aluminium alloys are the most popular matrix materials due to high corrosion resistance & thermal and electrical conductivity with lightweight nature. Novel aluminiumbased MMCs have been produced using a range of techniques such as ultrasonic casting, powder metallurgy in response to the demand for lightweight materials with high strength. Out of these techniques, Stir casting is the most popular fabrication method for AMMCs because of its economy and suitability for mass-production of machine components. Therefore, researcher shows that Stir casting is one of the most convenient process to produce particlereinforced MMCs.

Fabrication Process: Mechanical Stirring and Stir Casting The process of creating the aluminum metal matrix composite (MMC) using stir casting is both practical and cost-effective, particularly for large-scale production. Here's how it works step-by-step:

Melting the Aluminum Alloy: The process begins by placing scrap aluminium alloy (Al6061) into a crucible and heating it to about 745°C until it becomes molten.

Adding Reinforcements: To ensure the reinforcement particles (such as silicon carbide and molybdenum disulfide) are evenly mixed into the aluminum, they are added in two stages. Half of the total amount is introduced initially, followed by the remaining half. This step prevents the particles from clumping together. The mixture is then cooled to 250° C to stabilize the molten material.

Mixing the Components: Mechanical stirring is employed to achieve a uniform distribution of the reinforcements throughout the aluminum matrix. A hand drill powers the stirrer, which operates at a speed of 560 revolutions per minute (RPM). The stirring blades, coated with ZrO2 and preheated to 190°C, create a vortex in the molten aluminum, ensuring the reinforcements are thoroughly dispersed.

Removing Gases: To eliminate any trapped gases in the mixture, 2% NaCl powder is added as a degassing agent. This step is essential for producing a strong, high-quality composite.

Casting the Mixture: Once stirred and degassed, the molten composite is poured into a preheated mold cavity (20 mm in diameter and 125 mm in length). The mold, warmed to 200°C, helps ensure smooth filling and proper solidification.



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6.Extracting the Composite: After cooling, the mold is dismantled, and the newly formed MMC samples are carefully removed. These samples are ready for further testing and analysis



Fig. 1 Stir Casting setup



Fig. 2 Fabricated pin by stir casting process: Kind courtesy: Ragupathy Kuppusamy, et al [2]



Fig. 3 Hybrid MoS2 Composite Optical micrograph: Kind courtesy: M Arun, et al [1]

RESULT AND DISCUSSION

Hardness Testing of Aluminum Hybrid Composites Using the Brinell Method: The Brinell hardness testing machine is an essential tool for assessing the hardness of composite materials, including aluminum hybrid composites. This study highlights how the hardness of Al6061 composites improves with an increasing proportion of silicon carbide (SiC) particles. To prepare the samples for testing, they were polished using grit rough sheets ranging from 200 to 700, ensuring smooth and uniform surfaces. The Brinell hardness test was performed by applying a 550 kg force with a carbide ball indenter for 15 seconds at five different points on each sample, ensuring accuracy and consistency in the results.

The data, depicted in Figure 4.1, reveal a clear correlation between SiC content and enhanced hardness. This improvement arises from the thermal mismatch between the Al6061 matrix and SiC particles during solidification, which generates a higher density of dislocations within the material. This thermal mismatch occurs because aluminum and SiC expand at different rates when cooled, causing internal stresses that lead to increased dislocation density. The growing dislocation density impedes dislocation motion, a primary mechanism of material deformation, thereby enhancing the hardness. Moreover, the hard SiC particles act as physical barriers to dislocation motion, further reinforcing the material.

These findings underscore the role of SiC in significantly improving the mechanical properties of aluminum composites. By combining the high strength and thermal stability of SiC with the lightweight properties of aluminum, these hybrid composites are ideal for applications demanding superior hardness and wear resistance.



Fig. 4 (%) Composition vs. hardness (BHN). Ragupathy Kuppusamy, et al [2]

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Fig. 5. Samples after Hardness testing. Ragupathy Kuppusamy, et al [2]

Analysis of Variance and Wear Test Analysis for Al6061 Metal Matrix Composites: This study employs analysis of variance (ANOVA) to evaluate the effects of four key wear parameters-volume fraction, applied load, sliding speed, and sliding distance-on the wear rate of Al6061 metal matrix composites reinforced with 5 wt% SiC and 5 wt% MoS2. ANOVA provides insight into which independent variables dominate wear characteristics and quantifies their individual contributions. Factors with minimal impact, such as sliding speed in this analysis, are pooled, starting with the least significant, as significance tests depend on the availability of a non-zero error term degrees of freedom (DOF). The results indicate that wear is significantly influenced by applied load and reinforcement ratios, with wear increasing under higher applied loads, particularly at 40 N, and specific reinforcement levels like 4% MoS2 and 4% SiC. The study finds that increasing sliding distance reduces wear due to the self-lubricating properties of MoS2, which minimize friction. At a 95% confidence level ($\alpha = 0.05$), ANOVA highlights applied load as the most impactful variable, contributing 72.50% to wear, followed by volume fraction (9.90%), sliding speed, and sliding distance (1.49%). Reinforcement with 3% SiC and 5% MoS2 significantly decreases wear compared to 5% SiC and 3% MoS2, underscoring MoS2's superior selflubricating properties. This hybrid combination enhances the tribological properties of composites, improving wear resistance.

The study also demonstrates that aluminum hybrid composites become harder as SiC content increases, making them ideal for high-performance applications. For efficient experimentation, ANOVA proves effective in optimizing experimental design and parameters. Mechanical stirring and friction-based casting methods are highlighted for their cost-effectiveness and scalability in manufacturing. This research underscores the potential of MoS2 and SiC in advancing wear-resistant, high-hardness materials for industrial applications.



Fig 6. Pin on Disc Machine

CONCLUSION

This review explores the impact of silicon carbides (SiC) and molybdenum sulfides (MoS2) on the development of advanced aluminum metal matrix composites (AMMCs), focusing on their enhanced tribological and mechanical properties. Wear characteristics of these novel composites, with combined reinforcement levels of up to 8% Al-MoS2 and Al-SiC, are evaluated using suitable wear testing equipment. Hardness measurements reveal that increasing the proportion of SiC particles in the matrix significantly enhances the composite's hardness, a result attributed to the impediment of dislocation motion by hard SiC particles. Analysis of Variance (ANOVA) was employed to understand the influence of various parameters on wear performance. Results indicate that sliding speed is the most critical factor, followed by applied load (72.50%), volume fraction (9.90%), and sliding distance (1.49%). Using a reinforcement ratio of 3% SiC and 5% MoS2 proved more effective in reducing wear than 5% SiC and 3% MoS2, owing to MoS2's excellent self-lubricating properties. This characteristic enhances wear resistance by reducing friction during sliding. The study also highlights the efficiency of friction and mechanical stirring during casting as a fabrication method for AMMCs. These methods are not only economical but also suitable for mass-producing machine components, ensuring widespread applicability. ANOVA further streamlines the experimental process, helping identify optimal parameters and minimize experimental requirements. By combining the hardness benefits of SiC with the wear resistance of MoS2, this innovative approach to AMMC fabrication opens new



avenues for creating high-performance materials suitable for demanding industrial applications.

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Leveraging Industry 4.0 Tools for Parameter Identification in Performance Testing of MRI Machines: A Maintenance Practices Perspective

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ABSTRACT

Magnetic Resonance Imaging (MRI) machines are critical for accurate diagnosis and effective treatment planning in medical practice. Failures or inaccuracies in these devices can pose significant risks to patient health. This research aims to identify key performance parameters of MRI machines from a maintenance perspective and explore the integration of Industry 4.0 technologies to enhance their performance testing and reliability. By leveraging IoT-based sensors and actuators, this study proposes a condition-based monitoring framework that captures failure events, visualizes performance metrics in real time, and ensures seamless data transmission for diagnostic reporting. The methodology involves categorizing MRI machine components into diagnostic and non-diagnostic elements, analyzing their modes of failure, and identifying parameters affecting their performance. Data from IoT sensors will be transmitted to a central database for analysis, enabling predictive maintenance and regular performance evaluations. The findings demonstrate that condition-based monitoring improves fault detection, reduces downtime, and ensures consistent diagnostic accuracy. This study highlights the challenges of maintaining advanced MRI systems in medical device industries and underscores the importance of Industry 4.0 tools in addressing these challenges. By prioritizing maintenance with cutting-edge technologies, this research contributes to the development of high-performance MRI systems, ensuring reliable and high-quality healthcare services.

KEYWORDS : Industry 4.0, MRI machine, Parameter identification, Performance testing, Predictive maintenance, IoT, Digital twin.

INTRODUCTION

Magnetic Resonance Imaging (MRI) scanners play an essential role in modern medical diagnostics, providing detailed images of internal organs and tissues needed for accurate diagnosis and treatment planning. The reliability and accuracy of these machines is crucial, as any deviation or malfunction can lead to an incorrect diagnosis, negatively impacting patient health and outcomes [1]. Given the complex mechanical, electrical, and software systems in MRI machines, their maintenance requires meticulous attention to ensure consistent performance and minimize downtime.

Traditional maintenance practices for MRI machines, often reactive or scheduled, face numerous challenges. Reactive maintenance, where repairs are initiated only after failures occur, can result in significant downtime,



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resulting in service interruptions and financial losses for healthcare facilities [2]. Planned maintenance, although more proactive, often does not take into account the unique operating characteristics and conditions of use of individual machines. These limitations highlight the need for more advanced and predictive maintenance strategies that can meet the increasing demands for high-performance MRI systems in the healthcare sector [3].

Industry 4.0 technologies offer transformative solutions to these challenges, enabling smarter and more efficient service delivery methods. The Internet of things (IoT) facilitates the monitoring of MRI parameters in real time, allowing continuously collecting and transmitting data to evaluate performance. Artificial intelligence (AI) and large data analysts allow you to process extensive data sets to predict potential failures and recommend optimal maintenance actions. Digital twin technology, which creates virtual replicas of physical systems, enables simulations to anticipate machine performance and detect anomalies before they escalate into major problems [4].

Together, these technologies offer a path to move from traditional maintenance practices to predictive and condition based maintenance models.



Fig. 1 Research Flow for MRI Maintenance via Industry 4.0 [2]

The objectives of this study are threefold: First, it aims to identify the key parameters that affect the performance and reliability of MRI equipment. Secondly, it examines the integration of Industry 4.0 tools such as IoT-based sensors and actuators to provide condition-based monitoring and fault detection. Finally, the study proposes a comprehensive framework for implementing predictive maintenance techniques in MRI machines, thereby improving their performance and reliability. By addressing these challenges, we aim to contribute to the development of high-performance MRI systems that can provide the highest quality medical services.

LITERATURE REVIEW

The advancements in Magnetic Resonance Imaging (MRI) technology have made it a critical diagnostic tool in modern healthcare, relying on parameters like signalto-noise ratio, image resolution, and field strength for accurate performance [1]. However, maintaining these complex machines poses significant challenges, often hindered by traditional reactive or scheduled maintenance practices [2].

Industry 4.0 technologies, such as IoT sensors, AI-driven analytics, and digital twins, offer innovative solutions for predictive and condition-based maintenance [3]. These tools enable real-time monitoring, fault prediction, and performance optimization, reducing downtime and improving reliability [4]. Case studies in industries like manufacturing and aviation demonstrate the effectiveness of these technologies, but their application in healthcare, particularly for MRI maintenance, remains relatively underexplored [5][6].

Despite their potential, gaps in research persist, such as the lack of comprehensive frameworks and inadequate focus on MRI-specific performance parameters [7]. Traditional maintenance approaches often lead to inefficiencies, emphasizing the need for advanced methods tailored to the unique demands of these machines [8][9].

This study aims to address these gaps by integrating Industry 4.0 tools into MRI maintenance practices. By leveraging IoT-based sensors, AI-driven analytics, and predictive frameworks, the research focuses on identifying critical performance parameters, ensuring real-time monitoring, and optimizing maintenance schedules. The objective is to enhance MRI reliability and diagnostic accuracy, contributing to better healthcare outcomes and operational efficiency [10]



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METHODOLOGY

This study employs a systematic approach to revolutionize MRI machine maintenance using Industry 4.0 technologies. The methodology includes identifying key performance parameters, integrating real-time monitoring tools, designing a performance testing framework, and leveraging advanced analytics for predictive maintenance.

The first step, Parameter Identification, focuses on key indicators like signal-to-noise ratio (SNR), image resolution, cooling efficiency, and magnet temperature, which directly impact MRI accuracy and efficiency. Historical maintenance logs and machine data are analyzed using clustering, correlation analysis, and machine learning models to predict trends and identify critical elements requiring attention. This data-driven approach ensures targeted monitoring and optimization [1][2].

Next, Integration of Industry 4.0 Tools enables real-time condition monitoring and proactive maintenance. IoT sensors monitor parameters such as magnet temperature and gradient coil performance, transmitting data securely via platforms like AWS IoT and Azure IoT Hub. A digital twin—a virtual replica of the MRI machine—simulates operational scenarios, diagnoses potential failures, and optimizes maintenance schedules. An intuitive interface provides real-time insights, alerts, and actionable recommendations for technicians [3][4].

Finally, a Performance Testing Framework combines identified parameters with Industry 4.0 insights. Machine learning-driven workflows enable continuous monitoring, performance evaluation, and predictive maintenance. Field trials, conducted in collaboration with healthcare facilities, validate the framework's reliability in diverse real-world scenarios, ensuring robust and effective implementation [5][6].

To implement the methodology, specialized Tools and Technologies are employed to create a robust maintenance framework for MRI machines. MATLAB is used to process and visualize operational data, highlighting trends and anomalies in performance metrics. Python develops machine learning models for parameter identification and predictive maintenance, adapting to diverse data patterns. IoT platforms like AWS IoT and Azure IoT Hub enable real-time data acquisition and cloud-based analytics, ensuring secure communication and data privacy. These technologies collectively provide a seamless solution for monitoring and optimizing MRI performance [7][8].



Fig. 2 Methodology for Parameter Identification to monitor performance Analysis

This approach transitions maintenance from reactive to predictive strategies, ensuring reliability, improving diagnostic accuracy, and reducing costs. By addressing traditional maintenance challenges, Industry 4.0 technologies elevate the quality of medical services, ensuring efficient and reliable healthcare delivery.

CASE STUDY TO ELABORATE THE RESEARCH

At AVBRH Medical Center, frequent MRI breakdowns, high maintenance costs, and inconsistent imaging quality disrupted diagnostics and patient care. To address these issues, the center implemented an Industry 4.0-driven framework with key solutions: IoT sensors for real-time monitoring, predictive data analytics to forecast potential failures, digital twin technology for simulating MRI performance, and continuous performance testing to detect anomalies early.

The proactive maintenance approach yielded remarkable outcomes:

- Reduced Downtime: Machine availability improved with a 35% reduction in downtime.
- Enhanced Diagnostic Accuracy: Imaging quality increased by 12%, ensuring reliable diagnostics.
- Cost Efficiency: Maintenance expenses dropped by 28% within six months.

This framework demonstrated the effectiveness of Industry 4.0 technologies in minimizing disruptions, improving performance, and optimizing operational costs.


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Comparison with Traditional Methods

- Predictive vs. Reactive: Real-time data enabled issue prediction and prevention.
- Cost Savings: Optimized repairs reduced unplanned interventions.



Fig. 3 Statistical Comparison of Performance Metrics: Traditional vs. Implemented Framework

RESULTS AND DISCUSSION

Effectiveness of the Framework

The Industry 4.0 framework effectively predicted and prevented MRI machine issues through IoT sensors, real-time monitoring, and digital twin technology. Early anomaly detection enabled timely interventions, minimizing disruptions and improving reliability.

Illustrative Example: A potential misalignment in the MRI magnet coils was detected 48 hours before failure, allowing proactive correction and avoiding costly breakdowns.

Significant Outcomes

Reduced Downtime: Downtime decreased by 35%, with machines operational in 13 hours on average, compared to 20 hours previously.

Improved Diagnostic Accuracy: Continuous monitoring enhanced imaging quality, increasing diagnostic accuracy by 12%.

Cost Efficiency: Predictive maintenance reduced costs by 28%, lowering expenses from Rs. 1,020,010.05 to Rs. 734,407.23 per unit in six months.

Comparison with Traditional Methods using Metrics

The Industry 4.0 approach outperformed conventional reactive or time-based maintenance, ensuring higher efficiency and reliability.

Metric	Traditional	Proposed	Improve
	Methods	Framework	ment
Average Downtime (hrs)	20 hrs/month	13 hrs/month	0.35
Maintenance	Rs.1020010.05/	Rs.734407.23 /	0.28
Costs (Rs)	6 months	6 months	
Failure	10 failures/	3 failures/	0.7
Occurrence	6 months	6 months	
Diagnostic Accuracy (%)	0.85	0.97	0.12

Table 1 Comparison of Proposed framework with

CONCLUSION

The Industry 4.0-based maintenance framework at AVBRH Medical Center significantly improved the reliability, efficiency, and cost-effectiveness of MRI machines. By leveraging IoT sensors, data analytics, and digital twin systems, the framework enabled real-time monitoring, early fault detection, and minimized downtime. This also enhanced imaging quality and improved diagnostic accuracy. The reduction in unscheduled maintenance costs demonstrated the framework's practical value in resourcelimited healthcare settings.

This case study highlights the power of Industry 4.0 in transforming medical equipment maintenance by shifting from reactive to proactive, predictive maintenance, improving both operational efficiency and patient care. The outcomes at AVBRH validate the potential of such frameworks to enhance healthcare infrastructure and offer cost-efficient diagnostic services.

Future research could expand this framework to other medical equipment, like CT scanners and ventilators, and integrate advanced predictive algorithms like AI for more precise fault detection and optimized maintenance scheduling. These advancements would help healthcare institutions maintain uninterrupted services and improve patient outcomes.

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ABBREVIATION

MRI - Magnetic Resonance Imaging

SNR - Signal-to-Noise Ratio

AVBRH - Acharya Vinoba Bhave Rural Hospital

IoT - Internet of Things

AI - Artificial Intelligence

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Advances in Wear-Resistant Coating Technologies: A Comprehensive Review

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ABSTRACT

Wear-resistant coatings play a pivotal role in enhancing material performance under extreme conditions by improving properties such as hardness, corrosion resistance, and thermal stability. This review explores advancements in coating technologies, including innovative materials like ceramics, composites, and polymers, as well as deposition techniques such as Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), and thermal spraying. Applications span industries like aerospace, automotive, biomedical, and energy, tackling challenges like material compatibility and environmental impact. The paper also examines emerging technologies, such as hardfacing methods, nanostructured coatings, and self-lubricating systems, while emphasizing future directions in eco-friendly processes and AI-driven optimization. By referencing over 50 scholarly works, this comprehensive study provides a foundation for continued research and development in wear-resistant coatings, underscoring their role in improving industrial efficiency and sustainability.

KEYWORDS : Wear-resistant coatings, Surface engineering, Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Thermal spray coatings, Electrochemical coatings, Hardfacing techniques, Nanostructured coatings.

INTRODUCTION

Material wear remains a significant challenge across various industries, often resulting in equipment failure, increased maintenance costs, and operational inefficiencies. Wear-resistant coatings provide engineered solutions to mitigate these issues by enhancing surface characteristics. Advancements in ceramic, metallic, and composite coatings, combined with cutting-edge deposition techniques like Physical Vapor Deposition (PVD) and thermal spraying, have significantly improved wear resistance [1][2].

Objectives

This review aims to:

Explore advancements in materials and deposition

techniques for wear-resistant coatings.

Analyze their industrial applications.

Highlight challenges and suggest future directions for this field.

REVIEW OF COATING METHODS

Physical Vapor Deposition (PVD)

PVD techniques, such as sputtering and evaporation, are utilized to produce thin, durable coatings with enhanced hardness. Recent innovations, including hybrid PVD processes, have improved coating properties, making them ideal for aerospace and automotive applications [24][46]. Kumar et al. [1] demonstrated the effectiveness of molybdenum-based coatings enhanced through PVD



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for improved wear resistance. Patscheider [13] detailed advancements in nanocomposite hard coatings using PVD for superior wear protection. Ge et al. [24] highlighted the role of silicon-doped vanadium nitride coatings in achieving exceptional surface durability.

Chemical Vapor Deposition (CVD)

CVD is a reliable method for creating uniform ceramic coatings. Plasma-enhanced CVD (PECVD) has further expanded its applicability, especially in biomedical and energy sectors. Cheng et al. [2] showcased the enhanced tribocorrosion resistance of titanium alloys coated via PECVD, making them suitable for medical implants. Cao et al. [23] introduced innovative metal-ceramic coatings applied through CVD, improving overall wear resistance.

Thermal Spray Techniques

Thermal spray methods, including High-Velocity Oxy-Fuel (HVOF) and plasma spraying, produce thick coatings with excellent wear resistance. Al-Asadi et al. [3] and Tarbe et al. [25] reviewed composite coatings incorporating WC particles, noting their enhanced hardness and durability for industrial applications. Biermann et al. [20] discussed the improvements in thermally sprayed coatings achieved through microfinishing techniques, while Matsukawa et al. [28] examined coatings developed using electrical discharge-assisted spraying, revealing superior wear performance.

Electrochemical Methods

Electroplating and electroless plating are traditional techniques for depositing metallic coatings. Recent advancements, such as pulse plating, have improved uniformity and mechanical properties, making them effective in automotive and industrial applications. Yu et al. [34] analyzed hybrid nanocomposite coatings deposited electrochemically, highlighting their enhanced wear resistance. Hussain [11] explored the sliding wear behavior of composite coatings, emphasizing their durability under dynamic conditions.

Hardfacing Techniques

Hardfacing techniques are extensively employed to refurbish and improve wear resistance in components exposed to abrasive conditions. Shibe and Chawla [5] reviewed the effectiveness of materials like chromium carbide and tungsten carbide for mining and agricultural applications. Jones and Roffey [17] explored hardfacing methods for improving ground-engaging tools, while Wahlen et al. [30] focused on novel approaches for hard-facing components.

Advanced Coating Technologies

Advanced deposition methods, including laser-assisted techniques and magnetron sputtering, offer precision and the ability to create nanostructured coatings. Patscheider [13] emphasized the role of nanocomposite hard coatings fabricated using magnetron sputtering, showcasing their toughness and wear resistance. Özkan et al. [14] investigated graphene-based nanocomposites for improved wear and corrosion resistance. Cao et al. [45] proposed self-lubricating graphene nanotube coatings for enhanced durability in demanding environments. The figure 1 shows the categorization of research papers reviewed based on coating methods.



Fig. 1: Categorization of research paper review based on coating methods

APPLICATIONS OF WEAR-RESISTANT COATINGS

Aerospace Industry

In aerospace, wear-resistant coatings improve the durability of turbine blades, bearings, and landing gear. Gotman and Gutmanas [12] demonstrated the role of ceramic coatings in enhancing operational reliability under high-temperature conditions. Terleeva et al. [9] developed plasma electrolytic coatings with high friction coefficients, suitable for aerospace applications.

Automotive Industry

Wear-resistant coatings are critical for reducing friction and extending the lifespan of engine components like pistons and gears. Studies by Milutinović et al. [6] and Zhang [18] highlighted the advantages of metallic and composite coatings in improving automotive performance. Yamanoglu and Efendi [26] showcased the benefits of insitu hard nickel coatings for superior surface properties.



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Biomedical Applications

Biomedical devices, including implants, benefit from coatings that improve wear resistance and biocompatibility. Cheng et al. [2] investigated CVD coatings on Ti-6Al-4V alloys, demonstrating significant improvements in tribocorrosion resistance. Gotman and Hunter [22] reviewed ceramic coatings for medical implants, emphasizing their durability and compatibility.

Energy Sector

Energy applications, such as wind turbines and pipelines, rely on wear-resistant coatings to withstand abrasive and corrosive conditions. Al-Asadi et al. [3] highlighted the use of composite coatings for these applications, while Wei et al. [39] explored the anti-friction properties of coatings for oil and gas exploration.

CHALLENGES AND FUTURE DIRECTIONS

Challenges

Challenges in wear-resistant coatings include balancing hardness with toughness, minimizing environmental impacts, and optimizing costs without sacrificing performance [10][43].

Future Directions

Advancements in wear-resistant coatings are likely to focus on:

Nanotechnology: Developing nanostructured coatings for exceptional durability [13].

Sustainability: Exploring eco-friendly materials and deposition methods [3].

Digitalization: Utilizing AI and machine learning to optimize coating design and applications [8].

CONCLUSION

Wear-resistant coatings have emerged as transformative technologies in enhancing the durability, functionality, and efficiency of materials in diverse industries. By integrating innovative materials, advanced deposition techniques, and sustainable practices, these coatings address critical challenges in wear and corrosion resistance. Industries such as aerospace, automotive, biomedical, and energy are leveraging these advancements to improve operational efficiency and reduce costs. However, further progress requires addressing challenges such as costeffectiveness, environmental impact, and balancing mechanical properties like hardness and toughness. Future developments are anticipated to center on nanostructured and multifunctional coatings, sustainable deposition processes, and the incorporation of digital technologies like artificial intelligence for design optimization.

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Design Optimization and Rigid Body Dynamics of a Robot Arm Using Advanced Simulation Tools

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ABSTRACT

The design and optimization of robotic arms are essential for enhancing performance, precision, and dependability in a variety of applications, including automation, medical robotics, and manufacturing, according to this review paper. The objective of this work is to use sophisticated simulation tools, namely SolidWorks and ANSYS, to optimize the design and investigate the rigid body dynamics of a robotic arm. The focus is on increasing the mechanical design by optimizing critical parameters, including joint configurations, link lengths, and material qualities, to provide optimal performance while minimizing energy consumption, wear, and the danger of mechanical failures. The robotic arm is 3D modelled using SolidWorks, and comprehensive structural and dynamic simulations are performed using ANSYS.

These simulations analyze the arm's behavior under various loading circumstances, quantifying stress, strain, and deformation. To determine crucial design elements, the dynamic performance—which includes the arm's mobility, stability, and reaction to outside forces—is examined. The study's conclusions provide important information for enhancing the robotic arm's design, guaranteeing increased effectiveness, durability, and accuracy. The results contribute to the development of more dependable and efficient robotic systems, supporting their greater application across industries and advancing the state of robotics.

KEYWORDS : Robot arm, FEA, CAD, Optimization, Solid works, Ansys Workbench, Structural analysis.

INTRODUCTION

n a variety of sectors, such as manufacturing, Lautomation, and healthcare, robotic arms' performance, accuracy, and dependability are greatly improved by their design and optimization. Robotic arms must function in complex and dynamic environments with great efficiency, stability, and low wear. To accomplish these goals, a thorough comprehension of their dynamic behavior and mechanical design is required. By fine-tuning important characteristics such joint configurations, link lengths, and material qualities, this study aims to optimize the design of a robotic arm. To evaluate the arm's performance under various loading scenarios, sophisticated simulation tools are used, such as SolidWorks for 3D modeling and ANSYS for structural and dynamic analysis. Finding important design elements, increasing energy efficiency, lowering mechanical failures, and guaranteeing ideal motion and stability are all made possible by the analysis.

By using this method, the study hopes to aid in the creation of robotic systems that are more dependable and effective and appropriate for a variety of uses.

LITERATURE REVIEW

1. Kevin Morales, Carlos Hoyos, Jesús M. García study presents the building and mechanical structural design of a humanoid robot arm with four degrees of freedom for educational purposes. Beginning with the concept creation phase, the project gathered six recommendations to satisfy client demands. Next, based on the product specification, the concept to be developed is chosen. The final design idea for the suggested concept was the result of seven redesign phases. In particular, continuous simulation steps are performed to observe the stress condition of each component, study the dynamic reaction of the structure under load, and modify the connecting rod's size in accordance with the previously established limits and



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specifications. In light of the limits associated with the servo motor to be used and the maximum load to be handled, a structure that complies with the original design specification is created based on the results obtained. Lastly, the produced product's straight arm and reverse arm kinematics models are provided.

- 2. CHERIPALLY NAVEEN, G. BALAJI, Dr. N. JEEVAN KUMAR Study work on the robotic arm's mechanical design using CATIA software, and use Ansys software for structural and modal analysis. Base papers are used to discuss a design optimization and methodology that uses finite element analysis (FEA). This project's structural Ansys program analyzes steel, aluminum alloy, and titanium alloy materials by applying various loads. Deformation, stress, and strain levels are ascertained by the application of structure analysis. The natural frequencies and vibrations at various mode shapes are found via modal analysis.
- 3. JEEVAN, DR. AMAR NAGESWARA RAO study deal with a new high performance semi- direct drive robot arm's mechanical design, structural analysis, and results validation. A finite element analysis (FEA)based design optimization process is examined, and the arm design that results is presented. High structural vibration frequencies over the arms workspace are predicted by FEA models of the finished design. The projected structural vibration characteristics throughout the arm's workspace are confirmed by extensive structural vibration experiments conducted with the finished manipulator. To analyze the structural parameters, the model is subjected to both modal and structural analysis.
- 4. Samir Chakravarti, Souvik Sarkar, Suvro Mukherjee, Moinak Biswas Study deals on In the analysis system of static structural and stiff dynamics, a five-degreeof-freedom robotic arm with a gripper is subjected to both static and dynamic analysis using the ANSYS workbench. SolidWorks is used to create the full robotic arm and its griper. The maximum stress caused by applied force in each robotic arm and gripper component is observed in order to estimate the load carrying capacity of each component. By using the ANSYS simulation tool to observe the stress distribution of each component of the robotic arm, the weakest components are also identified. After the results of statics and dynamic analysis are evaluated, the robotic arm and its gripper are designed to their best potential.
- 5. Anurag singh, Rashmi Arora, Yashpal Singh Chouhan study deal The stresses and overall deformation

induced for a particular robot payload are analyzed and explored. A robot arm with five degrees of freedom (DOF) has been chosen to assess stress and deformation. Solid Works was used to create the design and model of the five-DOF robot arm, and ANSYS software was used to evaluate the entire construction. Nowadays, robots are employed in a variety of fields, particularly those requiring precision. The robotic arm is designed using a model design development technique that makes use of finite element analysis (FEA). Robot arm modeling, fabrication, and evolution have been extremely active study areas worldwide in recent years.

- 6. Dodla Mandeep, Mettu Ranjith, Paka Sumanth, Pola Ravi Kumar, Chetla Venu Gopal, Dr K. Siva Prasad study deal use SolidWorks Soft Motion tools to create a pick- and-place robots system. A Cartesian robot and an articulated industrial robotic arm with several grippers are designed using the program. To reduce the time needed to develop the robot and to increase its speed and quality, SolidWorks' 3D CAD software was used to design it.
- P Rajesh, Naveen Kumar, K Ganesh, study deal with 7. the study of how exposure to dangerous chemicals causes numerous workers to be hurt, sick, or murdered each year. These incidents result in substantial medical expenses, lost productivity, and human misery. In order to minimize accidents and foster a safe and healthy work environment, this robotic arm seeks to support and advise both employers and employees. Additionally, the two conflicting requirements of any industrial process are now high accuracy and repetitive duties. Simple repetitive operations can be completed with autonomous robotic systems, which take accuracy and speed requirements into consideration. The mechanical system design idea and construction of a three-degree-of- freedom jointed arm robot using locally accessible materials is shown in this study. The robot is intended to carry out industrial tasks including picking and placing waste materials that are chemically dangerous.
- 8. Deepak Katal, Amritpal Singh study deal with the In every industry, including automotive, industrial, and biomedical applications, robots are becoming indispensable for automation.

The goal of the current study is to use additive manufacturing techniques including lattice structures



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to maximize the mass of the robotic arm component. The ANSYS simulation package is used for the robotic arm component's design and FEA analysis. Without sacrificing much of its strength, the robotic arm component's mass has been greatly decreased by the use of beam lattice structure. The robotic arm's lattice structure design yielded a mass reduction percentage of 20.11%. With beam lattice design, the equivalent stress increases by 18.54%.

- 9. Harihara. S, Dr. Vivekananthan.R, Dr. Jamuna.R, Dr. Lavanya.D, Meenakshi.S, Because of its high level of precision when doing heavy tasks, research on articulated robotic arms is becoming increasingly important. The development and study of an articulated robotic arm that may be used for painting jobs is the focus of this project. SOLID EDGE software is used to develop and simulate the articulated robotic arm. The model of a robotic arm with varying dimensions and loading conditions was studied using finite element analysis utilizing the ANSYS software workbench. The analysis's findings are examined in order to determine the optimal structure parameter and to confirm the articulated robotic arm's high viability.
- 10. Renish P. Vadhadiya, Prof. B.K. Patel, Chiragsinh Zala, Chintan C. Patel The paper discusses the idea of a robot arm with five degrees of freedom. This will provide a great deal of freedom of motion by enabling a wide variety of arm postures for any particular target location. Additional constraints can control motion. The paper describes a method that uses modeling and static analysis of a five- axis robotic arm. The robot is made to carry a 5 kg payload, and analysis is done on each link to determine the precise stress pattern on each link. The factor of safety value is set at 2 and is verified to be safe.
- 11. Abhishek Gupta, Purushottam Sahu, Ghanshyam Dhanera study deals Lattice constructions and topology optimization techniques have been used to optimize the robotic arm's weight. The topologically optimized design, a generic design, and the lattice structure are then subjected to static structural analysis using the ANSYS software.

The equivalent stress, deformation, and safety factor are among the outcomes of the finite element analysis (FEA). This analysis aids in assessing how the robotic arm's strength-to- weight ratio is affected by decreased mass density. Based on these criteria, a comparison between the generic design and the topologically optimal design is subsequently carried out. Critical areas with high stresses and deformation are identified using contour plots derived from the FEA analysis.

- 12. Tauseef Uddin Siddiqui, study deals with The first step in designing an industrial robot is determining the needs of the clients. The robot's application, working space, reach, accuracy, repeatability, resolution, degree of freedom, and payload are the main criteria. They are helpful in industrial applications like welding, machining, painting, assembling, positioning, and inspection. The KUKA industrial robot's CAD model was created in Solid Works software initially, and then its arm and gripper—two major load-bearing components that are prone to breakdown under extreme stress conditions—were subjected to finite element analysis in ANSYS Mechanical Workstation.
- 13. Abdulhameed Muneam HAMEED and Serdar AY study deal with Based on measurements of maximum shear elastic strain, equivalent elastic strain, equivalent stress, and total deformation, the static structure of a spot welding (SW) robotic arm made of three different materials—copper alloy, aluminum, and titanium—is examined in the event that the arm is subjected to loads of 3900 N, 4000 N, 4400 N, and 5000 N that are applied to the upper tip of the spot welding gun by actuators using ANSYS WORKBENCH. The outcomes for distinct materials subjected to varied forces are contrasted with one another. As the load on the spot-welding tool increases, the robotic arm's total deformation and maximum shear elastic strain seem to increase as well. From the perspective of total deformation, the robotic arm's total deformation for spot welding is the least when operating on copper alloy material as opposed to aluminum and titanium.
- 14. Vijay Palled and Dr.M.S.Hebbal, study deals with the creation and design of the robotic arm's pickand-place mechanism. The five-degree-of-freedom robotic arm is programmed to perform precise light material pick-and- place tasks, which can help any industry's manufacturing line. The robotic arm's project components are made using the 3D printing technique. As a result, it offered more accurate measurements and significantly reduced time and expense. Six servo motors are included with the robotic arm to connect the components and provide arm movement. The open-source Arduino computer hardware and software is used to drive servo motors and operate the robotic arm, allowing it to change position.



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15. Mukund Narayan Pandey, Amit Kr Srivastava, Paveen Kumar Maurya, study says that to the knowledge and significance of digital prototypes in industrial engineering as opposed to prototypes. In the current, rapidly expanding industrial era, every business seeks to increase manufacturing speed in order to satisfy the demands and specifications of its customers. However, the agriculture sector continues to be an exception. Humans have never been faster, cheaper, or more accurate than robots. The materials that come into contact with the moving arm may move at a speed that is comparable to that of the tool due to extremely significant elastic deformations and stress.

CONCLUSIONS

After conducting a thorough literature review of fifteen research articles, we can say that in-depth analysis using advanced simulation tools, it is clear that design optimization plays a crucial role in enhancing the performance and efficiency of robot arms. The application of these tools allows for the precise modeling and analysis of rigid body dynamics, facilitating the identification of critical design parameters that affect the robot arm's motion and stability. Through optimization techniques, it is possible to improve factors such as weight distribution, material usage, and joint configurations, resulting in a more efficient and reliable robotic system. Furthermore, advanced simulations enable real-time adjustments and provide valuable insights into the dynamic behavior of the robot arm, reducing the need for costly physical prototypes. Ultimately, the integration of design optimization and rigid body dynamics through simulation tools leads to more cost- effective, high-performance robotic arms suitable for a wide range of applications.

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Investigating the Wear Characteristic of Cladded Surface Fabricated with Overlay Method

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ABSTRACT

The wear characteristics of cladded surfaces fabricated using overlay methods play a crucial role in extending the lifespan and performance of industrial components. This review focuses on advancements in overlay cladding techniques, including direct energy deposition, electron beam cladding, and plasma-transferred arc welding. These methods are explored for their ability to enhance wear resistance through the use of advanced materials such as tungsten carbide, silicon carbide, and solid lubricants. Hybrid processes, such as combining ultrasonic nanocrystal surface modification with cladding, show significant improvements, boosting wear resistance by up to 25%. Incorporating ceramic and metallic reinforcements has been found to reduce friction, lower wear rates, and improve surface hardness. These advancements demonstrate the effectiveness of overlay methods in creating durable, wear-resistant surfaces suitable for extreme environments, offering a pathway for industries to achieve longer-lasting and more reliable components. Future research is encouraged to focus on fine-tuning cladding processes and exploring novel reinforcement materials for even greater performance gains.

KEYWORDS : Wear resistance, Coating, Overlay technique, Cladded surfaces.

INTRODUCTION

Wear and tear are significant challenges in industries where components are exposed to friction, abrasion, and extreme operational stresses. To mitigate these effects, overlay cladding has emerged as an essential solution, providing enhanced surface durability while preserving the substrate's structural integrity. Cladding involves the deposition of a protective layer of material onto a base, forming a wear-resistant surface ideal for demanding applications. This technique has gained attention due to its adaptability in combining advanced materials and innovative processes to meet specific operational needs (Jo et al., 2023).

LITERATURE REVIEW

Various cladding methods, including direct energy deposition, electron beam cladding, and plasmatransferred arc welding, have been widely studied for their ability to enhance wear resistance. Materials such

as tungsten carbide, silicon carbide, and solid lubricants are commonly integrated into cladding layers to reduce friction and improve surface hardness. For instance, combining ultrasonic nanocrystal surface modification with cladding has shown improvements in wear resistance by up to 25% (Karimbaev et al., 2020). Moreover, hybrid methods have demonstrated excellent potential in achieving precise microstructural control and optimizing stress distributions for enhanced performance (Zhao et al., 2023). The introduction of computational tools like finite element modeling and laser lamination modeling has further refined cladding processes, allowing for precise control over the material's structural and wear characteristics (Guk et al., 2016). These innovations not only enhance wear resistance but also contribute to the efficiency and reliability of components operating under extreme conditions, making them indispensable across industries like aerospace and manufacturing.

This review explores the wear characteristics of cladded



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surfaces fabricated through overlay methods. By examining material properties, processing parameters, and cutting-edge technologies, it highlights the significant potential of overlay cladding to revolutionize surface engineering for high-performance industrial applications.

Wear is one of the most common causes of failure in mechanical components, leading to significant material damage and loss. According to ASM, wear is defined as damage to a solid surface caused by the mechanical action of a contacting solid, liquid, or gas. It is such a universal phenomenon that even slight contact between two surfaces typically results in measurable material transfer or loss. Mechanical components subjected to sliding or rolling contact invariably experience some level of wear and abrasion, making material selection critical to optimizing performance and production efficiency [(ASM, 2021)].

In the railway industry, train wheels play a vital role in operational safety. Factors such as complex track conditions, increasing train speeds, and heavier axle loads can lead to severe wear and rolling contact fatigue (RCF). These issues not only compromise the reliability of train operations but also result in significant material waste due to frequent turning and profile restoration. Laser cladding technology offers a promising solution for repairing localized damage, effectively improving wear resistance, prolonging wheel life, and enhancing the safety and comfort of train operations [(Qian et al., 2021)].

With industrialization, the widespread use of metal parts has become essential due to their excellent properties. However, friction and wear, especially in harsh environments, lead to energy losses, material degradation, and shortened component lifespans. Studies indicate that around 23% of total fuel energy is lost to frictional contact, with wear accounting for 80% of machine failures. This has significant economic implications, especially in manufacturing-heavy economies where friction and wearrelated losses impact GDP. Advanced surface technologies like cladding are critical for enhancing wear resistance, extending component life, and reducing economic losses [(Dingding et al., 2021)].

Cladding is a process of bonding an outer protective layer to a core material. This method is widely used in manufacturing to improve surface properties while minimizing costs. For instance, cladding allows for the use of scarce and expensive metals in small quantities, bonded to more readily available and cost-effective materials. Metal cladding processes, such as roll bonding, explosive bonding, and laser cladding, are commonly used to create durable surfaces capable of withstanding corrosive or abrasive conditions. Laser cladding, in particular, involves depositing a controlled layer of material onto a substrate using a focused laser and a stream of powdered material, offering precision and excellent wear resistance.

Weld overlay, another surface modification method, enhances substrate surfaces by applying specially designed alloys to improve corrosion and wear resistance in harsh conditions. This technique is extensively used in industries like chemical processing, offshore oil production, and power generation. Cladding materials, particularly corrosion-resistant alloys, have been employed for over 40 years to extend the lifespan of critical industrial components while reducing costs.

Recent studies highlight the advancements in cladding technologies and materials. For instance, Sudarshan Butaley, Lalit P. Dhole, and Vivek W. Khond reviewed various overlay techniques and their impact on surface properties. Their research explores cladding methods, tribological behavior, and advancements in hightemperature materials, providing insights into future directions and research opportunities [(Butaley et al., 2021)]. Similarly, Pranay Bagde, S.G. Sapate, R.K. Khatirkar, and Nitesh Vashishtha investigated the frictional and abrasive wear behavior of plasma-sprayed Al₂O₃-13TiO₂ coatings. They found that the addition of 15% nickel graphite significantly reduced wear rates and friction, attributed to the self-lubricating properties of graphite and tribochemical reactions, offering valuable solutions for enhancing material performance [(Bagde et al., 2021)].

VARIOUS MATERIAL USED FOR CLADDING

The exploration of materials for cladding has been a significant focus in recent research due to their role in enhancing surface properties and wear resistance. Sudarshan Butaley, Lalit P. Dhole, and Vivek W. Khond In[15]presented a comprehensive review on advancements in overlay techniques and the use of various materials for cladded surfaces. Their study analyzed research up to 2021, discussing the effects of different cladding methods on mechanical and tribological properties. The review highlighted key findings on metals and alloys, including their behavior under high-temperature applications, and identified the merits, limitations, and areas for future research in welding cladding techniques.



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Another noteworthy study by Pranay Bagde, S.G. Sapate, R.K. Khatirkar, and Nitesh Vashishtha examined the friction and abrasive wear behavior of plasma-sprayed Al₂O₃-13TiO₂ coatings. This study also investigated the effects of incorporating graphite into the coatings. Using XPS analysis, the researchers observed that γ - α Al₂O₃ phase transformations influenced friction and wear properties differently. Coatings with 15% nickel graphite (Al₂O₃-13TiO₂+15% Ni Graphite) exhibited significantly improved performance, demonstrating lower coefficients of friction and reduced abrasive wear rates compared to standard Al₂O₃-13TiO₂ coatings. The enhancement was attributed to the synergistic effects of a self-lubricating graphite film and tribochemical reactions.

Both studies underscore the potential of innovative materials and advanced cladding methods to enhance wear resistance and mechanical performance. By leveraging materials like nickel graphite and ceramic composites, cladding techniques can deliver significant improvements in durability and efficiency, paving the way for their expanded use in industrial applications. These findings also point to the importance of further research into the interaction of cladding materials and wear mechanisms for optimal application-specific performance.associated failure modes.

CONCLUSIONS

The study of wear characteristics in mechanical components using overlay techniques has been a focus of significant research. However, cladded surfaces—despite their potential in improving surface properties—have not been extensively explored in this context. Current literature reflects substantial efforts to enhance the wear resistance and mechanical properties of metals, but investigations specifically targeting cladded surfaces fabricated through overlay methods remain scarce.

This gap highlights the need for a comprehensive and detailed analysis of cladded surfaces, particularly their wear behavior under various conditions. The potential of overlay techniques to improve surface durability and extend component life warrants further research to establish effective methodologies and material combinations. Investigating the wear characteristics of cladded surfaces can provide valuable insights, contributing to advancements in industrial applications where wear resistance is critical. Future studies should address this research void to optimize the performance and reliability of cladded components.

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Parametric optimization of Test Variables that Influence on Ultrasonic Welding of Plastic (Acrylic) to Hybrid Composite by using the Taguchi Approach

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ABSTRACT

A solid-state joining technique called ultrasonic welding creates joins by applying high-frequency vibratory energy to work components that are kept together under pressure without melting. Plastic (acrylic) to hybrid composite are joined to the apparatus in automotive and electronic applications using a solid state joining technique. This work produces ultrasonically welding of Plastic (acrylic) to hybrid composite with a thickness of 1 mm while taking into account welding factors such as % of Eichhornia Fiber, Welding time, and Amplitude. To perform trials, an appropriate experimental design was created and carried out using Taguchi's robust design process. The ANOVA and S/N ratio studies are in use to study the impact of different welding parameters on the weld strength and to get the best parameters. The welding time of 5 (S), the % of Eichhornia Fiber 10 (%) and amplitude at 50 (μ m), are the parameter values that yield the greatest weld strength.

KEYWORDS : Hybrid composite; Ultrasonic plastic welding; Taguchi design of experiments; ANOVA; Weld strength.

INTRODUCTION

C ince the automotive sector relies heavily on welding materials for the assembly of vehicle-body structures, it is aggressively exploring several new joining approaches that could facilitate the utilization of lightweight and high-performance materials. Novel solid-state joining, a method that allows for the creation of metallurgy bonds between unlike or comparable materials without melting, is a key component of many alternative procedures. Ultrasonic plastic welding (USPW) is a solid-state joining technique. Oxides and contaminants are dispersed by the high-frequency, which cause incremental shearing and deformation of plastic between surface asperities to generate a solid-state weld. Additionally, it increases the region in which the surfaces to be connected are in pure plastic contact. The ultrasonic welding (USW) technique is a fast joining process, and provides excellent weld strength. It is more preferable technique over conventional adhesive, mechanical fastening and other joining process

because they bring problem like stress concentration at joint, increase weight of component, more laborious which brings human error. Process optimization of ultrasonic welding was studied by H.Van Wijk [1]. Optimization of parametric effect of ultrasonic welding studied by S. Sreekanth [2] and the model can predict the temperature and stress distribution with different shape of Sonotrode. According to T. Zhao [3], a larger sonotrode led to a greater heating rate, which shortened the welding time to reach the ideal welding stage. E.E. Feistauer conducted a study to examine the parametric influence of the ultrasonic joining procedure on the mechanical characteristics of metal-composite hybrid joints [4]. K. Anand [5] presented modeling and multi-objective optimization of ultrasonic insertion parameters using fuzzy logic and evolutionary algorithms. According to S. Elangovan [6-7], a secondorder mathematical model utilizing RSM was created in order to forecast the optimum weld resistance of spot and seam welds made by USMW employing aluminum sheets and Cu-Brass. Arthur Levy conducted a mesoscopic



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numerical investigation of the relationship between adhesion quality, polymer flow, and processing factors [8]. Experimental investigation and process optimization on ultrasonic welding of GF/PA6T composite were studied by R.Kalyan kumar [9].

MATERIALS AND METHODOLOGY

Materials

The material used for this research study are of two combination: -i) epoxy reinforced unidirectional Eichhornia fiber and acrylic thermoplastic (polymethyl methacrylate) which also named as PMMA. The hardener (HY951) was utilised at room temperature, and epoxy resin (LY-556) was utilised as the matrix material. The material of choice for reinforcing was eichhornia fiber. PMMA, commonly known as acrylic thermoplastic (polymethyl methacrylate).

Fabrication Method

Selection and preparation of mould for specimen preparation is very important. Hard page was selected as the mould material for mould preparation. Hard pages were covered & laminated with thin layer of polythene, it provided a very good surface finish. As it was easy to shape and removed from the prepared specimen, that's why it was selected for the mould preparation. For mould preparation, origami style was adapted to fold and shape the paper to make the mould cavity. The cover was cut in the required shape. The paper was folded about the faint black lines in order to make mould cavity.

After the mould preparation, the material was poured into the cavity. Epoxy-resin and epoxy hardener in quantity i.e.40% resin and 60% hardener was poured into the cavity along with reinforced unidirectional Eichhornia fiber and then leveled to the surface. It allowed to settle down for at least 5 hours in order to solidity to specimen. ASTM international guidelines were followed in the preparation of a sample for tensile loading testing of joint strength.

Experimental set-up

The welding was carried out with the help of industrial ultrasonic welding robot manufactured by YASKAWA as shown in figure 1 at centre for invention, innovation, incubation and training at Government College of Engineering, Chandrapur. All the welding experiments are performed at the laboratory conditions. Specification of Industrial Ultrasonic welding robot-1AR1440 High-Speed, Thru-arm Design, MAX.WORKINGRANGE-1 -44,

Technical Details

POWERSUPPLY-1.5 kV, NUMBEROF AXES - 60mm, REPEATABILITY - 0.02 mm,

Using flat surface joint design, spot welding technique, and lap joint we have performed the experiment using ultrasonic plastic welding machine of rinco standard 3000 series welders. Stepped titanium horn with 10 mm diameter was used during experiments. Since the sonotrode comes into touch with components close to the joint region, near field welding has been envisaged. The welding parameters which we able to vary are weld time, and amplitude. Clamping a wooden fixture on table. Keep both welding specimen in lap joint position. Program was created on controller screen according to our welding parameters requirement.



Fig. 1: Ultrasonic welding robot setup



Fig 2: Welded Specimen

Specimens were sterilized with acetone before to the procedure in order to eliminate surface impurities that might compromise the binding strength. Set the initial reference parameters so that welding should takes place. Run the program for specimen 1 and remove the welded specimen, cleaning the fixture, and similarly same procedure was repeat for all remaining specimens. By following above mentioned procedure, the total of 81 numbers of specimens was welded. The real welded samples that were utilized for joining are displayed



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in Figure 2. The weld strengths were measured using universal testing equipment at CIPET, Chandrapur.

Test Parameters

The welding trial was conducted in a laboratory environment, and the parameters that were tested were the percentage of Eichhornia fiber (0–20), the welding time (3–5 seconds), the amplitude (50–70 (μ m). The design of experiments (DOE) was done using MINITABTM version 19. Welding tests were conducted using three factors and three levels. Three columns and twenty-seven rows make up the L27 orthogonal array approach used in this investigation. The identical circumstances were used for at least three experiments. The two factors, welding time and amplitude, are the process dependent, while one of the factors chosen for testing was fiber weight percentage, which is material specific. Table 1 displays the trial's variables and levels.

The L27 orthogonal array, which is displayed in Table 2, shows the outcomes of 27 experiments with three repetitions for different factor permutations. For each set of weld parameters, the average tensile strength was computed and displayed in Table 2.

In Taguchi analysis, the S/N ratio is primarily divided into three categories for quality attributes: nominal is better, greater is better and smaller is better. The greater welding strengths were accepted. So that the S/N ratio of the "Greater is better" was selected for the analysis. The S/N ratio was computed using the following formula:

$$\frac{S}{N} = -10 * \log 10 \left(\frac{\Sigma(Y^2)}{n}\right) \tag{1}$$

Table 1: The Levels and Factors

Factor	Level 1	Level 2	Level 3
% of Eichhornia Fiber	0	10	20
Welding Time (sec)	3	4	5
Amplitude (µm)	50	60	70

Table 2: Experimental results

Expt. No.	% of Eichhornia Fiber	Welding Time	Amplitude	Average Tensile Strength
1	0	3	50	7.5
2	0	3	50	9
3	0	3	50	5.4
4	0	4	60	16.4

5	0	4	60	25
6	0	4	60	18.6
7	0	5	70	46.2
8	0	5	70	48.6
9	0	5	70	46.2
10	10	3	60	21.6
11	10	3	60	33.8
12	10	3	60	12.6
13	10	4	70	38.6
14	10	4	70	42
15	10	4	70	52.1
16	10	5	50	77.9
17	10	5	50	152.7
18	10	5	50	95.4
19	20	3	70	9
20	20	3	70	46.2
21	20	3	70	34.7
22	20	4	50	50
23	20	4	50	47.1
24	20	4	50	68.5
25	20	5	60	78.1
26	20	5	60	81.7
27	20	5	60	78.9

Table 3. Response Table for Signal to Noise Ratios -Larger is better

Level	% of Eichh. Fiber	Welding time	Amplitude
1	25.25	21.73	30.31
2	32.51	30.95	30.31
3	31.98	37.07	29.86
Delta	7.27	15.34	0.74
Rank	2	1	3

Table 4. Response Table for Means

Level	% of Eichh. Fiber	Welding time	Amplitude
1	24.77	19.98	57.06
2	58.52	39.81	40.74
3	54.91	78.41	40.40
Delta	33.76	58.43	16.66
Rank	2	1	3



P-Value Source DF Seg Contri-Adj Adj F-55 bution SS MS Value % of Eichhomia 2 6183.5 21.48% 6183.5 3091.7 0.000 1216 Fiher Welding Time 2 15893.3 55.20% 5893.3 7946.7 31.26 0.000 Amplitude 2 1630.7 5 66% 1630.7 815.4 3.21 0.062 Error 5084.8 20 5084.8 17.66% 254.2 Lack-of-Fit 2 645.7 2.24% 645.7 327.9 1.31 0.295 Pure Error 15.42% 4439.1 18 4439.1 246.6 Total 100.00% 26 28792.3





Fig. 3: Main effect plot for S/N ratio Tensile Strength









RESULT AND DISCUSSION

a result, Taguchi's experimental design was As methodically used to improve the process parameters for ultrasonic welding of plastic (acrylic) to hybrid composite with a thickness of 0.2 mm. Figure 3 displays the major effect plot for the S/N ratios for tensile strength, whereas Figure 4 displays the main impact plot for the means for tensile strength. The ideal experiment conditions for the greatest tensile strength include % of Eichhornia Fiber 10%, Welding time at 5 S, and Amplitude of 50 µm, as shown in Figure 3. The S/N ratios response table for tensile strength is displayed in Table 3, and the means response table for tensile strength is displayed in Table 4. Table 3 shows that welding time has the greatest impact on welding performance, with a delta value of 15.34 (maxmin value), followed by % of Eichhornia Fiber (7.27) and Amplitude (0.74). Figure 5 display the interaction graphs for average tensile strength, respectively, with regard to three parameters. Table 5 displays the response's ANOVA findings. Table 5 shows that the response (weld strength) is significantly impacted by parameters Welding Time, % of Eichhornia Fiber and Amplitude.

It should be remembered that the collection of elements that produce the process's central tendency (process average) is the ideal mix of components and their levels selected from the response analysis (weld strength).

CONCLUSIONS

- 1. Studies were conducted on the factors influencing ultrasonic plastic welding when welding of plastic (acrylic) to hybrid composite. The best parameter combinations were found to maximize weld strength and minimize fluctuation in weld strength.
- 2. The response (weld strength) is found to be significantly impacted by the include % of Eichhornia Fiber, Welding time, and Amplitude.
- 3. % of Eichhornia Fiber, Welding time, and Amplitude all account for 21.48, 55.20, and 5.66% of the observed differences in weld strength, respectively.
- 4. The amplitude of the horn at 50 (μ m), the welding time of 5 (S), and the % of Eichhornia Fiber 10 (%) are the parameter values that yield the greatest weld strength.

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Exploring the Versatility of E-Glass Fiber Reinforced Epoxy in Advanced Engineering Applications

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ABSTRACT

E-glass fiber reinforced epoxy composites have gained widespread popularity in advanced engineering applications due to their superior mechanical, thermal, and environmental properties. These composites offer a combination of lightweight, high strength, and resistance to corrosion, making them suitable for industries such as aerospace, automotive, construction, and renewable energy. This review paper aims to explore the versatility of E-glass fiber reinforced epoxy composites by synthesizing findings from over 25 research studies. The paper highlights the mechanical properties, thermal stability, and environmental durability of these composites and discusses the innovative fabrication techniques and diverse engineering applications. Finally, the challenges and future directions for the development of these materials are discussed.

KEYWORDS : E-glass fiber, Epoxy composites, Mechanical properties, Tribological behavior, Fabrication techniques.

INTRODUCTION

The demand for high-performance materials in advanced engineering applications has driven significant research in composite materials. Fiber-reinforced polymers (FRPs), particularly E-glass fiber reinforced epoxy composites, have emerged as a favored choice due to their excellent mechanical properties, corrosion resistance, and relatively low cost. E-glass fibers are made from silica-based glass and exhibit high tensile strength, low density, and high resistance to moisture and chemicals. Epoxy resins, when combined with E-glass fibers, form a composite that offers improved strength, impact resistance, and thermal stability.

This review paper focuses on the versatility of E-glass fiber reinforced epoxy composites, analyzing their properties, applications, and fabrication techniques. By reviewing the latest research, the paper aims to provide a comprehensive understanding of how these composites are utilized in various engineering sectors and their future potential.

LITERATURE REVIEW

E-glass fiber reinforced epoxy composites have been extensively studied over the years. A significant body of research has focused on their mechanical, thermal, and environmental properties, which make them suitable for advanced engineering applications.

Mechanical Properties

The mechanical performance of E-glass fiber reinforced epoxy composites has been the subject of numerous studies. Researchers have found that the fiber volume fraction, fiber orientation, and the interfacial bonding between the fiber and matrix significantly influence the composite's mechanical properties. According to Chen et



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al. (2020), increasing the fiber volume fraction improves tensile and flexural strength, while maintaining a balance between fiber content and matrix resin is crucial to achieving optimal performance (Smith et al., 2019).

In addition, studies have shown that the mechanical properties of E-glass fiber reinforced epoxy composites depend on the manufacturing method used. Vacuum-assisted resin transfer molding (VARTM) and hand lay-up techniques are commonly used to fabricate these composites, with VARTM providing better uniformity and lower porosity, leading to improved mechanical performance (Patel et al., 2023).

Thermal Properties

Thermal stability is another important factor in evaluating the performance of E-glass fiber reinforced epoxy composites. According to Brown & Patel (2020), the glass transition temperature (Tg) of epoxy resins can range from 120°C to 180°C depending on the resin formulation. The presence of E-glass fibers helps lower the coefficient of thermal expansion (CTE), making these composites suitable for high-temperature applications in aerospace and automotive industries (Zhang et al., 2018).

Environmental Durability

The durability of E-glass fiber reinforced epoxy composites under environmental conditions is critical for their performance in outdoor and marine applications. Singh et al. (2022) demonstrated that these composites show good resistance to moisture absorption, which is important for applications in humid or marine environments. However, prolonged exposure to ultraviolet (UV) radiation can lead to resin degradation and a decrease in mechanical properties (Zhao et al., 2023).

Innovations in Fabrication

Recent innovations in the fabrication of E-glass fiber reinforced epoxy composites have enhanced their properties and reduced production costs. Additive manufacturing (3D printing) has emerged as a promising technique for producing complex composite structures (Baker et al., 2020). Additionally, the development of hybrid composites, combining E-glass fibers with carbon or natural fibers, has led to improved mechanical properties, as shown by Gonzalez et al. (2021).

APPLICATIONS OF E-GLASS FIBER REINFORCED EPOXY COMPOSITES

E-glass fiber reinforced epoxy composites have found applications in several industries due to their versatile properties.

Aerospace Industry

In aerospace, E-glass fiber reinforced epoxy composites are used for structural components such as wing spars, fuselage panels, and tail sections. Their low weight and high tensile strength are crucial for improving fuel efficiency and performance. Mian et al. (2021) showed that these composites help reduce the overall weight of aircraft while maintaining or even improving the structural integrity of key components.



Fig. 1 Structure of an E-glass fiber reinforced epoxy composite

Automotive Industry

The automotive sector has increasingly adopted E-glass fiber reinforced epoxy composites in the production of body panels, bumpers, and interior components. These materials contribute to reducing vehicle weight, which enhances fuel efficiency and reduces CO2 emissions. Kumar et al. (2020) found that these composites also offer superior impact resistance, which improves vehicle safety.

Renewable Energy Sector

In the renewable energy sector, E-glass fiber reinforced epoxy composites are widely used in the manufacturing



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of wind turbine blades. Their high strength-to-weight ratio and resistance to fatigue make them ideal for withstanding the dynamic loads encountered in wind energy applications. Anderson et al. (2021) demonstrated that these composites help increase the lifespan and performance of wind turbines.

Marine Engineering

E-Glass/epoxy composites are extensively used in marine applications, such as boat hulls and underwater components, due to their excellent resistance to seawater and fatigue.

Table. 1 Summary of Mechanical and Thermal Propertiesof E-Glass Fiber Reinforced Epoxy Composites

Property	E-Glass Fiber Reinforced Epoxy Composites	Reference
Tensile Strength (MPa)	300- 550	Chen et al. (2020)
Flexural Strength (MPa)	500-700	Smith et al. (2019)
Young's Modulus (GPa)	30-45	Zhang et al. (2018)
Glass Transition Temp (°C)	120-180	Brown & Patel (2020)
Impact Strength (J/m ²)	50-120	Zhao et al. (2023)
Coefficient of Thermal Expansion (×10 ^{-6/°} C)	20-35	Singh et al. (2022)
Moisture Absorption (%)	<1	Zhang et al. (2018)
UV Resistance	Moderate to High	Anderson et al. (2021)

Table 2. Comparison of Surface Treatments for ImprovedFiber-Matrix Bonding

Surface Treat- ment	Tensile Strength (MPa)	Flexural Strength (MPa)	Shear Strength (MPa)	Effective- ness
Untreated	350	320	200	Baseline
Chemical Treat-ment	420	390		250

Plasma Treat-ment	460	420	280	Significant improve- ment
Coupling Agents	480	440	300	Highest im- provement

E-Glass Fiber Renurcted Epoxy Composites



Fig. 2 E-Glass fiber reinforced epoxy composites with different fiber-matrix bonding conditions

METHODOLOGY

This review paper is based on a comprehensive analysis of recent research papers, articles, and reports on E-glass fiber reinforced epoxy composites. The following methodology was employed:

- 1. Literature Search: A systematic search of academic databases such as Google Scholar, ScienceDirect, and Web of Science was conducted to identify relevant papers published between 2015 and 2024.
- 2. Data Extraction: The selected studies were analyzed for information related to the mechanical, thermal, and environmental properties of E-glass fiber reinforced epoxy composites, as well as their applications and fabrication techniques.
- 3. Synthesis and Analysis: Key findings from the selected studies were synthesized and compared to identify trends, challenges, and future directions in the field.



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RESULTS AND DISCUSSION

The review of over 25 research papers indicates that E-glass fiber reinforced epoxy composites possess several key advantages, such as high mechanical strength, excellent thermal stability, and good resistance to moisture and chemicals. However, some challenges remain, particularly concerning the environmental durability of the epoxy matrix under UV exposure. Research by Zhao et al. (2023) highlights the degradation of epoxy resins when exposed to UV radiation, which can reduce the composite's overall performance.

Recent advancements in the fabrication of hybrid composites and additive manufacturing have opened new avenues for improving the mechanical and thermal properties of these materials. Hybrid composites, combining E-glass fibers with carbon fibers, have shown superior performance in terms of strength and stiffness (Gonzalez et al., 2021). Additive manufacturing offers the potential for creating complex, lightweight structures with minimal material waste, further enhancing the sustainability and cost-effectiveness of E-glass fiber reinforced epoxy composites (Baker et al., 2020).

Based on the reviewed studies, the following conclusions can be drawn:

- Mechanical Properties: E-Glass/epoxy composites demonstrate superior tensile, flexural, and shear strengths compared to traditional materials like steel and aluminum. However, their brittleness and low impact resistance can limit their applications in some areas, particularly where high ductility is required.
- Durability: Environmental degradation, especially moisture absorption and UV radiation, significantly impacts the long-term performance of these composites. Research is ongoing to develop moisture-resistant coatings and improve the interface bonding to enhance their durability.
- Fabrication Techniques: The fabrication methods of E-Glass/epoxy composites, including hand layup, vacuum infusion, and filament winding, have been optimized to ensure the uniform distribution of fibers and efficient resin impregnation. The choice of manufacturing technique directly influences the mechanical properties and cost-effectiveness of the final composite.
- Future Trends: Future research is focused on enhancing

the matrix-fiber interfacial bonding, developing hybrid composites, and incorporating nanomaterials to improve the mechanical and environmental properties of E-Glass/epoxy composites.

CONCLUSIONS

E-glass fiber reinforced epoxy composites are versatile materials with a wide range of applications in advanced engineering fields such as aerospace, automotive, and renewable energy. Their excellent mechanical, thermal, and environmental properties make them ideal candidates for high-performance applications. However, challenges such as resin degradation under UV exposure and the need for more sustainable resin systems remain. Future research should focus on developing new resin formulations, enhancing the fiber-matrix interface, and exploring recycling techniques to address these challenges.

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Quantitative and Qualitative analysis of the Performance of State-Owned and Private Utility Companies in the Indian Electricity System

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ABSTRACT

The power sector is one of the most important sectors in the development of any country. The Electricity system in India is undergoing rapid changes with most of the utilities being state-owned, private utilities are also encouraged to participate to boost the growth opportunities in this sector. In this paper, quantitative and qualitative analysis is based on the comparative study of the performance of India's largest State-owned power supply utility, MSEDCL, and India's two largest private power supply utilities, Tata Power, and Adani Power. The quantitative analysis is based on 09 factors and the qualitative analysis is based on 05 factors which are influential in deciding the financial performance and sustainable operation of the utilities.

KEYWORDS : India, Electricity, Power distribution utilities, Operations analysis.

INTRODUCTION

The power distribution sector plays a role in delivering electricity to all the consumers. This major task is achieved through State government-owned and private distribution companies [1]. The Indian power sector is undergoing significant changes in all the segments i.e. generation, transmission and distribution, and demand side management [2]. Various technical suggestions are given in the worldbank report to improve the operational efficiency of power distribution companies. These suggestions include carrying out regular energy audits, mapping and proper allocation of their assets, and planning about procurement of power, energy metering of every distribution transformer, use of low-tension aerial bunched conductors, and spot billing leading to good working practices of the State Electricity boards [3]. On the financial front, almost every state power distribution company is incurring huge losses which is affecting the further expansion and modernization of distribution networks [4]. In the past decade use of AI-enabled technology has been available for optimizing the operation and detecting small variations in the demand and supply of electricity [5]. Modernizing the distribution systems is

a challenging task due to large and different geographical areas [6]. It is reported that more than 80 % of interruptions occur due to failures in the distribution systems [7].

The distribution networks should be able to accommodate variable supply from renewable energy sources, data flow, and the use of digital technology for efficient, cost-effective operations [8]. The GOI is implementing revamped distribution schemes to strengthen the distribution of electric supply to 100% of villages [9]. With the change in government policies, the Indian power distribution sector is encouraging the active presence of private distribution utilities [10]. Despite facing many difficulties like financial crisis, subsidies, debts, political interference, and slow privatization, India has removed its tag of power deficit country to a power-rich country [11].

This paper presents a quantitative and qualitative analysis based on the comparative case studies about the performance of India's largest State-owned power supply utility, Maharashtra State Electricity Distribution Company Limited (MSEDCL), and India's two largest private power supply utilities, Tata Power (TP), Adani Power (AP). The qualitative analysis is based on 09 factors: Year of establishment, No. of Consumers, Geographical Area



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covered, Installed Generation capacity, HT Distribution Lines Laid, contribution to Govt. Social Welfare Schemes, No. of Employees, Financial Performance, Raising Capital Investment, etc.

The qualitative analysis is based on five factors: renewable energy generation, Innovative measures for consumers, Innovations in technology, and Administrative setup. These parameters are the influential factors in deciding the financial performance and sustainable operation of the utilities and hence considered for the analysis.

CASE STUDY OF MAHARASHTRA STATE DISTRIBUTION COMPANY LIMITED (MSEDCL):

It is a state government-owned corporation incorporated in 2005 after the complete restructuring of the formerly known Maharashtra State Electricity Board (MSEB, 1960). The main objective of the MSEDCL is to distribute electricity from the end point of the transmission network to the consumers. It is responsible for developing, operating, and maintaining the distribution system for the consumers in its supply area. It provides electricity in the entire state of Maharashtra and a few suburbs in Mumbai. It is considered one of the largest electricity distribution companies in India and Asia with 2.7 Cr consumers and 70,000+ employees. Infrastructure-wise, it has 4000+ 33/11 KV substations, 25000+ HV feeders, and 8 lac distribution transformers. MSEDCL has erected 3.3 lac Km of 11 KV distribution lines and 50,000 Km of 33 KV distribution lines. It caters to a customer base spread over a geographical area of 3, 08,000 Km2. In association with, MAHAGENCO, the MSEDCL has a generation capacity of 13, 220 MW. The overall AT & C losses have reduced from 33.89% to 20.73% during FY 2006-07 to FY 2020-21. MSEDCL contributes effectively to the upliftment of the rural economy and agricultural loads by separating 40% of the total feeders and maintaining 8 hours of quality electric power supply for agricultural feeders. To enhance profitability, the major plan is to reduce the AT & C losses to 15%, improve IT interventions, and implement the "Substation Monitoring Scheme" & deployment of smart meters, and use the latest IT implementations to keep up with technological advancements in the power sector. The MSEDCL has an administrative and operational setup of a corporate office in Mumbai, 04 regional offices, 16 zonal offices, 147 divisional offices, and 652 sub-divisional offices. [12]

Table 1. MSEDCL's financial performance for thefinancial year 2022-23

Total Income:	Rs. 96, 318.79 Crore
Power purchase expenses:	Rs 89, 993.36 Crore
Financial loss:	Rs 5,254.86 Crore

*Figures from companies' audited financial reports

CASE STUDY OF TATA POWER LTD.

Tata Power Company Limited is an Indian electric utility and electricity Generation Company based in Mumbai, India, and is part of the Tata Group. It has a presence in power generation, transmission, and distribution in India and internationally. It has installed thermal power plants, hydroelectric power plants, and recently solar and wind power generation plants. It distributes power to 12.5 Million customers spread across Mumbai, Delhi, Ajmer, and Odisha over an area of 1.55 lac Km2. The power generation was started in 1922 (75MW) with a hydroelectric power plant at Khopoli and subsequently increased to 5860 MW till 2020. The group has a presence in wind and solar power plants. The first solar power plant was in 1996 (110 KW) and subsequently increased to 110 MW till 2018.

Tata Power offers many innovations to ensure a reliable power supply. It has continuously committed to innovation and technological advancement in the power sector which has placed it in the top 25 of smart grid index benchmarking [13].

The company is listed on the stock market and can raise funds from the public. On the financial side, Tata Power is a profit-making company.

Revenue Generated:	Rs 63,272.32 Cr
Operating Income:	Rs. 417.88 Cr
Net Profit :	Rs 4280.10 Cr

*Figures from companies' audited financial reports

CASE STUDY OF ADANI POWER LTD.

Adani Power is another major private utility in India, with its headquarters at Ahmedabad in Gujrat. The company was established in the year 1996. The company has an installed power generation capacity of 15250 MW. And operate a mega solar power plant of 40 MW capacity at Nalia, Gujrat. Adani Electricity is a company established



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as a subsidiary of the company and it caters to the power requirements in some parts of Mumbai. It is well known for its customer-centric services through innovative and advanced solutions such as smart meters, and electricity mobile app. The company has 8274 employees (3315 for Adani Power and 4959 for Adani Electricity). Adani Electricity set up its own 500 MW coal-based thermal power plant in 1996. It is one of the best power plants in the country. The plant is known for its distinctive features in terms of technological innovations, superior performance, and continuous sustainability for a longer period. The plant uses integrated management systems, and is certified for quality management, environment management, occupational health and safety assessment studies, social accountability management, information management, security energy management, and accreditation for coal and ash testing laboratory [14]. The company is listed on the stock market. Adani Power is a profit-making company.

Table 3. Adani Power's performance for the FY2023-24

Revenue Generated:	Rs. 60,281 Crore	
Operating Profit:	Rs. 20,792 Crore	
Consolidated Profit after tax:	Rs. 20,829 Crore	

*Figures from companies' audited financial reports

QUANTITATIVE ANALYSIS OF THE ABOVE THREE COMPANIES

The above three companies are analyzed quantitatively based on various parameters such as Year of establishment, Number of Consumers, Geographical Area, Installed Generation capacity, HT Distribution Lines Laid, contribution to Government social welfare schemes, Number of Employees, Financial Performance, Listing in the Stock Market.







Fig.2 Utility-wise installed generation capacity



Fig.3 Utility-wise Number of employee



Fig. 4 Utility-wise Financial performance

Fig.1, Fig. 2, Fig.3, and Fig. 4 show the graphical representation of the number of consumers, the installed generation capacity, the number of employees, and the financial performance of these utilities respectively [12, 13, 14, 15]. It can be observed that the highest number of consumers is with MSEDCL spread over the entire state of Maharashtra. The private utilities are serving the needs of their consumers which are located in the specific locations. Also, it can be seen from Table 1 that MSEDCL employs the highest number of employees and contributes to the implementation of 06 social welfare schemes, thereby adding to the operating cost of the utility and affecting its profitability. Also, MSEDCL is unable to raise capital



from the public as it is not listed in the stock market and solely depends upon the government. This is not the case with private utilities.

Sr. No.	Parameter of performance	MSEDCL	Tata Power(TP)	Adani Power (AP)	Observation
1	Year of establishment	2005(After restructuring of MSEB 1960)	1911	1996	Tata Power is the oldest utility among the three
2	No. of Consumers	2.7 Cr	1.25 Cr	1.2 Cr	TP- 46.3% of MSEDCL AP- 44.4% of MSEDCL
3	Geographical Area covered	3.08 x 10 ³ Km ²	1.55 lac Km ² .	400 Km ²	MSEDCL has the largest geographical area coverage
4	Installed Generation capacity	13220 MW	7058 MW	15250 MW.	AP has the largest capacity. MSEDCL has 87% of AP and TP has 53% of AP
5	HT Distribution Lines Laid	3.3 lac Ckt. km	4.17 lac Ckt. Km	21,100 Ckt. Km	TP has the largest Distribution lines as it covers state of Odisha
6	If contributing to Govt. Social welfare schemes	06 schemes of social welfare related to agricultural loads	No	No	Except MSEDCL TP & AP do not implement government welfare schemes
7	Number of Employees	70,000 +	23000 +	8200 +	TP has 33% AP has 12 % Employees compared to MSEDCL
8	Financial Performance	Loss of Rs 5,254.86 Cr	Profit of Rs 4280.10 Cr	Profit of Rs. 20,829 Cr	MSEDCL is loss-making while TP & AP are profitable
9	If Listed in the Stock Market	No	Yes	Yes	TP & AP can raise capital from stock markets while MSEDCL is not listed.

Table 4 shows the comprehensive quantitative analysis of all three utilities

Qualitative analysis of the above three companies

The qualitative analysis is done for the above three companies based on parameters such as the area of service

covered by the company, whether Renewable energy generation is used, Innovative measures for consumers, and Innovations in technology to upgrade Administrative setup [12, 13,14,15].

 Table 5. Qualitative analysis of the three companies

Sr. No.	Parameter of performance	MSEDCL	Tata Power (TP)	Adani Power (AP)	Observation
1	Caters to	Entire state of Maharashtra	Maximum portion of Mumbai, Delhi, Ajmer, Odisha	A specific portion of Mumbai	MSEDCL & TP cover a larger geographical area than AP
2	If Renewable energy generation used	thermal, wind, solar	thermal, wind, solar	thermal, wind, solar	All utilities use thermal, wind, solar generation
3	Innovative measures for consumers	Dedicated portal for consumers, mobile app, advanced IT infrastructure	mobile-assisted GIS system in Mumbai for real-time technician support,	smart meters, electricity mobile app	All utilities are offering the best to their consumers.
4	Innovations in technology to upgrade	Substation Monitoring Scheme, Smart Metering	Within the top 25 of smart grid index benchmarking, Implemented Asia's largest BESS	Technological innovations, Continuous sustainability, accreditation for coal and ash testing laboratory	Technological advancements and R & D activities are stronger in private utilities than MSEDCL, which affects profitability
5	Administrative set up	Large	Large	Large	All the utilities have a large setup

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As observed from Table 5 the private utilities are focusing on technological development more than MSEDCL, the In-house R&D lab at Tata Power for smart grid is within the first 25 best facilities in the world. At Adani Power, implementation of technological innovations, superior performance, quality and environment management, and use of latest technologies in IT, energy, etc.

RESULTS & CONCLUSION

From the quantitative and qualitative analysis, it is found that MSEDCL is a huge loss-making utility while Tata Power and Adani Power can maintain profitable operations. The following recommendations are suggested to MSEDCL to enhance its profitable operation:

- (a) Effective measures to reduce distribution losses.
- (b) Revenue losses due to social welfare schemes need to be accounted for separately in their balance sheets.
- (c) Appropriate manpower planning.
- (d) Separate arm to handle agricultural feeders and social welfare schemes.
- (e) In-house R&D activities to focus on their internal technical problems and keep track of technical developments in the power sector.
- (f) Reduce political interference.
- (g) Listing on the Stock market to raise capital from the public.

Hence, it can be concluded that private utilities are operating profitably and more flexibly. They can focus on development more than the state-owned utility. This leads to many opportunities for private utility companies in India. However, it is a concern that it needs huge investment costs and the companies have to sustain for a longer time to recover their investment and start to generate profits for the organization.

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An Innovative Approach to Mitigate Outage Reduction Time on Electric Power Distribution Networks

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ABSTRACT

The power sector is one of the most important sectors in developing any country as it helps enhance the nation's business and simplify life. India has seen rapid development in all three sectors of the power industry i.e. generation, transmission, and distribution since 2014. According to the latest data available on the website of the Ministry of Power (MoP), Government of India, the overall generation capacity has increased by 9.88%, the transmission network has increased by 1, 14,599 km and the government is focusing on revamping the distribution sector to improve the reliability, quality, and affordability of electric power supply. The power distribution sector is the most challenging one due to large geographical areas, environmental challenges, and system breakdowns due to faults, component failures, and aging of conductors. Almost 80% of breakdowns in the power system are due to faults in the distribution system. Considerable time is lost in locating the faults resulting in loss of revenue and consumer dissatisfaction. This paper focuses on distribution system innovations and infrastructure. It presents a model for automatic fault detection and its location, which will directly inform the maintenance personal about the nature and location of the fault occurred in the form of SMS resulting in reduced manual efforts and the time needed to locate the fault.

KEYWORDS : India, Electricity, Sustainable development, Power system planning, Demand growth, Grid management.

INTRODUCTION

The power distribution sector is vital in the development f any country. This vital responsibility is accomplished by the effective working of state government-owned and private distribution companies to deliver reliable electric supply to all its consumers [1]. With various influencing factors such as continuously increasing electricity demand, better access to electricity, and challenges to match dynamic demand side management with available resources, the Indian power sector is undergoing major changes in all the segments like distribution, generation, and transmission [2]. As per the directions received from the World Bank about the development of the energy sector in India, a Restructured Accelerated Power Development and Reform Programme has been implemented by various states to improve the efficiency of electricity distribution utilities [3]. Indian distribution utilities have significant potential for improvement on the technical and financial fronts.

In the present scenario, due to huge financial losses incurred by these utilities, modernization and upgradation of distribution networks are affected [4]. The technological development of AI-enabled software for operation optimization and optimum demand-supply management has a great role to play in the modernization of the networks [5]. Huge geographical areas and different climatic conditions increase the challenges of the upgradation of the distribution systems [6]. Faults on the distribution systems resulting in frequent power cuts affect the productivity of industrial consumers and compel them to erect their selfgeneration facilities [7]. For cost-effective operation of the power distribution utilities, along with digital technology, the use of renewable energy sources should be encouraged [8]. The focus of the Government of India is to electrify 100% of villages through the expansion of distribution networks [9]. Although the Indian distribution sector is full of challenges due to political, economic, and technological factors, it is full of opportunities. Various new approaches are being implemented to enhance their



operational profitability such as the deregulation of the distribution sector, enhanced use of renewable energy sources to provide access to rural India and promote the use of electric Vehicles in India to reduce dependency on fossil fuels. This will exponentially enhance power consumption and promote the application and usage of technologies to increase reliability and power quality while maintaining a balance in demand and supply [10]. Despite facing many challenges such as financial limitations due to Subsidies and debts, political interference, and sluggish privatization, India has removed its label as a country of power shortage and has become a power-rich country and has acquired the third position China and the USA in terms of power generation. The energy shortage has dropped from 11.1% to merely 0.6% (MoP Annual CEA Annual Report) [11].

Power outages and interruptions in power supply due to faults in the system are the most common phenomena in power distribution systems. Almost 80 % of outages are due to faults in the distribution system. Such outages occur for many reasons, such as the aging of conductors, abnormal weather conditions, sudden changes in the load, failure of system components, etc. The outage must be kept to a minimum to maintain the operation's profitability. Distribution utilities need to implement modern fault detection methods.

GPS-based sampling and high-speed communication networks for intelligent electronic devices (IEDs), methods based on negative sequence components [12], application of wavelets, neural network-based approaches, and GSM-based smart meters have been developed by many researchers for the detection and classification of faults occurring on the power distribution network [13-17]. A fault detection and classification approach based on an ensemble classifier-based smart meter is also developed [18].

Thus it is seen that the power distribution sector in India is full of challenges and therefore full of opportunities. The main challenges are mitigating high losses on the technical and commercial side, the condition of overloading of the system especially in densely populated urban areas, opportunities for improvement in the metering and billing systems of DISCOMS, and issues related to power quality. However, it is not possible to address all these issues simultaneously. An attempt is made to address one specific issue in this paper i.e. innovations in electric power distribution networks and related infrastructure.

PROPOSED MODEL WHICH CAN BE USED TO LOCATE THE FAULT IN A DISTRIBUTION SYSTEM

This research work was inspired from day to day life's common observation, that a distribution utility maintenance team attempting to locate the fault occurred on a distribution network which is spread over a large geographical area. Locating the fault along with its location is a tedious job and many a time consumes a lot of time as it is generally done mostly manually due to lack of automation on distribution systems. The maintenance team has to search many places to find out the correct fault location resulting in increased breakdown duration. The use of IT-enabled technologies in our daily activities has helped things to become faster, easier, and comfortable. Similarly, with the use of technology, finding the location and nature of electric faults in a distribution network can be done rapidly and easily, thereby reducing the system breakdown time considerably.

Methodology used to construct a model demonstrating the concept of smart grid

The distribution system model was divided into nine different sections. Current sensors were used at appropriate locations to measure variations in current during normal and fault conditions. The current sensor output was given to an analog-digital converter (A-D converter) to obtain output in digital pulses. Section-wise fault conditions were programmed using an ARDUINO MEGA 2560 microcontroller. The concept of abnormal increase in current during fault conditions was used. Therefore digital output of the A-D converter in the form of digital pulses increases. The micro-controller evaluates this variation in the number of pulses during normal and fault conditions by comparing it with programmed conditions and the fault signal is generated accordingly. The micro-controller output was given to the Global System for Mobile (GSM) module and LCD to communicate the nature of the fault to the intended user. Communication with users is one of the important features of smart grids [19].

The concept described above is shown with the help of a block diagram below.

Fig. 1 represents the block diagram used to develop the GSM-based model. The output of the model is in the form of a message on an LCD and the message is communicated to the maintenance personnel of the distribution company.



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Fig.1 Methodology used to develop the working Model

Ready information about the location and the nature of the fault is directly available, thereby eliminating the time to locate the fault on the system and reducing breakdown time.

Formulation of different fault conditions

The ARDUINO micro-controller was programmed by creating different fault conditions in different sections. The A-D converter output was observed to note down the variations in the number of pulses it generated. The following table shows various fault conditions that were observed to generate the output of the micro-controller.

Table 1. Various fault conditions used to program the micro-controller

Sr. No.	Out Put of A-D Converter to program Micro Controller	Result of Micro Controller
1	Number of pulses for R, Y, B> 15000	Healthy condition.
2	Number of pulses in S1, R phase < 200& Iy < 1	R phase section 1 open
3	Number of pulses in S1, Y phase < 200& Ir < 1	Y phase section 1 open
4	Number of pulses in S1, B phase < 200& Ib < 1	B phase section 1 open
5	Number of pulses in S2, R phase < 200& Ir < 1	Y phase section 2 open
6	Number of pulses in S4, Y phase < 200 & Iy < 1	R phase section 4 open
7	Number of pulses in S6, B phase < 200 & Ir < 1	Y phase section 6 open
8	Number of pulses in S5, R phase < 200 & Ib < 1	R phase section 5 open

9	Number of pulses in S7, Y phase < 200 & Iy < 1	Y phase section 7 open
10	Number of pulses in S3, B phase < 200 & Iy < 1	Y phase section 3 open
11	Number of pulses in S8, R phase < 200 & Ir< 1	R phase section 8 open
12	Number of pulses in S9, R phase < 200 & Ib < 1	B phase section 9 open
13	Number of pulses in S1, R phase < 1000 & Iy > 5	Y phase section 1 short
14	Number of pulses in S1, Y phase < 1000 & Ir > 5	R phase section 1 short
15	Number of pulses in S1,B phase < 1000 & Ib > 5	B phase section 1 short
16	Number of pulses in S2, R phase < 1000 & Ir > 3 & Ir <4.5	Y phase section 2 short
17	Number of pulses in S4, Y phase < 1000 & Iy > 3 & Iy <4.5	R phase section 4 short
18	Number of pulses in S6, B phase < 1000 & Ir > 3	Y phase section 6 short
19	Number of pulses in S5, R phase < 1000 & Ib > 2	R phase section 5 short
20	Number of pulses in S7, Y phase < 1000 & Iy > 2	Y phase section 7 short
21	Number of pulses in S3, B phase < 1000 & Iy > 2 & Iy <3.5	Y phase section 3 short
22	Number of pulses in S8, R phase < 1000 & Ir > 2.1 & Ir < 3.5	R phase section 8 short
23	Number of pulses in S9, R phase $< 1000 \&$ Ib > 2.1	B phase section 9 short

Using the fault conditions formulated to program the micro-controller as shown in Table 1, the output of the micro-controller was generated and it was given to the GSM module and LCD.

Photographs of the model

The photographs of the model developed are shown below. Photograph 1 shows the overall view of the model. Photograph 2 represents the control section of the model and photograph 3 shows the output of the model when the Y-phase of section 7 of the model was made open as a fault condition.



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Fig 1. Model Overview



Fig 2. Model Control Section



Fig 3. Output of Model

The model was tested successfully for various fault conditions as described in Table 1.

RESULT AND CONCLUSION

The faults in the distribution system are the main reasons for the outages of the supply. Almost 80 % of the outages are due to faults in the distribution systems. With the continuously growing use of electricity and the expanding nature of distribution systems, new methodologies, and innovative devices can be used to increase the operational profitability of distribution companies and add to consumer satisfaction, which is one of the important objectives of the working of power distribution companies. The working model discussed above can be developed commercially with the adequate implementation of suitable technologies to achieve this prime goal of distribution companies. Recent technologies such as AI and ML can be suitably used instead of using a microcontroller-based approach.

FUTURE WORK

The model presented is a prototype to demonstrate the automated fault detection concept using commonly available resources, such as microcontrollers and GSM modules. For commercial deployment on a large scale, the application of advanced technologies such as AI and ML can be suitably used instead of using a microcontroller-based approach. The accuracy and speed of fault detection can be increased while reducing the error with such advanced technologies. However, the cost of such systems may be a matter of study and requires funding from research organizations to carry out further work in this direction.

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Analyzing Active and Reactive Power Sharing Techniques of Distributed Optimal Power Flow

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ABSTRACT

Active & reactive power-sharing strategies are analyzed for distributed optimal power flow in specific load scenarios. Optimal power flow finds steady-state operation points that lower generation costs, losses, etc. In the last five decades, Distributed Optimal Power Flow (DOPF) has emerged to be among the most significant and broadly examined nonlinear optimization issues while preserving a system performance that is acceptable in terms of limitations on the line flow, active along with reactive powers of the generators, the output of different compensating devices, etc. OPF has become complex due to the addition of various devices and the power industry deregulation. Economic market management has been placed on top of the conventional power system concept practices. This paper provides an in-depth exploration of optimizing power flow using distributed techniques, specifically focusing on theIEEE-14 Bus system. Here's a detailed analysis and summary based on the content presented.

KEYWORDS : OPF, DOPF, Active power, Reactive power, Equality and inequality constraints.

INTRODUCTION

The paper discusses the challenges of solving Optimal Power Flow (OPF) problems, which are essential for determining the optimal operating conditions of power systems while minimizing costs and losses. The Distributed Optimal Power Flow (DOPF) approach has emerged as a solution to handle large, complex power systems by dividing the system into smaller, manageable subsystems. Each subsystem optimizes power generation and distribution while considering various constraints.

The objective of this research is to:

Examine the optimization of power flow (both reactive and active power) in distributed systems.

Examine how minimizing generation costs is affected by equality and inequality requirements.

Apply these techniques to Distributed OPF to enhance system efficiency [7] [11][12].

LITERATURE REVIEW

The paper provides a comprehensive review of existing studies on DOPF and related optimization methods for large-scale power systems. Key highlights include: The distributed optimization methods for active and reactive power sharing.

Previous works examining system convergence and the challenges of optimizing large power networks.

How different optimization techniques are used to address non-convex AC OPF problems.

The nonlinearity and complexity of OPF are due to factors like the introduction of new devices and deregulation in the power industry.

The review references notable studies in the field, which focus on improving system performance through enhanced power sharing and optimization [1][2] [9] [14] [15] [18].

The IEEE 14-Bus system is revealed in Figure 2.1 [25], where the Consensus Area, Area-A, & Area-B are indicated. The system consists of loads, generators, and transformers.

Certain restrictions are needed to solve the dynamic control of the DOPF issue, which involves determining the control variable for the system as well as describing the mathematical expression [1][5][7][11].


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Fig 1: The IEEE-14 Bus system[25]

Minimization of total generation cost as under;

$$\min_{\mathbf{u}} \sum_{i=1}^{N_{G}} C_{i}(\mathbf{P}_{i}) \tag{1}$$

Here,"Pi is no. of generators having capacity,

Ci is the Cost of per generator-\$/MWhr"

The function of the system includes generation cost, power injection as well as voltage phase, equality constraints, power generation inequality constraints, and line flow limitations [1] [3] [6] [7] [8] [9] [10] [15] [20] [21].

METHODOLOGY

The strategy for resolving the OPF problem in a distributed fashion is described in the technique section:

The methods section describes the distributed approach to solve the OPF problem:

Each region (or area) in the system is modelled using quadratic programming techniques, and the Newton-Raphson system is applied for iterative solutions.

The optimization variables shown in equation (2) include reactive power (Qg), voltage magnitude (Vm), active power (Pg), & phase angle (θ) [1] [3] [4] [11] [14].



Inequality Constraints

The formulae for inequality constraint (3) to (6) display high &low limits of Pgi & Qgi, V & θ [1] [3] [5] [7] [9] [10] [15] [21] [23] [25].

"Regarding

$$\underline{P_{gi}} \le P_{gi} \le \overline{P_{gi}}$$
⁽³⁾

$$\underline{Q_{gi}} \le Q_{gi} \le \overline{Q_{gi}}$$
⁽⁴⁾

$$\underline{V_i} \leq V_i \leq V_i \tag{5}$$

$$\underline{\Theta_i} \le \Theta_i \le \Theta_i \tag{6}$$

Equality Constraints

The" equality constraint equation involves real and reactive components to present the generation of Pg, Q_g , and functions of V & Θ . P_d , Q_d is real as well as reactive load demand at each bus, normally it should be considered as constant.

$$P_{gi} - P_{di} - P_i(V, \theta) = 0$$
⁽⁷⁾

$$Q_{gi} - Q_{di} - Q_i(V, \theta) = 0 \tag{8}$$

RESULTS AND DISCUSSION

RESULT

This sectionshown in Table 4.1 provides MATPOWER simulation outcomes for the IEEE-14-Bus system under three different event studies. Key performance metrics are compared, including:

Generation cost, convergence time, generation capacity, and system losses.

The study compares the performance of Area-A, Area-B, as well as a Consensus Area, which represents a globally optimized approach.

DISCUSSION

Generation Costs: The cost increases as you move from Area A to Area B, with the Consensus Area providing the most optimized cost structure.

Convergence Time: The Consensus Area method significantly reduces convergence time compared to traditional area-based methods.



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System Losses: The DOPF approach with active and reactive power sharing successfully minimizes system losses, as demonstrated by the lower losses in the Consensus Area.

The "non-convex nature of the AC OPF problem is handled effectively, ensuring that both active and reactive power outputs, along with voltage magnitude and bus angle, are optimized".

		(CASE IEEE	-14 BUS	
SN	C		Area A & B	Area A	Area B
1	COST(\$/ Whr)	M	8081.53	8879.52	10903.48
2	Converge e Time (Second	nc	3.32	0.19	0.70
3	Generati	P	772.40	572.40	500.00
1	on Capacity	Q	148.0	100.0	96.0
4	Generati on	Р	268.29 Pg1=194.33 Pg2=36.72 Pg3=28.74 Pg6=0.0 Pg8=8.49	263.08 Pg1=96.15 Pg2=66.94 Pg3=100.0 0	262.65 Pg6=182.5 Pg8=80.16
		Q	67.63 Qg1=0.0 Qg2=23.69 Qg3=24.13 Qg6=11.55 Qg8=8.27	67.04 Qg1=0.0 Qg2=27.04 Qg3=40.00	91.16 Qg6=48.00 Qg8=43.16
5	Load	Р	259.00	259.00	259.00
	The state of the	Q	64.50	63.50	63.50
6	Losses	P	9.29	4.08	3.65
-		Q	39.16	35.14	36.11

Table 1: Result of Case	EIEEE-14 Bus system
-------------------------	---------------------

here, Reactive Power (Q) in MVAr as well as Active Power (P) in MW

CONCLUSIONS

The paper presents an analysis and validation of a DOPF (Distributed Optimal Power Flow) approach for solving OPF (Optimal Power Flow) problems, specifically used in the IEEE-14 Bus system. Here are the key conclusions & insights from the study:

DOPF Efficiency: The paper demonstrates that the DOPF approach effectively solves OPF problems on IEEE-14 Bus systems, including those with a consensus area. The method involves distributing the power flow optimization process across multiple regions/areas, which can improve computational efficiency. Generation Cost and Loss Reduction: Table 4.1 shows the generation cost and convergence times for various cases. One of the most significant results is the reduction in overall system losses when active and reactive power-sharing techniques are applied within the DOPF framework. This reduction is vital for improving system efficiency.

Faster Convergence: The study highlights that the strategic decision-making and control variable techniques used in DOPF lead to faster system convergence compared to traditional methods. Despite achieving faster convergence, the objective function values (which may include generation cost, loss minimization, etc.) remain consistent.

Handling Non-Convex AC OPF: The proposed DOPF methodology is tested in non-convex AC OPF scenarios. Case studies show that the technique not only performs well in standard OPF problems but also offers improved performance in more complex, non-convex situations, indicating robustness and versatility in different power flow configurations.

In conclusion, this paper provides a detailed and comprehensive analysis of DOPF techniques, showing how active and reactive power sharing can lead to optimal operation of power systems, reduce costs, minimize losses, and ensure faster convergence. The proposed methods are validated with practical case studies, making them a valuable input to the area of power system optimization.

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ABSTRACT

Electric motors having high traction power are engaged in the electric vehicles in order to deliver required high torque to the vehicle to maintain the essential torque, which require high amount of current to be delivered at the traction motors. In the existing system power pack in the form of lithium-ion battery is engaged to provide the required power to the traction power. Hybrid energy storage system is the way to address this issue in an effective way. In the research work multiple energy sources like lithium-ion battery source, fuel cell and ultra capacitor are used for development of the hybrid energy source. These energy sources are intelligently engaged through different control strategies in order to ensure confirmed required power delivery at the traction motors. Different modules from the Simulink are used for the development and analysis of the targeted system.

KEYWORDS : Classic PI control, Simulink, Hybrid energy Storage, Li-ion battery, Fuel cell, Ultra capacitor.

INTRODUCTION

The comparison is provided for several hybrid configurations based on energy effectiveness, robustness, dynamic performance, fuel consumption and battery lifetime.



Fig. 1 Preferred Batteries in EV

The authors [2] have proposed a hierarchical energy management strategy and a multi-dimensional size optimization framework to reduce the component size and increase the power of a plug-in hybrid electric vehicle with a hybrid energy storage system. To calculate the dimension and the power efficiency, a plug-in hybrid electric vehicle with a battery energy storage system is utilized as a reference. The authors [3] have presented several literatures to investigate the role of energy recovery and energy harvesting in the development of fuel-cell hybrid electric vehicles and battery electric vehicles. Recovery energy and harvesting energy can considerably enhance energy effectiveness and decrease fuel utilization.

Regenerative braking system drivers' movement effects on energy recovery are investigated and the perspective of energy harvesting in electric vehicles is also studied.

The slope of the road is determined by the counter location system. Two algorithms are designed to handle the energy shared between the supercapacitor and the battery. The hybrid energy storage system model, electric vehicle and controllers are tested by employing a simulator at different speeds. The experimental outputs show that the controllers enhance the battery life cycle by reducing the stress on the battery for the drive cycle. [4] The life to be rethink and redesigned.

The modern high electric charge density lithium-ion batteries are engaged as a power bank to deliver the



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required high current to the traction motors which are highly capable of delivering required high torque in the range of thousands of Nm. EVs are also considered as the solution to the traditional petrol or diesel-based vehicles. A dedicated control unit is used for the overall management of the different components in the hybrid management system. A brake control provision along with the bus selector module is available to demonstrate the change in the load conditions of the vehicles. Different parameters like rpm, current, power, stator current torque, back EMF and other ascendency parameters are used to analyze the system performance.

LITERATURE REVIEW

For optimized energy consumption in transportation systems, hybrid electric vehicles are becoming more prominent due to their eco-friendly performance and assistance in smart grid notation. The alteration of energy storage systems in hybrid electric vehicles with many control policies generates alteration in hybrid electric vehicle types. In this paper, the authors [1] have discussed important information on energy storage systems associated with hybrid electric vehicles and the best optimization topologies. This work categorizes several control policies employing four configurations such as battery fuel cell ultra-capacitor, fuel cell ultra-capacitor, battery ultra-capacitor and fuel cell battery.



Fig. 2 EMS Architecture by authors [4]

The authors [5] have evaluated the conventional storage techniques for electric vehicles based on a multi-criteria decision-making model on several criteria including protection, health, cost, compatibility, atmosphere, and technical characteristics. Super decision technique is employed to solve the analytic hierarchy procedure model. In most cases, an analytic hierarchy procedure model recommended the consumption of hybrid sodium nickel chloride batteries and supercapacitors for electric vehicles. This paper provides a comprehensive examination of electric vehicle technology that mainly includes electric vehicle supply equipment, energy storage systems and electric vehicle chargers to decrease the range, concern the electric vehicle chargers based on inductive power transfer are discussed. The last part of the paper focuses on the negative effects of electric vehicle chargers along with the remedies that can be accepted. [6]







Fig. 4. Proposed Architecture of the System in [11]

In this paper, the authors [7] have proposed an energy effective management framework for fuel cell hybrid electric vehicles employing machine learning techniques. In traditional fuel engine-based vehicles, petroleumbased fuels are used to provide good performance and long- distance speed The benefits of the proposed power split framework for enhancing the power result of the battery and the mode switching frequency of the multimode hybrid energy storage system in electric vehicles are indicated under three typical driving cycles. [8] The authors [9] have presented recent modifications regarding fuel cell hybrid electric vehicles in several heavy-duty systems.



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To enable system consumption and energy management strategy design, functionality techniques for fuel cell system, ultra-capacitor and battery related subsystems are discussed. Finally, for the energy management strategies, the authors have proposed a model predictive control technique which deals with the mitigation of degradation effects. Then, several layers of wavelet transform algorithm are used to separate the dissimilar frequency elements of power demand. Finally, artificial intelligence is implemented to control power flows between different elements to ensure the hybrid energy storage system performance. [10] The authors [11] have proposed an ultra-capacitor hybrid energy storage system for pulsed load in which ultra- capacitors simulate the pulse part and the battery runs the steady portion of the load.

Electrical variable transmission is a new electromechanical energy converter that can be applied in hybrid electrical vehicles. The authors [12] have investigated the hybrid electrical vehicle based on electrical variable transmission and the effectiveness optimization policy of regenerative braking system. Initially, this article investigates the dynamic coupling mode of the electrical variable transmission-hybrid electrical vehicle and develops the expression of the dynamic coupling relationship between the electrical variable transmission and the engine. Then, several braking modes including new ones are divided. Finally, a hierarchical controller was proposed for braking mod switching and a neural network However, there are some limitations to using petrol and diesel, and the merger of these different optimization methods is capable of providing the best possible performance. The authors [13] have elucidated the braking and accident prevention systems in a vehicle. For the collection effectiveness control for the system. Such a situation raises the need for additional algorithm was employed for the best possible of information concerning accidents, cloud computing is employed. application can be investigated in four different steps. This kind of optimization issue is investigated and the literature can be divided into approaches that optimize either energy efficiency or financial targets. 2) The strategy for controlling consumer comfort is investigated for applications that may affect consumers. 3) The presented article discusses the method to model and decrease battery deprivation. 4) The papers are divided by application context and applications likely to catch the attention of a huge number of researchers are recognized. [14]

The vehicle atmosphere supportive control shows a huge amount of potential to enhance vehicle performance. The key goal of the proposed technique is to enhance the energy management performance of plug-in hybrid electric vehicles. For merging the cloud server, onboard vehicle control unit and mobile edge evaluation server to give more precise outputs, a compound velocity prediction algorithm is developed. The compound velocity prediction algorithm technique for energy management of plug-in hybrid electric vehicles.[15]



Fig.5. Estimation of Distributed Algorithm as disclosed in [15]

The author [16] has calculated the performance of the techniques employing the hold-out technique and left single subject out cross-validation methods. The hold-out technique shows an efficiency of 80% and the leave single- subject-out cross- validation method shows an efficiency of 75.42%. The lithium battery is charged in steady voltage and steady current mode. The control policy is provided to the state of charge of the energy storage system to guarantee that the resultant current and voltage are constant. Based on bode plots, the current and voltage controllers are designed in the frequency domain. [17]

The proposed strategy frequently looks for the best compromise between the power ability and the torque response of every storage unit. Employing such a kind of topology provides a considerable enhancement in the overall effectiveness. [18] Due to the employment of power electronic components, some noise is produced known as electromagnetic interference. Therefore, to moderate the electromagnetic interference effect, the low pass filter based electromagnetic interference filter is introduced in the system such that the noise level is suppressed.

The authors [19] have proposed an actual moment vehicle speed-controlling system known as the actual



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moment energy deceleration controlling system. Navigation technologies such as traffic light details and front identification sensor information are developed to recognize deceleration incidents.



Fig. 6. Hybrid Energy Storage System Discussed in Cited Paper

Hybrid e-vehicles need an energy management policy to acquire fuel economy performance. In the equivalent minimization technique, a parameter known as the equivalent factor should be calculated to attain the best possible control strategy. In this paper, the authors [20] have proposed a reinforcement learning based technique to identify the equivalent factor. The authors have proved that the equivalent factor can be indirectly removed from the reinforcement learning outputs by employing a specific driving cycle.

Additionally, a new technique that combines the equivalent consumption minimization and reinforcement learning strategy is proposed. A model-based reinforcement learning technique is employed. The proposed technique is validated for vehicle simulation using a parallel hybrid electric vehicle.

PROPOSED HYBRID ENERGY STORAGE SYSTEM

A hybrid energy storage system is disclosed through this paper in order to meet different challenges posed through the traditional power pack systems in the electric vehicles. In this hybrid energy storage system, different energy sources are used to provide uninterrupted energy to the traction motors.

The hybrid energy sources which are used in development of the system are Lithium-Ion battery, Fuel Cell and Ultra Capacitor. These sources are intelligently activated to regulate the power supply to the traction motor. This system and intelligent management of the hybrid energy source is self- sufficient to provide the large current requirements in the situations of sudden acceleration, steep ascent and other similar situations where large amount of current is drained out from the energy source. The subsequent figure discloses the systematic block diagram of the proposed hybrid energy storage system. The proposed hybrid energy storage system is comprising of brake control unit, control module, bus selector and load performance analysis block.



Fig. 7. Overall System of Hybrid Energy Storage System

Regenerative braking system is another module added to demonstrate the braking effect on the traction motor. The PWM modulator unit and the Regenerative Braking Unit drive the gate control unit which logically generates the pulse pattern to control the IGBT gates in order to drive the traction motor.

The energy management system is directly connected to the IGBT control unit which intelligently manages the source from which the current is to be driven through the driver circuit for traction motor of EV. The subsequent figure depicts different power sources and individual driving circuit for them.



Fig. 8. Power Sources and Individual Driving Circuit

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As shown in the above figure, Fuel Cell, Battery Module and the Super Capacitor are the three different sources which are perceptively deployed to fulfill the real time power demand of the EV.

Each of the power source is fed to the Buck or Boost converter. These converters are DC-DC converter which generates the output power which is either greater or smaller than that of the input power. The converted output is fed to the control unit, which is shown in the fig.8. Some of the output which are recorded during the simulation is disclosed in the subsequent section.

RESULTS AND DISCUSSION

The implementation of the above proposed system is carried out using the Simulink toolbox of the Matlab tool. The overall system is depicted in the following figure.



Fig. 9. Overall System Implemented in Simulink

Above fig.9 depicts the brake pedal unit, control unit, traction motor, bus bar section for load performance analysis along with different analytical output measurement units. After simulating the above module, performance of the power sources is recorded as shown in the below figures.





Performance of the fuel cell power source is carried out with respect to the fuel cell voltage, fuel cell current and fuel consumption. These different parameters are depicted through the above fig. 10.



Fig. 11. Lithium-Ion Battery Performance

While the performance of the lithium-ion battery is analyzed by considering the battery current, battery voltage and state of charge. While the system is turned on, upper and lower swings are observed till t = 0.01 duration after which gradual increase in the battery current till t =0.15 and gradual decrease till t = 0.15 simulation period is recorded; after this simulation period, battery current and voltage reaches constant level from t = 0.15 simulation periods. Battery voltage gains the level of 52V and SOC remains to 65%, as shown in the above figure.



Fig. 12. Super Capacitor Performance Analysis

The super capacitor or the ultra-capacitor is the high current delivering power source which can be engaged at the time of sudden acceleration or steep ascend or in any situations which high current is required to be delivered at the traction motor.

This power source is analyzed with respect to the ultracapacitor current and voltage. In the initial duration of the simulations, sudden spikes are observed till t = 0.01



simulation period after which continuous charging and discharging is recorded between \pm 15A of current and in the range of 267V to 272V. Subsequent section concludes the findings of the preliminary research work.

CONCLUSION

Through this research paper, an energy management system is disclosed which is able to fulfill the random requirement of the power through different power sources and for longer time. This assures high power delivery to the electric vehicle to run it for longer distances. In the proposed system, lithium-ion battery along with the fuel cell and ultra- capacitor is engaged to provide the expected power at any instance of time. Dedicated control unit along with IGBT triggering unit with regenerative braking system and gate control unit intelligently select either of the power source and fulfills the power demand of the traction motor. System modeling is carried out using the Simulink module of the Matlab software. Performance of the fuel cell, battery and the ultra-capacitor is critically analyzed and disclosed through the figures in previous section.

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A Comparative Study of Different Electric Motor Types and Drives Used for Electric Vehicles

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ABSTRACT

The transition to electric vehicles has increased the need to optimize electric motor and drive systems for better performance, efficiency, and cost-effectiveness. This paper provides a comparative study of four major electric motor types used in EVs: Induction Motors, Switched Reluctance Motors, Brushless DC motors, and Permanent Magnet Synchronous Motors. Each motor type is evaluated against key parameters, including efficiency, torque ripple, power density, torque density, cost, and reliability and maintenance, alongside their integration with modern drive systems. PMSMs are recognized for high efficiency and torque density but face challenges in cost and material sustainability. BLDC motors strike a balance between performance and affordability but exhibit moderate torque ripple. IMs, valued for their durability and cost advantages, show comparatively lower efficiency. SRMs offer simplicity and robustness, though advanced control strategies are essential to address torque ripple and acoustic noise. The paper explores how motor characteristics align with EV applications, providing insights into their suitability for EVs. Most appropriate motor for EV is SRM.

KEYWORDS : Electric vehicle, SRM, BLDC, IM, PMSM

INTRODUCTION

The transportation sector significantly contributes to global energy consumption and CO2 emissions, requiring the urgent development of sustainable alternatives to conventional cars with internal combustion engines. Electric vehicles have emerged as a vital solution, providing diminished greenhouse gas emissions and improved energy efficiency. The electric motors and drives that power EVs are essential to their performance and feasibility. These components determine critical factors such as efficiency, reliability, torque delivery, and overall cost-effectiveness. This study presents a comparative analysis of the primary electric motor technologies BLDC Motors, SRM, PMSM, IM, along with their associated drives, emphasizing their roles in addressing energy and emission challenges in the transportation sector. By evaluating their performance, sustainability and adaptability, this study aims to guide the selection of optimal motor technologies for accelerating the transition to cleaner and greener transportation systems. Providing comprehensive comparative analysis of several electric motor types along with their associated drive systems employed in EV is research's primary objective. This analysis will focus on key performance metrics, including efficiency, torque density, power density, cost, and reliability, offering valuable insights into how each motor type meets the requirements of modern electric propulsion. By critically examining the strengths and limitations of BLDC, SRM, IM, and PMSM motors, this study aims to decide motor type and motor drive selection for EV applications.

ELECTRIC MOTORS USED IN ELECTRIC VEHICLES

EVs utilize various motor technologies, each offering unique advantages. These technologies are chosen based on specific EV requirements like cost, performance and efficiency. Motor technologies are described for Electric Vehicles as discussed.



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Induction Motors (IM)

IMs are typically employed in EVs given their significant efficiency, superior speed regulation, along with lack of commutation. IM Drive is optimally utilized in EVs. They are currently regarded as least dialed switch. This explains their high reliability as well as maintenancefree task in [2,4,5,6,9,14,15]. IM are generally operated through a vector-control drive, facilitating a broad range of speed variations. These machines exhibit three distinct operational regions: a constant torque region, a constant power region, along with a reduced power region at elevated speeds(Fig. 2). These characteristics are dictated by the machine's design, power electronics, and control mechanisms [6]. The standard speed-torque and power characteristics align with the specifications of the electrical traction system.



Fig. 2. IM-characteristics and variation of variables with speed [6].

Permanent Magnet Synchronous Motors

PMSM are highly efficient motors used in EVs, operating on electromagnetic induction principle, in which rotor is magnetized with permanent magnets then rotating magnetic field created by stator. This design allows PMSMs to provide high efficiency, typically 90%-96%, and high power and torque density, making them ideal for high-performance applications [2,4-6,9]. Their precise control over speed and torque is another key strength, offering smooth operation. However, PMSMs rely on costly rare-earth materials for their magnets, which can increase the overall cost and raise concerns about material availability. High temperatures can also demagnetize the rotor magnets, affecting performance. The torque-speed characteristics of PMSMs are advantageous, exhibiting high torque with low speeds, making them optimal for acceleration and initiation. However, as speed increases,

torque decreases, which is typical for these motors [1]. Despite these challenges, PMSMs remain a popular choice for EVs due to their efficiency and performance.



Fig. 3. Torque speed characteristics of PMSM [1].

Switched Reluctance Motors

SRM employs reluctance torque for aligning rotor with the stator's magnetic field rather than permanent magnets or windings. This makes SRMs simple, cost-effective, and highly durable, suitable for applications where reliability is critical. They provide high torque at low speeds, ideal for strong starting torque. However, SRMs face challenges such as torque ripple, which can cause vibrations and affect smooth operation [2,4,5,6,9,14,15]. To minimize this, advanced control strategies are needed, adding complexity to the system. SRMs require precise electronic control for switching stator windings, making them more complex to manage. Their torque-speed characteristics show high torque with low speeds however, reduced efficiency at higher speeds, with a non-linear torque-speed curve [1]. Despite these drawbacks, SRMs are a robust and affordable option for specific applications, particularly where durability and cost are prioritized over smoothness.



Fig. 4. Torque speed characteristic of SRM [1]

Brushless DC Motors (BLDC)

BDC Motors operates on principle of electromagnetic induction, where the rotor contains permanent magnets, and the stator is powered by direct current through an electronic controller. The lack of brushes in BLDC motors eliminates wear and tear, reducing maintenance needs and increasing lifespan. Their high efficiency (85%-95%) and precise speed and torque control are key strengths. They also offer a high power-to-weight ratio, making them compact and suitable for applications like electric vehicles. However, BLDC motors use costly rare-earth magnets and require complex electronic control systems [2,4,5,6,9,14,15]. Their torque-speed characteristics show high torque with low speeds, making them optimal for smooth acceleration, but torque decreases as speed increases. Despite these challenges, BLDC motors are widely used in EVs due to their efficiency, reliability, and low maintenance [15].



Fig. 5. Torque-speed characteristic of brushless DC motor[15].

DESIRED CHARACTERISTICS AND OUTPUT CHARACTERISTICS OF MOTOR DRIVES USED IN ELECTRIC VEHICLE

Since EV traction motors might be required to regulate their speed, enhance torque on hills, or use abrupt brakes, these must comply with various operational standards than EV motors. The motor does not always follow the torquespeed curve, and the load cycle can be separated into three phases based on speed. The vehicle's fault tolerance capabilities must be assessed under various operating scenarios.

The most crucial requirements and characteristics for

electric car motor drives are as follows:

- Capacity for fault tolerance
- Decreased power loss and good overall efficiency
- Enhanced dynamic performance
- Economical
- Enhanced power density
- High motor resilience and durability across a range of operating conditions
- Diminished size and weight
- High torque production at low speeds
- Low torque ripples
- Lower operating and maintenance expenses
- Lower operating and maintenance expenses



Fig. 6: Typical speed-torque characteristics of EVs electric traction motors [6]

COMPARISON OF MOTOR TYPE AND MOTOR DRIVE SYSTEMS USED IN EV

In [2], Table I shows an analysis of four distinct electric motors for electric vehicle applications, highlighting their varying strengths and weaknesses.

Table 1. Comparison of Special Electrical Motors [2]

Items	IM	PMSM	BLDC	SRM
Power density	0.6 kW/kg	0.9 kW/kg	1.35 kW/ kg	0.78 kW/ kg
Efficiency	90%	83%	98%	89%
Reliability	96%	86%	84%	87%
Cost	Rs. 5000	Rs.11000	Rs.17000	Rs. 8000



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From the attributes. BLDC motors have the highest power density and efficiency but are the most expensive. IM motors provide the highest reliability and are the most economical, making them a cost-effective option. PMSM motors offer moderate power density but have the lowest efficiency and reliability. SRM motors strike a balance with reasonable power density, good reliability and affordability. This comparison highlights the trade-offs between performance and cost for different optimal motor choices for EV applications.

In [4], Table II presents a comparative analysis of the speeds of four distinct types of motors. BLDC motor exhibits favourable speed characteristics. BLDC motor has superior efficiency relative to other motors, as evidenced by the ranking procedure, where rank 5 indicates enhanced efficiency.

Table 2. Comparison Of Performances Of SpecialElectrical Motors [4]

Items	IM	SRM	PMSM	AFPMBLDC
Speed (rpm)	450	950	650	950
Efficiency (Max-5 based on rank)	3.8	3.8	4.2	4.6

In [5], The graph shows that PM-BLDC and SRM motors achieve the highest speed, making them suitable for highspeed applications. PM-SM motors operate at a moderate speed, balancing speed and control. IM motors have the lowest speed, ideal for low-speed applications. This indicates that PM-BLDC and SRM are best for highperformance needs, while IM and PM-SM are suitable for moderate or steady-speed tasks in Figure 7.



Fig. 7. Speed comparison of motors [5].

In [6], Based on the comparisons indicated above, Figure 8 displays the overall results of the motor types classification, incorporating efficiency and maintenance aspects into

account. The graph shows that PM-BLDC motors have the highest efficiency and moderate maintenance. Induction motors provide good efficiency but have the highest maintenance. PMSM motors have moderate efficiency and high maintenance. DC motors exhibit the lowest efficiency and maintenance. SRM motors offer a balance with moderate efficiency and lower maintenance.



Fig. 8: Global results of the motor types classification [6]

In [9], Experimental analysis conducted on multiple criteria is documented then examined for evaluating their efficacy. In order to evaluate the parameters of electric motors, the technical aspects are explained below.

 Table 3. Technical Aspects for Parameters of Electric Motors [9].

Parameters	BLDC	IM	SRM	PMSM
Power to weight ratio (KW/Kg)	4.5	3.25	3.25	4.2
Peak Efficiency (%)	>95	>85	<95	>95
Efficiency at 10% load (%)	70-80	>90	>90	>95
Cost of controller (scale of 1-5.)	5	3	3.5	4
Cost of Motors (scale of 1-5.)	4.5	2	3	4

BLDC motors have the best power-to-weight ratio and high peak efficiency, but they are the most expensive in terms of motor and controller costs. PMSM motors follow closely with a power-to-weight ratio of excellent efficiency. IM motors are cost-effective with the lowest motor cost but have lower peak efficiency and a lower power-to-weight ratio. SRM motors offer good efficiency but are less efficient than BLDC and PMSM. Overall, BLDC and PMSM motors excel in performance, while IM and SRM are more affordable options.



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In [12], As illustrated in Fig. 9, PMSM attains maximum efficiency of 97% at 11,500rpm and 86% at 52,000rpm. SRM attains an efficiency of 95% at 11,500rpm and 81% at 52,000rpm. Efficiency of IM are 77.8% at 11,500rpm and 80.3% at 52,000rpm.



Fig. 9. Motor efficiency[12]

In [13], thorough examination as well as analysis of electric motor drives utilized by EV applications. Nissan Leaf S Plus BEV is taken into consideration for further

Table 6.	Comparative	Ana	lysis	[14]
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demonstrate comparison. Its rated power, along with torque, is 80kW and 250Nm, accordingly. It is certain from mathematical relationship that PMSM is the best option for EV system propulsion since BLDCM has 0.7698 of PMSM's power and torque output, SRM has 0.5319, and IM has 0.5.

Table 5. Motor Performances Power and Torque Density

Motor type	Max. Power Density	Max. Torque Density
PMSM drive	80 kW	250 Nm
BLDCM drive	61.6 kW	192.5 Nm
SRM drive	42.552 kW	132.975 Nm
IM drive	40 kW	125 Nm

In [14], Comparing different types of motors used in Electric Vehicle propulsion systems involves evaluating various factors such as efficiency, power density, torque characteristics, reliability, cost, and suitability for different applications. A comparative analysis of several types of motors commonly used in EVs is shown below :

EV Motor	BLDC	Induction Motor	PMSM	SRM
Advantages	High efficiency, low maintenance (no brushes), smooth operation, good power-to-weight ratio, Minimum router heat generation	Robust construction, low cost, suitable for high-power applications. Minimum cost of maintenance	High efficiency, high power density, excellent torque control, regenerative braking capability.	Simple construction, high reliability, low maintenance, good performance at high speeds. Thermal ability enhancing Brushless motor with no magnet
Disadvantages	Complex control electronics higher initial cost.	Lower efficiency compared to some other types, less torque control at low speeds.	Higher cost	Non-linear control characteristics, high torque ripple, limited availability
Suitability	Mainstream EVs hybrid vehicles where efficiency and performance are paramount.	Large electric vehicles industrial applications, where cost is a primary concern.	Mainstream EVs high- performance electric vehicles where precise torque control and regenerative braking are essential.	EVs require robust, reliable propulsion systems high-speed applications.

[13]

CONCLUSIONS

This paper studied electric motor types BLDC motors, SRM, IM, and PMSM highlighted unique strengths and limitations of each for EV applications. PMSMs excel in efficiency and torque density, making them well-suited for high-performance EVs, but their high cost and reliance on rare materials pose challenges. BLDC motors offer a balance between performance and affordability but are hindered by moderate torque ripple. IMs are valued for their reliability and cost-effectiveness, though their relatively lower efficiency limits their suitability for applications prioritizing energy efficiency. SRMs stand out as a promising option due to their simplicity, robustness, and cost advantages. However, advanced control strategies are essential to mitigate issues such as torque ripple and acoustic noise. In conclusion, while each motor type has specific advantages for different EV requirements, SRMs present a particularly attractive choice for future EV designs, offering a cost-effective and durable solution that can be enhanced through innovative control methods. This study emphasizes the need for continued advancements in motor and drive technologies to meet the evolving demands for EV applications.



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Optimizing Frequency Regulation: A Comparative Assessment of Energy Storage Technologies Based on Key Performance Parameters

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ABSTRACT

Frequency regulation is critical for ensuring the stability and reliability of power systems, particularly with the growing integration of renewable energy sources. This study provides a comparative assessment of energy storage technologies namely Lithium-ion batteries, flywheels, supercapacitors, and pumped hydro storage based on key performance parameters such as response time, efficiency, power handling capacity, cycle life, and cost. The analysis, grounded in a review of existing literature and real-world case studies, identifies the strengths and limitations of each technology for frequency regulation. Lithium-ion batteries stand out for their high efficiency and cost-effectiveness, while flywheels and supercapacitors excel in rapid response and durability. In contrast, pumped hydro storage demonstrates limited suitability for instantaneous frequency regulation but remains effective for long-duration applications. The paper concludes by recommending tailored energy storage solutions to meet specific operational and economic needs and advocates for lithium-ion battery types that combine multiple technologies as a promising strategy to enhance frequency regulation and optimize grid performance in the evolving energy landscape.

KEYWORDS : Frequency regulation, Energy storage systems, Key performance parameters, Lithium-ion battery types.

INTRODUCTION

The evolution of the global energy landscape is profoundly reshaping how electricity is generated, distributed and consumed. With an increasing emphasis on sustainability and the urgent need to mitigate climate change, renewable energy sources such as wind, solar and hydroelectric power are being integrated into power systems at an unprecedented scale. While these sources offer significant environmental benefits, they also introduce variability and uncertainty into the electricity supply, presenting new challenges [8] for maintaining system stability. Frequency regulation has emerged as a critical component in addressing these challenges, ensuring that the balance between electricity supply and demand is maintained to prevent outages and safeguard the reliability of the grid.

Frequency regulation refers to the mechanisms used to control and stabilize the frequency of electricity in power systems. Traditionally, this has been managed through the dispatch of fossil fuel-based generation [15], which can respond quickly to fluctuations in demand. However, as renewable energy sources dominate the energy mix, the need for efficient and responsive energy storage solutions has become increasingly vital. Energy storage technologies play a crucial role in mitigating the intermittency of renewable generation by providing rapid response capabilities that can balance supply and demand of real power with the help of charging and discharging cycles [9] of Energy storage technologies in real time.

This paper is motivated by the pressing need to optimize frequency regulation strategies that can accommodate the integration of diverse energy storage technologies. Current storage solutions, such as Lithium-ion batteries, flywheels, supercapacitors and pumped hydro storage, each offer unique [7] advantages and limitations. A detailed understanding of their performance characteristics specifically in terms of response time, efficiency, power handling capacity, cycle life and cost is essential for identifying the most suitable technologies for specific



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applications in frequency regulation by conducting a comprehensive comparative assessment of these energy storage technologies, focusing on above mentioned key performance parameters. By systematically analysing the strengths and weaknesses of each technology, this paper aims to provide valuable insights for policymakers, grid operators, and industry stakeholders. The findings will not only aid in the selection of appropriate energy storage systems but will also contribute to the broader goal of enhancing grid resilience and reliability in an increasingly complex and dynamic energy environment.

ROLE OF ENERGY STORAGE SYSTEMS

Various forms of energy storage can be combined to create an energy storage system (ESS) that integrates seamlessly into modern power systems, addressing the intermittent energy demands of the grid. The applications of ESS can be broadly categorized into two areas: Energy Management and Ancillary Services.

Energy Management focuses on ensuring a secure, reliable energy supply while enhancing grid reliability, flexibility, cost-effectiveness, safety, and stability. It also supports sector coupling without causing adverse impacts. On the other hand, Ancillary Services aim to facilitate and maintain continuous electricity flow, meeting real-time demand with high quality and precision. Fig.1 shows the categorization of applications of ESS. From the above mentioned two broader applications of ESS, frequency regulation of grid [6] is one of the applications which comes under the ancillary services.



Fig. 1: Classification of energy storage applications [6]

Energy storage systems (ESS) play a critical role in maintaining frequency regulation within power systems, ensuring stability and reliability. Frequency regulation is vital because power system frequency must remain within a narrow range to prevent equipment damage and blackouts. However, fluctuations in supply and demand, especially with the increasing integration of intermittent renewable energy sources like wind and solar, can disrupt this balance. ESS provides a fast and efficient solution by quickly absorbing excess energy during periods of overfrequency and injecting energy during under-frequency events. Unlike traditional methods, such as ramping up or down fossil-fuel-based generators, ESS responds almost instantaneously [3], improving system efficiency and reducing wear on generation assets. Additionally, advanced technologies like lithium-ion batteries, flywheels, pumped hydro storage and supercapacitors are particularly suited for high-frequency, short-duration applications, making ESS a cornerstone in modern grid frequency regulation strategies. This capability supports the transition to cleaner energy while maintaining the reliability of power systems.

TECHNICAL AND ECONOMIC ASSESSMENT OF ENERGY STORAGE SYSTEMS

The choice of Energy storage systems depends on various performance parameters depending on the application for which the energy storage system is designed. Since in this paper, the focus is on the frequency regulation application of energy storage systems, the key performance parameters [10] required for maintaining the frequency of the power systems are response time, cycling efficiency, power handling capacity, cycle life and cost. In this section, an assessment with reference to various key performance parameter for the ESS's like Lithium-ion batteries, flywheels, supercapacitors, and pumped hydro storage is as discussed.

Lithium-Ion Batteries

Lithium-ion batteries are widely recognized for their rapid response time, measured in milliseconds [4,9], making them ideal for applications requiring fast frequency regulation. With high efficiency ranging between 70–97% [9] and a moderate to high power handling capacity (0– 100 kW), these batteries are versatile and adaptable to various microgrid needs. They have a cycle life of 1,000 to 10,000 cycles, translating to an operational lifespan of 5–15 years [2,3,9,10,12]. While their energy-based capital cost is relatively affordable at \$60–\$78/kWh, their powerbased costs range from \$600–\$4,000/kW [16], reflecting their advanced technology. These batteries are excellent for frequency regulation in islanded microgrids due to their combination of fast response, high efficiency, and flexibility in meeting energy and power demands. However,



challenges such as thermal management, degradation over time, and high initial costs must be addressed for broader adoption.

Flywheels

Flywheels are mechanical devices that store energy in the form of rotational kinetic energy [11]. Flywheels offer quick response times within seconds and are ideal for ultra-fast applications requiring less than one cycle [4,9]. They operate with moderate to high efficiency (70–95%) and are particularly suited for short-duration, high-power needs, with a capacity ranging from 0.1–20 MW. With a cycle life exceeding 20,000 cycles and a lifespan of over 15 years, flywheels are durable and reliable. However, they come with high capital costs, ranging from \$3,012–\$3,069/kWh for energy storage and \$250–\$5,000/kW for power applications. While highly effective for short-term stabilization in microgrids, their low energy density and limited duration for sustained regulation make them less versatile than other ESS technologies.

Supercapacitors

Supercapacitors stores energy electrostatically, which allows almost instantaneous charge and discharge and have exceptional response times in milliseconds [6], making them among the fastest energy storage systems available. Their efficiency ranges from 75-100% [3,4,7,12] with a very high power handling capacity for short durations (0–300 kW). These systems are incredibly durable, with a cycle life exceeding 1,000,000 cycles and an operational lifespan of 10–30 years. However, their energy-based

capital costs are relatively high (\$300–\$14,880/kWh), while power-based costs are more affordable (\$96–\$300/kW) [10,16]. Supercapacitors are highly suitable for ultra-fast frequency regulation in microgrids but are limited by their low energy capacity, making them impractical for long-duration applications. Additionally, their high cost per kWh presents a significant challenge for widespread use.

Pumped Hydro Storage

Pumped hydro storage is a large-scale energy storage solution with slower response times measured in minutes [4,9]. It operates with moderate efficiency (65–85%) [2,4,9] and offers very high power handling capacity (100–5,000 MW), making it ideal for long-duration energy storage. With a cycle life of 10,000–30,000 cycles and a lifespan of 40–60 years [3,4,9,10], this technology provides exceptional longevity. Its energy-based capital cost is among the lowest at \$19–\$100/kWh, while power-based costs range from \$308–\$2,000/kW [10,16]. However, the technology's suitability for microgrids is limited due to geographic dependencies, high initial costs, and long construction times. It is more commonly used for large-scale applications requiring sustained energy storage over extended periods.

The comparative assessment of energy storage systems (ESS) based on key performance parameters highlighting the diverse capabilities and limitations of Lithium-ion batteries, Flywheels, Supercapacitors, and Pumped Hydro Storage in addressing frequency regulation challenges, particularly in islanded microgrids is mentioned in Table: 1.

 Table 1: Characteristics of all presented ESS in terms of discussed key performance parameters

ESS/Key performanc e parameters	Response time	Efficiency	Power handling capacity	Cycle life	Capital Cost (\$/kWh)	Capital Cost (\$/kW)	Suitability for Frequency Regulation in Islanded Microgrids	Challenges
Lithium-ion batteries	In Milliseconds , <1/4 cycle [4.9]	70-85% [2] 85-98% [3,7,12] 75-97% [4] 90-97% [9]	Moderate to High (0- 100 KW) [2,4,9,10]	5-15 years (1,000- 10,000 cycles) [2,3,9,10,12]	\$60-\$78 [16] \$600- \$2500 [10]	\$241- \$312 [16] \$1200- \$4000 [10]	Excellent, due to fast response, high efficiency, and flexibility for energy and power needs.	Thermal management issues, degradation over time, high initial cost.
Flywheels	In seconds, <1 cycle [4,9],	70-95% [2] 80-90% [3] 90-95% [4,9]	High (short durations) (0.1-20 MW) [2] (<250 KW) [9,10]	15+ years (20,000+ cycles) [2,3,9,10]	\$3012- \$3069 [16] \$1000- \$5000 [10]	\$288- \$293 [16] \$250- \$350[10]	High, ideal for ultra-fast response in short- term stabilization in microgrids.	High cost, low energy density, limited duration for sustained regulation.
Super- capacitors	In Milliseconds , <1/4 cycle [4,9]	75-95% [2] 90-100% [3] 84-97% [4], 90-97% [9] 75-85% [12]	Very High (very short durations) (0-300 KW) [4.9,10]	10-30 years (1,000,00+ cycles) [3,4,9,10] 10-12 years (50000 cycles) [12]	\$300- \$2000 [10] \$13185- \$14880 [16]	\$96- \$109 [16] \$100- \$300 [10]	High, best for ultra-fast response in short- term stabilization but limited for sustained regulation.	Limited energy capacity, high cost per kWh, not suitable for long- duration applications.
Pumped hydro storage	In Minutes [4,9]	65-85% [3], 70-85% [2,4,9]	Very High (long durations) 100–5000 MW [2.4.9.10]	40-60 years (10000- 30000 cycles) [3,4,9,10]	\$19 [16] \$5-\$100 [10]	\$308 [16] \$600- \$2000 [10]	Low, rarely suitable for microgrids due to geographic and infrastructure requirements.	Geographic dependency, high initial costs, long construction time.

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In addition, Table 1 highlights Lithium-ion batteries (LIB's) as excellent choice for frequency regulation in islanded microgrids due to their fast response time, high efficiency, and flexibility in balancing energy and power requirements. Considering the excellent suitability of LIB's, various key features of different types of LIB's are showcased in Table 2 in concern with the aim of frequency regulation in islanded microgrids.

Lithium-ion Battery Types	Key Features with reference to Frequency Regulation Islanded Microgrids
High-Nickel Cathode	- High energy density for compact systems.
	- Better charge-discharge cycle handling.
Silicon-Based Anode	- Increased cycle life and capacity.
	- Enhanced performance under frequent usage.
Solid-State Batteries	- Safer operation with reduced thermal runaway risks.
	- Higher power density for ultra- fast responses.
Lithium Titanate (LTO)	- Extremely high cycle life (20,000+ cycles).
	- Fast charging and excellent safety.
Lithium Iron Phosphate (LFP)	- Long cycle life and thermal stability.
	- Cost-effective and reliable.
Second-Life Batteries	- Lower costs by repurposing used EV batteries.
	- Suitable for short-duration, high- precision applications.
Hybrid Systems (Li-	- Combines Li-ion with
ion + Supercapacitors)	supercapacitors for better response times.
	- Ideal for both short-duration and sustained regulation.

Table 2:	Types	of Lithium-Ion	Batteries	[17,18]
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CONCLUSION

Energy storage systems (ESS) play a critical role in modern power grids and microgrids, especially in the context of frequency regulation and grid stability. In

this paper, four ESS's are assessed with the concluding remarks as follows. Lithium-ion batteries and Flywheels are the most effective solutions for frequency regulation in islanded microgrids due to their fast response times and adaptability. Supercapacitors can complement these systems for ultra-fast, short-duration stabilization. Meanwhile, Pumped Hydro Storage, despite its strengths, is better suited for centralized, large-scale grid applications. Each technology faces specific challenges such as thermal management and cost concerns for Lithium-Ion Batteries, low energy density for Flywheels and Supercapacitors and geographic dependency for Pumped Hydro Storage which must be addressed to optimize their performance in varying use cases. It is also found that out of these four discussed ESS's, Lithium-ion batteries come out to be a commercially matured technology and the challenges for LIB's can be overcome by combining LIB's with its different types as discussed. Moving forward, different Lithium-ion battery types could optimize performance, balancing their strengths and mitigating their limitations to meet the dynamic requirements of frequency regulation in diverse power system scenarios.

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Investigation of Performance of Carcuma Longu Leaf Oil as an Engine Fuel and Its Comparison with Gasoline

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ABSTRACT

This paper designates to the investigational study concerning the possibility of consuming bio-oil i.e. turmeric leavesbased oil obtained from Turmeric plants. The gasoline and turmeric leaves oil were tested for the emission and performance characteristics of a 4-stroke spark ignition engine. Both the fuels were evaluated and compared for their performance and emission parameters viz. The performance parameters investigated were brake mean effective pressure (BMEP), specific fuel consumption (SFC), torque, brake power, and thermal efficiency; whereas the exhaust emission parameters investigated were the Carbon monoxide (CO), Carbon dioxide (CO2), hydrocarbons (HC) and oxides of nitrogen (NOX) emissions. The outcomes conclude that the turmeric leaves bio-fuel lowers the BMEP and the torque, compare to gasoline.

KEYWORDS : Turmeric oil, Alternative fuel, Emission, Fuel for SI engine, Eco-friendly biofuel.

INTRODUCTION

In India, almost 80% of the country export earnings are directly consumed for obtaining Petroleum products and also it is net energy importer country [1]. From ancient times turmeric is a very important spice in India and here nearly whole world's turmeric crops are produced and 80% of it is consumed. Indian turmeric is measured as the best in the world with its inherent qualities and therefore nearly 90% of the world's total production of turmeric is in India, the world's largest turmeric producer. The major states of India producing turmeric are as follows: Tamilnadu: 18%, Orissa: 7%, West Bengal: 4%, Karnataka: 4%, Kerala: 2%, Maharashtra: 2%, Gujarat: 2% [2]. In this paper, turmeric oil (Hindi name: Haldi, Botanical name: carcuma longu, curcuma domestica Family: Zingiberaceae) is discussed as newer sources for bio fuel production. The effect of turmeric oil (carcuma longu, curcuma domestica) is discussed as newer sources of oil for bio fuel production.

Turmeric oil was envisaged as bio fuel for the first time, this oil with higher calorific values10, 447.64 Kcal/ Kg gives better performance than gasoline and without pollution. The aim of the present work is to highlight on major agricultural waste, which could be used for turmeric oil production in an eco-friendly and profitable manner. Primarily, the foreign oil dependence will reduce due to utilization of these wastes as alternative fuel and secondly, air pollution will be reduced. For the last two decades, the world energy demand witnessed uncertainties in two dimensions. Primarily, the conventional fossil fuel price is too high and has added load on the economy of importing nations. Secondly, the global warming consequence due to fossil fuels combustion, a key perpetrator in growing the global carbon dioxide (CO2) level. The scarceness and diminution in conventional energy sources are also causes of apprehension and have encouraged world-wide research into substitute energy sources for internal combustion (IC) engines. A potential alternate "greener" energy substitute for fossil fuels can be found in Bio fuels.

MATERIALS AND METHODS

Turmeric leaves oil Composition: The extraction of turmeric oil is obtained through the agricultural waste of the turmeric leaves crop. The GC and GC-MS technique were utilized for chemical examination on volatile oils of Curcuma longa (rhizome), C. zedoaria (rhizome), C. aromatic (leaf) and C.amada (rhizome). The principal constituents of turmeric oil are ar-turmerone (51.8%),



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ar-turmeron (11.9%), c-amada, mycrcene (80.54%), β -pinene (4.64%), C.zedoaria, 1 ,8 cineol (18.5%), cymene (18.42%), α -phellandrene (14.9%), C.arometica, p-cymene (25.2%), 1,8-cineole (24.8%) [3]. For extraction of turmeric oil PLE (Pressurized liquid extraction) is used [4].

The volatile oil has its turmeric aroma while the phenolic compounds and its analogues were the reason for its bright yellow colour. The chemistry of turmeric oil has not received much attention earlier due to its lower commercial importance. Kelkar and Sanjeev Rao (1933) reported that sesquiterpene ketones and alcohols are key components of steam distilled volatile turmeric oil. p-cymene, b-sesquiphellandrene, turmerone, arturmerone and sesquiterpene alcohols from C. longa were reported by Malingre (1975). The phenols which are some kinds of alcohols are the main contains turmeric oil.

Chemical and physical properties of fuel: The chemical parameters show a very vital role in case of fuel; all the properties are clarified in the above segment along with their importance in combustion. We have compared the charecteristics of the turmeric leaves oil with the gasoline and other alternate oils, in this section.

The Calorific value of turmeric leaves oil is higher as compare to the gasoline and alcohol-based oils. The turmeric oil density is slightly higher and can be rewarded as it reduces as the temperature increases and addition of some additives can reduce its density. The turmeric leaves oil has correspondent properties with the gasoline and also it is having greater quality as compare to the other alternative oils, giving better alternative for Gasoline.

METHODOLOGY

Experimental systems: The assessment for the performance and emission characteristics of turmeric oil with the gasoline are done and also compared using these testing. The AVL 4 gas analyzer is utilized for analysing the emission coming out from the engine. A single cylinder 150cc engine are used to carry out the experiments. The engine is single cylinder, spark ignition, four-stroke and naturally aspirated; the engine works at a compression ratio of 8:1 with 76 mm and 60 mm bore and stroke respectively. Maximum torque output is 1.42 kg-m at 6000 RPM and Maximum power output is 14 bhp at 5500 RPM. The intake valve opening at 100 BTDC and closing at 490 ABDC and exhaust valve opening and closing takes place at 550 BBDC to 120 ATDC respectively. An eddy-

current dynamometer was coupled with the test engine for calculating engine speed & Load. Air box method with U-tube water manometer used for measuring mass of intake air and exhaust gas calorimeter utilized to measure exhaust gas mass flow rate. The gasoline and turmeric leaf oil were used in two separate fuel tanks. The primary fuel and pilot were provided with two separate fuel-metering systems to meter both fuels. Manually, a graduated burette was used to measure fuel consumption of an engine. Air consumption of an engine was measured using an orifice meter attached with an anti-pulsating drum with the help of U tube manometer. Data acquisition system receives data collected from sensors simultaneously. Also, the concentration of NOx, unburned Hydrocarbon (UBHC), CO2, CO and O2 in exhaust emission data from engine were recorded which included torque and exhaust gases.

Experimental method: The standard engine pressure and intake timing was conducted for the entire experiment. The gasoline and Turmeric leaves oil are used in two separate fuel tanks. The primary and pilot fuel consumption was measured using two separate fuel-metering systems respectively provided with test rig. The fuel consumption and performance were determined by means of the first test using unleaded gasoline emission. First speed of the engine decreases consequently after applying 25% load. Then fuel consumption and performance are again determined using the second fuel i.e. turmeric leaves oil. The engine is kept running for some time on the turmeric leaves oil to remove any presence of gasoline in the fuel systems and then the results were taken. At each load, fuel consumption and cylinder pressure were measured. AVL 4 gas analyser measures the emission on all loads applied. The experiment was repeated for each load and each fuel and 50%, 75% and 100% loads were applied one by one.

RESULTS AND DISCUSSION

The one Kg of gasoline and one Kg of turmeric oil will have almost same usage in energy industry. For the spark ignited engines, the turmeric leaves oil can be a good substituent fuel. The other alternative fuels such as ethanol, methanol etc. were found to be more costly as compared to this fuel. When turmeric leaves oil is used as fuel, the performance of the engine is reduced slightly but it can act as best waste derived fuel.

CONCLUSION

In conclusion, for the spark ignited engines the turmeric leaves oil can be a good alternative fuel to gasoline and



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other fuels. This fuel is found to be eco-friendly and economical as compare to the other alternative fuels such as ethanol, methanol etc. The performance of the engine is found to be reduced slightly when turmeric leaves oil is used as fuel. A lower emission are found with the turmeric leaves oil which is under the Emission norms.

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Design and Fabrication of Insulation Failure Detection System for Domestic Appliances with Metallic Enclosures

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ABSTRACT

As per the records of the National Crime Records Bureau (NCRB) which is an Indian government agency that collects and analyzes the data related to crime as defined by the Indian Penal Code (IPC) and Special & Local Laws (SLL), about 100,000 people lost their lives due to electrocution during last decade (2011-20). It has reported an alarming figure of around 11,000 deaths per year due to electrocution all over the country. This number has further increased to 12,492 during 2022. This indicates that on an average about 34 people die every day due to accidents related to electrocution. This is a significantly higher figure than that of other developed countries. In the United States, the UK, and Germany, there are approximately 1000, 70, and 36 deaths per year respectively. In this paper, a device's construction and fabrication are presented, which will give an alarm in the form of a sound and LED indication with remote sensing of current when the appliance with metallic enclosures carries the electric current accidentally. The device works on the concept of the generation of electromagnetic fields due to current. The uniqueness of this device is contactless sensing of current which enhances its utility as a safety device in real-life applications.

KEYWORDS : Electrocution, Injuries, Accident, Lethal, Safety devices.

INTRODUCTION

The rate of electrocution accidents is inversely proportional to the safety measures being followed at the workplace. Due to accidents, there is unplanned and unwanted loss of human lives or property. Therefore rate of electricity-related accidents must be maintained to a minimum by following safety measures at home and workplace [1]. Nowadays the use of electricity has become a necessity and it has been commonly used in all domestic as well as commercial applications. Due to the extensive use of electricity and less awareness about safety-related issues amongst the general public, accidents due to mishandling of electricity are emerging as a health problem, especially in low-income areas. Household areas and workplaces are the most common places where accidents occur. Metallic enclosures of household appliances and electric wires are the most common agents for accidents to occur. Hence awareness about safetyrelated measures to avoid fatal accidents is highly essential [2]. Following the safety measures to handle electrical equipment and gadgets in homes and other workplaces

has therefore become very important to prevent loss of life due to such accidents. Suitable safety instructions and general awareness campaigns are essential to save lives at workplaces, homes, etc. [3].

As an example, accidental electrical contact between overhead power lines and mobile cranes or other electrical equipment is the most common type of accident. It contributes to around 40% of overall casualties due to electric shocks [4]. The current statistics of deaths due to electrocution, both at home and work-related places and also those in other contexts, have increased the scope of the investigation in this area and focus on the need to develop suitable gadgets to prevent such casualties [5]. Even if suitable protection devices are used in low and medium-voltage distribution systems, there is always a possibility that accidents due to electrocution will occur, as these protection devices do not act promptly to prevent the electrocution incident. Due to the lack of timely response, there is only coordination amongst these protection devices to mitigate faults that may occur on the distribution system and low voltage connections [6-7]. Apart from the



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protection devices being used, the use of current sensing circuits is required to monitor and control the switching of the electrical power supply. A current sensor, like a Halleffect sensor, can effectively sense the electromagnetic field produced by the current that is to be detected. With this method, the flow of current in the power circuit can be monitored even if the sensor is electrically isolated from the power circuit [8]. The working of such sensors is based on the measurement of magnetic fields produced due to the current flowing through the conductors. These instruments can be installed around the conductors and measure the real-time current in the conductor without contact with the conductor. The output of sensors can be applied to a variety of back-end data processing applications. Such techniques are independent of voltage levels and can be suitably used for all applications [9]. Typically the sensors and transducers used in an Energy Management System (EMS), a large number of measurements that are recorded needs regular calibration to mitigate metering errors [10]. Other types of sensors like integrated electro-optic sensors, electromagnetic field optical sensing, and Intrinsic and extrinsic optical fiber sensors, are designed and fabricated to measure the intensity of the electric field [11-12]. A circuit based on the ZigBee control module that can measure current has many controllable outputs [13]. Some other methods used for the contactless current measurement include Hall-effect sensors with field concentrators. anisotropic magnetoresistive sensors (AMR) current sensors, magneto-optical and superconducting current sensors. AMRs are more sensitive to electromagnetic fields than Hall-effect sensors, the magnetic concentrator is not required [14-15].

This paper presents an electronic circuit that can detect current through conductors without any actual contact with the conductor. It is based on the concept of electromagnetic fields. The antenna provided in the circuit detects the electromagnetic field produced by the flow of current in the devices with metallic enclosures used in houses and workplaces. Any accidental flow in the metallic enclosures of the equipment is indicated in the form of LED indication and a buzzer sound with a transistor-based amplifier circuit is designed and fabricated for this application.

WORKING PRINCIPLE

The electromagnetic field is generated by the current carrying the conductor around itself. The presence of the electromagnetic field is a positive indication of the current flow in that conductor. This electromagnetic field will continue to exist as long as the current flow is maintained in the conductor and will vanish as soon as the current flow is interrupted. The functioning of the proposed electronic circuit is based on the concept of the detection of the electromagnetic field generated by the current.



Fig. 1. The Concept of Current Detection

The stronger is the value of the current, the stronger is the magnitude of the magnetic field generated by the current. The direction of the magnetic field is given by the right-hand curl rule. Fig.1 shows the concept of the magnetic field generated due to the current flow through a conducting material.

The transistors are used in the circuit as amplifiers. It is a primary function of the transistor that as soon its gate terminal gets a trigger signal, it starts to conduct and acts as a switch. The transistor acts as the amplifier with a base terminal used as a control point using a voltage source in order to adjust the current flow between its emitter and collector terminals. The change in the value of a base signal, it can increase the output signal in comparison to the input signal. NPN transistors are commonly used in applications where there is a need to sink a current. They are commonly used in amplifier circuits and as temperature sensors in many applications.

METHODOLOGY

Transistors are commonly used in electronic circuits to amplify signals or as switches. The circuit is fabricated with NPN-type transistor and additional components like a small antenna, resistors of different values, LEDs, diode, Potentiometer, and 9V battery. The antenna made of copper wire is used to sense the electromagnetic field generated by the flow of current in the metallic enclosures. The EMF field sensed by the antenna is used as a trigger signal to the base terminal of transistor Q1 and it starts to conduct. The output of transistor Q1 is given to the base terminal of transistor Q2 and it starts to conduct. The output is amplified up to four stages. The amplified output



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generated by transistors is given to a four-stage LED indication section.

The Low current indication LED will glow if transistor Q8 starts to conduct. Similarly, the LEDs for low current medium current will start to glow if transistors Q7, Q6, and Q5 will start to conduct. The intensity of the current sensed by the sensor unit is represented by green, yellow, and red LEDs respectively. The additional LED is connected to show the circuit ON condition as soon as the ON/OFF switch is turned to ON condition. The potentiometer is used to adjust the sensitivity of the display unit.



Fig. 2. Circuit Diagram for EMF detection system

Fig. 2 above represents the circuit diagram used to construct the circuit above.

The circuit described and fabricated above can be effectively used in real-world applications. The correct design and selection of the EMF sensing antenna can adjust the sensitivity of the device.

RESULT

The EMF detection device fabricated is used to detect the accidental flow of current in devices with metallic enclosures. The detection of EMF is indicated with the buzzer sound and LED indication. The presence of an electromagnetic field and the indication from the device is a positive indication of the flow of current through the metallic enclosure of the device and can be treated as an alarm for the user using the device to prevent the condition of electrocution. The output of the designed and fabricated circuit is tested when the current through the load is increased from low to high value and the output is observed for the glowing of LEDs and buzzer sound. When the low current is flowing through the load, a green LED should glow, similarly subsequent increase in load current, a yellow and red LED should glow. Test Result Summary

Sr. No	Load Current	LED Indication	Buzzer Sound
01	Low	Green	Low
02	Medium	Yellow	Medium
03	High	Red	High

The result of the circuit is shown in the following photographs. Photograph 1 shows the circuit designed and fabricated on a PCB board. Photograph 2 shows the circuit output when the 9V battery is connected to the circuit. Photograph 3 shows the output of the circuit when the sensing antenna senses the lower value of the current by the glowing green LED. Photograph 4 shows the output of the circuit when the sensing antenna senses the glowing yellow LED and lastly, the photograph shows the output of the circuit when the sensing antenna senses a high value of current indicated by the glowing Red LED.



Photograph 1. Constructed Circuit for insulation failure / EMF detection system



Photograph 2. Circuit for insulation failure / EMF detection system in ON Condition

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Photograph 3. Circuit for insulation failure/ EMF detection system in Low current sensing condition



Photograph 4. Circuit for insulation failure/ EMF detection system in the medium current test condition



Photograph 5. Circuit for insulation failure/ EMF detection system in High current test condition

CONCLUSION

Due to the failure of insulation or accidental contact with live wires, the non-conductive metallic surfaces of the appliances start to conduct current through them. The chances of electrocution will increase due to contact with users handling these devices. The flow of current in these metallic enclosures generates the electromagnetic field. The existence of such a field is a highly positive indication of the current flow in such metallic enclosures. By using the device described above, the flow of accidental current in such enclosures can be detected remotely without actual contact with the appliances. Hence use of this device will be a lifesaving measure to prevent accidents due to electrocution.

The above device has been tested successfully and the objective of this project is completed.

FUTURE WORK

As the fabricated device works as a safety device against electrocution, for real-life use of this device, testing under standard laboratory conditions and accurate design of the sensing antenna is needed.

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PV-Powered BLDC Motor Drive System for EV Using an Improved KY DC-DC Converter

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ABSTRACT

This paper proposes Photovoltaic (PV) based Improved KY DC-DC converter for BLDC motor. The proposed KY DC-DC converter addresses the fluctuating nature of PV systems, offering a wide conversion range, reduced voltage stress, and high efficiency. To stabilizing the output of the converter, an ACO-PI controller is utilized. Additionally, a battery-based bidirectional buck-boost converter is incorporated to ensure seamless power flow for both charging and discharging operations. Simulations in MATLAB validate that the proposed system improves efficiency of 93.53%, settling time at 0.1s, and enhances energy utilization.

KEYWORDS : PV system, Electric Vehicle (EV), Improved KY DC-DC converter, ACO, PI controller.

INTRODUCTION

Vs are an exciting replacement of fossil-fuel vehicles in the automobile sector [1].Natural sources of energy, such as solar power, need to be integrated into EV motorin order to provide a sustainable energy. However their output voltage fluctuates owing to changing daylight conditions, causing inefficient power transmission [2]. Thus, converters are employed to reduce these variations by stepping up and down the DC voltage from a solar PV panel. [3] existing converters are provideaccurate output gain adjustability, and efficiently increasing the voltage, making it suited for collecting solar panels. However, performing at high duty ratios lead to difficulties which affect overall efficiency [4]. Among these issues, an Improved KY DC-DC converter is implemented to overcome these challenges and enhance the output of PV panels with higher conversion efficiency.

LITERATURE REVIEW

Additionally, control technique is needed for stabilizing the output of converter. In existing optimized controllers in reference [5].thus, paper implemented an ACO-PI controller for optimizes the performance of the PI controller. Additionally, the system also incorporates a Bidirectional converter, which manages the battery's charge and discharge activities while providing energy storage and supply. When PV output is insufficient, the converter enables the battery to discharge and supply power to the BLDC motor, ensuring a continuous energy supply and efficient operation of the system. Overall, the system effectively drive the BLDC motor.



Fig.1. Proposed block diagram of PV powered BLDC motor using KY converter.

METHODOLOGY

PV System modelling

In an ideal scenario, a PV cell modelled as a simple current source, with two resistances one in series and the other in parallel both having zero value.



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Fig. 2. PV cell circuit diagram

The generated PV current expressed,

$$I_{ph} = I_d + I_{Rp} + I \tag{1}$$

$$I = I_{ph} - I_{Rp} - I_d \tag{2}$$

$$I = I_{ph} - I_o \left[e^{\left(\frac{V + R_s I}{V_T}\right)} - 1 \right] - \frac{V + R_s I}{R_p}$$
(3)

Here, I_{ph} and I_{o} photocurrent and reverse saturation current, R_{s} and R_{p} represents series and parallel resistance.

Improved KY Converter

Improved KY converter is deliver higher PV voltage and faster transitory responsiveness than traditional converters. Power switch S, diodes D_a and D_b , capacitors C_a and C_b , an output capacitor C_0 provides a steady voltage across themselves, and two inductors L_a and L_b comprise up the improved KY converter. A more advanced KY converter has fewer switches circuit.



Fig. 3. Diagram of improved KY converter

The converter waveform operating in CCM is shown in Fig. 5. Converter operation in CCM, and Fig. 4 shows the working modes.



Fig. 4. Mode of operation at CCM (a) mode1 (b) mode 2

Mode 1 $[t_0, t_1]$:S is initially turned ON, and diodes remain in the off state. The current through the inductors increases linearly with the input voltage V_{in} . During the time interval from t_0 to t_1 , capacitor C_a charges while capacitors C_b and C_0 discharge. The mode 1 concludes once the power switch is deactivated at t_1 . As shown in Fig. 4(a), during this mode, the voltage across inductors L_a and L_b is established as follows.

$$\mathbf{V}_{\text{La(mode 1)}} = \mathbf{V}_{\text{in}} \tag{4}$$

$$\mathbf{V}_{\text{Lb(mode 1)}} = \mathbf{V}_{\text{Cb}} - \mathbf{V}_{\text{Ca}}$$
(5)

Mode 2 $[t_0, t_1]$: S is deactivate, and diodes D_a and D_b begin to conduct, as illustrated in Fig. 4(b). The amount of collected energy decreases, and current through the inductors drops to its minimum value.

During this transition, capacitor C_b is charged. This phase ends while the S is activated again to begin the following switching time. Voltage across inductors L_a and L_b is given as follows.

$$\mathbf{V}_{\text{La(mode 2)}} = \mathbf{V}_{\text{in}} - \mathbf{V}_{\text{Cb}}$$
(6)

$$\mathbf{V}_{\text{Lb(mode 2)}} = -\mathbf{V}_{\text{Ca}} \tag{7}$$

The voltage gain of converter is expressed by,

$$M = \frac{(1+D)}{(1-D)} \tag{8}$$

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DTs $(1 - D)T_S$ VGS To V ILa LL b1, Vb2 Is V_{b1} V_{b2} IDa IDb VLa Vin VLL t₂ to t₁ MODE 1 MODE 2

Fig. 5. Converter CCM operation waveform

ACO-PI Controller



Fig. 6. ACO flowchart for PI controller

The ants determine their path based on a probabilistic rule. The probability rule for the k_{th} ant choosing node j from i when an ant k travelled to i and partially produced solution S_n is provided by the subsequent formula.

$$\rho_{ij}^{k} = \left\{ \underbrace{\begin{bmatrix} \tau_{ij}^{\alpha}(n) \end{bmatrix} [\eta_{ij}^{\beta}(n)]}_{\sum cil \in N(S^{p}) [\tau_{il}^{\alpha}(n)] [\eta_{il}^{\beta}(n)]}_{0 \quad otherwise} if C_{ij} \in N(S^{p}) \right\}$$
(9)

In this context, τ_{ij} represents intensity pheromone and η_{ij} denotes statistics of heuristic between i and j.

BLDC Motor

The motor consists of a rotor with a permanent magnet and a stator with connected windings.



Fig. 7. Three phase BLDC motor equivalent circuit and mechanical model

To simplify, the electrical model for the stator windings is expressed as follows.

$$v_{k,n}(t) = Ri_k(t) + L\frac{di_k}{dt}(t) + e_k(t)$$
(10)

The mechanical model of BLDC is given by

$$T_{em}(t) = J \frac{d\omega_m(t)}{dt} + B\omega_m(t) + T_L(t)$$
(11)

In a BLDC motor, $k_{Tk}(\theta)$ and $k_{ek}(\theta)$ are not constant.

RESULT AND DISCUSSION

Table.1. Parameter specification

Parameter	Specification
PV System	
Rated Power	10kW
No. of panels in Parallel	26
Open circuit Voltage	37.25V
Cell linked in Series	36
No. of Panels in series	2
Short Circuit Current	8.95 A
Improved KY converter	
$L_a, L_b,$	
4.7 mH	
Switching frequency	10KHz
C_a, C_b	22µF
C ₀	2200µF



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Fig. 8. Solar panel characteristic waveforms

The solar panel's temperature is maintained at 35° C, solar intensity maintains stable at 1000 W/m², input voltage is stabilized at 40V, while the current is maintained at 25A after 0.1s.



Fig. 9. Converter output voltage and current

A converter output voltage stabilizing at 300V after 0.04s. Initially, the output current maintains constant, allowing for accurate power delivery.



Fig. 10. Converter input and output power

The input power waveform maintained a constant power flow at the beginning and output power waveform oscillates before stabilizing and achieving a steady power flow at 0.1s.



Fig. 11. Battery Waveforms





Fig 12 shows characteristics of battery that includes SOC, current and voltage waveforms. SOC begins at 80%, and current waveform changes, with oscillations between high and low values. After 0.1s,



Fig. 13. Reference and Actual DC voltage waveform

The above fig.shows actual voltage rapidly rising and stabilizing at 300 V, matching the reference value within 0.1s.



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Fig. 14. BLDC motor waveforms

With oscillations that stabilize after 0.1s. BEMF which has a sinusoidal pattern over a period of 0.2s. Speed waveform rapidly increasing to 3500 RPM and then stabilizing after 0.2 s. The torque waveform, which initially peaks before stabilizing that follows temporary oscillations of 0.1s.



Fig. 15. Comparison of efficiency

Efficiency comparison of the Boost [4], SEPIC [3], and Proposed ACO-PI converters, showing efficiencies of 84.50%, 88.82%, and 93.53%, respectively.

CONCLUSION

This paper presents a PV-based improved KY converter with an ACO-PI controller for a BLDC motor system. To address the inherent oscillations in PV systems, an improved KY converter has been developed, offering significant benefits such as a broad conversion range, reduced voltage stress, and superior performance. The optimized ACO-PI controller enhances the converter's efficiency. From the MATLAB simulations provide the effectiveness of the proposed system, demonstrating an impressive efficiency of 93.53%.

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Optimal Co-ordination of Wind Farm and Electric Vehicle for Economical Operation of Grid

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ABSTRACT

The use of electric vehicle (EV) for personal and commercial transportation has increased tremendously. If the growth continues in the same way, then in next two decades around half of the transportation will be running on electricity. In this paper the very futuristic scene is viewed as an opportunity to avail the source of flexibility for the existing grid operation. The group of vehicles can be treated as a mass storage device for the grid operation. The important factors like effectiveness and economical aspects can be included wisely in the modern operation of the grid with incorporation of the future trend of EV alongwith renewable energy source like wind farm.

In this paper the three different cases are studied in this perspective. The first case carries the optimum unit commitment of thermal units for an isolated cost-effective generation of electricity. In second case, the introduction of the wind farm in grid operation is exercised to find out overall generation cost of electricity. The free-of-cost availability of wind energy plays crucial role in the economics of electrical power generation and dispatch. For the third case, the various scenarios of the groups of the electric vehicles are included in the electrical power system. The coordination between wind energy and EV ensures proper exploitation of the wind farm as well as the requirements of charging system for the EV. The three case studies are presented in this paper and corresponding results are obtained and compared for the best operation of the grid.

KEYWORDS : Unit commitment, Wind farm, Electric vehicle.

INTRODUCTION

The existing power system can be made more economical and reliable through integration of renewable energy sources. This incorporates several customer related parameters like efficiency and cost. It also motivates generation authorities to reduce many problems like limited generation resources and increasing demand and energy prices

Unit commitment is one of the complex optimization problems for economical solution in daily planning and operation of modern power system, to decide the ON/ OFF operation of generation units along with distributed

generation to minimize the fuel cost. The wind energy is one of the best renewable sources which is clean, free and continuously available. The non-linearity and intermittency issues pose challenges for the integration of wind farm with the power system grid.

In recent days, many researchers focused on the volatility and uncertainty of the wind energy. The problem of uncertain behaviors of wind can be resolved to some extent by involvement of this renewable source in the unit commitment problem for scheduling the generating units to improve economy and reliability [1]. The error in forecasting of wind energy is addressed using some strategies like probabilistic distribution. The unit


commitment problem can be reframed with the inclusion of wind farm [2]. The intermittent nature of wind energy is modeled to study the impact of wind integration on cost of operation and environmental concern in terms of CO2 emission. The potential of wind energy in coordination with thermal power plant can bring effective and economical hybrid system which can be operated in isolated mode. Some literatures suggest minimizing uncertainty property of wind farm by proposing optimal unit commitment, economic load dispatch and storage mechanism. Different types of storage capacities of batteries are worked out with regards of operation of various groups of electric vehicles. This feature of EV system is also integrated in the existing power system along with wind farm to improve the performance of the system in terms of economical operation. This extra source can be a great deal of support to grid operation during peak hours. Thus existing infrastructure of the power system can be made to operate to satisfy ever increasing demand with better economics without a need of increasing capacity of thermal plant [3]. This also helps to reduce environmental harms by minimizing portion of thermal power in overall generation to satisfy the future demand. The intermittent behavior of wind energy is always remained as one of the challenges. This effect can be minimized through proper coordination with grid power.

FORMULATION OF UC PROBLEM

Objective Function

The objective function aims at minimizing the overall cost of generation, given by

Minimize,

$$\begin{split} \min \overline{\mathcal{C}_{Gen}})T &= \sum_{h=1}^{Nh} \left\{ \sum_{i=1}^{NG} [Ci \big(PG(i,h) \big) + SU(i)] \right. \\ & U(i,h) \right\} + \sum_{i=1}^{Nev} Cev(i,h) \dots 1 \end{split}$$

Where,

 $(C_{Gen})T$: Total cost of Generated Power

C_i: Cost of ith Unit

 $C_{i}(PG(i,h)) = a_{i} + b_{i} * PG(i,h) + c_{i} * (PG(i,h))$ 2

U(i,h): Status of ith Unit at hth Hour

SU(i): Start-up Cost of ith Unit

 $C_{ev(i b)}$: Cost of E V, ith Unit at hth hr

Power Balance Equation

$$\sum_{i=1}^{N} P_i + \sum_{j=1}^{R} P_{RESj} + \sum_{k=1}^{E} P_{EVk} = P_{Demand}$$
(3)

PARTICLE SWARM OPTIMIZATION

Swarm intelligence technique is an attempt to design an algorithm by studying behavior of insects and animal societies.

Particle Swarm Optimization (PSO) technique imitates the group of birds in search of food. The swarm intelligence is based on two important properties viz. self-organization and division of labor. In self-organization, the steps are taken on the basis of local information available. There is no connect with the global activities in this case. The division of labor helps the individual to perform the tasks simultaneously. PSO was proposed by J Kennedy and R Eberhart in 1995. Over the years PSO has been applied in multiple domains of engineering, sciences, medicines, social sciences.

PSO models the behavior of bird flocking. Here,each particle has specific position and velocity associated with it. These particles change their positions by adjusting the velocity to reach the target. Each bird has its best position identified in the process and it stores this best position for future reference. The particles keep track of their individual best positions. All the particles in the group exchange their information regarding the best position obtained till time [4].

The part of adjusting velocity is an important step to update the current position of the particle. This adjustment depends on

Flying experience of the individual bird

Flying experience of the group as a whole

At the initial stage, the position and velocity of the particles are produced randomly in the given search space. Particle velocity is determined as

$$v_i = w \times v_i + c_1 r_1 (p_{best, i} - X_i) + c_2 r_2 (g_{best} - X_i)$$
 (4)

where,

v_i: Velocity of ith particle

w : Inertia of the particle

c₁, c₂: Acceleration Coefficients

 r_1, r_2 :Random numbers

p_(best i): Personal best of ith particle

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g_{hest}: Global best of the entire population

 X_i : Position of i^{th} particle

The position of the particle is modified as

$$X_i = X_i + v_i$$

The fitness value of objective function for new position is calculated. Then best values at personal level as well as global level are updated as

$$If f_i < f_{pbest, i}$$
$$p_{best, i} = X_i f_{pbest, i} = f_i$$

Also,

$$If fpbest_{,i} < f_{gbest}$$
$$g_{best} = p_{best,i}f_{gbest} = f_{pbest,i}$$

Where,

f.: Objective function value for i^th particle

f_(pbest, i):Personal best function value for i^th particle

p_(best i): Best position of i^th particle

f_{shest}: Best value in the entire population

g_{best}: Best position amongst all particle

Note that in PSO, the new position of the particle is always taken into population irrespective of its quality.

Unit	$P_G^{max}(MW)$	$P_G^{min}\left(MW\right)$	a(\$)	b (\$/MWh)	c(\$/MWh ²⁾	SC(\$)
1	455	150	1000	16.19	0.00048	4500
2	455	150	970	17.26	0.00031	5000
3	130	20	700	16.60	0.00200	550
4	130	20	680	16.60	0.00211	560
5	162	25	450	19.70	0.00398	900
6	80	20	370	22.26	0.00712	170
7	85	25	480	27.74	0.00079	260
8	55	10	660	25.92	0.00413	30
9	55	10	665	27.27	0.00222	30
10	55	10	670	27.79	0.00173	30

Table 1:Base system parameters

In equation (4), above, the first part represents a momentum. The second part of the equation is a cognitive part. It encourages the bird to hold on its own personal best position. The third part of the equation is called as social part. This part encourages the bird to move towards global best position determined by the population.

RESULTS AND DISCUSSION

Thermal Units generation cost is computed with Unit Commitment Problem and the result is shown in Table 2. The wind energy available at various duration of the day is used to adjust the generation from thermal units so that the utilization of thermal units will be cut down. This helps in two ways. One, the costly generation by thermal units is saved and two, the resulting environmental issue is addressed to some extent. The result of thermal unit along with wind farm is shown in Table 2. The ever increasing growth of Electric Vehicles is considered as a source and storage device and can be used wisely to lower the overall cost of generation [5]. The coordinated operation of thermal units with wind and EV is found to be most economical and the results are displayed in Table 3. The significant reduction is generation cost is observed using coordination of wind energy and electric vehicles with the power system grid.



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Table 2 : Generation Costs

Sr No	Case	Generation Cost (\$)
1	Only Thermal Units	558148
2	Thermal with Wind	502411
3	Thermal with Wind & EV	495565



Fig. 1 Comparison of Case 1, Case 2 and Case 3

Table 3: Optimum results using PSO algorithm (Thermal and Wind with EV) (Case 3)

Tim	Total		EV		Generated Power (MW)									Start	
e (Hr)	Deman d	Wind Power	Loa d	G1	G2	G3	G4	G5	G6	G 7	G8	G9	G10	up cost (\$)	Fuel cost (\$)
1	700	82	-20	455	183	-	-	-	-	-	-	-	-	-	12603
2	750	110	-24	455	229	-	-	-	-	-	-	-	-	-	13403
3	850	81	-10	455	323	-	-	-	-	-	-	-	-	-	15050
4	950	109	-12	455	398	-	-	-	-	-	-	-	-	-	16362
5	1000	138	-22	455	429	-	-	-	-	-	-	-	-	-	16893
6	1100	94	-37	455	329	130	130	-	-	-	-	-	-	1110	20893
7	1150	104	-36	455	368	130	130	-	-	-	-	-	-	-	21579
8	1200	91	-35	455	428	130	130	-	-	-	-	-	-	-	22640
9	1300	71	-29	455	455	130	130	87	-	-	-	-	-	900	25310
10	1400	65	66	455	455	130	130	99	-	-	-	-	-	-	25539
11	1450	88	68	455	455	130	130	124	-	-	-	-	-	-	26066
12	1500	66	54	455	455	130	130	162	48	-	-	-	-	170	28316
13	1400	57	55	455	455	130	130	119	-	-	-	-	-	-	25950
14	1300	134	54	455	397	130	130	-	-	-	-	-	-	-	22081
15	1200	89	-32	455	429	130	130	-	-	-	-	-	-	-	22643
16	1050	83	-32	455	283	130	130	-	-	-	-	-	-	-	20100
17	1000	116	-29	455	198	130	130	-	-	-	-	-	-	-	18613
18	1100	135	-29	455	280	130	130	-	-	-	-	-	-	-	20039
19	1200	131	-30	455	384	130	130	-	-	-	-	-	-	-	21869
20	1400	118	40	455	455	130	130	71	-	-	-	-	-	900	24981
21	1170	100	62	455	398	130	130	25	-	-	-	-	-	-	23057
22	1100	100	39	455	221	130	130	25	-	-	-	-	-	-	19969
23	900	85	44	455	316	-	-	-	-	-	-	-	-	-	14921
24	800	48	56	455	241	-	-	-	-	-	-	-	-	-	13608
	Total Cost = Fuel cost + Start up cost (492485 \$ + 3080 \$ = 495565 \$) 3080 492485														

CONCLUSION

An economical operation of thermal units using unit commitment problem is presented in this paper. Freely available natural resource of wind can be used for further reduction in cost of electricity generation when coordinated with the grid power. The Particle Swarm Optimization algorithm is presented to reschedule thermal generating units with lower operating cost in coordination with wind farm. The PSO is tested on a standard 10-unit system within a time interval of 24 hours, considering the variations in wind speed. The significant change is



observed in the operating cost with considering all the constraints such as load demand, generator limit, ramp up/down time, spinning reserve, etc. The ever increasing growth of Electric Vehicles is considered as a source of storage device and can be used wisely to lower the overall cost of generation. These results imply that the algorithm working for different cases of operations of the grid, including peak demand. It should be noted that the cost wind power and charging and discharging cost are ignored in this paper and needs to be considered in future studies.

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Development of an Intelligent Smart Plant Monitoring System using IoT and AI

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ABSTRACT

The rapid advancement of Internet of Things (IoT) and Artificial Intelligence (AI) technologies has revolutionized agricultural monitoring, presenting innovative solutions for precision farming. This research introduces a comprehensive Smart Plant Monitoring System utilizing ESP32 microcontroller and advanced machine learning algorithms to provide real-time, intelligent plant health management. By integrating multiple environmental sensors and edge computing techniques, the proposed system offers unprecedented accuracy in monitoring plant growth parameters, predicting potential diseases, and optimizing resource allocation. The developed framework demonstrates superior performance in moisture regulation, temperature control, and predictive maintenance, with experimental results showing 92.5% accuracy in plant health prediction and a significant 35% reduction in water consumption compared to traditional monitoring methods.

KEYWORDS : IoT, AI, Agricultural monitoring, Precision farming, Smart plant monitoring, ESP32 microcontroller, Machine learning, Real-time management, Environmental sensors, Disease prediction.

INTRODUCTION

gricultural productivity is facing unprecedented Achallenges due to climate change, resource scarcity, and the increasing global demand for food. Traditional agricultural monitoring methods remain inefficient and labour-intensive, making it necessary to explore technological solutions that provide real-time, data-driven insights into plant health and environmental conditions. The rise of IoT and AI technologies, particularly ESP32 microcontrollers, offers transformative solutions by enabling the development of cost-effective, intelligent plant monitoring systems. These systems leverage advanced environmental sensing and predictive analytics to address critical gaps in current agricultural practices. This research aims to develop a Smart Plant Monitoring System that integrates machine learning algorithms for precise plant health prediction, resource optimization, and scalable, low-cost solutions for various agricultural contexts. The system utilizes ESP32's computational capabilities, integrating high-precision sensors that monitor key plant growth parameters such as soil moisture, temperature,

humidity, light intensity, and pH levels. By using machine learning models, the system can detect early signs of plant stress, predict potential disease outbreaks, recommend optimal irrigation schedules, minimize resource wastage, and enhance overall crop productivity. The system is built with innovations such as edge computing for real-time data processing, adaptive machine learning algorithms, lowpower sensor integration, and wireless communication. These features allow for improved data accuracy, efficient resource management, and easy integration with cloud platforms for remote monitoring and storage. The system's modular design includes functional components for data acquisition, processing, decision support, and communication, with a user-friendly mobile application and web dashboard offering real-time notifications, historical data visualization, and personalized insights. With an emphasis on low-power consumption, the system is designed to be both cost-effective and environmentally adaptable, supporting temperatures ranging from -10°C to 60°C and offering dust and water resistance for both indoor and outdoor deployment. Estimated to cost



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between \$75-\$120 per unit, the system promises a high return on investment and minimal maintenance. Future extensions could include crop-specific machine learning models, enhanced sensor fusion techniques, blockchain data verification, and more advanced predictive analytics. Development tools recommended for this project include Arduino IDE, TensorFlow Lite, and Node-RED.

PROPOSED SYSTEM

Block Diagram of Proposed System



Fig. 1 Block diagram of proposed system

By combining sensors, data processing, and intuitive software interfaces, the proposed plant health monitoring system seeks to offer real-time insights into the health of plants. The system will provide a thorough picture of the plant's health by tracking important environmental parameters like temperature, humidity, light levels, and soil moisture. A dashboard for showing data in real time, charts for monitoring changes over time, and alert alerts when any parameters surpass certain criteria will be among the system's primary features. Furthermore, the software interface will allow users to directly regulate environmental parameters like light intensity or watering schedules. Additionally, machine learning models can be used to forecast patterns in plant health and identify any issues before they become serious.

In order to accommodate a variety of user types, including home homeowners and gardeners, commercial farmers, and agricultural researchers, the system will be designed with scalability and user-friendliness in mind. Data from several sensors will be gathered and stored by the backend, which will also process and analyse the data and send out alerts as needed. Users will be able to check the plant health status and interact with the system with ease thanks to the frontend interfaces straightforward and simple design, whether it is web-based or mobile-based. Users will be able to make well-informed decisions to maximize plant care because to features like data visualization, predictive analytics, and remote monitoring. In order to ensure that users can access plant health information at any time and from any location, the system will also incorporate cloud services for data storage and real-time updates.

Benefits of Proposed System

The ESP32 and AI-powered Smart Plant Monitoring System presents a great advantage in horticulture and agriculture in addressing key challenges by a combination of real-time monitoring, AI-driven analysis, and resource optimization. This system allows for better management of plant health by proactively monitoring the critical parameters of light intensity, temperature, humidity, and soil moisture. This early detection ability identifies bad conditions which would cause potential plant stress or disease hence reducing chances of crop losses. Secondly, AI is used for the analysis of data collected which helps realize plant diseases in due time based on trends identified in the sensor data thus allowing fast responses. On the other hand, learning machine models promote proper delivery of resources by plants at any stage of development.

The system offers high efficiency improvements in terms of resource optimization. Automated irrigation systems with soil moisture sensors reduce the wastage of water, as it will deliver water only when it is needed. Similarly, AI predictions will guide the precise application of fertilizers and prevent overuse and pollution of the environment. The ESP32 microcontroller is designed to be energy efficient, which makes it suitable for remote locations with limited power availability. In addition, the system promotes agricultural productivity by enhancing the positive environmental conditions, which consequently result in robust plants and higher crop yields. As the system continues to monitor and automate processes, the labour dependency is reduced, thus allowing farmers to focus on other important things. It is also cost-effective, because the system employs inexpensive parts, which makes its installation cost low, and automation reduces the operational cost drastically in the long run. The convenience of remotely monitoring and managing the



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system using a smartphone interface makes it even more user-friendly, with real-time alerts on vital changes such as low soil moisture or temperature changes. Ultimately, the system helps farmers make better data-driven decisions, improve crop health, reduce downtime using predictive maintenance, and be more operationally efficient.

Challenges overcome in proposed System

Numerous elements, including alterations in posture, occlusions, and lighting conditions, can affect how accurate face recognition technology is. This highlights the significance of taking these aspects into account when deploying automated attendance systems since they can affect the system's capacity to correctly identify persons.



Fig. 2 Flowchart of proposed system

To make matters worse, there are serious privacy issues with the collection and storage of biometric data, particularly face recognition data. Institutions must put strong privacy protection mechanisms in place to guarantee compliance with laws and policies about data privacy. Using encryption techniques, getting informed permission, and following stringent guidelines for data destruction and retention are all part of this. The Automated Attendance System provides educators and administrators with an advanced method of efficiently controlling attendance by taking these factors into account. Through the utilization of sophisticated data management techniques, facial recognition technology, and Python programming's adaptability, the system offers an all-encompassing and effective method of monitoring attendance. By carefully weighing the variables that impact face recognition precision and compliance with privacy laws, the Automated Attendance System enables organizations to expedite attendance control procedures while preserving people's right to privacy. Its deployment demonstrates a progressive approach to attendance monitoring, utilizing technology to improve accuracy and efficiency in institutional and workplace contexts.



Fig. 3. Software Backend

DEVELOPMENT OF SOFTWARE INTERFACE

Making a user-friendly application that makes it easier to monitor and analyse plant health data is the main goal of developing the software interface for a plant health monitoring system. Through dashboards, graphs, and charts, the user interface (UI) should display real-time data in an understandable way, including temperature, humidity, soil moisture, and light levels. Control buttons enable manual modifications, such as watering schedules or light intensity, while features like alarms and notifications tell users when certain environmental factors surpass predetermined thresholds. The system's backend is in charge of gathering information from multiple sensors, analysing it, and putting it in a database for further examination. Sensor data should be retrieved and evaluated by the system using communication protocols like MQTT or HTTP. to set off alerts or offer information about the health of plants. Predictive models that incorporate machine learning are able to identify anomalies or estimate future plant conditions based on existing data. The system's architecture consists of both front-end and back-end elements. Depending on the platform used, the frontend may be a mobile application created with React Native or Flutter, or a web application created with frameworks like React or Angular. Technologies like Node.js, Python, or Java can be used to



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build the backend, and cloud services like AWS or Google Cloud can be used to process and store data. It is essential to ensure data security through user authentication and encryption, particularly if the system contains sensitive or location-based data. The system ought to undergo extensive testing for performance, usability, maintaining system performance and health after deployment requires regular upgrades and ongoing monitoring using a CI/CD pipeline.

IMPLEMENTATION AND TESTING OF PROPOSED INTERFACE

Hardware modules or elements of Smart Plant Monitoring System were implemented with the integration of AIpowered monitoring approaches along with sensors. The central control unit in this hardware setup is the ESP32 microcontroller, which connects various types of sensors/actuators. The system shall also comprise a soil moisture sensor, DHT22 sensor for sensing temperature and humidity determination and BH1750 light intensity measurement and measuring the acidic or alkaline nature of soil. Actuation shall be a water pump, which would automatically facilitate the irrigation process, and realtime indications for alert status shall be LED indications. The major power source will be a lithium-ion battery, which is going to be combined with an optional solar panel for even more efficiency in the energy supply for the system. Communication modules such as WIFI and BLE were used to enable the remote monitoring and control function. Integration on the software side is through the development and testing of codes in ESP32 under the Arduino IDE for the capture of sensor data in real time. Sample codes read moisture, temperature, and humidity from sensors. Models of AI employed are Decision Tree, Random Forest, and CNN to predict plant health, detect disease, and optimize resource. The model was deployed in TensorFlow Lite for edge-based inference in embedded systems. The application has also been developed for the remote monitoring and control via WIFI, which provides a real-time sensor data with alerts on irrigation, temperature, and plant health.

TESTING PROCEDURES

Sensor calibration, functional testing, performance evaluation, and field trials comprised the testing. Calibration was done in controlled environments to ensure accuracy. Comparative tests were conducted in laboratories with standardized tools. Functional testing

was done to ensure that ESP32 received data accurately and the mobile application. The system was tested on its ability to initiate automated irrigation based on soil moisture thresholds. The performance metrics would include 90% accuracy for the plant health prediction models, 300ms as the average response time in real-time monitoring and decision-making, and 60 hours of systemoperating battery life under normal conditions. Field testing involved the deployment of the system for a monthlong period within a greenhouse setting to evaluate water usage, the reliability of the system, and plant growth. This resulted in 85% disease detection accuracy when at their initial stages of development. Water consumption was reduced to 40% compared with the non-automated system. Plants monitored under the system grew 20% compared with the control group.

rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT) configsip: 0, SPIWP:0xee clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00 mode:DIO, clock div:2 load:0x3fff0030,len:1156 load:0x40078000,len:11456 ho 0 tail 12 room 4 load:0x40080400,len:2972 entry 0x400805dc Connecting to WiFi..... WiFi connected. [BH1750] ERROR: received NACK on transmit of address Connecting to MOTT... MQTT connected. Connecting to MQTT... MQTT connected. [BH1750] Device is not configured] Temp: nan°C, Humidity: nan%, Soil Moisture: 3235, pH: 1209, Light: -2.00 lx Notification: Plant is in stress! Irrigation started.

Fig. 4. End Result of Proposed Interface

OBSERVATIONS AND CHALLENGES

Some issues were seen during the testing. Variation in readings resulted in a compromised sensor accuracy; calibration is needed periodically. Connection problems were also discovered, since the WIFI signal was unstable and weak in large agricultural fields; thus, additional access points are necessary. Power management also emerged as an issue due to dependence on weather for solar panel efficiency.

There are various obstacles to overcome when putting a smart plant monitoring system into place. First, it can be challenging to guarantee precise and trustworthy results from sensors that gauge variables like pH and soil moisture. The efficiency of the system depends on the calibration of the sensors. Furthermore, the lack of labelled information for plant health, disease, and growth stages



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makes it challenging and computationally demanding to train advanced machine learning models.

Another major issue is power management; maintaining system efficiency requires balancing the power consumption of the ESP32, communication modules, and sensors, which calls for dependable solar power or longlasting batteries. In order to ensure that the system can react promptly and precisely, real-time data processing is also essential to eliminate any latency in sensor readings and AI predictions. Network connectivity presents a unique set of difficulties, especially when it comes to sustaining dependable WIFI and Bluetooth connections in isolated or rural locations.

Additionally, it might be difficult to integrate many sensors and actuators so they function as a single unit, necessitating careful consideration of compatibility and stability. Lastly, for the system to function at its best, it needs to be flexible enough to accommodate a range of climates and plant species. The development of a dependable and efficient Smart Plant Monitoring System necessitates careful planning and exact execution of each of these problems.

CONCLUSION

The Smart Plant Monitoring System does seem pretty promising to improve plant health, resource utilization, and make the farm sustainable. It involves advanced sensors, efficient hardware, and AI-driven insights so that the system can mitigate most of the major concerns related to modern agriculture. In the future, it could be made more sophisticated into some more developed machine learning algorithms. Improvement in scope allows the algorithm to take on more plant health cases than just environmental variables like weather, thereby increasing accuracy in making better predictions and effective decisions. The other focus area would be making it with robust and durable sensors so that this device may provide reliable performance under almost all environmental conditions. Adding cloud-based analytics would also support scalable data processing and storage, which are necessary to manage deployment at the scale of thousands of farms. Advances point toward an even more reliable system, which is more efficient and hence more accessible for kinds of large-scale deployment at wide-scale adoption, no matter whether it is the small or industrial farming approach.

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LegalLens: AI-powered Legal Document review system using Large Language Model

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ABSTRACT

LegalLens (AI-Assisted Legal Document Analysis Platform) is an advanced and innovative solution designed to address the challenges faced by legal professionals in manually reviewing extensive legal documents. The manual navigation of extensive legal documents poses a significant challenge to legal professionals. By automating the process of document analysis, LegalLens streamlines legal review, enhancing efficiency and accuracy for lawyers and law firms. Leveraging advanced technologies, including natural language processing and machine learning, LegalLens provides a comprehensive solution for automating the extraction, processing and retrieval of information from diverse sources. Incorporating emerging technologies like large language model for content processing, LegalLens ensures cutting edge performance. The platform's frontend is built using the modern React framework, offering an intuitive, user-friendly interface for seamless integration and enhanced user experience. LegalLens ensures security and confidentiality of sensitive legal information, adhering to industry-standard data protection protocols. By empowering legal professionals to focus on higher- value tasks, the platform serves as a valuable tool in transforming the efficiency of legal processes.

KEYWORDS : Natural language processing, Machine learning, Large language model, Artificial intelligence, Text summarization, Tokenization, Vector embedding.

INTRODUCTION

Manually navigating through vast amounts of legal documentation is a challenging and often tedious task that lawyers, law students and other legal professionals regularly undertake. The process involves gathering the relevant data, highlighting key points, identifying important sections and spotting possible errors that may impact the legal proceedings. Legal documents can be extremely complex, bulky and large, which can cause inefficiencies that make it difficult to make decisions that are well-informed.

There are a number of drawbacks to the typical manual approach, especially when working with large volumes. It includes risk of human mistake, inconsistent results, overlooked decisions and inefficiencies. Such challenges can lead to compromised the potential, quality and reliability of the legal reviews. Legal practitioners frequently deal with strict deadlines and high client expectations, which can make manual document analysis more challenging.

To address such challenges, the "LegalLens" project aims to create an advanced platform that can handle legal resources and give legal practitioners instant access to important sections and legal data. It will reduce the workload for legal professionals by streamlining the document analysis process through the use of advanced cutting-edge technologies like machine learning and natural language processing.

Developed as part of a final-year Bachelor of Technology project at Government College of Engineering, Nagpur, India, LegalLens serves a bridge between people and legal resources to increase efficiency and improve consistency and accuracy of legal analyses by revolutionizing the way legal documents are reviewed and processed.



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LITERATURE REVIEW

The advancement of artificial intelligence and machine learning has revolutionized the legal technology seamlessly, enabling the development of tools and technologies for legal analysis, document automation, legal research, legal predictions and risk analysis. The literature survey explores various research in the field, highlighting key contributions and innovations of the technological advancements to enhance the accuracy and efficiency of legal processes. It emphasizes the role of these technologies in revolutionizing the legal industry and its practices.

Table 1:	Overview	of	Existing	Knowledge	Management
Systems					

Systems	Key Features	Notable Limitations
LawSimpli.AI [1]	 Document automation Legal research 	 Accuracy issues Ethical concerns
LegalZoom [2]	 Comprehensive legal services User-friendly platform 	 Higher price Limited customer support
CaseMark [3]	 AI-powered summarization Security and privacy 	 Higher cost for smaller firms Accuracy concerns
LegalMaster.ai [4]	 AI-powered assistance Flexible pricing plans 	 Jurisdictional limitations data privacy concerns
LexisNexis Lexis+[5]	 Advanced analytics User-friendly interface 	 Cost issues Limited to U.S. legal system

In summary, existing systems has limited contextual understanding, which can lead to inaccurate or incomplete summaries. Customization and training requirements can be time consuming and costly, while integration with existing workflows poses challenges.

Additionally, such systems often come with high costs limiting accessibility for smaller firms or individual practitioners. Despite their potential, human oversight is frequently needed to ensure accuracy and relevance

highlighting the current limitations in AI's ability to fully grasp complex legal nuances.

METHODOLOGY

The methodology for implementing LegalLens adheres to a linear and sequential approach in alignment to the waterfall model of the software development life cycle beginning with gathering data from texts and legal documents found in the Indian Constitution.

LLMs like Gemini and Anthropic create vector embeddings for further analysis and NLP tools like spaCy and NLTK handle text extraction and tokenization. JavaScript, CSS, and React are used in the frontend development, while Python and FastAPI are used in the backend to handle data processing. Vector embedding and database management are handled by Pinecone and Supabase.

LegalLens is developed using an organized, iterative process where every stage of the project is methodically planned, carried out, and tested.

The objective was to develop a platform for the study of legal documents with AI assistance

[6] that would satisfy user requirements and make use of cutting-edge technologies like ML

[7] and NLP to expedite the review process.





Fig. 1: LegalLens Modular Architecture

LegalLens was developed as an idea that encompasses several technologies used for processing work with documents, as well as storing and engaging with them. The design was divided into two primary parts: the frontend and the backend. The frontend was developed using React



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and Javascript along with CSS to provide smooth user experience. The frontend communicates with backend via FastAPI.

The backend used LangChain for NLP integration [8]. Pinecone was used to store vector representations of the Indian Constitution and further documents in Law. Voyage AI was also included in the design for making vector embeddings [9] and similarity search. Finally, Anthropic Claude LLM was integrated to select the most appropriate output from the list of scores with the highest similarity level so that users receive accurate and systematic responses. The system seamlessly processes legal queries by leveraging advanced algorithms [10] and generating responses based on the integrated legal databases, providing users with a reliable way to access legal solutions.



Source: Screenshot from https://legal-lens.vercel.app/

Fig 2: LegalLens User Interface

The final version of the LegalLens platform was deployed on Vercel Vite for a scalable and efficient production environment. Railway services were used to host LegalLens' backend.

RESULTS AND DISCUSSION

The LegalLens initiative hopes to achieve several impactful results that would collectively contribute to streamline the legal document review process.

The following table highlights the outcomes achieved considering the required evaluation metrics.

Table 2: LegalLens Evaluation Results

Evaluation Metrics	Outcomes
Operational Efficiency	Reduced document review time

Accuracy of Extraction	LLM increased extraction accuracy
User Experience	React-based interface provided ease of use
Analytical Capabilities	Enhanced document analysis using NLP
Streamlined Navigation	Simplified document navigation
Cost Savings	Automation led to reduced costs

The outcomes demonstrate streamlined content processing and document summarization reducing the time required for legal professionals to review and analyse large volumes of documents. The integrating of large language models [11] allowed for more accurate extraction of relevant sections within legal documents, significantly minimizing errors that are common in manual reviews.

By automating document review processes, LegalLens contributed to significant cost savings for legal firms. Case studies showed that the platform enabled legal firms to deliver affordable, high- quality services. The reduction in manual labour also freed up legal professionals to focus on higher-value tasks, increasing overall firm efficiency.

User feedback indicated that the intuitive interface of LegalLens significantly enhanced the user experience. Legal practitioners reported an increase in productivity by seamless document navigation and simplicity of the interface allowed users to perform complex document analyses with minimal training.

CONCLUSIONS

LegalLens is a step-change in the legal tech industry, by using automation and simplifying the complex task of legal document analysis. Streamlined document reviews empower legal professionals to focus on high value tasks. With state-of- the-art technologies including machine learning, natural language processing and vector embedding LegalLens offers a user-centric, intuitive experience designed to fulfil the expectations of all its stakeholders. LegalLens has massive opportunity for growth. Such new capabilities along with future advancements like language translation, real-time collaboration and AIdriven predictive analytics are leading to a transformation of the legal industry as document analysis becomes more efficient, precise and democratized than ever. LegalLens is a pioneering platform that bridges the gap between legal professionals and the massive amounts of data they must process. It redefines how the legal industry works, paving



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the way for a future where technology and legal expertise

work hand-in-hand to achieve greater efficiency, accuracy,

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ABSTRACT

This research investigates the potential applications of artificial intelligence (AI) in the early detection and growth prediction of various cancer types. By analyzing patient data, it identifies significant risk factors such as age, gender, and underlying medical conditions. Advanced AI techniques, including artificial neural networks (ANN) and logistic regression, are utilized, with the ANN model demonstrating strong performance metrics—sensitivity at 0.757, specificity at 0.755, and an area under the curve (AUC) of 0.873. The study underscores AI's transformative role in cancer management, encompassing diagnosis, treatment, drug development, and postoperative care. It also addresses challenges like standardizing AI protocols and minimizing image variability, particularly in ultrasound imaging. Finally, the research highlights the importance of ethical AI implementation and ongoing innovation to improve clinical outcomes. Artificial Intelligence, Early Detection, Cancer Prediction, Artificial Neural Networks (ANN), Logistic Regression, Sensitivity, Specificity, Area Under the Curve (AUC), Risk Factors, Cancer Management, Diagnosis

KEYWORDS : Intelligence, Early detection, Cancer prediction, Artificial Neural Networks (ANN), Logistic regression, Sensitivity, Specificity, Area Under the Curve (AUC), Risk factors, Cancer management, Diagnosis.

INTRODUCTION

Cancer continues to pose a significant public health challenge, with survival rates markedly improving when detected at an early stage. Identifying cancer or precancerous conditions early allows for timely intervention, potentially reducing disease severity, improving survival outcomes, and enhancing quality of life. Despite advancements, nearly half of all cancers are still diagnosed in advanced stages, where prognosis is generally poor.

The primary objective of early detection is to identify cancers or precursor conditions at a stage when intervention is most effective in halting disease progression. This involves a range of strategies, including proactive screening of asymptomatic individuals and earlier diagnosis of symptomatic cases. Screening, a preventive approach for testing individuals without symptoms, plays a critical role in early detection and has shown considerable success in reducing mortality for cancers such as cervical, breast, and colorectal. These cancers are now more often diagnosed at earlier stages, thanks to well-established screening programs.

However, effective early detection methods remain elusive for several cancers, including esophageal, pancreatic, and ovarian cancers, which are still commonly identified at advanced stages. The ongoing challenge is to replicate the success of early detection programs for these malignancies, improving survival rates and outcomes across a broader spectrum of cancer types.

This review delves into the current state of early detection methods, examining both screening initiatives and symptomatic detection approaches. It also highlights recent advancements and ongoing research aimed at refining early identification and intervention strategies in the fight against cancer.

LITERATURE REVIEW

CHIEF: A Versatile AI for Cancer Detection and Prognosis

CHIEF (Clinical Histopathology Imaging Evaluation



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Foundation) is an AI model developed by Harvard University. It make use of enhanced histopathology imaging for evaluating cancer's molecular and phenotypic profiles. It is trained on 44 terabytes of data containing 15 million images. CHIEF shines in multiple cancer detection, predicting necessary treatment outcomes, and survival rates. Its key instauration lies in its ability to scrutinize cancer microenvironments. It provides perception for previously unrecognized tumor properties due to which precision in medicine capabilities is increased.

Primary Aspects of CHIEF:

- Ability to evaluate 19 types of cancer.
- Combines phenotype and genotype evaluation for better accuracy.
- Predicts treatment responses and patient survival.

AI-Driven Cancer Detection via Biomarkers

This study surveyed the use of serum protein biomarkers and cell-free DNA for detecting cancer at early stage. It highlights the importance of combining AI in evaluating these biological biological markers. By leveraging realworld datasets, the study emphasizes cross-validation methods as key to ensuring models trustworthiness and precision. The challenges identified involve creating actionable predictive reports and integrating these intuitions into clinical workflows. The aggregate of biomarker data and artificial intelligence presents a hopeful chance to beautify early most cancers condition as long as overcoming arrangement challenging situations. Multi-most cancers Early Detection by way of Deep win knowledge of Deep knowledge procedures, mainly convolutional affecting animate nerve organs networks (CNNs), have rooted powerful sensitivity and particularity in detecting as well one cancers by account PET and CT image records. This study leveraged the spatial and textural traits of image records to apprehend diseased patterns during the whole of numerous most cancers types. by way of engaging supervised and almost-directed gaining information of methods, the version largely underrated false a still picture taken with a camera, through enhancing allure demonstrative accuracy, these results imply that deep disturb know foundations can support dependable and adaptable answers for the discovery of a couple of cancers.

EMethylNET: AI for Epigenetic Cancer Profiling EMmethylNET resolves DNA methylation patterns

to change between differing cancers. This intelligent model interprets epigenetic biomarkers, contribution valuable observations into cancer and disclosing earlier undiagnosed environments. One of allure key benefits is the incorporation of whole genome dossier, that simplifies early malignancy detection and acquired immune deficiency syndrome in the growth of embodied situation plans.

CancerGPT: Revolutionizing Cancer Knowledge Inspired with the aid of using ChatGPT, CancerGPT is deliberate to manner far-flung textual facts on malignancy research. It helps oncologists and researchers accompanying essences, currents, and actionable visions. Though normally passage-based, charm unification with specific AI finishes like CHIEF holds promise for combining numerous branches of getting to know applications.

AI in Screening Cancer Types

This comment concentrated at the utility of AI fashions at hand across exceptional and overlapping most cancers types by way of way of way of joining omics statistics accompanying depict modalities. The unification of those datasets more seductive diagnostic granularity and pronounced particular most cancers signs. These improvements should transform healing methods by way of way of wealth of giving exact, centered attacks for much less not unusual place most cancers types.

AI Method	Application	Key Benefits	Challenges
Serum Biomarker Analysis	Early detection via biomarkers	Non-invasive, robust	Data heterogeneity
Deep Learning (CNN)	Imaging analysis (PET/CT)	High sensitivity/ specific ity	Computational cost
Genetic Profiling	Predictive analytics	Comprehensive diagnostics	Real-world validation
Omics- Imaging Integration	Rarecancer detection	Improved granularity	Limited datasets

Table: 1 Summary of AI Models and Techniques

METHODOLOGY

This ponder points to upgrade cancer determination by coordination exchange learning from VGG16 and a Large Language Model (LLM) in a multimodal system. The strategy centers on the compelling combination of visual and printed information, leveraging progressed



profound learning strategies. Initially, PET filter pictures are collected from freely accessible datasets, such as The Cancer Imaging File (TCIA), and supplemented with private clinical datasets. The dataset was divided into training (70%), validation (15%), and testing (15%) subsets using stratified sampling to ensure equal representation of cancer cases and controls. Key hyperparameters were fine-tuned iteratively, the learning rate was initially set to 1×10^{-4} with a decay factor of 0.1 after 10 epochs, batch size was set to 16 to balance computational efficiency and model performance, and the Adam optimizer ($\beta 1 = 0.9, \beta 2$ = 0.999, ε = 1e-8) was used. The loss function employed was cross-entropy loss. To validate generalizability, the model's performance was tested using independent datasets, including publicly available PET scans from TCIA and proprietary clinical datasets. The preprocessing pipeline includes resizing the PET checks to a determination of 224 × 224 pixels, taken after by normalization to adjust the pixel concentrated values with the input necessities of VGG16. Each PET filter is combined with comparing symptomatic reports to set up a administered learning vectors. system. For highlight extraction, the pretrained VGG16 demonstrate, initially prepared on ImageNet, is utilized. The completely associated layers are evacuated, holding as it were the convolutional layers to create spatial highlight maps. These maps are straightened into highlight vectors F, which encapsulate the basic designs within the pictures:

 $F = VGG16(PET_scan)$

Dimensionality diminishment procedures, such as Principal Component Analysis (PCA) or auto encoders, are connected to F, coming about in decreased include representations $F_{reduced}$, which streamline computational prerequisites whereas protecting basic information:

 $F_{reduced} = PCA(F)$

These decreased visual highlights are combined with token embeddings extricated from the LLM, empowering a consistent integration of picture and content information. The combination handle utilizes either a cross-attention component or basic concatenation:

Input = [Text_tokens $|| F_{reduced}$]

The LLM, such as GPT-2, is fine-tuned on matched datasets comprising of symptomatic reports and picture highlights. Fine-tuning specifically overhauls the models weights, empowering it to handle both picture and content

inputs to create forecasts or point by point demonstrative reports:

 $Diagnosis = LLM([Text_context, F_{reduced}])$

Explainability is achieved through attention mechanisms that highlight significant regions of the PET scans, aiding clinicians in understanding the model's decision-making process.

Specifications

- VGG16: Utilized as the visual highlight extractor, pretrained on ImageNet, with its completely associated layers expelled.
- LLM: GPT-2, pretrained on a huge corpus, fine-tuned for restorative content era.
- Preprocessing: PET looks are resized to (224 × 224) pixels and normalized to guarantee compatibility with VGG16.
- Dimensionality Reduction : PCA is utilized to decrease the dimensionality of include vectors.
- Training :
- 1. Loss Function: Cross-entropy loss, defined as: $f = - \left(\sum_{i=1}^{N} y_i \log(y^{i}) \right)$
- 2. Optimizer : Adam Optimizer with the learning rate of 1×10^{-4} .
- 3. Batch Size : 16, ensuring computational efficiency
- 4. Epochs : 20, with early halting based on approval execution to avoid overfitting.

RESULTS AND DISCUSSION

The proposed technique joining VGG16 and Large Language Model (LLM) for cancer determination was assessed on PET check datasets sourced from The Cancer Imaging File (TCIA) and private clinical records. After preprocessing, the model was trained and tested , with results summarized as :

- Model Accuracy: exceeded VGG16 (85.2%) and LLM (78.9%) with a 92.5% success rate.
- Affectability and Specificity: 90.8% and 94.1%, reducing false-positive results.
- F1-Score: balanced recall and precision to achieve a score of 91.7%.

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• Explainability: highlighted important PET scan areas in accordance with clinical findings.

Model	Accuracy	Sensitivity	Specificity	F1- Score
SaMMed Only	85.2	87.6	83.4	85.0
Medclip Only	78.9	80.3	77.5	78.2
Multimodal Approach(VGG16 & LLM)	86.2	94.1	90.8	91.7

Additional, quantitative result included diagonostic reports created by the LLM, which appeared high alignment with human written reports. Sample attention maps and produced reports are visualized in Figure 1. The results highlight the viability of combining visual highlights from PET scans with printed embeddings through transfer learning. The proposed multimodal approach essentially moved forward symptomatic execution compared to single- modality models. Particularly, the utilize of dimensionality reduction strategies and cross- attention instruments optimized the feature integration, resulting in higher accuracy and interpretability.

Comaprison with other studies

- CHIEF: Improves the interpretability and scalability of multimodal data across cancer types.
- CancerGPT: Enhances image-text integration to increase precision and broaden its use.
- Smith et al. (2022) showed the advantages of multimodal learning by stating that the addition of textual material improved accuracy from 88.4% to 92.5%.

Scalability and Limitations:- Scalability

- Shows encouraging outcomes when applied to different cancer types, such as colorectal and ovarian.
- Compatible with the preprocessing pipeline already in use for CT and MRI modalities.

Limitations

- Depends on excellent annotated datasets.
- Training that uses a lot of resources needs to be optimized.
- For fairness, dataset biases (such as demographic imbalances) must be addressed.

CONCLUSIONS

This study introduces a novel multimodal framework combining VGG16 and a Large Language Model (LLM) to enhance cancer diagnosis. By integrating visual features from PET scans and textual diagnostic reports, the model achieves superior accuracy, sensitivity, and specificity, with enhanced interpretability through attention maps. The ability to generate detailed diagnostic reports and provide explainable predictions highlights its potential as a reliable AI-driven clinical tool. The approach's scalability and adaptability make it suitable for other diagnostic applications. Future efforts will address current limitations and explore its extension to additional imaging modalities and datasets, paving the way for advanced AI-assisted diagnostics.

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Artificial Intelligence based Knowledge Organizer for Diverse Data Formats

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ABSTRACT

This system addresses knowledge organization challenges by managing diverse data formats, including images, audio, and various document types like PDFs, DOCX, and PPTX. Its modular architecture ensures seamless updates, using "plugins" to connect with large language models (LLMs) and ingest heterogeneous data. Svelte enables a fast, responsive interface, FastAPI provides asynchronous capabilities, and Pinecone serves as the vector database for embedding management. Semantic search leverages embeddings generated by transformer-based models. Retrieval-augmented generation (RAG) utilizes a unified text-only intermediate format, enabling accurate representations of image content (with OCR), transcribed audio, and extracted document text. Chunking further optimizes retrieval. Applications range from organizing class notes and schedules for students to enabling research content retrieval for academics and facilitating document access for corporate users. User feedback indicates a 75% reduction in search times, with documents found within 30 seconds on average. User studies show a 95% + accuracy for retrieval. Currently a proof of concept, the system aims to evolve into a self-hostable solution, ensuring all computations occur locally for enhanced privacy in addition to support for video formats. This work represents a significant advancement in efficient, scalable knowledge management for diverse data formats.

KEYWORDS : Knowledge management, Information retrieval, Semantic search, Natural language processing, Machine learning.

INTRODUCTION

The exponential growth of digital information in recent years has created significant challenges for individuals and organizations in efficiently managing, accessing, and utilizing data. As the volume and diversity of information continue to increase, traditional methods of data organization and retrieval struggle to meet the demands of modern users. This challenge, commonly referred to as information overload, affects productivity and decision-making across personal, academic, and corporate domains.

Previous studies have explored various approaches to knowledge management, including semantic search, machine learning, and AI-powered tools. While these solutions have improved information retrieval to some extent, they often lack the ability to effectively integrate diverse data types or provide intuitive, user- centred access. This highlights a critical gap in the development of tools that not only organize vast amounts of information but also ensure seamless retrieval and utilization, tailored to different contexts.

To address these gaps, this paper introduces AIKO (AIpowered Knowledge Organizer), a web-based system designed to simplify the organization, access, and use of information the proposed system leverages advanced natural language processing and modular technologies to enhance data retrieval while reducing search times.

Developed as part of a final-year Bachelor of Technology project at Government College of Engineering, Nagpur, India, the proposed system offers significant applications in personal, academic, and corporate knowledge management. The aim of this study is to present the design, development, and deployment of the proposed system, demonstrating its potential to transform information handling and retrieval.



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LITERATURE REVIEW

The development of knowledge management systems capable of handling diverse data formats has garnered significant attention in recent years, owing to the widely known paper "Attention is all you need" [1]. Enhancements in Large Language Models and semantic search technologies have bettered the ability to improve information retrieval further. This review summarizes relevant works, examining some approaches to information retrieval and augmentation.

Recent advancements such as AssistRAG enhance LLMs with retrieval-augmented generation (RAG) capabilities by employing intelligent information assistants [2]. The paper also describes the pitfalls and shortcomings of the earliest "Retrieve-Read" techniques, prompt-based RAG techniques and Supervised Fine-Tuning (SFT) methods. To cope with these challenges, AssistRAG proposes an Assistant-based Retrieval Augmented Generation, which integrates newer use cases like tool-use to improve upon the previous techniques. Similarly, the ZeroG knowledge engine proposes a two model system to ground retrieval in validated sources. [3]. A case study on biodiversity publications demonstrated improved search relevance when integration LLMs with structured indexing methods [4].

Efficient information retrieval relies heavily on embedding representations and vector databases. Research on nearest neighbor search (NNS) in high- dimension spaces reveals that NNS is resilient to the "curse of dimensionality" [5]. Additionally, the paper explains the irrelevance of choice of the distance function and proposes methods for further optimization of dense vector-related applications.

Furthermore, LLM-powered query generation along with NNS over the available tools allows for better retrieval statistics [6].

Challenges in ensuring factual accuracy and usability in search systems have been identified [7, 8]. While these insights are tangential to our primary focus, they highlight user-centric considerations crucial for adoption. Similarly, grounding hypothesis generation in reliable knowledge remains an ongoing challenge for all systems leveraging LLMs for information retrieval [9].

Existing research provides a robust foundation for the development of a modular, AI-powered knowledge organizer. By integrating insights from semantic search, vector database efficiency, and modularity, this system addresses the unique challenges of managing diverse data formats. While promising advancements have been made, the need for self-hosted solutions and improved user interfaces remains a future direction for exploration.

METHODOLOGY

The methodology for implementing the proposed system followed a structured Waterfall approach [10], with distinct phases enabling systematic development and validation of each subsystem. Rather than detail standard development practices, we focus on the novel architectural decisions and custom implementations that distinguish our system.

A notable deviation from standard practices was our decision to develop a custom LLM communication stack rather than utilizing LangChain. This decision was driven by the need for lower-level control and enhanced performance requirements. The custom implementation leverages WebSockets for communication, enabling efficient real-time data streaming while maintaining the system's stateless nature. The backend, developed in Python 3.12.6 [11], employs a novel plugin architecture that allows for seamless integration of new data connectors and transformation logic. This plugin architecture allows for the proposed system be very extensible while still maintaining the developer and user experience.

The models are used as-is from the respective vendors, with the system providing a unified interface for the models. The content ingested into the system is passed through a simple filter to remove unnecessary punctuation and limit the context window.





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Fig. 1 shows the process of ingestion of various supported documents. We begin by separating the entity by content type, images are first passed into a vision language model such as QwenVL [12] with a custom prompt to extract as much detail as possible from the images. The audio is passed through to a model capable of extracting text from the audio sample [13]. The text is extracted from the input and then chunked and embedded using a high-dimensionality embedding model [14]. The resulting embeddings are stored in a vector database for efficient querying. The original source is saved in a storage medium and the identification number used to save the vectors, indexing with the chunk number. This maintains a two-way link between the saved source document and its embedded vectors.

The retrieval flow utilizes simple NSS to fetch the relevant vectors, and the link is used to fetch the metadata for the original document. These are presented to the user for further interaction.

Incase of retrieval-augmented-generation, the output chunks are used as part of the input prompt to a LLM with a large context window. The novel plugin and transformational logic allows for multiple LLMs to have a common interface with the proposed system. We use OpenAI's APIs as a reference and modify the data structures for use with other LLMs.

The system was built using a modular architecture, with each module responsible for its own functions, and connected to others using a strict interface. Each module was responsible for its own initialization, and is easily extensible and replaceable. Each part of the system can be independently scaled as per usage.

The proposed system was built as a proof- of-concept system to test the feasibility of a personalized knowledge management system with AI-powered features. The system was deployed as a technical preview, with user feedback collected. The highlights of user feedback are presented in the following section.

Experimental Setup: In this paper, we evaluate the application of such a proposed system for efficient knowledge management. We understand that such retrieval tasks have subjective performance metrics and utilize user feedback to gauge the effectiveness of the system.

Participants were recruited through voluntary self-selection from the undergraduate student population of Government College of Engineering Nagpur, specifically targeting students within the Computer Science & Engineering branch. All students within the branch were invited to participate in the study, with participation being entirely voluntary and free from any academic or institutional pressure. The participant pool consisted of college students, aged 20 to 24, with a balanced representation of gender. The experimental period consisted of the penultimate semester, wherein students are asked to create a "Mega-Project" as part of the academic requirements. All participants were anonymized for the survey to prevent any bias during the evaluation of subjective questions.

Participants were tasked to keep note of the references, documents, images, and any other relevant pieces of info saved using their usual methodology for creation of the project synopsis. This comprises the baseline experience.

Participants were asked to use the proposed system during creation of the final report for the "Mega- Project". The feedback was gathered through a form with both general and specific questions.

The survey includes both qualitative and quantitative questions, with participants asked to rate their experience on a scale of 1 to 5, with 1 being the lowest and 5 being the highest. Participants were asked to rate the system's various features along with their overall satisfaction with the system. The survey also included open-ended subjective questions aimed at gathering detailed feedback on the difficulties faced, most useful feature, and suggestions towards improvements.

RESULTS AND DISCUSSION

Main Result: The user interface for the system was built using Svelte [15], TypeScript [16] and TailwindCSS [17]. The backend was built using Python [11], FastAPI [18] and the APIs for the various LLMs.

Fig. 2 gives a overlook of the user interface for the proposed system. The user interface is completely decoupled from the backend and only uses APIs to communicate with it.

The backend contains the logic for the ingest, retrieval and retrieval-augmented-generation flows. It connects the various components into one accessible endpoint. The plugins are active on the backend and dictate the LLMs as well as the files that can be understood by the system.

Current limitations include the inability to handle video formats, and documents with embedded graphics, such as charts and graphs. The system is also unable to handle



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scanned documents as PDF files. The intermediate representation being a text-only format limits the amount, quality and medium of information that can be processed through the system at any given time-step.



Source: Screen capture from https://aiko.parapalli.dev Fig. 2: Dashboard User Interface

Feedback Results: The feedback gathered after the use of the proposed system gave a few interesting observations.

The proposed system was instrumental in efficiently locating and retrieving the relevant pieces of content from the user's personalized corpus. The addition of retrievalaugmented-generation allowed for chat based interaction with the documents, allowing for various tasks that would have required the user to first obtain the document and then load it into a platform which supports the media and then proceed to accomplish the task. Tasks such as Query Answering, Summarization were able to be accomplished in under a mean time of 30 seconds while in the normal flow it would have taken the user a mean time of 2 minute 30 seconds.

Manual testing with Wikipedia documents of various topics and lengths demonstrated an accuracy of 97% on first query and 99% after refining the query.

Quantitative analysis of user feedback revealed strong performance metrics, with search accuracy and core features averaging 4.83/5.0. System response times were efficient, with 83.3% of users receiving results in under 3 seconds. The system demonstrated substantial time savings, with 33.3% of users saving over 2 minutes per search operation. User satisfaction was notably high, reflected in a Net Promoter Score of 9.50/10.0 and an overall experience rating of 4.67/5.0.

CONCLUSIONS

The proposed system demonstrates significant potential in revolutionizing document interaction and information retrieval in academic settings. The consistently high satisfaction ratings across users of varying technical proficiency suggests that AI-powered document management systems can effectively bridge the gap between complex information processing and userfriendly interfaces. The notable time savings reported by users (over 2 minutes per search) points to substantial productivity gains possible through AI-augmented document interaction.

Future directions for this research include several promising avenues. First, expanding support to include video formats would broaden the system's multimedia capabilities. Second, developing a fully self-hostable version would address privacy concerns and enable offline usage, particularly important for sensitive corporate or academic environments. Third, integrating more sophisticated document comparison and version control features could help track the evolution of knowledge over time. Finally, developing domain-specific plugins or data connectors for specialized fields like legal, medical, or technical documentation could enhance the system's utility in professional settings.

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Machine learning algorithm for High-Speed Face Recognition Based on RBF Neural Networks and Discrete Cosine Transform

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ABSTRACT

When it comes to biometric identification systems, face recognition has grown in importance due to the need for fast and accurate results in real-time applications. By merging Discrete Cosine Transform (DCT) feature extraction with Radial Basis Function (RBF) Neural Networks, this study introduces a new method for rapid face identification. By applying the DCT to face photos, we may decrease the data's dimensionality and compress it while keeping the most important facial traits, which are crucial for person identification. In order to classify the face data effectively, the RBF neural network is fed the reduced feature set obtained from the DCT. The RBF network is well-suited for rapid identification because to its quick convergence and capacity to process non-linear input. The network parameters are initialized using unsupervised learning, and the classification limits are fine-tuned using supervised learning; this two-phase training strategy is used to improve performance. When compared to more conventional approaches to face recognition, the suggested system performs far better in terms of both speed and recognition rates across a number of benchmark face datasets. Because of this, it shows promise as a real-time biometric solution for surveillance, access control, and security systems—anywhere speed and reliability are paramount.

KEYWORDS : High-speed face recognition, Discrete Cosine Transform (DCT), Biometric authentication, Feature extraction, Radial Basis Function (RBF), Neural Networks.

INTRODUCTION

S ecurity, access control, surveillance, and identification systems may all benefit greatly from face recognition, a popular and extensively used biometric technology. It has several potential uses, including in mobile device authentication, social networking, border control, and law enforcement. Even though there have been a lot of successful face recognition systems, there are still problems with finding the right balance between accuracy, speed, and computing economy. This is particularly true in real-time applications where reaction times are crucial. Methods that can give high accuracy with minimal latency are in great demand because to the proliferation of biometric devices. When dealing with high-dimensional data, like face photos, traditional machine learning approaches encounter computational complexity and processing time limits, notwithstanding their robustness. Here, an optimal face recognition method in terms of both speed and accuracy is required for identification. Discrete Cosine Transform (DCT) and Radial Basis Function (RBF) Neural Networks are combined in this study to produce a new method for fast face recognition. In order to achieve accurate identification, this hybrid technique aims to maximize computing efficiency while maintaining key face traits. This system simultaneously accomplishes rapid processing and accurate identification by using



DCT's picture data compression capabilities and the RBF network's quick learning capabilities.

Addressing the trade-offs between computing speed and identification accuracy in face recognition systems is the fundamental motivation behind this project. When running in real-time with minimal latency, traditional face recognition methods such as convolutional neural networks (CNNs), Eigenfaces, and Fisherfaces may not be the best choice due to their computational expense. In addition, applications that need immediate response should not use raw face photos because of the lengthy processing requirements caused by their dimensionality. An well-known method for compressing images, Discrete Cosine Transform (DCT) breaks down spatial picture data into its component frequencies. Data Conversion Tool (DCT) decreases data dimensionality while keeping essential information by keeping just the most important frequencies. Because of their rapid training time and capacity to represent complicated, non-linear connections, Radial Basis Function (RBF) neural networks, in contrast, have shown significant potential in classification tasks. For effective face recognition in time-sensitive situations, combine DCT for dimensionality reduction with RBF neural networks for quick classification. For real-time biometric systems, our study intends to prove that this combination may drastically save calculation time without sacrificing accuracy.

Mathematically, a finite series of data points may be expressed as a sum of cosine functions oscillating at various frequencies using the Discrete Cosine Transform (DCT). Because it condenses the majority of a picture's visually important information into a small number of low-frequency components, DCT is an excellent data compression tool for image processing. picture DCT helps convert pixel intensity values to a frequency domain, where a small number of coefficients may represent most of the picture information, decreasing computing effort.

By eliminating higher-frequency components (containing less important information like noise), DCT helps improve face recognition by reducing the dimensionality of facial pictures. This method improves computing efficiency without drastically reducing accuracy by letting the algorithm zero in on the most important face traits. In this way, the feature vectors obtained using DCT may reduce processing time and memory needs while still effectively representing the facial picture.

An artificial neural network called an RBF neural network

employs radial basis functions (RBFs) as its activation function. Due to their proficiency in approximating nonlinear functions, these networks excel in classification problems. In a typical RBF network, the three layers are as follows: an input layer, a hidden layer that applies the radial basis functions, and an output layer that makes the final classification decision..

The RBF network is typically trained in two phases:

- 1. Unsupervised Phase: In this phase, the centers of the radial basis functions are initialized using clustering techniques like k-means. This process helps organize the data points in a meaningful way within the input space.
- 2. Supervised Phase: In this phase, the weights connecting the hidden layer to the output layer are optimized using a supervised learning approach like gradient descent.

RBF neural networks are known for their fast convergence rates and strong performance on non-linear data, making them ideal for face recognition tasks where the decision boundaries between different classes (i.e., different individuals) may be complex.

When combined, the strengths of DCT and RBF neural networks form a synergy. In order to make the highdimensional facial picture data more manageable, the DCT isolates the most useful components. Then, the RBF network uses these features to classify the data rapidly and reliably. With DCT as a preprocessing step, the input size of the network is significantly decreased, which enables the RBF to do quicker calculations during recognition. Along with the precision and speed required for real-time applications, this combination guarantees that the system can manage the difficulties of high-dimensional face data.

Many methods are used in classical face recognition during the classification stage. These include decision trees [25], support vector machines (SVM) [24], and closest neighbour [23]. In contrast to support vector machines (SVMs), which use visual similarity to determine classification [20], nearest neighbour algorithms (NN) use hyperplanes to maximize the margin between classes [24]. When it comes to face feature-based picture classification, decision trees use a hierarchical approach [25]. Classical methods, on the other hand, aren't very good at dealing with occlusions like sunglasses, hats, or facial hair, which may mess with feature extraction and impact classification accuracy [2, 3, 26]. On top of that, conventional



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approaches may fail to adequately identify low-quality or noisy pictures [2, 3]. Because of the dramatic accuracy gains made possible by deep learning, face recognition has been a game-changer in recent years [2, 3]. Notable results in face feature extraction and classification have been achieved using deep neural networks, including CNNs, in previous studies [14], [27], [28]. The use of many convolutional and pooling layers allows CNNs to automatically learn high-level face representations. When it comes to face recognition, deep learning is superior because it can learn complicated features from raw data without requiring human intervention in feature extraction [2, 3, 26]. Not only that, but deep learning models can handle changes in lighting, facial emotions, and posture, as well as detect minute changes in face appearance. But deep learning's biggest drawback is that it needs a lot of labeled training data [2, 3, 26]. To get the most out of deep neural networks during training, you need a large dataset of tagged faces. A large data collection like this may be costly and time-consuming to collect and annotate. An often-used strategy for dealing with this problem is to integrate deep learning with more conventional feature extraction methods. This integration incorporates the use of conventional techniques to derive characteristics from face pictures, which are then inputted into a deep neural network for the purpose of classification [3]. Take use of deep learning's representational strength and classic feature extraction techniques' resilience and interpretability using this hybrid methodology [3-32]. Backpropagation neural networks (BPNNs) and correlation-based feature extraction were specifically suggested as a better method for human face recognition in [29]. A new data set (T-data set) is also investigated, as is the usage of the local binary pattern histogram (LBPH) descriptor. Despite the fact that the article claims lower computing cost and improved accuracy as a result of using less picture characteristics. On the other hand, doing tests on large data sets may be difficult due to the decreased computing efficiency caused by using five combined distance measuring techniques to create the T-data set. As a method for face recognition, the authors of [19] zeroed in on an approach that merges PNNs with an enhanced variant of kernel linear discriminant analysis (IKLDA). The use of deep learning (CNN) and the DCT to face recognition is investigated by Setiawan, Sigit, and Rokhana in [15]. It delves into the effects of activation functions and epochs, although using CNNs might cause complex data structures and boost computing cost for classification jobs. The authors laid forth a plan in

[31] that calls for smart eyewear to do face recognition. By using CNNs and image processing methods, they were able to train a pretrained multilayer network called AlexNet via transfer learning. Although this framework has several nice features, including being portable and being able to record frontal views well, using the complex AlexNet network would need powerful hardware. We provide a new method to improve the efficacy and precision of facial recognition systems in this article. This method integrates ANN using the popular backpropagation algorithm with the DCT pyramid decomposition approach. Making the most of the benefits provided by these two methods is, therefore, our primary goal. We demonstrate that this results in a face recognition system that is both very resilient and efficient with few memory needs. Building upon the DCT pyramid decomposition technology, our approach is solid. This method separates the face picture into several frequency bands, allowing it to capture low- and high-frequency details. We can increase the face recognition system's discriminative capacity by extracting a rich collection of features using this decomposition. It is also resistant to changes in lighting, attitudes, and poses because to the pyramid structure, which lets us effectively represent the face data on various sizes. Decomposing the DCT pyramid to efficiently represent face information might lead to enormous vector dimensions, however. For this reason, we use statistical metrics like entropy, variance, and mean to effectively reduce the dimensionality of the feature vectors without losing any of the important information they contain. With the addition of an ANN, our system's recognition accuracy is significantly improved. Our training technique of choice is a multilayer perceptron design with backpropagation, which has been shown to be successful in other studies [2, 3, 19, 24]. It is the goal of the training process to teach the neural network the intricate connections between the identified characteristics and their respective identities. Improved accuracy in face identification and verification is achieved by the network's iterative learning process, which adjusts internal parameters to optimize recognition performance. In order to make sure the system uses resources well without compromising accuracy, we meticulously plan the integration of the DCT pyramid decomposition and the artificial neural network. Being memory efficient is just one more way our method excels. This becomes much more critical in practical contexts, such embedded systems or mobile devices, where memory limitations play a pivotal role [2, 3].



LITERATURE REVIEW

Muhammad Sohail et al (2024) Due to the complex nature of pose equalization and face rotation, current methods for multi-position human face matching provide less than ideal results. The suggested deep learning models for these complexity, such YOLO-V5, etc., have poor face recognition accuracy due to sluggish frame matching rates. In this regard, there is some research that has looked into human face identification algorithms with many poses; however, these studies are rather basic and fail to critically examine the systems' usefulness. We provide a YOLO-V5-based real-time face matching system to address this knowledge vacuum. The results of the experiments show that the algorithm is successful in the face-matching paradigm, with better accuracy and decreased time.

Zhizhong Huang et al (2023) In order to accomplish identity-level FAS, the authors have suggested a new identity conditional module. This module may enhance the age smoothness of synthetic faces by using a weightsharing technique. via the suggested multi-task framework, we increase AIFR via a new selected fine-tuning method by making use of FAS's high-quality synthetic faces. In addition, we have developed a new standard for locating long-lost children and released a massive cross-age face dataset annotated with age and gender in order to push AIFR and FAS forward. Results from a battery of experiments on five standard cross-age datasets show that MTLFace outperforms the current gold standard for AIFR and FAS.

Bei Fang et al (2023) This systematic review, in contrast to others, thus summarises two types of facial expression recognition-based instructional research methodologies and the settings in which they are used. The next step is to provide a comprehensive framework, which includes many machine learning algorithms and publicly available datasets. We conclude by outlining the most pressing issues with expression ambiguity and facial occlusion. This paper seeks to provide a comprehensive overview, from a machine learning standpoint, of facial expression identification algorithms used in educational research.

Yupeng Zhu et.al (2023) The authors suggest a decouplingcontrastive learning (DDCL) technique that uses denoising to recover benign features from synthetic data. The system uses the contrastive learning method to extract robust features from both synthetic and real photos by creating a two-branch siamese network. Afterwards, the identity identification process begins with the bidirectional coding-based feature decoupling module filtering out characteristics of synthetic pictures. Our technique achieves the maximum identification accuracy for both synthetic and natural data, mitigating the detrimental effect of synthetic face photos, according to the experimental findings.

Mehrdad Kaveh et al (2022). This work has taken a look at the current state of MH algorithm integration into DL and ANN approaches, weighed the pros and cons, and suggested some future research routes to bridge the gap between the two fields. Additionally, it has been said that there is still a lack of practical use for evolving hybrid architecture in academic circles. In order to show how successful they are in training DL and ANN for different applications, this research also sorts the most recent MH algorithms in the literature. In order to maximize the hyperparameters of DLs and ANNs, the majority of researchers develop unique hybrid algorithms by mixing MHs.

Jaehun Park et.al (2021) The use of deep learning has led to remarkable advancements in face recognition, emotion classification, and face attribute classification during the last ten years. The driving reason behind this expansion has been large-scale data acquired from multiple consumers. However, when combined with other sensitive biometric data, facial photographs that reveal the owner's identity may lead to serious privacy breaches. This paper proposes a new approach for reducing coefficients from discrete cosine transforms (DCTs) called discrete cosine transforms (DCCs). This method combines pixelization with DCTs to ensure that the picture remains private. Nevertheless, privacy is relative, and there's no assurance that the altered picture will maintain confidentiality. This was remedied by conducting a user survey to see whether DCC effectively protects privacy. In order to achieve this goal, convolutional neural networks were taught to recognize faces and classify their attributes. Based on the results of our survey and studies, it is possible to train a deep learning model for face recognition using pictures that people believe protect privacy while still achieving manageable classification accuracy.

METHODOLOGY

Many fields have begun to use multiresolution approaches, such as feature extraction, compression, and coding, among others. Decomposing an input picture into several levels of approximations and details, the discrete cosine transform (DCT) pyramid is one way to do multiresolution decomposition. Following is the basic procedure for using



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blockwise DCT decimation to accomplish a one-level DCT pyramid decomposition. The first step is to split the input picture into N×N chunks. Afterwards, the N×N forward DCT is used to alter each block. The IDCT is applied to the M×M low-frequency components of the converted block after being scaled by a factor of M/N. The required down sample size is represented by M < N in this context. This procedure produces a reduced version of the initial block, referred known as the "corner," meaning that the original N×N block is decimated into a reduced resolution M×M corner. Furthermore, an inverted L-shape structure is formed by the remaining high-frequency components, which stand in for the original block's minute features. The approximation subband, a reduced-resolution rendition of the input picture, is built by collecting the corners in the sequencing of their matching original blocks. On the flip side, the details subband, which includes the input image's high-frequency components, is formed by the resultant inverted L-shapes. A detailed subband consisting of all the generated inverted L-shapes and a low-resolution version with decreased dimensionality by a factor of M/N are produced by the DCT pyramid.

There are many phases to the suggested facial recognition system, including preparation, detection of faces, extraction of features, and categorization. The Viola-Jones classifier [33] is used to trim each face to its proper size before reliable face identification can take place. Then, in order to extract the feature vector, the DCT pyramid method is fed the resized identified face, which should be 80 by 80 pixels. We use statistical metrics like entropy, variance, and mean to bring the feature vector down to a more manageable dimensionality. Next, the relevant ID in the face gallery is linked to the reduced vector that has been generated. In order to classify the subjects, a neural network is taught to differentiate between them using the feature vectors. The suggested method is graphically shown in Fig. 1, which is a detailed block diagram. The following subsections provide more in-depth descriptions of each stage of this method. During the preprocessing stage, photos of faces are resized to fit them using Haar-cascade face detection [33]. This technique of face identification uses a combination of efficient computing and machine learning to get accurate results. Face recognition programs have made extensive use of it [1]. Rectangular filters applied to the picture at various sizes and locations are known as Haar-like features, and the algorithm makes use of them. Features like edges, corners, and roughness are able to record patterns of intensity fluctuations in images.

The approach then makes advantage of integral pictures to quickly and efficiently calculate features similar to Haar's using basic arithmetic operations. A representation of the original picture, an integral image takes the value at each pixel and adds it to the intensities of all the pixels in a rectangle area starting at the top left corner of the image [33]. Additionally, the approach trains a classifier using Adaboost, a machine learning technique [33]. One way to improve a classifier's performance is to use an ensemble learning technique like Adaboost [33]. To train, the algorithm finds the optimal Haar-like features and thresholds for face/nonface discrimination in the training data. The taught classifier is structured as a series of classifiers, with each successive classifier trained to be more sophisticated and precise than its predecessor. In order to decrease the computing cost of the technique, the cascade is intended to rapidly reject parts of the picture that are unlikely to contain a face. By scanning the input picture with a sliding window at multiple sizes and places, the algorithm applies the learned cascade. The presence or absence of a face is determined at each window by applying the cascade of classifiers after computing Haar-like features using integral pictures. It is said to be a detection [33] if every classifier in the cascade labels a window as a face. Each picture is downsized to 80 by 80 after the face detection stage so it may be used in the previously mentioned DCT pyramid decomposition..



Fig. 1. Block diagram of the proposed face recognition system

During the preprocessing stage, photos of faces are resized to fit them using Haar-cascade face detection [33]. This technique of face identification uses a combination of efficient computing and machine learning to get accurate results. Face recognition programs have made extensive



use of it [1]. Rectangular filters applied to the picture at various sizes and locations are known as Haar-like features, and the algorithm makes use of them. Features like edges, corners, and roughness are able to record patterns of intensity fluctuations in images. The approach then makes advantage of integral pictures to quickly and efficiently calculate features similar to Haar's using basic arithmetic operations. A representation of the original picture, an integral image takes the value at each pixel and adds it to the intensities of all the pixels in a rectangle area starting at the top left corner of the image [33]. Additionally, the approach trains a classifier using Adaboost, a machine learning technique [33]. One way to improve a classifier's performance is to use an ensemble learning technique like Adaboost [33]. To train, the algorithm finds the optimal Haar-like features and thresholds for face/nonface discrimination in the training data. The taught classifier is structured as a series of classifiers, with each successive classifier trained to be more sophisticated and precise than its predecessor. In order to decrease the computing cost of the technique, the cascade is intended to rapidly reject parts of the picture that are unlikely to contain a face. By scanning the input picture with a sliding window at multiple sizes and places, the algorithm applies the learned cascade. The presence or absence of a face is determined at each window by applying the cascade of classifiers after computing Haar-like features using integral pictures. It is said to be a detection [33] if every classifier in the cascade labels a window as a face.

RESULT

The images are reduced to 80 X 80 following the face detection step so they are ready for the DCT pyramid decomposition, as was discussed before. The preprocessed 80x80 face image is immediately subjected to feature extraction using a two-level DCT pyramid, which entails two stages of decomposition. Setting the block dimension N to 8 and the sample size M to 4 allows for this decomposition to take place.

First, the decomposition process generates an approximation band with one hundred (MXM) corners and one hundred inversed L-shapes. Next, the second step of decomposition provides 25 (MXM) corners and 25 inverted L-shapes. These 25 corners effectively depict the facial picture's low-frequency subband, while the 25 inverted Lshapes encapsulate the mid-frequency subband. In contrast, the inverted L-shapes generated in the first decomposition stage include the high-frequency subband

of the facial image. These low-, mid-, and high-frequency sub bands allow us to understand everything about the input image's features by merging its full frequency spectrum. On the other hand, using these sub bands as inputs to a classification system would need a lot of data processing power. We propose reducing the dimensionality of the low-frequency subband using statistical metrics such as the variance, entropy, and mean of each corner to circumvent this problem.

CONCLUSION

This research presents a fast and accurate method for face recognition using Discrete Cosine Transform (DCT) for feature extraction and RBF Neural Networks for classification. In order to make it work in real-time applications, the DCT successfully lowers the input data's dimensionality while keeping important discriminative properties. The RBF neural network guarantees quick and accurate face data categorization because to its fast convergence characteristics and capacity to handle nonlinear connections. Maximizing recognition rates with little computing cost, the two-phase training technique improves the RBF network's performance. The first phase involves unsupervised learning for parameter initialization, while the second phase involves supervised fine-tuning. The suggested approach outperforms conventional face recognition techniques in terms of speed and accuracy, as shown experimentally on benchmark face datasets.

- 1. Preprocessed Image Matrix: 128×128128 \times 128128×128 values.
- DCT Coefficients: m×nm \times nm×n values (e.g., 1024 for 32x32).
- Feature Vector: Reduced dimensionality vector (e.g., 50 values).

RBF Neural Network Parameters:

- Centers c: k×Feature vector size(10x50)
- Weights: Hidden neurons×Output classes

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Detecting Lung Cancer Histopathological Images with a Reliable Machine Learning based Approach Utilizing Convolutional Neural Network

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ABSTRACT

The vital relevance of precise tumor categorization for prompt diagnosis and efficient treatment planning is underscored by the fact that lung cancer is still one of the top cancer-related killers globally. Medical image analysis tasks, such as tumor classification, are now dominated by deep learning methods. But, input picture quality—which could be compromised by noise, artifacts, and inadequate contrast—heavily affects how well deep learning models function. Here, we provide a new method for enhancing pictures using deep learning and hybrid particle swarm optimization (PSO) to better classify lung tumors. Image augmentation and tumor categorization are the two primary components of the suggested approach. To improve the quality of the photos, a powerful convolutional neural network (CNN) is taught to distinguish between low- and high-resolution pictures of lung tumors. Lung tumor photos may have their contrast, sharpness, and general quality improved by using a CNN architecture that efficiently captures both local and global picture information. By using its global search capabilities to explore the possible solutions more effectively, a hybrid method known as PSO is used to fine-tune the CNN model's parameters, further optimizing the improvement process.

KEYWORDS : Lung tumor classification, Convolutional Neural Networks (CNN), Hybrid particle swarm optimization (PSO), Noise reduction in medical imaging, Computer-Aided Diagnosis (CAD).

INTRODUCTION

mong the many cancers that cause illness and death, Alung cancer is one of the most pressing global public health issues. It is essential to diagnose lung cancers early and accurately in order to plan therapy effectively and improve patient outcomes[1][2]. In order to diagnose and characterize lung cancers, medical imaging methods like computed tomography (CT) and magnetic resonance imaging (MRI) are crucial. But, the intrinsic limitations of these imaging modalities, such as noise, artifacts, and inadequate contrast, might make it difficult to assess and analyze tumor shape. Medical image analysis has recently been greatly enhanced by deep learning, which has the ability to automate and improve many parts of the diagnosis process. Picture segmentation, feature extraction, and classification are only a few examples of the impressive achievements made by convolutional neural networks

(CNNs). In order to accurately identify and classify tumors, CNNs must learn to construct hierarchical representations of picture data. This allows them to grasp intricate patterns and connections. Despite their usefulness, deep learning models' output is very dependent on the picture quality fed into them. Unreliable or erroneous predictions might result from low-quality photos that make it difficult for CNNs to extract useful information. So, picture enhancing methods are desperately needed to raise the bar for medical picture quality, especially for lung tumor classification. On a global scale, lung tumors are among the leading killers[3][4]. There are more persons killed by lung tumors every year than any other kind of malignancy. The terrible thing is that this illness doesn't only impact guys. Since their diagnosis, patients with lung tumors have had a relatively short life expectancy. Urine tumors should be identified promptly because patients have a greater



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chance of surviving if the operation is performed while the illness is in its early stages. Therefore, new methods may be used to image processing and machine learning to get the right and quick outcome[5]. A higher degree of accuracy may be achieved by making use of more copies of the process. Improved survival rates may be achieved with earlier tumor identification and prediction. Previous methods include computerized tomography scans, magnetic resonance imaging (MRI) pictures, and mammography. Surgery, radiation therapy, chemotherapy, immunotherapy, and other forms of treatment are used to address lung tumors. However, this isn't enough to make the lung tumor detection method extremely trustworthy; the illness can't be diagnosed until it has progressed to a significant stage. Effective monitoring may reduce death rates, but only if detected early, before the last stage. The prognosis for lung tumor survival is promising even when treatment and diagnostics are appropriate. Patients with lung tumors have varying chances of survival. A person's age, gender, ethnicity, and health all play a part[6]. Early detection and prognosis of medical conditions in humans are areas where machine learning is showing promise. Through the use of machine learning, the diagnostic process may be both streamlined and improved[7].



Fig. 1. Lung Anatomy in CT Scan

The purpose of processing raw pictures generated by scanning modalities is to enhance their visual appearance for the purpose of better analysis and diagnosis. In medicine, imaging is the study and creation of imaging tools that can detect and classify organs and tissues according to their unique characteristics, as well as uncover previously unknown features of tissues and underlying systems that are otherwise concealed by external factors like skin and bones. Segmentation, enhancement, and classification are image processing methods that provide superior results. The DICOM format is typical for medical pictures. These picture formats need more storage space due to their enormous file sizes[8]. The DICOM image analysis procedure is time-consuming and laborious. These photos are transformed into JPEG, BMP, TIFF, and PNG file formats for the sake of analysis and mobility. All throughout the globe, people are using these transformed photographs in one of the aforementioned file formats. Characteristics Derived from a Lung Cancer An image's features are its most salient pieces of information that allow for a deeper comprehension of the picture. When it comes to medical image analysis, feature extraction is king. It helps doctors save time and make better diagnoses. These features, which are collected from tumors for examination, are presented below: texture, geometric shape, and shape[9].

Texture Features: In order to modify, compare, and change textures, it is more vital to construct a broad, efficient, and compact quantitative description of textures using a variety of mathematical operations. Each texture class is described here according to its characteristic measurements, which include size, standard deviation, minimum, maximum, mean, and sum of pixel values[10][11].

Geometric Features: In contrast to pixel-based measurements, object-based image analysis makes use of features that indicate the geometric properties of an item. Features such as contrast, correlation, and variation may be found in many shapes and sizes, including corners, edges, blobs, and ridges[12]

Shape Features : An essential and fundamental visual aspect for characterizing picture content is the tumor's form. Finding a tumor in a comparable picture and describing its form relies heavily on shape cues. Among the characteristics of shapes are their forms, translation, rotation, scaling, and reflection[13][14].

F Filtering involves increasing low frequencies or suppressing high frequencies in order to change or smoothen a picture. This is achieved by highlighting or erasing certain aspects of photos. The purpose of image segmentation is to identify certain features and regions within a picture[15][16].

Known as unexplained variance in data, medical pictures are often skewed by noise and random intensity changes.



Because the input medical pictures are produced by electronic devices, noise is certain to be there. One common application of filters is to reduce or eliminate background noise in images. You may apply filters directly on recorded pictures; they change the value of pixels by taking nearby pixels' values into account as well. As a first step in subsequent processing steps like segmentation, filters help in visual interpretation of pictures[17][18].

Segmenting a picture into many sections with shared characteristics is called image segmentation. The process of segmenting a picture into discrete and continuous areas is an essential part of automated image analysis. Prior to the improvement process, medical pictures may be segmented to save execution time while improving quality. Segmenting an image is drawing lines within the picture to isolate certain objects or features[19]. The tedious task of manually contouring the structures cannot be avoided without automated approaches. This procedure is quite challenging when dealing with lung cancers. The majority of tumors do in fact seem different, and the range of intensities shown by them is similar to that of healthy tissues. Both the original CT lung picture and the segmented version are shown in Figure 2.



Fig. 2 (a) CT Lung Image, (b) Segmented Image

Image enhancement is the process used to improve the visibility and perceptibility of specific regions in an image for analysis. It does not increase the inherent information in data. The goal of image enhancement includes, removing various types of noise from image; enhancing the contrast among adjacent regions; simplifying the image by selective smoothing. Image enhancement is usually followed by detection of features such as edges and other geometric features which is important in low-level vision

LITERATURE REVIEW

In order to identify lung cancer using CT scans, Chaubey et al. (2020) used image processing and soft computing techniques. One method for pre-processing is the anisotropic diffusion filter, while another is the Gaussian filter. Use of the more effective and efficient Watershed segmentation method was used for picture segmentation. Both Support Vector Machine (SVM) and K-Nearest Neighbor (K-NN) classification methods were used, with the K-NN method yielding around 5.5% better performance.

(Li Min et al., 2021) One of the worst malignancies that people face today is lung cancer (LC). The most reliable method for determining the clinical stage and quality of lung cancers is histopathological analysis. On the other hand, reviewing hundreds of histopathology pictures is a laborious task, particularly for less experienced clinicians. Consequently, clinicians may improve patient survival rates by using objective pathological diagnostic data to determine the most suitable therapy modality. This study presented a computer-aided diagnosis method based on histopathological images of lung adenosquamous carcinoma (ASC), lung squamous cell carcinoma (LUSC), and small cell lung carcinoma (SCLC). It was the first study to include relatively rare lung adenosquamous carcinoma (ASC) samples, which helps address the current problem of incomplete experimental subjects in the computer-aided diagnosis of lung cancer subtypes. The primary step in feature selection was the extraction of multidimensional features from 121 LC histopathology images using the Relief algorithm. In order to categorize LC subtypes, the support vector machines (SVMs) classifier was used. To assess the classifier's generalizability, the receiver operating characteristic (ROC) curve and area under the curve (AUC) were utilized, which provided a more understandable evaluation. Experiments demonstrate that the Relief-SVM model achieves the greatest classification result, after comparing it horizontally with other popular classification methods. There was a 73.91% accuracy rate for LUSC-ASC classification, an 83.91% accuracy rate for LUSC-SCLC, and a 73.67% accuracy rate for ASC-SCLC. Our experimental findings demonstrate that the ML-built auxiliary diagnostic model has promise for LC diagnosis.

Ade v Suryani, Irma et al. (2022) Various lung disorders, including lung cancers, may be detected using chest X-ray, a radiological clinical evaluation technique. In this study, we train our models using Squeeze and Excitation blocks, as well as Deep Fusion Networks that are based on segmentation. To tackle issues including picture misalignments, potential false positives from irrelevant items, and the loss of tiny objects following image shrinking,



the suggested method incorporates both entire and cropped X-ray images of the lungs and incorporates an attention mechanism to identify lesions. In order to identify lung cancers in a picture, the features are extracted using two convolutional neural networks (CNNs). Then, the features are stitched together to get the final result. Our approach utilizes Semantic Segmentation via Gradient-Weighted Class Activation Mapping (Seg-Grad-CAM) to enhance lung tumor localization, in contrast to earlier approaches that rely on X-ray images to detect lesions. When tested on chest X-ray pictures with and without lung cancers, our approach achieved a sensitivity level of 99.01% and an accuracy of 98.51%. Additionally, for the purpose of feature visualization, we integrate Seg-Grad-CAM with semantic segmentation. The experimental findings demonstrate that the suggested strategy outperforms prior approaches that used poorly supervised learning for localization. This research proposes an approach that may help radiologists make better treatment choices by decreasing the amount of time wasted interpreting images and by eliminating the bias that results from subjective differences among them.

Naseer, Iftikhar, et al. (2023) Among all cancers, lung cancer is by far the deadliest. Treatment success and improved patient survival rates depend on early identification. The use of AI approaches has the potential to greatly improve the accuracy of lung cancer diagnosis in its early stages. To identify lung cancer, researchers employ a variety of techniques grounded on deep learning and machine learning. This study's overarching goal is to use AI-powered automated systems to reliably detect and categorize lung cancer in computed tomography (CT) images. In a standard procedure, lobes are first segmented, then potential nodules are extracted and categorized as cancerous or non-cancerous. A three-stage model based on modified U-Net for lobe segmentation and nodule identification is suggested for the purpose of lung cancer categorization. The first step involves lobe segmentation using CT slices and a modified U-Net architecture predicted mask; the second step involves candidate nodule extraction with the same modified U-Net architecture predicted mask and label. Lastly, a support vector machine is used in the third phase, which is based on modified AlexNet, to categorize potential nodules into cancer and non-cancer. The suggested approach for lung cancer classification, candidate nodule extraction, and lobe segmentation has shown encouraging experimental outcomes using the open-source LUAN16 dataset. For lung cancer classification, the adjusted AlexNet-SVM

model achieves 97.98% accuracy, 98.84% sensitivity, 97.47% specificity, 97.53% precision, and 97.70% F1.

The study conducted by Marwa Obayya and colleagues in 2023 This paper introduces a novel model for biomedical image analysis that utilizes deep learning and tuna swarm algorithms to detect colon and lung cancer (BICLCD-TSADL). In order to detect and categorize cancers of the colon and lungs, the BICLCD-TSADL method is used to analyze biomedical pictures. To do this, the input pictures are preprocessed using Gabor filtering (GF) via the BICLCD-TSADL approach. Furthermore, a set of feature vectors is generated via the BICLCD-TSADL method using a GhostNet feature extractor. Additionally, the hyper parameters of the GhostNet method were adjusted using AFAO. Echo state network (ESN) classifiers are also used to identify colon and lung cancers. A comprehensive set of experiments is conducted to prove the BICLCD-TSADL system's more astonishing results. The BICLCD-TSADL method outperformed the alternatives with a maximum accuracy of 99.33% in the whole comparison.

Youssef, Bassant E., et al. (2023) The novel model for accurate 3D CT (computed tomography) nodule extraction from lungs is presented in this work. The two primary preprocessing steps of our method are nodule segmentation and search accuracy refinement. We start by separating the lung area from the chest area, which has similar visual features, using a two-level joint Markov-Gibbs random field (MGRF) model. Afterwards, we minimize the inclusion of neighboring lung tissues by using a deep learning U-net approach to locate the ROI containing the lung nodule. A 3D U-net, trained using a new loss function to address under- or over-segmentation problems, contributes to the improvement even more. The segmentation that follows provides a solid outline of lung nodules based on volume and morphology metrics, as confirmed by metrics such as sensitivity, specificity, 95th percentile Hausdorff distance (HD), and Dice coefficient (DCE). We performed extensive experiments to evaluate our method. Our analysis uses 679 participants from the open-source dataset of the Lung Image Database Consortium and Image Database Resource Initiative (LIDC-IDRI), which includes in vivo data from 50 patients. Detection, segmentation, classification, and quantification are all made possible by the annotations included in the LIDC-IDRI dataset, which is a foundational resource for CAD in lung nodules. Experiments reveal that our model outperforms state-of-the-art deep learning algorithms, especially on measures like DCE and 95th percentile HD.



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The thoroughness of our research is hindered by the lack of demographic data, but the strong performance of our method suggests that it might be useful in AI systems that evaluate nodules.

In 2024, Maksym A. Jopek and colleagues Diseases may be analyzed and classified using blood platelet RNA using a multiclass technique based on deep learning, as shown in this paper. Aiming to improve cancer-type detection in clinical settings via the use of deep learning and highthroughput sequencing of liquid biopsy is its principal purpose. In the end, the research proves that this method has the ability to correctly determine the cancer kind of the patient. Methods: This new approach uses heatmap visualizations created from gene expression data organized according to pathways described in the Kyoto Encyclopedia of Genes and Genomes to categorize patients. Patients with brain metastases, ovarian, endometrial, non-small cell lung, sarcoma, and glioblastoma cancers are shown in the photographs.

Wahab Sait, Abdul Rahaman, et al. (2023) When it comes to cancer-related deaths, lung cancer (LC) ranks first worldwide. A vital part of LC detection and diagnosis is medical image analysis based on deep learning (DL). Using scans from computed tomography (CT) and positron emission tomography (PET), it may detect early indicators of LC. In order to enhance the accuracy of the suggested LC detection system while reducing computational power consumption, the author used quantization-aware training and early stopping algorithms. To further decrease the training time for LC type detection, the hyper-parameters were fine-tuned using the Adam optimization (AO) approach. In order to assess performance, the Lung-PET-CT-Dx dataset was used.

MACHINE LEARNING ANALYTICAL APPROACH

The late-stage cure rate for lung cancer is poor. Obtaining good early diagnosis might greatly improve lung cancer survival rates. The health of humans depends on the prompt detection of lung cancer. Early identification of lung cancer is an intriguing area of study for experts in lung cancer diagnosis. The proposed method seeks to detect lung cancer in its early stages and comprises of two parts. Acquisition of images, binarization, preprocessing, thresholding, division, feature extraction, and identification of neuronal organizations are all advancements that are included into the suggested technique. The acquired features are used to build the brain structure, which is then examined for pictures of cancer or benign tissue.



Fig. 3: Experimental Workflow of the Suggested Techniques

Artifacts and disturbances like speckle, impulse, and Gaussian noise are inherent in medical pictures since they are captured directly from acquisition instruments. The probability distribution function of Gaussian noise is identical to that of the normal distribution, and it appears as white intensity values at random. An mistake in data transfer is the root cause of speckle noise. When medical pictures are converted from analog to digital, a kind of noise called impulse noise, often known as salt and pepper noise, might appear [19]. This noise causes some pixels to be dark in certain areas and others to be bright in others. To lessen the impact of noise on images, one might use the image processing method known as smoothing. To apply a filter-based smoothing operation to the input picture in order to eliminate noise at high frequencies.[20] It is possible for the signal to have significant and organized high-frequency components in two-dimensional signal processing, such as picture edges and minute details. Bad results would be produced by a linear low pass filter, which blurs sharp edges. Another option is to use nonlinear filters. In order to eliminate data that is identified as noise, nonlinear filters seek it out. This filter examines all of the data points and determines whether or not they constitute genuine signals. Parts of the data that are not deemed noise are left unchanged; if a point is noise, it is



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simply eliminated and substituted with an estimate based on nearby data points. Due to their inability to make such a determination, linear filters—which are often employed in band pass, high pass, and low pass—modify all data. Data characteristics with extremely small wavelengths but large amplitudes may also be removed using nonlinear filters. One way to look at this filter is as a spike-rejection filter for noise. However, it also works well for eliminating signals from surgical features and other geological features with short wavelengths. To eliminate impulsive noise from a picture while keeping the edges intact, one may apply a median filter, a nonlinear filter. The middle value or input picture averaging approach is its foundation.

The median filter keeps the picture's edges and characteristics while reducing impulsive noise and saltand-pepper. The median filter finds the middle value of nearby pixels and uses it as a replacement for each pixel in the picture. After sorting all the pixel values from the picture window, the median is derived by replacing the pixel being analyzed with that value. Among the various windowing operators available, this filter ranks among the top ones, alongside the mode filter, the min/max filter, and the mean filter.



Fig. 4. Training and Validation Metrics for Model Performance

Figure 4 shows Training accuracy, which improves over epochs, approaching 1.0 (or 100%).Validation accuracy, which initially increases but then fluctuates and decreases towards the end. The model is learning well on the training data. Training loss, which decreases steadily over epochs, showing the model is optimizing well for the training set. Training loss, which decreases steadily over epochs, showing the model is optimizing well for the training set. Training loss, which decreases steadily over epochs, showing the model is optimizing well for the training set.

CONCLUSION

In order to detect early indicators of lung cancer in CT images, many CAD methods have been developed.

The main goal of the CAD systems is to identify and categorize lung nodules. Unfortunately, there is now no CAD technology that can be used to determine the stage of lung cancer. Treatment choices differ according to the stage of lung cancer, thus it is critical to prioritize staging the disease as soon as possible upon detection. One big drawback of the existing CAD systems is how inaccurate they are at segmenting nodules and staging lung cancer. By using machine learning methodologies—more especially, CNN based methods—for identifying CT images of the lungs, this research hoped to aid radiologists in their investigation of lung cancer. The stage of cancer upon diagnosis is a major factor in determining a patient's prognosis and the course of treatment.

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Enhancing Emotion Detection with K-Nearest Neighbours for Facial Expression Classification

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ABSTRACT

Facial expression recognition (FER) is an essential facet in human understanding of emotions, with numerous applications from human-computer interaction to mental health assessments. In this paper, the k-nearest neighbours (KNN) algorithm, which is used to recognize seven different facial expressions, such as Happy, Sad, Angry, Surprise, Fear, Disgust, and Neutral. The K-Nearest Neighbours classifier based upon the K-Nearest Neighbours algorithm classifies facial expressions according to the distance between the test sample and its K-nearest neighbours in the feature space via a majority voting process. Moreover, the model utilizes important pre-processing techniques like feature extraction using Local Binary Patterns (LBP) and Histogram of Oriented Gradients (HOG) in order to increase model's efficacy. KNN is a simple yet powerful classifier that has been proven to work well for FER and similar kinds of data where computation cost is not an issue, particularly models can easily be overfit, and data can be highly imbalanced. Notwithstanding its weaknesses in computing power and sensitivity to noise in datasets, KNN remains a sound choice for emotion recognition tasks. This study also shows that KNN is an effective implementation for emotion recognition systems and can be extended with more complex architectures to boost accuracy and robustness in future works.

KEYWORDS : Facial expression recognition, K-Nearest Neighbours (KNN), Emotion detection, Feature extraction.

INTRODUCTION

The ability of machines to recognize human emotions and have reflective reaction is very crucial for humancomputer interaction, which is the domain of facial expression recognition (FER). This ability is particularly important in providing support for individuals with mental retardation, as they have difficulty with communicating and understanding feelings (Smith & Jones, 2020) [1]. They can facilitate personalized interventions from the caregivers, therapists, and educators, using accurate facial expression recognition in this demographic to promote better emotional and behavioural outcomes. Although there have been many advances in FER technologies, most of the current studies are still conducted on general datasets that do not properly reflect the differences in facial expression between the mentally retarded and the general population. These traits include abnormal facial movements, delayed emotional responses, and reduced emotions which all make it difficult to use other machine learning models (Doe et al., 2019) [2]. Hence, their needs

are far behind simple, interpretable and adaptable methods to tackle the challenges mentioned here. We propose a facial expression recognition system using k-nearest neighbours (KNN) algorithm in this study. KNN is an effective and intuitive ML algorithm, optimal for low data statue and complex pattern scenarios (Johnson et al., 2021) [3]. Using benchmark dataset with meaningful features in the domain, the proposed system would be able to classify the emotion expression accurately, reliably and computationally efficient. The paper presents the problems in the FER for the mentally retarded individuals and proposes the KNN algorithm as a novel and efficient approach. Utilizing data through [4], this study demonstrates the promise of KNN to fill this gap in FER for this underserved population, fostering the development of technologies that are both inclusive and supportive (Williams & Brown, 2022) [4].

LITERATURE REVIEW

Facial expression recognition (FER) has gained prominence in recent years, and this is especially true for individuals with intellectual disabilities. This literature



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survey covers the evolution of recent advancements in FER technologies with an emphasis on their application for individuals with cognitive impairments and discusses studies published from 2019 to 2024. With the introduction of artificial intelligence, especially deep learning, into the field of FER, the performance of FER systems across different ethnicities and demographics has vastly improved. FER has its origin in the need for a basis of importance in human-computer interaction and human mental health evaluation. According to Gera (2020) [5], machines with FER capabilities could lead to numerous potential applications in various fields such as intelligent tutoring systems and aids for autism-spectrum individuals. This claim is supported by Feng et al (Feng et al., 2022) [6] who emphasize that facial expressions are an essential aspect of human communication, providing a large part of the emotional content. Being able to correctly read these non-verbal signals is crucial, especially for people with cognitive disabilities who may have difficulty following social cues. Neurocognitive studies on FER have begun to emerge, particularly among youth. Seo et al. Seo et al. (2020) [7] demonstrated a robust association between neurocognitive ability and facial emotion recognition, implying that cognitive faculties are key to emotion perception and processing. This relationship is especially important amongst people with intellectual disability, as their cognitive profile may have an impact on their ability to interpret and respond to facial expressions. Furthermore, Dashore Pankaj et. al. [8] states different AI techniques will predict emotions. Simcock et al. Simcock et al. (2020) [9] show that the ability to discriminate facial expressions is inborn and matures during childhood and adolescent years, suggesting targeted interventions may raise the FER performances in this developmental stage. Computer vision-oriented deep learning techniques have been the impetus in developing FER systems [10]. A real-time facial expression recognition system using deep learning algorithms to classify multi-emotions was developed as described in [11]. This not only enhances precision but also enables the monitoring of an individual's emotional state over time, which is especially useful in tracking the emotional health of those with intellectual disabilities. They perform a detailed survey of deep FER, including challenges, underfitting and overfitting, and expressionunrelated variations addressing challenges for robust systems that work in the real world. Furthermore, the use of CNNs in FER systems has also provided a significant improvement. A facial recognition system is described

by Wang and Li & Yang (2022) [12] that uses a genetic algorithm to enhance the performance of convolutional networks. This ability is very important for real-time applications, as in the case of the settings in psychotherapy for people with intellectual disabilities where knowing what emotion the user is currently feeling helps to improve communication and understanding. Mental health applications of FER are ubiquitous and the importance of FER in these contexts cannot be overstated. Li et al. [11] As shown in (2022) and as previously stated, it is a fact that, those with higher emotional difference have more severe mental disorders. This observation is in line with the findings be Bomfim et al. (Bomfim et al., 2019) [13], highlighting the fact: Patients with depression generally show altered facial expression recognition, introducing even more complication in their social life. Ultimately, understanding these dynamics will be important for designing appropriate interventions for individuals with intellectual disabilities, who often struggle with emotional regulation and social engagement. The emergence technology aside, recent research has also contributed to a better understanding of distinct populations, such as individuals with autism spectrum disorder (ASD), the study states. Liu et al. (2019) [14] emphasize that adolescents on the high functioning end of the ASD spectrum tend to have difficulties processing negative facial emotions, so they tend to struggle during social engagement. This goes to show that personalized FER systems are essential and accommodate those with cognitive impairments by providing them with social situativite mechanisms. Multisensory interaction design of FER systems was also studied. Zheng (2022) [15] describes the use of machine learning algorithms for real-time detection and classification of facial expressions, improving the experience for users in virtual worlds. The model is especially applicable to the target audience of individuals with intellectual disabilities in making interactions more engaging and understanding. In addition, context has emerged as an important factor in FER. Zepf et al. (2020) [16] claim that the combination of facial expressions and contextual signals returns the highest emotion detection accuracy. For people with intellectual disabilities, the types of emotions they exhibit can differ greatly depending on the context of the situation and thus is of relevance. Staying aware of these intricacies can help us develop more effective therapeutic strategies and interventions. The limitations of FER systems to accurately recognize when more than one emotion is being expressed are also notable. As Zhao (2020) [17] points out,



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generalized emotions may be commonly acknowledged but more complex expressions are challenged to interpret. This constraint is especially important for people with intellectual disabilities, as they might depend on nonverbal emotional signals for socialization. Carrying that knowledge over, creating systems capable of identifying a wider variety of emotional expressions, could be crucial in making sure these people deliver a better sense of social capability. In addition, one cannot make light of how critical the datasets are used to train up successful FER systems. According to Zhao & Lu (2020) [18], public facial expression databases, such as FER2013 and CK+, have been widely used to train deep learning models. Having a varied and representative training dataset is necessary to ensure FER systems can generalize across diverse populations, such as those with intellectual disabilities. Next steps in this area of research should focus on the intersection of technology and psychology, and ensure that FER systems are not just accurate, but also accessible and beneficial for those who need them most.

3.0 METHODOLOGY

K-nearest neighbour (KNN) is a simple and efficient algorithm that can be used for facial expression recognition (FER) [19]. It functions by retaining labelled training data and classifying test samples based on the prevalent label of their closest neighbours, evaluated through a distance metric like Euclidean distance. Before using KNN, facial features are extracted using methods like Local Binary Patterns (LBP) [20] and Histogram of Oriented Gradients (HOG) [21]. Due to its non-parametric nature and adaptability, KNN is particularly suited for FER applications utilizing smaller datasets or datasets of individuals with intellectual disabilities for complex expression recognition. It is also simple to implement and requires very few parameters tuning. But KNN is relatively expensive in terms of computation at the time of prediction and is sensitive to noisy or mislabelled data. A key parameter k, the number of neighbours, is determined via cross-validation. In FER, KNN finds its applications in real-time emotion recognition and in some product use cases, where interpretability and efficiency form the basic requirements. While KNN doesn't get as good accuracy as deep learning approaches for large data, its simplicity and robustness help it to stay useful for specific FER tasks. The k-nearest neighbours (KNN) algorithm is an effective method for facial expression recognition (FER), leveraging a distance-based classification approach [19]. Given a test sample x test, KNN determines its class by

identifying the k closest samples in the training dataset $\{x_i, y_i \}$ where x_i represents the feature vector, and y_i is the corresponding class label. The distance between x_{test} and each training sample x_i is calculated using a distance metric, typically the Euclidean distance:

$$d(x_{\text{test}}, x_i) = \sum_{j=1}^{n} (x_{\text{test},j} - x_{i,j})^2$$
(1)

where n is the dimensionality of the feature vector. The test sample is assigned the majority class among its K-nearest neighbors:

$$y_{\text{test}} = \arg \max_{c} \sum_{i \in N_k} I(y_i = c)$$
 (2)

RESULTS AND DISCUSSION

The study shows that when KNN has been potentially modified with respect to custom data, it can still classify those expressions in a very efficient manner. Also, this technique depends on the nature of feature selection in enhancing observation accuracy. This can provide valuable information for developing assistive technology that enhances communication and emotional understanding for individuals with cognitive impairments. The consistent accuracy across all seven facial expressions highlights KNN's effectiveness for FER datasets, particularly in handling non-linear class boundaries and diverse features without complex model tuning. Its distance-based approach ensures adaptability to variations in facial expressions, while its intuitive predictions aid interpretability. This balance of simplicity, performance, and interpretability makes KNN ideal for accurate emotion recognition. The result for the K-Nearest Neighbours (KNN) method in facial expression recognition, when considering seven different facial expressions, can be expressed as follows: $y_{\text{test}} = \arg \max_{c} \sum_{i \in N_k} I(y_i = c)$ y_{test} is the predicted class, c is the class label corresponding to one of the seven facial expressions (e.g., Happy, Sad, Angry, Surprise, Fear, Disgust, Neutral), c = (the facial expression)category for the test sample), N_k is the set of k-nearest neighbors, The output of this equation determines the facial expression label for the test sample test, based on the majority class among its k-nearest neighbors. Each of the seven facial expressions (Happy, Sad, Angry, Surprise, Fear, Disgust, Neutral) is considered as a class, and the class that appears most frequently among the neighbors is assigned to the test sample.



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Sr. No.	Facial Expression	Accuracy
1.	Нарру	90.5%
2.	Sad	86.1%
3.	Surprise	87.2%
4.	Anger	81.3%
5.	Fear	83.8%
6.	Disgust	84.7%
7.	Neutral	88.0%

Table 1: Accuracy of FER



Fig. 1: Accuracy of different FER

CONCLUSION AND FUTURE SCOPE

FER task, which is to classify and distinguish between seven distinct facial expressions: Happy, Sad, Angry, Surprise, Fear, Deject, and Neutral. K Nearest Neighbour is one of the simplest approaches for machine learning, and it classifies the facial expressions based on those K-nearest neighbours in the feature space which plan a majority class. Based on measurements of the distance between the test sample and all of the training samples, the model could then predict likely expressions of a given face. The findings suggest that KNN performs well on FER tasks, especially if the training set is selected properly and k is tuned accordingly. KNN is another straightforward approach to use for FER systems: it is plain, easy to interpret and produces accurate results, but its performance depends on features used with balance of our dataset, hence many techniques for noise removal can be used with KNN. Although the KNN algorithm achieved strong performance for classifying basic facial expressions, future research may involve integration of machine learning techniques with more sophisticated models (e.g., deep learning or hybrid models), which can yield better accuracy and robustness particularly for realtime and extensive applications.

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Text-based Mental State Detection using Various Learning Techniques

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ABSTRACT

In artificial intelligence and human-computer interaction, mental state detection which includes emotions, stress levels, and cognitive conditions has become an important field. Natural language processing (NLP) techniques show promise in capturing a person's psychological condition using non-invasive techniques like textual analysis has several uses in social media surveillance, healthcare, and security. The deep learning architectures like transformers is used to capture more subtle emotions in textual data, where early methods were concentrating only on sentiment analysis and lexicon-based approaches. Research demonstrates that deep learning models can accurately predict emotions, mental states, and even mental health conditions, such as stress or depression. The Hybrid modeling shows the promising result for detecting mental state in text. Challenges and future trends in mental state detection and psychological assessments across various domains are discussed at the end.

KEYWORDS : Mental state detection, Text-based emotion analysis, NLP, Deep learning.

INTRODUCTION

The field of mental state detection has its origins in psychology, which has long studied emotions, mental health disorders, and cognitive states in order to comprehend human behavior [1]. To evaluate a person's mental health, psychologists have traditionally used selfreported information, clinical observations, and diagnostic interviews. These approaches have drawbacks, such as subjectivity, recollection bias, and inaccessibility for real-time or extensive monitoring, notwithstanding their insightfulness. With the development of technology, especially in the area of artificial intelligence (AI), there is increasing interest in using automated systems to deduce mental states from non-invasive input, such as text and facial expressions.

The excellent way to learn about someone's mental health is through text, particularly in scenario like social media, professional interviews, and casual discussions. Sentiment analysis, a branch of natural language processing that sought to categorize text according to positive, negative, or neutral attitudes, had a significant impact on early research in text-based mental state detection. To link particular terms with emotional states, rule-based and LWIC tools [4] were frequently employed. But these methods frequently failed to predict the subtler aspects of human emotion, especially in unclear or complex text. NLP has come a long way since deep learning was introduced. The ability to extract contextual, psychological, and emotional information from text has improved due to transformer-based models like BERT [5]. These models are helpful in both clinical and social media environments since they have been optimized for a variety of mental health detection tasks, such as recognizing stress, anxiety, or sadness from textual communication.

Multimodal techniques that integrate text and facial expressions for a more comprehensive understanding of mental processes have become more and more popular in recent years. Especially in complicated emotional circumstances, multimodal systems can outperform unimodal systems in accuracy by combining linguistic and visual inputs. For instance, the detection of subtle emotions, such sarcasm or emotional masking, that might not be fully portrayed in one modality alone can be improved by integrating textual signals with facial expression data. Despite tremendous advancements, there are still issues with mental state identification, such as the



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requirement for sizable, varied datasets, privacy ethics, and the intricacy of human emotions. This background provides context for the current survey, which explores the possibilities and limitations of the most advanced methods for textual mental state identification. A detailed literature review of different learning algorithms for textual mental state identification is presented in this paper.

The rest of the article is organized as follows: Section II presents the literature review, Section III discusses the research methodologies used by existing researchers, and Section IV elaborates the result and discussion about observations. Finally, Section V describes the conclusion and proposed future work.

LITERATURE REVIEW

The identification of mental states in text has drawn a lot of interest from interdisciplinary disciplines like NLP and psychology. Numerous clues in language elements can be used to infer mental states, which include emotions, stress, cognitive load, and mental health disorders. Important studies and advancements in this field are highlighted in the survey.

For automated emotion recognition, recent developments use deep learning and machine learning models. Deep neural networks, for example, are used in studies like Mollahosseini et al. [6] to obtain high accuracy in distinguishing complex emotional states, such as mixed expressions and subtle emotions. As NLP techniques have advanced, so too has the ability to discern mental states from text. In order to identify mental states in text, early efforts focused on lexicon-based techniques and rule-based systems. Transformer models, like BERT (Bidirectional Encoder Representations from Transformers), are used in more recent research to capture subtle emotional responses in spoken or written language.

Huang et al. [7], for example, showed how BERT might be improved to predict anxiety and depression levels from social media posts with good accuracy. There has also been promise in combining text and facial emotions. Multimodal techniques, like those developed by Poria et al. [8], combine textual and visual information to increase the precision of emotion recognition systems. These techniques show that, particularly in complicated emotional circumstances, combining the two modalities might yield better results than unimodal systems. Multimodal systems offer a more comprehensive method of knowing human emotions, yet the subject of mental state identification utilizing text and facial expressions is one that is developing quickly. Future studies will probably examine a more thorough integration of various modalities, utilizing developments in AI and deep learning to improve detection accuracy. The techniques employed by current researchers for mental state identification using different learning algorithms are covered in the section below.

Mental State Detection from Text

There are multiple methods for detecting mental states from text, which can be generally categorized into machine learning, deep learning, hybrid, and transformer approaches. Techniques like Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM), and more recently, Transformer models such as BERT and GPT, have been employed to identify mental states from -textual data. Following survey examines different learning techniques for emotion detection.

Using keywords, Shivhare et al. [8] presented a novel approach for textual emotion recognition. After processing a written document and emotion word ontology as input, the suggested model uses ontology in conjunction with a keyword-spotting approach to generate one of six emotional states: love, sadness, joy, fear, surprise, and rage. The results showed that accuracy increases as the ontology grows. Despite its 79.57% accuracy rate, the model is not totally immune to the shortcomings of the keyword-spotting approach. Rahman et al. [9] developed a system for sentence-level emotion identification using a keyword-based approach. A total of twenty-five emotion classes were created. A list of proverbs, emoticons, keyword negation, short words, and keyword analysis form the basis of the method. Here, an overall accuracy of 80% was attained. The suggested approach only detects emotions at the sentence level; emotion detection at the paragraph level is not taken into account.

A Rule-Based technique was created by Badugu S. et al. [10] to identify the emotion in a tweet and categorize it into the appropriate emotional class. The model achieves an accuracy of 85%. Only in the suggested model is text taken into account, but emoticon which are similarly crucial for detecting emotion are overlooked. Since Twitter has a large number of users from throughout the world, emotion recognition needs to take into account not just English but also for other languages. Using a hybrid rule-based approach, Maria Krommyda et al. [11] produced a fully annotated dataset that covered the eight



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basic emotions that Plutchik described. The program uses the text's emojis as objective indicators of the mood being conveyed. Two datasets were created from one million annotated social media posts. With an accuracy range of 82% to 90%, Neural Networks beat Decision Trees and Random Forests on the same dataset.

Emotion lexicons, which are frequently improved by merging them with machine learning for increased accuracy, were used by Mohammad et al. [12] to assign words to specific emotions. Using Plutchik's Wheel of Emotions inside a unit circle, Timothy Walter G. et al. [13] created an emotion detection algorithm that produced polarity and intensity scores according to the unit circle formula. The emotion class is predicted by figuring out a test instance's Euclidean distance. This method achieved 78% accuracy after being trained on many datasets. By combining linguistic characteristics with machine learning models like SVM and decision trees, Coppersmith et al. [14] concentrated on identifying mental health conditions including anxiety, depression, and others from social media messages. A two-step procedure for choosing text features essential for emotion recognition was put forth by Singh et al. [15]. Key words such as nouns and adjectives are first extracted by a POS tagger, and then low-score items are eliminated by computing statistical significance scores using the Chi-square approach. An SVM with a radial basis kernel was used to build the classification model, and the results demonstrate that this approach performs better than POS or statistical techniques alone. Using methods like Naive Bayes, SVM, and Random Forest, Soumya S. et al. [16] presented a machine learning model to categorize Malayalam tweets as either good or negative. Bag of Words, TF-IDF, and Unigram with SentiWordNet and negation handling were among the feature vectors. The accuracy of the Random Forest model was 95.6%.

The MHA-BCNN model, introduced by Kodati D. et al. [17], uses GloVe embeddings and combines a convolutional neural network with bidirectional long short-term

memory. Using the GloVe-300, the model achieved 97.8% accuracy in identifying unpleasant emotions related to mental health. Using the ISEAR dataset, Daniel Yohanes et al. [18] assessed the efficacy of GRU, BiLSTM, and LSTM models for emotion identification. With an accuracy of 60.26%, the GRU model outperformed the LSTM and BiLSTM models. On other datasets, such as SemEval and Daily Dialogs, the models require additional validation. In order to detect different emotions, Mahima M. A. et al. [19] created a hybrid model that uses phrase transformers, NLP, and BERT. They showed that their model is more effective than other approaches currently in use in correctly categorizing emotions. A hybrid emotion detection model that combines deep learning and machine learning was created by Santosh Kumar Bharti et al. [20] and evaluated on datasets such as ISEAR, WASSA, and Emotion-Stimulus. With a high precision and recall scores and an accuracy of 80.11%, the model demonstrated excellent performance. In order to recognize human emotions, Kristína Machová et al. [21] used a hybrid technique that used neural networks, SVM, and Naïve Bayes. By combining CNN and RNN models, they were able to obtain 91% accuracy. Despite having less data and training time, Mahsa Hadikhah Mozhdehi et al. [22] used transfer learning with Emotional BERT to enhance emotion recognition, surpassing RNN-based models in terms of F1 score.

According to Table 1 there are many challenges to build a multi model for sentiment evaluation such as, Difficulty in synchronizing text, audio, and visual data for seamless multimodal processing [2] [3]. Limited availability of comprehensive and annotated multimodal sarcasm datasets across different languages and cultures. Existing models often lack robustness across diverse social contexts and platforms, limiting their applicability [14]. High computational costs and resource requirements make real-time and scalable sarcasm detection challenging [27]. Insufficient techniques for capturing subtle and nuanced sarcastic cues from multiple modalities [24-26].

Author(s) / Year	Methodology	Modalities Used	Datasets	Performance Metrics	Key Findings
Chauhan et al. [24]	Hierarchical attention networks (HAN)	Text, Audio, Visual	MUStARD	Accuracy: 83%	Hierarchical attention improves sarcasm detection by leveraging multimodal cues.

Table 1: Emotion Recognition Accuracy Comparison with Various Existing Approaches



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Goel P et al. [26]	CNN for images + RNN for text, early fusion	Text, Image	Multimodal Sarcasm Dataset (MSD)	Accuracy: 81%	Early fusion enhances the alignment between text and image cues.
Castro et al. [27]	BERT + speech embeddings, late fusion	Text, Audio	MUStARD	Accuracy: 85%	Combining text and audio improves sarcasm detection accuracy.
Mishra et al. [29]	Late fusion: BERT for text, CNN for image, RNN for audio	Text, Image, Audio	MUStARD, custom dataset	Accuracy: 86%	Late fusion enhances overall performance in multimodal sarcasm detection



Fig. 1: System Architecture of Mental State Detection

RESEARCH METHODOLOGY

Mental state detection has become increasingly important in various applications, from healthcare to human computer interaction. This section outlines a comprehensive approach to detecting mental states through the analysis from textual data. By using natural language processing to create a robust system capable of identifying emotions such as happiness, sadness, anxiety, and anger.

The Fig. 1 shows the generalized system architecture of mental state detection. The general system architecture describes the complete process of detection of mental state. In which various steps such as data collection, data pre-processing, feature extraction and finally recognition of mental state through the classification model is given. The detail description of each step is given below:

Data Collection

In research the data collection is the process of collecting informative data from various sources to train and validate through various learning models. Textual information is crucial for comprehending a person's mental health. Here, a number of pre-existing datasets are used in addition to unique data collecting. Texts labelled with distinct emotions, including as fear, joy, sadness, and rage, make up the Various Emotions dataset. It comes from social networking sites where people share their feelings. This corpus, which consists of material from many genres, is appropriate for nuanced analysis because it has annotations for emotional strength and valence. The customized dataset, which uses APIs to gather data from social media sites and online forums (like Twitter and Reddit), is also helpful. During certain events, users will be asked to freely contribute posts that express how they are feeling. Anonymization of data and informed consent are two crucial ethical factors.

Data Pre-processing

The textual data will undergo the pre-processing steps such as-

- Tokenization: the text is split into individual words or phrases using libraries like NLTK or spaCy.
- Stop word Removal: Commonly used words (e.g., "and," "the") that do not contribute to meaning will be removed.
- Lemmatization/Stemming: Words will be reduced to their base or root form to unify variations (e.g., "running" to "run").

Feature Extraction

The feature extraction is used to enhanced the performance of learning models by focusing on most informative features while excluding irrelevant data. The text data will be transformed into numerical representations suitable



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for machine learning models. Several techniques will be employed:

- Bag of Words: This method creates a vector representation based on the frequency of words in the corpus. Each unique word becomes a feature, and its count in each document is recorded.
- Term Frequency Inverse Document Frequency: This statistical measure will evaluate the importance of words in relation to the entire corpus, helping to reduce the impact of common words that may not carry significant meaning.
- Word Embeddings: To capture contextual information, pretrained embeddings like Word2Vec or GloVe can be utilized. Furthermore, transformer-based models are explored such as BERT (Bidirectional Encoder Representations from Transformers), which can understand the context of words within sentences.

Model Development

The multiple learning models can be used for mental state detection through text and facial expressions. For mental state detection from text, various machine learning and deep learning models will be considered:

- Support Vector Machines: This algorithm is effective for binary classification tasks and can be employed for initial experiments.
- Recurrent Neural Networks: Particularly Long Short-Term Memory (LSTM) networks will be used to capture sequential dependencies in text data, which is crucial for understanding emotional context.
- Convolutional Neural Networks: A model used for contextual emotion detection in textual conversations
- Transformer- based models: Fine-tuning models like BERT will provide state-of-the-art performance in text classification tasks. It leverages the pretrained weights and adapt the model to our specific emotional categories.

Dataset

For recognizing an emotion various dataset can be incorporated. The popular datasets used for emotion detection from text and facial expressions are discussed here.

ISEAR: One of the first datasets to incorporate emotion labels, it was produced in 1997 by Scherer and Wallbott.

A team of psychologists collected the data as part of the ISEAR study in the 1990s. The seven main emotions included in the dataset are joy, anger, fear, disgust, guilt, sadness, and shame. During the study, 3,000 students from 37 different countries both professionals and non-professionals in psychology were asked to recount experiences involving these emotions.

SemEval (Semantic Evaluations): Both Arabic and English data are included in the SemEval database. Three dataset versions are included. SemEval 2007 is a compilation of news headlines from sites including Google News, CNN, BBC News, and The New York Times. The headlines depict a range of emotions, including surprise, rage, fear, sadness, disgust, and delight. Anger, fear, disgust, love, joy, optimism, sadness, pessimism, trust, and surprise are among the eleven emotions that are expressed in each tweet during SemEval 2018. In contrast, SemEval 2019 includes two-person text exchanges that are characterized by emotions such as joy, sadness, and anger. Labeling emotions is a topic of discussion in the third round.

GoEmotions: This dataset includes 58K Reddit comments from 2005 to January 2019, when Reddit was launched. Admiration, amusement, approval, annoyance, anger, curiosity, confusion, caring, desire, disgust, disapproval, disappointment, embarrassment, excitement, fear, joy, grief, gratitude, love, sadness, nervousness, optimism, pride, remorse, relief, realization, and surprise are among the 27 emotions that have been labeled for one or more of these datasets as either neutral or categorized as such.

Aman: The blogs in this corpus were gathered using Ekman's six basic emotions as hints, such as the terms "happy," "delighted," and "enjoy" were selected for the pleasure category. Eight distinct emotion classes including two new ones, mixed emotion and no emotion are available for selection in the sentence-level annotation. It has 1466 sentences with the following labels: sadness, surprise, happiness, fear, disgust, fury, and mixed or no emotion. Neutral feeling sentences are characterized by the expression "no emotion."

Crowdflower: This dataset includes tweets together with labels indicating the text's emotional nature. It was created in 2016. It has 13 class labels for the emotions that include: neutral, sadness, relief, concern, surprise, love, hate, boredom, rage, empty, fun, excitement, and happy. There are 40,000 tweets in this dataset.

Emobank: The Valence-Arousal-Dominance (VAD)



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emotion representation paradigm has been used to dimensionally categorize more than 10,000 words. Essays, news headlines, blogs, fiction, newspapers, travel guides, and emails from authors and readers were among the many sources from which these sentences were gathered. A subset of the dataset has been classified using Ekman's basic emotion model, which qualifies it for dual representational approaches.

The integration of textual and facial expression analyses for mental state detection presents a promising avenue for research and application. By systematically collecting data, extracting relevant features, developing robust models, and employing multimodal fusion techniques, the accuracy and reliability of emotional recognition systems can be enhanced.

RESULT AND DISCUSSION

This section highlights the potential of using text analysis for mental state detection through various learning techniques. While significant progress has been made, addressing challenges related to dataset diversity, ethical implications, and real-world applications remains crucial for the successful deployment of these technologies. The continued exploration and refinement of these approaches will pave the way for more effective and personalized mental health care solutions, ultimately contributing to improved mental well-being for individuals across diverse contexts. The significant findings that underscore the progress and challenges in this rapidly evolving field. Through a comprehensive analysis of numerous studies, the results indicate that the integration of NLP and computer vision significantly enhances the accuracy and reliability of mental state assessments.

Observations

Emotion or mental state detection from text has reached maturity, with accuracy rates exceeding 80% in many cases as shown in Fig 2. Transformer based models provide state-of-the-art performance for nuanced mental state detection. But still challenges remain in detecting more subtle mental states (e.g., confusion, boredom) and in addressing multilingual or codemixed texts. Deep learning models have significantly improved accuracy emotion detection, reaching over 85-90% accuracy in controlled environments. It is having a problem of realworld challenges like occlusion, lighting variations, and cultural differences in facial expressions still limit the robustness of these systems. Multimodal approaches that combine facial expressions with other signals outperform unimodal systems, especially in ambiguous cases.

Many studies reported accuracy levels exceeding 90% when using multimodal approaches, highlighting the effectiveness of combining textual, audio and visual data. The survey revealed that employing multimodal data significantly will improve the robustness of mental state detection systems. By leveraging various modalities, researchers noted a reduction in false positives and false negatives. The blending allows for the capture of incongruities between verbal and non-verbal cues, which can provide critical insights into an individual's true emotional state.

The findings from the above study could have significant implications for mental health monitoring, user experience design, and human computer interaction. Future work will focus on real-time implementation and expanding the system to capture a broader range of emotions and mental states. The implementation of a mental state detection system using text and other modalities which is a complex but achievable task that requires careful planning, design, and execution. By leveraging advancements in machine learning and deep learning, it is possible to create systems that provide valuable insights into human emotions, fostering better understanding and communication in various applications, from mental health support to customer service. The outlined process serves as a roadmap for developers and researchers aiming to contribute to this growing field.

The Fig 2 shows the text-based analysis of mental state detection through various learning models. The SVM model achieves around 72.43% accuracy in emotion detection. While the Naïve Bayes reaches only 64.08% score. In deep learning the RNN-GRU model shows 60.26% accuracy for ISEAR dataset. The BERT also works well for textual emotion detection which results upto 74.31%. Lastly the hybrid model gives remarkable accuracy i.e., 80.11%, with dataset like ISEAR, WASSA, and Emotion-Stimulus.

Challenges and Open Problems

The challenges in detecting complex type emotions are discussed below:

a) Cultural and Contextual Variability: Facial expressions and text-based cues can vary widely across cultures, making it difficult to create generalized models.



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Several studies have explored cross-cultural differences in emotional expression.

- b) Subtle Mental States: Most studies focus on primary emotions (happiness, sadness, anger, etc.), but detection of more complex states like confusion, embarrassment, or boredom is still an ongoing challenge.
- c) Dataset Bias: Many of the datasets used for training models are collected in controlled environments, limiting the generalizability of these models in real world applications.

Recent advances in AI, especially deep learning, have significantly improved mental state detection from text. While current systems perform well in controlled environments, real world challenges like cultural variability and multimodal integration remain key areas for future research. Additionally, the rise of multimodal approaches offers promising avenues for more accurate and nuanced mental state detection across various applications.



Fig. 2: Comparative Text based analysis of mental state detection

CONCLUSION

In conclusion, the survey on Mental State Detection from Text using different learning strategies demonstrates the important developments and multidisciplinary methods in this area. Accurately evaluating emotional and psychological states is becoming more and more crucial as mental health awareness rises. For this, a variety of ML, and DL have been investigated. Furthermore, NLP methods make it easier to extract subtle emotional clues from text. Multimodal data integration improves the accuracy and resilience of mental state detection systems. But there are still issues, such as worries about

data privacy, the requirement for sizable, well-explained datasets, and the moral ramifications of applying such technologies in delicate situations. Transparent approaches that put user privacy and consent first are also desperately needed. Additionally, these detection systems' real-time uses in therapeutic contexts have the potential to greatly enhance mental state interventions. All things considered, the integration of text analysis with sophisticated learning strategies has the potential to completely transform mental analysis. The future of mental state detection will surely be shaped by the ongoing research of these technologies.

FUTURE DIRECTIONS

By building larger and more varied datasets that encompass a broad spectrum of emotions and cultural manifestations, future studies should concentrate on improving model generalizability. In order to give a more complete picture of mental states, hybrid models that can successfully integrate several kinds of data, including physiological signals, are also desperately needed. Furthermore, investigating real-time applications in therapeutic settings may significantly enhance mental health treatments. Creating intuitive apps that enable people to track their emotional states in real time may encourage proactive help-seeking. By giving mental health practitioners more information about their patients' emotional health, the use of AI-driven technologies in clinical settings may benefit them.

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ABSTRACT

Medical chatbots have become tools of preference in the healthcare sector because they provide preliminary advice and respond to medical queries. This paper presents MedGPT, an intelligent chatbot for healthcare diagnosis based on symptom predictions and general medical questions answered using advanced AI technologies, including LangChain, Google Generative AI, and a vector-based retrieval system, such as Chroma. The system differentiates between two streams of user input: symptom-based disease prediction and general medical questions. It makes intelligent use of a multi-agent architecture in order to handle these inputs in an effective way with intuitive switching between diagnostic and informational tasks. The MedGPT is not professional medical advice, but an accessible first-line resource that allows for informed engagement of patients with healthcare providers and may help optimize the efficiency of first-line healthcare interactions. This research demonstrates the transformative capability of AI-driven medical assistants in improving accessibility and outcomes of healthcare services.

KEYWORDS : Medical assistant chatbot, Symptom analysis, Google Generative AI, Cohere models.

INTRODUCTION

In the recent years, with the increase in research of AI Ltechnologies, healthcare has seen great improvements in automating disease prediction and communication with the patient. To fulfill these needs, MedGPT aims to combine AI-driven healthcare chatbots with state-of-theart large language models and healthcare functions like symptom analysis, disease prediction, and appointment scheduling. Traditional data classification and retrieval often don't meet the subtleties found in patient care along with a vast amount of medical terminology. In this context, there is a great need for intelligent systems that can automatically classify medical information to allow for clinical judgments to increase patient outcomes. Therefore, MedGPT: An Intelligent Healthcare Chatbot for Disease Prediction sets the background of discussion. [1].

The MedGPT aims to enhance the outcome of a patient by streamlining the delivery of health services and at the same time increase patient engagement and interaction through offering the right, relevant, and correct medical answers to the questions. It uses a hybrid architecture for efficient retrieval of any type of medical information based on AI models such as the Chat Google GenerativeAI, Google GenerativeAI Embeddings, and a vector store, known as Chroma [2]. The two general categories into which it can place the user inputs are general medical questions and those related to symptoms. This allows MedGPT to respond to very general medical questions while also providing symptom-based disease forecasts. It comes preequipped with features that ensure contextual relevance, such as an API custom retriever for the matching of diseases with symptoms and Tavily Search for web-based information. [3] [4]. The system is multi-agent based



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architecture. It provides its power to it. A total of three agents exist according to user input and these are agent, agent1, and agent 2. In the beginning, the first agent has to determine whether the question of the user is either generic or symptom-based.

LITERATURE REVIEW

Theoretical Investigation: MedGPT integrates the power of advanced AI technologies, including large language models (LLMs) and machine learning algorithms, to significantly improve patient interaction, symptom analysis, and predictions made for disease. Using models such as Chat Google Generative AI, Google Generative AI Embeddings, and Chroma vector storage, MedGPT can convert the inputs from a patient into a vector to provide accurate, context-aware medical advice. Its hybrid architecture invokes specialized agents for either symptom-based disease prediction or general medical queries. MedGPT offers real-time search functionalities and user friendly interface built on Streamlit that presents current medical information and assists in scheduling appointments, hence improving patient engagement and streamlining health services within a framework presented here that demonstrates the potential of AI-driven solutions within modern healthcare systems.

Related Works: During COVID-19, chatbots provided highly scalable, real-time solutions in ways that greatly improved responses to public health challenges like self triage, symptom tracking, and personal risk assessment [5]. It also served to share the right health information to eliminate myths, aid in vaccination, and to cater to recovery post COVID and monitor illness surveillance. Applying a combination of the traditional models with large language models, such as GPT, opens new prospects for MedGPT. Such models are very good at risk evaluation and diagnosis but do not handle unstructured data, in contrast LLMs are great with natural language questions and offer real-time conversational support. [6].

A medical chatbot based on BERT increases healthcare communication significantly through advanced natural language understanding that delivers the precise and personalized response to medical queries, respectively [7]. Compared with traditional chatbots, it addresses issues like misinterpretation of medical terms and generic answers and has an accuracy rate of 98% in predictions and patient engagement. Therefore, BERT-based solutions are very crucial to deliver high-quality healthcare services. An example of versatility in conversational AI is "Health Assistant Bot," a personalized health assistant for Italianspeaking users [8].

Universitas Negeri Semarang introduced AI-powered chatbots into research for improving customer services in higher education institutions. Introduction of AI-powered chatbots led to the lessened time needed for a response and increased satisfaction by students since the inquiries covered on administrational work as regards registration and records of students, thus displaying the possibility of enhancing service delivery through AI in education according to Ref [9]. Similarly, the AI Chaperone chatbot helps caregivers take care of patients with Alzheimer's through real-time provision and personalized support addressing the psychological and practical needs. This was the ability LLMs possessed in processing the complexities of medical data. This is very good for developing conversational agents for patient management and personalized healthcare [10].

The authors proposed a BERT-based model, "Predicting Medical Specialty from Text Based on a Domain-Specific Pre-Trained BERT", that improved the prediction of medical specialties from ehr very significantly and outperformed traditional methods in specialist categories recognition [11]. This demonstrates BERT's ability to master a complex medical language. Similarly, "The Health Chatbots in Telemedicine: Intelligent Dialog System for Remote Support" focuses on the role of chatbots in telemedicine by making it possible to hold remote consultations with patients through engagement, providing real-time responses, and streamlining healthcare delivery [12].

METHODOLOGY

The increasing demand for efficient, accessible, and personalized healthcare services, coupled with the complexity and volume of medical data, presents significant challenges for healthcare systems worldwide. Traditional methods of patient interaction, symptom analysis, and appointment scheduling are often time-consuming and can overwhelm healthcare providers, leading to delays in diagnosis and treatment. Additionally, many individuals, especially those in underserved regions, face barriers to timely access to medical information and care. To address these issues, there is a need for an AI-driven solution that can automate patient interaction, provide accurate symptom analysis, predict potential diseases, and streamline appointment scheduling, ultimately improving



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healthcare accessibility and reducing the burden on healthcare professionals.

Dataset Description: The proposed dataset for the Disease Symptom Description aims at developing health-care prediction systems. This dataset is a structured collection of diseases with their associated symptoms. This capability allows users to analyze the disease symptom relationship. As it can analyze such relationships, the dataset is suitable for application of machine learning in predicting diseases. The dataset is user-friendly, designed to be easily cleaned and processed for further use in analysis or training of models. It can be a key resource for healthcare domain researchers and developers, allowing them to better create predictive algorithms and improve diagnostic accuracy.

Data Acquisition and Pre-processing

Data Acquisition: The success of MedGPT relies on highquality data that accurately represents medical queries and responses.

The data sources will include:

- Medical Literature: Access to up-to-date medical journals, articles, and guidelines to inform the chatbot's knowledge base.
- Symptom-Disease Databases: Datasets like the Symptom2Disease dataset, which includes annotated examples of symptoms and corresponding diseases.
- User-Generated Data: Collecting data from previous patient inquiries through surveys or existing healthcare chatbots, ensuring consent and anonymity.
- Appointment Scheduling Data: Data from healthcare facilities regarding common patient inquiries and booking patterns to refine the scheduling functionality.
 2) Pre-processing: The raw data must be cleaned and transformed to be usable for training the models:
- Data Cleaning: Remove duplicates, irrelevant information, and inconsistencies from the dataset. Ensure that symptom descriptions and disease labels are accurately annotated.
- Normalization: Standardize the text data by converting it to lowercase, removing punctuation, and correcting typos to maintain consistency across inputs.
- Tokenization: Convert sentences into tokens or words to facilitate input into the LLMs and models. This may involve using libraries such as NLTK or spaCy.

Embedding Generation: Use the Google Generative AI Embeddings model to convert pre-processed text data into numerical representations (embeddings), enabling the model to understand and analyze the relationships between symptoms and diseases effectively

Architecture of the Models

Model Architecture Overview: MedGPT will employ a hybrid architecture that integrates several advanced models:

- Chat Google Generative AI: This LLM will serve as the core conversational engine, responsible for understanding and generating responses to user queries. Its ability to process natural language allows for engaging and contextaware interactions [13].
- Google GenerativeAI Embeddings: Used to transform user inputs and symptom descriptions into numerical vectors, this model aids in semantic understanding and matching between symptoms and diseases.
 Chroma Vector Store: A vector-based retrieval system that stores medical data and allows for efficient querying and retrieval of relevant information during interactions.



Fig. 1 Flow Chart

Model Components

• Query Classifier: An initial agent that categorizes user inputs into symptom-related inquiries or general



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medical questions. This will guide the subsequent response generation process.

• General Medical Inquiry Agent: This agent utilizes external search tools, such as Tavily Search, to retrieve comprehensive medical information for general questions.

RESULTS AND DISCUSSION

The evaluation of MedGPT performs in the three related areas which are symptom analysis, disease prediction, and appointment booking facilitation. The system's efficiency can be established quantitatively and qualitatively while asserting its potential to improve the healthcare delivery system and enhance patient involvement.

Quantitative Analysis

- Accuracy: From Fig.2, MedGPT achieves high accuracy in predicting diseases through advanced AI models, which include Lang Chain and Google Generative AI, thus helping analyze the degree of matching symptoms with relevant diseases more efficiently.
- Efficiency: This chatbot delivers quicker responses, thus suitable for the real-time interactions during health care. Moreover, it has a great success ratio for appointment handling, and hence it further optimizes health care workflow.
- Comparative metrics: (e.g., METEOR scores for ChatGPT and Copilot) illustrate the effectiveness of MedGPT in handling diverse medical inquiries. It outperforms alternatives in providing precise responses tailored to user needs.

Prompt	ChatBot	Meteor Score	
I have Lower	Our ChatBot	1	
Abdominal Pain	ChatGPT	0.611575492	
	Copiolt	0.57265584	

Table. 1. Quantitative Analysis

The results of the evaluation demonstrate that MedGPT effectively addresses the challenges faced in healthcare delivery by leveraging AI technologies. The high accuracy in symptom analysis highlights the chatbot's potential as a reliable resource for patients seeking medical advice, potentially leading to quicker diagnoses and better patient outcomes.

😚 i have abdominal pain

I understand you're experiencing abdominal pain. To help me understand better, could you tell me:

- Where exactly is the pain located? (e.g., upper left abdomen, lower right abdomen)
- What does the pain feel like? (e.g., sharp, cramping, dull, burning)
- When did the pain start?
- Is there anything that makes the pain worse or better?
- Do you have any other symptoms? (e.g., nausea, vomiting, diarrhea, constipation, fever)

The more information you can provide, the better I can assist you.

Fig. 2 Chat Bot Query (Exchange – 1)

CONCLUSIONS

The project "MedGPT: An Healthcare Chatbot for Disease Prediction" successfully integrates advanced AI technologies, including LangChain, Google Generative AI, and vector-based retrieval systems like Chroma. It's aimed to be a perfect chatbot that delivers good, accurate symptom-based disease predictions and answers general medical questions. The modular design of this chatbot allows it to use specialized agents for different types of queries and guarantees proper, contextually appropriate replies. It is a useful tool for first medical advice and reduces the administrative burden on medical practitioners due to its user-friendly design, thereby also increasing accessibility and participation. MedGPT has a bright promise in improving healthcare efficiency and access, even if it cannot replace consulting with an expert.

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Automatic Disease Identification and Detection for Jasminum Leaf using DL Methods

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ABSTRACT

Indeed, the effects of plant diseases on agricultural productivity are gigantic, so early detection becomes the key to effective management. This paper uses a deep learning approach that can be used for automatic identification and determination of diseases attacking the leaves of Night Jasmine, Cestrum nocturnum. We used a dataset, categorized in three classes—Healthy, Multiple (leaves with multiple diseases or stages), and Rust (leaves affected by rust or fungal diseases)—to develop the classification model using the MobileNet V2 architecture and compare that to CNN architecture and Inception V3. We have used the MobileNet V2 model because of efficiency in doing image classification on fewer computational resources. Hence, it is best suited for usage in real-time applications. These results suggest that deep learning approaches, where lightweight architectures like MobileNet V2 could form an important component of plant disease detection, can open up scalable solutions toward field applications. Future work includes improving the model's generalization capability and considering other categories of diseases.

KEYWORDS : MobileNet V2, CNN, Inception V3, Deep learning, Accuracy.

INTRODUCTION

The major problems in agriculture are crop diseases that cause a huge loss in crop yield every year. Detecting the disease early at high accuracy is highly important to avoid the spread of this kind of disease and to get maximum yield of the crop. Conventional techniques used for disease diagnostics depend basically on visual inspection by expert personnel, cumbersome, prone to error, and not applicable for large area monitoring. Advanced technologies, on their part, have made it possible to create automated disease detection systems, which effectively solve these problems. [1]

Deep learning, especially CNNs, has been a class of suc cessful approaches for image classification tasks and contains plant disease detection. They have shown the efficacy of feature extraction from images through selflearning and has produced promising results for diagnosis of plant and leaves diseases based on leaf images. Here, we propose a deep learning approach using the architecture of MobileNet V2 in an effort to detect and classify the disease occurring in Night Jasmine leaves.[2] The revolution brought into plant disease detection by recent advances in deep learning methods sets the stateof-the-art approaches of agricultural challenges to their most accurate and efficient solution in agricultural issues, mainly because of recent architectures of convolutional neural networks used to adapt image classification tasks that tackle more complex patterns at higher precision in the identification of subtle features related to plant diseases. We have tested three of the most well-known deep architectures, namely MobileNet V2, CNN, and Inception V3, on the task of classifying disease among Night Jasmine leaves in this paper. MobileNet V2 is a lightweight CNN model. It shows an excellent balance between top classification accuracy and computational efficiency, making it suitable for real-time appli cations on mobile devices.[3]

LITERATURE REVIEW

Automatic disease recognition of plants is the key to further development in agriculture. Deep CNN models have a higher accuracy and efficiency for their detections. Design and test four deep CNN models to achieve plant



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disease detection. Domain adaptation techniques are to be applied to the constructed models regarding robustness, accuracy, and training.

Related Works: A scientific analysis of the study. The paper presents machine learning algorithms for detecting agricultural crop leaf diseases. Many classification algorithms are used during the preparation, such as Fuzzy Logic, KNN, PNN, SVM, and ANN. Diseases detected early affecting leaves of plants. Improve the disease control rate for crops in agriculture. A number of machine learning algorithms like CNNs, SVM, PNNs, KNNs have been effective in identifying leaf diseases with a classification rate ranging from 76% to 100%. [4]

Identification of Tomato Leaf Disease Increase the disease detection accuracy with the help of Yolov8 architecture. Based on a provided dataset, with thorough observation, In the paper, totally automated identification of tomato leaf diseases uses Yolov8 architecture and follows benchmark performance history. Development of a deep learning model should be worked out in tomato leaf disease identification and also be aimed at realizing higher accuracy rates in disease detection.[5]

Poor disease control in agriculture causes yield loss. CNN is employed in the proposed system for automatic detection of diseases in leaves. Automatic identification of leaf diseases by convolutional neural networks evaluates images to identify healthy and affected leaves and provides suitable treatments according to the diseases detected. Deep learning and image processing-based automated identification of the leaf disease, providing a future nextgeneration machine learning-based illness detection approach. [6]

Deep learning for plant leaf disease classification impacts on agriculture productivity, fast yet very accurate results. The paper makes use of deep learning, more specifically deep convolutional networks, to detect diseases in plant leaves that may very rapidly and reliably diagnose plant ailments. Design an approach for the disease classification of plant leaves. Implement deep CNN for the classification of the images of the leaves with accuracy. [7]

Crop diseases have de-terred crop productivity in the agriculture sector of India. In case early diseases are detected, the growers must take appropriate measures. CNN-based approaches can classify plant leaf diseases with a correctness rate of 90%. A lot of classification approaches like k-Nearest Neighbor Classifier, Probabilistic Neural Network, Genetic Algorithm, and

Support Vector Machine, have been used already for the automatic identification of crop diseases from images. Such an approach relies upon heavy-duty databases and numerous algorithms for the training mechanism so that reasonable accuracy is obtained for detection purposes. Application of CNN for better detection of plant leaf diseases so that it may be more accurate.[8]

Legumes support food security by enhancing nutrition and providing ecological services. In Faba beans, machine learning improves the accuracy of disease detection. Use CNNs to detect illnesses of Faba bean leaves. Attain a high degree of disease detection accuracy. The study shows the possibility for efficient disease management by using convolutional neural networks to diagnose Faba bean leaf illnesses with 99.37% training accuracy and 89.69% validation accuracy. [9]

METHODOLOGY

Dataset Description: The Night Jasmine Leaf Diseases dataset used in this research is directly aimed at performing detection and classification on the diseases infesting the leaves of plants Cestrum nocturnum, known as Night Jasmine. Deep learning models, which are the primary elements involved in most complex image classification tasks applied in plant pathology, require adequate training and evaluation. Number of Images: The dataset consists of 12,000 images, thus providing a considerable volume of data in the train and test model. In this way, the large dataset helps ensure the model's strong robustness. It gives reasonable flexibility to handle the different instances of diseases. Image Size: All the images are resampled to 256x256 pixels. This ensures that all images fed into the model are at the same resolution, which simplifies the pipeline in preprocessing and makes all images resized to the same dimension.

Data Collection: For this paper, the data source is taken as Night Jasmine Leaf Diseases Dataset available on Kaggle, a widely known online resource for datasets as well as machine learning challenges. It is indeed the gateway to a gigantic dataset comprising diversity and of highly quality and richly labeled datasets suitable for machine learning practitioners and re searchers. The dataset comprises 12,000 preprocessed images of Night Jasmine (Cestrum nocturnum) leaves classified into three different classes: Healthy, Multiple (multiple diseases or stages), and Rust (rust or fungal infections). The images used in this dataset were sourced from a mix of varied sources and fixed to an



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image size of 256x256 pixels to allow homogeneity in the dataset.



Fig. 1. Dataset Split

Data Acquisition:

Preprocessing is essential for preparing datasets for deep learning. In this study, several techniques were applied to the Night Jasmine Leaf Diseases Dataset:

- 1. Image Resizing: All images were resized to 256x256 pixels to ensure uniformity and reduce computational load.
- 2. Normalization: Pixel values were scaled from 0-255 to 0-1, optimizing model performance and speeding up convergence.
- 3. Data Augmentation: Techniques such as random rotations, flips (horizontal/vertical), zooming, and brightness/contrast adjustments were used to prevent overfitting and improve model generalization. These methods help the model learn more robust features and handle variations in the data.

Dataset Preparation: After pre-processing and getting all the data together, training methods and testing methods are produced from that set of data. Some of the data is already pre-classified and is used in training, while the rest is used to evaluate the performance of the model. Keeping the balance between robust evaluation and the need for enough training data, the split is put at 0.8 for training and the rest for testing.

Architecture of the Models

1) MobileNet V2: A lightweight CNN architecture ideal Fig. 2. Training Accuracy

for image classification on devices with limited computational power. Key features include depthwise separable convolutions to reduce computations, inverted residuals for efficient feature learning, and linear bottleneck layers to maintain computational efficiency and prevent overfitting. It performs multiclass classification with a softmax output for Healthy, Multiple, and Rust classes.[10]

- 2) Convolutional Neural Network (CNN): A fundamental architecture for image classification, consisting of convolutional layers to extract features (edges, textures, etc.), pooling layers for dimensionality reduction, and fully connected layers for final classification. This structure helps in determining leaf health based on learned features.[11]
- 3) Inception V3: A complex architecture with multiple convolution layers of different filter sizes to capture features at various scales, ideal for detecting disease symptoms in leaves. It uses factorized convolutions for efficiency, auxiliary classifiers to avoid overfitting, and global average pooling to reduce parameters and prevent overfitting. While highly effective, its depth requires significant computational resources, making it challenging for mobile deployment.[12]

RESULTS AND DISCUSSION

Across all metrics, MobileNet V2 performed the best with 97% accuracy, precision at 87%, recall at 88%, and F1-score at 87.49. This model was very efficient and thus perfect for mobile deployment. It would be an excellent option to be used in resource-constrained environments, such as farming communities where smartphones are the primary tool for disease detection.





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The CNN model performed at a middle degree, and its results were: its accuracy was at 82.56%, precision at 84.39%, recall at 82.56%, and its F1-score was at 83.46%. Since the CNN was not that much of an accurate model than MobileNet V2, this is still valid because it offers valid results. Complexity performance balance is found in the model; hence, it is feasible for environments with slightly higher computational capabilities. The more complex Inception V3 model had lower performance in terms of accuracy, and an f1-Score of 81.09%. Although it had a deeper architecture, the model was very inefficient and inaccurate, hence less adaptable to be used in real time on the mobile devices because it consumed more computational power.



Fig. 3. Training Loss

The outcome suggests that MobileNet V2 is the best trade off between a more accurate model and computational efficiency in this task, which is basically required by the project for providing a tool that is accessible and also accurate enough to help farmers identify diseases on Night Jasmine leaves. It rather provides an alternative simplicity. Inception V3 happens to be costly in resources but not as good in terms of accuracy for this specific use case.

CONCLUSIONS

In this project, we employed three models from deep learning to identify and diseases in the leaves of Night Jasmine, which include MobileNet V2, CNN, and Inception V3. We derived the best model after testing it. Having evaluated it with our metrics, we establish that the best model we have here is MobileNet V2 with accuracy levels of 97%, precision levels of 87%, recall levels of 88%, and an F1-score of 87.49%. This is a model equipped with high-performance computing and has very low resource consumption, making it the best to be deployed in mobile applications, mainly the main platform for the farmers. The CNN model achieved 82.56% accuracy and 83.46% F1-score, offering a good balance between simplicity and performance. However, it is less optimized for mobile devices compared to MobileNet V2. Inception V3, with its deeper architecture, had a lower accuracy of 79.03% and an F1-score of 81.09%. While precise, its high computational requirements make it less suitable for mobile deployment.

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Review on Intelligent IoT-Enabled Vehicle Parking System for Urban Efficiency

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ABSTRACT

Urban parking challenges, including congestion, time wastage, and inefficient space utilization, are significant issues in modern cities. With increasing urbanization and vehicle ownership, the demand for innovative parking solutions has surged. The integration of the Internet of Things (IoT) presents transformative potential for addressing these challenges by enabling real-time communication between devices, optimizing parking space utilization, and reducing congestion and pollution. IoT-enabled parking systems leverage technologies such as sensors, mobile applications, and automated payment mechanisms to enhance user convenience and operational efficiency. This paper provides a comprehensive review of IoT-based parking systems, exploring their technological frameworks, implementation strategies, and societal impacts. It synthesizes existing research to identify trends, innovations, and persistent challenges, offering insights into the role of artificial intelligence, machine learning, and cloud computing in improving these systems. The analysis emphasizes the significance of IoT-enabled parking in the broader context of smart city initiatives, highlighting their contributions to sustainability and urban development. By consolidating fragmented research, this study serves as a valuable resource for urban planners, policymakers, and technology developers, offering recommendations for future systems. The findings aim to inspire further innovation in parking management, paving the way for more efficient, sustainable, and user-friendly solutions to urban mobility challenges.

KEYWORDS : IoT-enabled parking systems, Smart cities, Sustainability, Urban congestion, Urban mobility.

INTRODUCTION

rbanization has led to an exponential increase in vehicle ownership, presenting significant challenges to effective parking management in cities worldwide. Congested parking lots, extended search times for available spaces, and inefficient utilization of parking infrastructure are commonplace in urban areas. The resulting inefficiencies contribute not only to time wastage but also to elevated fuel consumption and increased environmental pollution. Studies indicate that as much as 30% of urban traffic congestion can be attributed to vehicles searching for parking spaces. Such issues are further exacerbated during peak hours, highlighting the pressing need for innovative solutions [1]. The integration of the Internet of Things (IoT) has emerged as a transformative approach to addressing these challenges. IoT enables realtime communication between interconnected devices, such as sensors, cameras, and mobile applications,

creating a seamless and intelligent ecosystem for parking management [2].



Fig. 1. Smart Parking

By leveraging IoT technologies, parking systems can provide real-time information about available spaces, guide users to their destinations, and even enable reservations



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and automated payments. These capabilities not only enhance user experience but also optimize the utilization of parking spaces and reduce traffic congestion. IoTenabled solutions hold the potential to transform parking systems into more efficient, sustainable, and user-friendly infrastructures, making them an essential component of smart city initiatives.

Scope and Objectives of the Paper

This review aims to explore and synthesize existing research on IoT-enabled parking systems, examining their technological frameworks, implementation strategies, and practical outcomes. By analyzing various studies, this paper seeks to identify key trends, innovations, and challenges in the field, providing a comprehensive understanding of the current state of IoT-based parking systems.

The scope of this review encompasses a broad range of technological aspects, including sensor networks, communication protocols, data processing methods, and user interfaces. It evaluates the role of advanced technologies such as artificial intelligence (AI), machine learning (ML), and cloud computing in enhancing the functionality of these systems [3]. Furthermore, the review investigates the social, economic, and environmental impacts of IoT-enabled parking solutions, emphasizing their significance in the context of urban development and sustainability.

Overall, this paper seeks to bridge the gap between technological advancements and practical applications in the domain of parking management. Through an in-depth examination of existing research, it aspires to foster a deeper understanding of how IoT can revolutionize urban parking, ultimately contributing to more sustainable and livable cities.

LITERATURE REVIEW

Research into IoT-enabled vehicle parking systems has significantly evolved to address challenges such as traffic congestion, inefficient parking management, and environmental concerns. Abbas et al. (2023) highlighted the use of machine learning models, such as AlexNet and YOLO, to enhance object identification in smart parking solutions [4]. Their system demonstrated stability and procedural improvement in smart city ecosystems. Similarly, Ali and Khan (2023) explored trust-based secure parking allocation using SVM and ANN classifiers, achieving 96.43% accuracy in identifying malicious nodes, thereby addressing privacy and security concerns [5].

Studies by Jabbar et al. (2024) introduced a LoRaWANbased system that integrates sensors for vehicle occupancy detection and solar-powered batteries for energy efficiency. The real-time updates provided by this system are effective in alleviating urban parking challenges [6]. Bante et al. (2024) emphasized the convergence of IoT and AI for predictive parking solutions, using historical and dynamic data to recommend spaces and reduce search time. Finally, Abo-Zahhad and Abo-Zahhad (2024) proposed a two-stage system integrating infrared sensors and genetic algorithms for self- parking and automatic payment, presenting a seamless and user-friendly parking experience [7]. Research extensively explores various sensors, such as ultrasonic, RFID, and infrared, for vehicle detection. Jabbar et al. (2024) demonstrated the effectiveness of ultrasonic and triaxial magnetic sensors for accurate vehicle occupancy detection, while Bante et al. (2024) noted the reliability of AI- integrated sensors in monitoring parking spaces.

Cost-effectiveness and precision remain critical factors in sensor selection [8][9].

Protocols like Zigbee, LoRaWAN, and 5G play a crucial role in data transmission. Jabbar et al. (2024) highlighted the benefits of LoRaWAN, including its energy efficiency and wide coverage, making it suitable for urban settings. Comparatively, Abbas et al. (2023) discussed the integration of 5G networks to enhance real-time communication and reduce latency.

Cloud computing, edge computing, and AI/ML approaches dominate the literature on parking data processing. Abbas et al. (2023) demonstrated the utility of machine learning for predictive analytics, while Ali and Khan (2023) utilized ensemble models for enhanced security. Edge computing systems have been proposed to reduce latency, particularly in high-density areas.

Mobile applications have become integral to IoT-enabled parking systems. Bante et al. (2024) highlighted intuitive interfaces offering real-time space availability and payment options. Abo- Zahhad and Abo-Zahhad (2024) added functionalities such as reservation and automated fee processing to enhance user convenience.

Challenges Identified in Literature

Despite advancements, several challenges persist. Connectivity issues and latency in urban environments, particularly under high user loads, limit system scalability. Privacy and security concerns, as emphasized by Ali



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and Khan (2023), pose risks related to data breaches. Additionally, most systems face scalability issues in densely populated areas, where high parking demand overwhelms available resources [10].

The reviewed studies demonstrate the promise of IoTenabled parking systems in optimizing urban mobility. Sensor integration, AI-driven analytics, and innovative user interfaces are emerging as critical components. However, addressing connectivity, privacy, and scalability challenges remains essential for realizing the full potential of these systems [11]. Future research should focus on enhancing security frameworks, reducing latency, and designing scalable architecture tailored for urban applications.

COMPARATIVE ANALYSIS

Evaluation Criteria

The comparative analysis of IoT-enabled parking systems was conducted based on key criteria critical to their effectiveness and usability. These included sensor technologies, focusing on the types, accuracy, reliability, and cost-efficiency of sensors employed in the systems. Communication protocols were evaluated for their efficiency, scalability, and latency, particularly in dense urban environments [12]. Data processing capabilities were assessed in terms of the use of cloud computing, edge computing, and AI/ML technologies to enable predictive analytics and improve system performance. User experience was another significant criterion, encompassing mobile application usability, real-time updates, reservation systems, and payment integration. Finally, the sustainability of these systems was analyzed, with a focus on energy efficiency and their environmental impact [13].

Comparative Table

Study	Sensors Used	Communic ation Protocols	Data Processing	User Features	Key Innov- ations
Abbas et al. (2023)	Ultrasonic, AI-based cameras	5G, SDN	Transfer Learning (AlexNet, YOLO)	Real- time slot detection	Two-tier ML-based learning controller
Ali & Khan (2023)	RFID, Smart Sensors	Hybrid	ML algorithms (SVM, ANN)	Security- focused allocation	Trust- based security enhanc- ement
Jabbar et al. (2024)	Magnetic, Ultrasonic IoT-SPMS	LoRaWAN	Edge computing		

Bante et al. (2024)	Smart Sensors systems	IoT Networks	AI-based predictions	Reservati on & payment analysis	User- centric AI for behavioral
Abo- Zahhad & Abo- Zahhad (2024)	Infrared, RFID	WiFi	Genetic Algorithms	Automati c payment	Self- parking integration

Insights from Comparison

From comparative analysis, several best practices and innovations emerged. Abbas et al. demonstrated the efficacy of advanced machine learning techniques such as YOLO and AlexNet for high-accuracy parking slot detection. Jabbar et al. highlighted the benefits of using LoRaWAN for energy-efficient communication, coupled with solar power, to enhance scalability [14]. Bante et al. made strides in user experience by employing AI to deliver predictive parking recommendations, significantly reducing search times and alleviating traffic congestion.

In addressing challenges, Ali & Khan integrated trustbased machine learning algorithms to enhance system security and privacy, while Abo- Zahhad introduced self-parking capabilities to meet the growing demand for automation in urban smart cities. However, certain challenges remain unresolved across these systems [15] [16]. Connectivity issues in densely populated urban areas continue to hinder consistent performance despite advancements in communication protocols. Additionally, privacy and security concerns persist, particularly in dataintensive systems like IoT- enabled parking management systems.

Synthesis of Analysis

The analysis revealed that the most effective systems leveraged a combination of robust sensor technologies, scalable communication protocols, and AI/ML-driven data processing. LoRaWAN emerged as a standout communication protocol due to its low cost and wide-area coverage, making it ideal for urban deployments [17][18]. Hybrid ML models provided a reliable framework for both performance optimization and security enhancement. The integration of renewable energy sources, such as solar power, added significant value by improving sustainability.

Future systems can be improved by adopting hybrid sensor networks that combine ultrasonic, magnetic, and infrared sensors to achieve higher accuracy and reliability [19] [20]. Energy-efficient communication protocols, such as LoRaWAN or 5G, should be prioritized to ensure scalability



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and performance in urban environments. Incorporating trust-based ML frameworks can address lingering privacy and security concerns. Finally, enhancing user-centric features, such as predictive analytics and seamless payment systems, will further optimize the functionality and appeal of IoT- enabled parking systems [21][22].

CONCLUSIONS

Several kinds of smart parking systems have been introduced. Its effectiveness in reducing traffic issues, particularly in urban areas where congestion and a lack of parking places are evident, is demonstrated by the numerous instances of smart parking system deployment that are being given. It accomplishes this by guiding customers and making the best use of parking spaces [23]. The advantages and disadvantages of each sensor technology can be examined with the study of all the sensor technology used in vehicle detection, which is one of the most important components of the intelligent parking system [24]. As previously mentioned, there are certain drawbacks to using a visual-based system for vehicle detection, but they are greatly outweighed by the benefits.

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Wild Animal Detection Using Convolutional Neural Networks in Residential Area

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ABSTRACT

Habitat disturbances and modern lifestyle needs has caused by human-promoted activities such as industrial, commercial and residential developments, logging, farming, deforestation in forest reserved areas, livestock grazing, mining, roads and dam building has charged heavily on the wildlife populations to shift in civil areas for food and shelter. Therefore, Human-wildlife conflicts in residential areas have become a major safety concern for both humans and animals too. To mitigate these conflicts the system is proposed for wild animal detection using Convolutional Neural Network (CNN) R-CNN and Faster R-CNN algorithms along with the warning system to alert residents and hence to control any life damage. The system performance has shown 95% accuracy in detecting variety of wild animals.

KEYWORDS : Convolutional Neural Network, R-CNN, Faster R-CNN.

INTRODUCTION

In India and throughout the world, wildlife raids on Lerops have introduced a major problem in farmers' life. Indian economy is majorly ruled by farming. The major source of income and hence the survival of the Indian population is farming.[1][2] It is naturally connected with many animal species such as wild cats, bears, elephants, bears and monkeys, and so on. This has led to introducing conflict between humans and wildlife. The frequency of crop-raiding by wild animals uses to end with damage to humans or cows, buffalos, and other pet animals' life. There are comparatively few recordings available to investigate patterns of crop-raids by wildlife and its impact on farmers' security. Unfortunately, most of the information is not available in refereed journals [3]4]. The coexistence of humans and wildlife has been a topic of concern for decades, as human activities often result in the loss of natural habitats and the displacement of wild animals. The increase in urbanization and industrial

development has led to a rise in human-wildlife conflicts as wild animals, usually enters in residential areas in search of food and shelter. This issue has become a global problem and several techniques as described below have been used.

Natural repellents

The farm areas may be protected by using naturally available resources rather using mechanical or chemical ones such as smoke by burning cow dung or other materials, onion emulsion to repel rabbits and deer, fencing of beehives which acts as repellent for elephants, chilli pepper as an excellent repellent against elephants, monkeys, egg-based repellent used against deer [5][6][7].

Visual Aids to discourage Wild animals

Farmers can use bright colour flags, reflectors or florescent lights [7][8]. Animal becomes uncomfortable and hence encourage them to be distant from such deterrents.



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Fencing

Fencing is a popular but costlier option to restrain the wild life reaching the marked area. Agricultural fencing is one of the effective wild animal protection techniques [8]. Electric fence is built for electric shock to the animals that coming in contact with the fence to prevent animal from crossing the fence. However, utilizing certain types of fences by local and state entities has been restricted. Therefore, deciding a suitable fence is based upon the local laws, regulations and the cost. Additionally, the warning sign to be displayed to avoid human contact.

Camera Trap

The camera trap is used for wildlife detection. The camera trap captures images or videos of wild animals in their natural habitat. They are widely used in wildlife conservation and research to monitor and study animal behavior [1][9]. These camera traps can provide valuable information for developing effective strategies to mitigate human-wildlife conflicts.

Electronic repellents

This is an effective and environment friendly method crop protection technique with wildlife at risk [10]. Farmers use Ultrasonic or Sonic electronic repellent for their crop protection.

Drones

Drones are used to keep watch on crops and livestock from wild animals [10][11]. They are available with remote control system, camera, motion detector and alarm system to alert farmers. Drones are remotely handled and fast in survey of large areas hence makes them an invaluable tool.

All the above mentioned techniques are sufficient for farm and crop protection but not enough for any kind of life. In this paper, the system is proposed to detect wild animals using camera traps installed in residential areas. Our approach uses a Convolutional Neural Network (CNN) to automatically detect and classify the animals based on their images captured by the camera trap [1][3].The approach evaluates the dataset of wild animal images and compared with the live stream of camera to give the decision whether the detection is wild or not by using CNN technique. The experimental result has shown better accuracy as compare to existing techniques.

METHODOLOGY

The Convolutional Neural Network (CNN) is a kind of machine learning functionality. It is used for different

data types, image recognition and the processing of pixel data. It is the specific neural networks in deep learning for identification and recognition of objects because CNNs are the network architecture of choice. This makes them highly suitable for Computer Vision (CV) tasks and for applications where object recognition such as self-driving cars and facial recognition [6] [7][9]. The CNN can find out important information in time series and image data also. A CNN's architecture is equivalent to human brain. A CNN's neurons are arranged in layers equivalent to human brain controlling and decision making abilities of processing visual signals. As compared to the previous networks, CNN performs better in image, speech or audio signal processing.

The Layered structure of CNN

A Layered structure of CNN has three layers:

First layer is convolutional layer, pooling layer as middle layer and third one fully connected (FC) layer. All the layers are arranged as per the chronological order of complexity in operations.

The Convolutional layer: It is the first and important building block which performs majority of computations regarding feature extractions in the convolutional layer [4].The second step of convolutional layer is to perform convolution and in addition, a filter inside moves the receptive fields of the image and checks for the presence of any feature in the image.

The filter calculates dot product between input pixel and filter in single iteration and sweeps the entire image after multiple iterations. The final output of the filter is called as a feature structure. Finally, the image is transformed into equivalent numbers in the same layer for interpretation and pattern extraction of the image.

Pooling layer: The pooling layer also performs similar work as of convolution layer but unlike the convolutional layer, it performs compression operation by reducing the irrelevant parameters causing information loss[12]. The efficiency of CNN algorithm is enhanced in this layer only.

Fully Connected (FC) layer: The "fully connected" indicates the connection between all inputs or node of one layer with every node of next layer. The FC layer works on image classification as per the information of features extracted in the pooling layer[13][14]. To avoid computational complexity, increase in losses and degradation in output quality, all the layers are not fully connected. The overall work by CNN is concluded as: By using convolution, the input image is processed through



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set of filters. One filter activates specific features of the image and passes its output to next layer filter. The feature identification undergoes multiple in iterations for hundreds of the layers. Finally, the entire object is reconstructed from the image data progressed through the layers.

DESIGN PROCEDURE

The primary work consist of foreground-background segmentation, object detection and image classification and image verification and object region proposal. The review of related work is given here.

Foreground-Background Segmentation: Foregroundbackground segmentation involves separating objects of interest in an image from the background by using thresholding, background subtraction, and graph-based approaches[2].

Object Detection, Image Classification and verification using R-CNN and Faster R-CNN:

In this section, R-CNN model and Faster R-CNN Network shown in Fig.1 and Fig.2 respectively demonstrates Convolution layers, Pooling layers and Fully Connected layers for the application.

- i. Step-1: Import all the necessary libraries
- ii. Step-2: Set the seed for reproducibility and load the data
- iii. Step-3: Convert the data into float values
- iv. Step-4: Normalize the data



Fig.1 Proposed feature extraction by R-CNN module

The R-CNN model as in fig. 1 for live image detection has the first Convolutional layer as input layer. It has feature maps with defined size and filter functionality. The pooling layer is Region of Pooling (ROI) pooling layer takes the maximum value which is regularised by dropout layer. The ROI Pooling layer is max-pooling, in which the pool size is as per the size of input to ensure the output and input size of the object is same. This layer is used because the FC layer may have different sizes. The dropout layer by name indicates the dropping of irrelevant data, filter out irrelevant data. This avoids over sizing of construction of output image. The fourth layer converts the compressed data into Flatten vector which is further processed by fully connected layer. This layer classifies the image data by using Support Vector algorithm (SVM). The FC layer generates the output image with neurons and filter based on probability predictions.

The Faster R-CNN model indicates that its processing is faster than R-CNN model for object detection. All the work flow of R-CNN and Faster R-CNN is same only with the difference that the pyramid of images is replaced by pyramid of filters. The pyramid of filters means multiple filters with different sizes. This made it possible to detect the object with different sizes and aspect ratios.

The Faster R-CNN working is given below.



Fig. 2 Proposed method by Faster R-CNN Model

- The RPN directs the Fast R-CNN detection module towards the objects in the image.
- Fixed-length feature is extracted by ROI Pooling layer of Fast R-CNN.
- The object verification process is applied and Signal to alarm is activated /deactivated.

RESULTS AND DISCUSSIONS

While implementing both algorithms, it was tested for different cameras to check the dependency of the algorithms on camera used for image capturing along with accuracy and processing time. The result is shown in Table 1.



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CNN Algorithm	Camera	Processing Time in Seconds	Accuracy
R-CNN	Arlo pro 3	9.6	90%
R-CNN	Nest cam	9.6	95%
R-CNN	Ring stick up camera	9.6	94%
R-CNN	Blink XT2	9.6	90%
Faster R-CNN	Arlo pro 3	4.8	80%
Faster R-CNN	Nest cam	4.8	85%
Faster R-CNN	Ring stick up camera	4.8	84%
Faster R-CNN	Blink XT2	4.8	78%

 Table 1. Performance of R-CNN and Faster R-CNN R

 algorithms for Wild animal Detection

The processing time requires solely depends on the samples of single ROI in R-CNN and that of samples of multiple ROIs from same image. e.g. In R-CNN the batch of 64 regions of 64 different images will take processing time of 64*S he Faster R-CNN, the batch of 64 regions selected from 2 regions then the processing time will be only 2*S second. This shows that Faster R-CNN is much faster in operation whereas the accuracy of detected image is poor as compare to R-CNN algorithm. Hence, the choice has to be made based on the application necessity for accuracy or speed. To further improve the accuracy of wild animal detection, we also employed a post-processing step, which filters out false positive detections based on the size and shape of the detected object regions. This may help to eliminate spurious detections caused by noise or other objects in the image

CONCLUSION

The implementation of R-CNN and Faster R-CNN algorithms for Wild animal or similar object detection performance not only depends upon the algorithm but also the cameras used to capture the images. As far as the accuracy of object detection is concern, R-CNN algorithm with Nest Camis the best option and when it is the matter of time, the Faster R-CNN outperforms irrespective of camera resolution. Irrespective of camera, R-CNN algorithm accuracy is above 90% and Faster R-CNN algorithm is fast in operation. The algorithm selection should be based upon the application requirements.

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ABSTRACT

Wireless Sensor Networks (WSNs) play a pivotal role in the Internet of Things (IoT), enabling efficient data collection and monitoring across varied environments. This study examines the performance of three WSN technologies—ZigBee, LoRa, and NB-IoT—by analyzing key metrics such as latency, throughput, energy efficiency, and reliability in simulated real-world IoT scenarios.

The results reveal distinct strengths for each technology: ZigBee is optimal for low-latency, high-throughput applications like real-time monitoring; LoRa excels in energy-efficient, long-range communication, making it ideal for remote and low-power use cases; and NB-IoT provides robust connectivity and broad coverage, particularly in densely populated areas.

A comprehensive literature review situates these findings within current industry practices, highlighting the importance of matching WSN technology to specific IoT application needs. Practical recommendations for deployment strategies are included to guide implementation.

Future research will explore integrating emerging technologies and hybrid WSN solutions to enhance adaptability and performance in evolving IoT ecosystems, providing actionable insights for developers and engineers.

KEYWORDS : Data transmission, IoT technologies, Network operation, Sensor network.

INTRODUCTION

Background

Wireless Sensor Networks (WSNs) are spatially distributed systems designed to monitor and collect data on environmental factors like temperature, humidity, and motion. Each WSN node typically comprises a microcontroller, power source, transceiver, and sensors. These nodes communicate wirelessly, transmitting collected data to a central system for analysis. Advances in MEMS, wireless communication, and digital electronics have significantly enhanced WSN capabilities(Gupta & Sharma, 2023)

WSNs are integral to the Internet of Things (IoT), which connects devices embedded with sensors, software, and communication technologies to share data over the Internet(Chen & Li, 2024). IoT devices range from household appliances to industrial systems, enabling automation and collaboration. Key features include sensors and actuators, communication networks, data processing, and user interfaces, improving efficiency and decision-making across 4. Data Processing: Cloud or edge computing systems applications.

Key Contributions of WSNs to IoT

- 1. Real-time Monitoring: WSNs enable continuous data collection, essential for applications like smart agriculture, where soil moisture, temperature, and humidity are monitored to optimize irrigation and yield(Chen & Li, 2024).
- 2. Automation and Control: In industrial IoT, WSNs facilitate automation by triggering actions such as predictive maintenance and equipment monitoring(Gupta & Sharma, 2023).

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3. Scalability: WSNs are easily expandable, allowing additional nodes to cover larger areas or monitor new parameters(Bhatnagar & Singh, 2023).

IoT Overview and WSN Integration

IoT Overview

IoT connects devices to exchange data and automate processes, enhancing productivity, safety, and decision-making. Its features include:

- 1. Sensors and Actuators: For environmental data collection and actions.
- 2. Communication Systems: For seamless data exchange.
- 3. Data Processing: Extracts insights for actionable outcomes.
- 4. User Interfaces: Enable user-device interaction through mobile apps and dashboards(Zhang & Zhang, 2024).

WSN Integration in IoT

WSNs provide the sensing and communication infrastructure for IoT. Integration steps include:

- 1. Sensor Deployment: Strategic placement to collect environmental data.
- 2. Data Transmission: Using protocols like Zigbee and LoRaWAN for wireless communication.
- 3. Data Collection: Central gateways aggregate and preprocess data.
- 4. Data Processing: Cloud or edge computing systems analyze and derive insights(Chen & Li, 2024).

Examples

- 1. Smart Agriculture: WSNs monitor soil and environmental conditions for optimized irrigation and pest management(Chen & Li, 2024).
- 2. Smart Cities: WSNs track air quality, traffic, and energy consumption, enhancing urban planning and sustainability(Bhatnagar & Singh, 2023).

Problem Statement: Challenges in WSN

Performance Analysis

Analysing WSN performance in IoT applications faces challenges due to system diversity and complexity:

- 1. Heterogeneous Devices and Protocols: Diverse hardware and networking patterns complicate standardization and comparison.
- 2. Energy Consumption: Varying operating conditions and power sources impact network reliability and longevity.
- 3. Scalability: Larger networks face higher latency and data loss, affecting performance.
- 4. Environmental Factors: Deployment in dynamic environments causes fluctuating performance metrics(Tiwari & Kaur, 2023).

Objectives of WSN Performance Analysis

- 1. Energy Efficiency: Monitor and optimize energy usage for extended network life(Tiwari & Kaur, 2023).
- 2. Data Transmission Efficiency: Assess throughput, latency, and packet loss to enhance communication (Bhatnagar & Singh, 2023).
- 3. Scalability: Analyze network performance as the number of nodes increases.
- 4. Environmental Impact: Study how external factors affect WSN operations.

LITERATURE REVIEW

Overview of Wireless Sensor Networks (WSNs)

Wireless Sensor Networks (WSNs) are independent systems comprised of sensor nodes that gather and relay environmental data to facilitate timely and informed decision-making. These systems play a pivotal role in diverse applications such as environmental monitoring and industrial automation. Despite their benefits, WSNs face significant challenges including signal interference(Gupta & Sharma, 2023), data integrity issues, and energy limitations, which can compromise their reliability and effectiveness.

Key Features

- 1. Sensor Nodes: Compact devices integrating sensors, microcontrollers, and wireless communication modules.
- 2. Base Station: Acts as a central node for aggregating and processing data.
- 3. Dynamic Topology: Flexible network structure that adjusts to changing conditions, ensuring scalability.



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Classification of WSNs

WSNs are categorized based on their application domain, architecture, or communication protocol:

- 1. By Application Domain:
- a. Environmental Monitoring: Monitoring weather patterns and pollution levels.
- b. Healthcare: Enabling remote patient observation.
- 2. By Network Architecture:
- a. Flat: Nodes with identical functionality.
- b. Hierarchical: Assigns specific roles to certain nodes for improved efficiency.
- 3. By Communication Protocol:
- a. Zigbee: Low-power, short-range applications(Zhang & Zhang, 2024).
- b. LoRa WAN: Designed for long-range, energy efficient communication(Chen & Li, 2024).

Advancements in WSN Technologies

Recent innovations in WSN technologies emphasize enhanced energy efficiency and seamless IoT integration. For example, solar powered nodes and adaptive communication protocols extend network lifespans. Additionally, edge computing has gained traction, allowing local data processing to reduce latency and alleviate system loads. This is evident in smart agriculture, where AI-powered WSNs optimize irrigation schedules.

Emerging Trends in WSN Research

- 1. Enhanced Security: Incorporation of lightweight encryption algorithms and blockchain-based authentication mechanisms to bolster data security.
- 2. Energy Harvesting: Development of sustainable power solutions such as vibration-based energy harvesting.
- 3. AI Integration: Employing artificial intelligence to improve data analytics and detect anomalies effectively.
- 4. Environmental Monitoring: Utilizing sensor networks to monitor water salinity for marine ecosystem conservation.

METHODOLOGY

WirelessSensorNetworks(WSNs)consistofinterconnected nodes equipped with sensors, microcontrollers, and

communication modules, working together to monitor environmental parameters like temperature, humidity, and motion. These nodes process data locally and transmit it to a central hub for further analysis. For example, in agriculture, WSNs enable precise irrigation management by monitoring soil moisture levels. The Internet of Things (IoT) enhances WSNs by integrating them into a broader ecosystem of internet-connected devices. IoT leverages WSNs to gather and process data efficiently, reducing latency through local computing while utilizing cloud analytics for deeper insights. IoT systems provide intuitive interfaces, such as apps and dashboards, for real-time monitoring and control. Users can remotely adjust devices, such as thermostats or irrigation systems, enhancing convenience and efficiency.

This methodology focuses on integrating WSNs with IoT to create smart systems for homes, industries, and cities.

WSN IN IOT APPLICATION

Applications of Wireless Sensor Networks (WSNs)

- 1. Environmental Monitoring
- a. Function: Weather tracking, air and water quality monitoring, and disaster forecasting.
- b. Example: Deploying sensors in forests to measure temperature, humidity, and soil moisture, aiding in wildfire prevention.
- 2. Smart Agriculture
- a. Function: Precision farming, soil moisture analysis, and crop health monitoring.
- b. Example: Using WSNs to optimize irrigation by tracking soil conditions, improving water efficiency and crop yield.
- 3. Industrial Infrastructure
- a. Function: Equipment monitoring, system diagnostics, and predictive maintenance.
- b. Example: Monitoring vibrations and temperatures in manufacturing equipment to predict failures and minimize downtime.

CONCLUSIONS

In this report, we have analyzed and compared the performance of Zigbee, LoRa, and NB-IoT technologies in various IoT applications, focusing on key metrics such as latency, throughput, energy efficiency, and reliability.



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Our findings indicate that the optimal WSN technology depends largely on the specific needs of each application. We concluded that Zigbee is best suited for IoT scenarios requiring low-latency, real-time communication. Its ability to handle rapid data exchanges makes it ideal for applications where immediate response is crucial. In contrast, LoRa excels in applications needing long-range, low power communication. Its efficiency in covering extensive distances while consuming minimal energy makes it ideal for remote monitoring and similar use cases. NB-IoT, on the other hand, provides superior connectivity and reliability, particularly in harsh or coverage-challenged environments. This analysis has provided us with valuable insights into how different WSN technologies can be strategically applied to optimize IoT deployments. By carefully aligning the technology with the requirements of the application, we believe developers can significantly enhance system performance and efficiency. In conclusion, we recommend selecting the most suitable WSN technology based on the unique characteristics of each use case to maximize the effectiveness of IoT solutions.

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Smart Alert System for Road Accident Detection: A Design and Implementation Framework

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ABSTRACT

The growing number of vehicles on roads has contributed to an alarming rise in traffic accidents, often leading to significant loss of life due to delays in emergency response and medical care. To mitigate these challenges, the development of an automated accident detection and alert system has become crucial for improving road safety. This study proposes a cost-effective and reliable solution that leverages sensor technology and communication systems to detect accidents in real-time and promptly alert emergency services and relevant authorities. By incorporating components such as GPS modules, GSM technology, and accelerometers, the system ensures precise accident detection and rapid transmission of location details to responders. This innovation aims to reduce response times, enable timely medical assistance, and streamline investigative processes, thereby minimizing the consequences of road accidents and saving lives.

KEYWORDS : GSM, GPS, Accident detection, Alert system.

INTRODUCTION

Road accidents contribute significantly to global losses, and a timely response can greatly improve the chances of survival for victims. However, existing solutions often encounter issues related to cost, complexity, and scalability. This paper presents a straightforward yet effective system that utilizes accessible technologies to overcome these limitations. The system detects accidents through an accelerometer and sends location-based alerts via GSM communication to ensure a prompt response. Furthermore, it employs an algorithm to identify the nearest hospital and alerts them, facilitating quicker medical intervention.

PROBLEM STATEMENT

With the growing population and the increasing use of vehicles, road traffic congestion has become a significant challenge, leading to a rise in accidents. These incidents often result in critical injuries or fatalities due to delays in ambulance services reaching the accident site or transporting victims to the hospital. The lack of a prompt and efficient mechanism for accident reporting and emergency response further exacerbates the situation. Additionally, the delayed intimation of accidents to investigation units increases the time required for enquiry and resolution. Therefore, there is an urgent need for a reliable accident detection and alert system that can instantly identify accidents, notify emergency services, and inform investigative authorities. Such a system can minimize delays, improve response times, and ultimately save lives while expediting the investigation process.

LITERATURE REVIEW

Several studies have explored accident detection systems, often incorporating technologies such as IoT and AI. For example, Kumar et al. (2021) proposed an IoT-based road accident detection system that integrates smart sensors with cloud-based analytics for real-time monitoring [2]. Similarly, Singh and Gupta (2020) developed a GPS and GSM-based alert system focusing on urban implementation, highlighting its efficiency in transmitting data in real-time [3]. K. Das and P. Sharma introduced an IoT-driven machine learning framework for real-time vehicle collision detection, combining deep learning algorithms with cloud computing and IoT sensors to evaluate accident risks and prevent incidents. Their



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approach also emphasizes energy optimization using sleep scheduling and adaptive data transmission, while ensuring system scalability and ongoing learning through cloudbased integration[1].

However, such solutions often face challenges related to cost and infrastructure, particularly in rural settings.

In recent years, AI-driven solutions have been increasingly used for predictive analytics and automatic accident detection, enabling systems to classify accident severity and prioritize alerts. However, these systems often require high-speed networks and substantial computational resources, which can limit their feasibility in resourceconstrained environments. The proposed system addresses these challenges by focusing on cost- effectiveness and practicality while retaining essential functions such as accident detection, location identification, and alerting. This approach makes it more applicable for regions with limited infrastructure, where more complex systems relying on expensive technology or advanced infrastructure may face difficulties.

System Design and Components

The proposed system consists of the following key components:

- 1. Arduino Nano: Acts as the central processing unit, coordinating all inputs and outputs.
- 2. GPS Neo 6M: Provides accurate location data to identify the accident site.
- 3. Patch Antenna: Enhances GPS signal reception, ensuring reliable location tracking.
- 4. GSM 800L: Sends SMS alerts with location details to pre-defined emergency contacts.
- 5. LCD I2C: Displays system status and operational feedback.
- 6. Button: Allows manual cancellation of false alarms or initiation of alerts.
- 7. Capacitor: Stabilizes the power supply, preventing fluctuations. (100 microfarad)
- ADXL335 Accelerometer: Detects s u d d e n changes in motion indicative of accidents. (Threshold = ± 3g)
- 9. Buzzer: Emits a local alert sound to notify nearby individuals.

10. Power Supply: Ensures consistent and reliable operation of the system. (3.7V - 5V)

METHODOLOGY

The system operates as follows

The accelerometer monitors acceleration changes in realtime. Sudden impacts exceeding a threshold trigger the detection mechanism.

Upon detection, the GPS module captures the location coordinates.

The GSM module sends an alert message containing the location to pre-configured emergency contacts.

The LCD displays the system's status, and the buzzer activates to draw local attention.

A button allows the user to manually override the alert in case of false detection.

IMPLEMENTATION AND TESTING

The hardware components are meticulously assembled and programmed using Arduino IDE. The system design includes a comprehensive block diagram mapping out all components and their interactions. Key algorithms include:

- 1. Accident detection logic using ADXL335 readings.
- 2. GPS data parsing for latitude and longitude extraction.
- 3. GSM message formatting and transmission.

Testing involved simulated accident scenarios, including sudden deceleration and collisions.



Fig 1. Circuit Testing

Testing Process and Results

Testing of the Accident Detection and Alert System was carried out under various controlled scenarios to ensure robustness and reliability.



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The primary objective was to evaluate the system's performance across different environmental conditions, types of simulated accidents, and specific metrics such as response time, location accuracy, and system reliability.



Fig. 2 Accident Magnitude Display

Environmental Conditions

The system was tested in urban and rural environments. In urban areas with robust infrastructure, it performed efficiently with minimal delays. In rural settings, while weaker GSM signals caused slight message delays, alerts were reliably transmitted within network range.

Types of Accidents Simulated

Various accident scenarios were simulated to evaluate the accelerometer's sensitivity and system responsiveness:

Head-on Collisions: Simulated by frontal impacts. Side-Impact Collisions: Tested using lateral forces. Sudden Deceleration: Created through abrupt braking. Rollovers: Induced by tilting the system to extreme angles to exceed accelerometer thresholds.

Metrics Observed

Response Time: Alerts were transmitted within 8.5 seconds on average, ensuring quick notifications.

Location Accuracy: GPS error was under 5 meters, allowing precise site identification.

Message Reliability: Tests showed a 96% delivery success rate across varied conditions.

User Interaction: The manual override button canceled alerts in under 1 second.

Buzzer and LCD: The buzzer activated promptly, and the LCD displayed real-time system updates.

Table 1 Observed Metrics

Metric	Value		
Detection Accuracy	95%		

GPS Precision	±5 meters
Communication Delay	<10 seconds

Testing confirmed the system's reliability across scenarios. Simulated accidents triggered accurate alerts, though poor GSM coverage highlighted the need for alternative communication options in future versions.

Result of Testing

The accident detection system is designed to ensure quick and effective emergency responses. Upon detecting a collision via the accelerometer, the Arduino Nano microcontroller immediately initiates the process. The GPS module identifies the accident's location, while the GSM module sends an SMS alert containing a concise "Accident Alert!" message with a Google Maps link. This alert is sent to preconfigured emergency contacts, including family, authorities, and the nearest hospital.

Key Enhancements

- Preconfigured Numbers: Ensures critical contacts are notified instantly.
- Hospital Alerts: Automatically detects and informs the nearest hospital for timely medical response.



Fig. 3 Accident GPS Location Alert

DISCUSSION

The proposed accident detection system demonstrates significant improvements in terms of accuracy, speed, and functionality. With a 95% detection rate and a response time of less than 10 seconds, this system exceeds the performance of existing models, which typically have 80% accuracy and a 20-second delay. These enhancements are made possible through precise sensor calibration and the integration of GPS and GSM modules, which enable timely and accurate accident detection with real-time notifications.



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One of the standout features of the system is its ability to send alerts to predefined emergency contacts and the nearest hospital, ensuring quick medical intervention. Unlike traditional systems, this one incorporates traffic management and live location sharing, adding value to the overall emergency response framework.

Additionally, the system is designed with cost efficiency in mind, utilizing standard components to ensure broader accessibility and implementation. These advantages highlight the system's potential to improve road safety and save lives. Future iterations may explore the integration of AI and IoT technologies to offer predictive capabilities and further expand its functionality.

Finally, ethical concerns around data usage should be transparently addressed. Clear policies on data storage and privacy compliance are vital to building public confidence in the system as a dependable accident detection solution.

COMPARATIVE STUDY

The proposed system demonstrates superior performance compared to conventional solutions. Traditional systems, with a detection accuracy of 80%, often lack reliability in diverse scenarios. In contrast, the proposed system achieves 95% accuracy through precise sensor calibration and enhanced integration of GPS and accelerometer technologies. Furthermore, it reduces response time to under 10 seconds, compared to the 20-second delay in existing systems. Unique features like real-time traffic management and ambulance routing make it a holistic approach to accident response, filling critical gaps in earlier designs.

System	Detection Accuracy	Response Time	Additional Features
Existing Systems	80%	20 seconds	Basic detection and reporting
Proposed System	95%	<10 seconds	Traffic control, ambulance routing

CONCLUSION

This paper presents a cost-effective and reliable solution for real-time accident detection and alerting. By addressing key gaps in existing methodologies, it offers significant advancements in emergency response systems. Future developments will focus on expanding system capabilities and exploring IoT and AI integrations to further enhance performance.

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ABSTRACT

Human-machine interaction (HMI) describes the process through which information is transferred between individuals and machines. It involves gathering information from users to convey their intentions, which the machine then processes and acts upon. Traditional HMIs, such as mice and keyboards, often require a designated workspace, limiting users' movements and failing to accurately represent their intentions. This setup necessitates that individuals learn how to operate these devices effectively, which can hinder overall work efficiency. HMI encompasses a variety of communication and control methods, simplifying the management and understanding of intricate systems. There are numerous forms of HMI, such as graphical user interfaces (GUIs), commonly seen in software and touchscreen devices, enabling users to engage with visual components. Voice control, another type, employs speech recognition to enable users to command machines verbally. HMI and sensor technologies are essential components of contemporary technology systems, facilitating communication and interaction between humans and machines while gathering and supplying data for multiple applications.

KEYWORDS : Flexible Tactile Sensor, Human-machine interaction (HMI), Infrared and Proximity Sensor.

INTRODUCTION

The link between a user and a machine, system, or device is referred to as a human-machine interface (HMI), often called a user interface or control panel. Although the term "human-machine interface" can describe any display that allows users to interact with a device, it is primarily associated with manufacturing processes. Graphical User Interfaces (GUIs) are frequently incorporated into HMIs because of their ability to visualize information. While HMIs and GUIs share some common features, they are distinct from one another. Human-Machine Interfaces communicate data with PLCs and I/O sensors, presenting the results for human review. Depending on the configuration, HMI displays may support simple functions like monitoring and tracking or more complex activities, such as shutting down machines or increasing production rates. The majority of industrial enterprises, along with numerous other sectors, rely on HMI technology to improve machinery efficiency and foster better human interaction. HMIs act as essential interfaces, bridging the gap between human operators and machines for seamless communication. They provide the software interface and corresponding hardware that enable humans to understand what is happening in a process, grasp the current state of operations, and exercise manual control when necessary. Poorly designed HMIs can lead to reduced efficiency in industrial operations, increased downtime, and heightened safety risks. A human-machine interface (HMI) is a bidirectional electronic system that connects people and machines, allowing efficient communication of human intent to the machine while also receiving responses from it. HMIs can be categorized based on the target of their actions: one category focuses on the human body, including health monitoring, voice recognition, and motion detection; the other targets machinery, featuring devices like flexible gloves that conform to the human hand, adaptable touch screens, and robotic manipulation.

LITERATURE REVIEW

Human-Machine Interface (HMI) systems play a critical role in improving interactions between humans and machines across diverse fields such as industrial



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automation, healthcare, and consumer electronics. The performance and precision of an HMI system are heavily dependent on the sensors utilized. This literature review explores current research on sensor technologies, focusing on recent advancements, existing challenges, and potential future innovations aimed at enhancing the accuracy and dependability of HMI systems.

For example, flexible tactile sensors integrated with robotic systems offer enhanced sensitivity and adaptability, as highlighted by Huang et al. (2023). Similarly, advancements in AI-powered systems have improved the precision of voice-controlled HMIs (Kumar & Sharma, 2023). However, challenges remain, including sensor energy efficiency and real-time data processing (Maddikunta et al., 2022). Addressing these areas will significantly enhance the reliability of HMI systems.

SENSORS

A sensor is a device designed to detect and measure specific physical properties in its surroundings, such as temperature, pressure, motion, or light. These devices convert the detected properties into signals that can be interpreted by humans or machines. The core functionality of a sensor revolves around translating physical phenomena into electrical signals for further analysis and use in various applications.

Fundamental Principles of Sensors

Detection: The primary role of a sensor is to identify a specific physical quantity, referred to as the measurand, within its environment. Examples include detecting temperature variations, light intensity, or pressure changes.

Conversion: Sensors employ transducer elements to transform the physical quantity into a measurable electrical signal. This conversion might produce outputs such as voltage, current, or resistance variations.

Signal Processing: The initial signal generated by a sensor may be weak or contain noise. To address this, signal processing techniques, such as amplification, filtering, and conditioning, are applied to prepare the signal for accurate analysis or display.

Output: The refined electrical signal is presented in a usable format, such as an analog voltage, a digital signal, or communication protocols like I2C or SPI, enabling integration with display systems or control mechanisms.

A sensor's efficiency is influenced by a variety of critical factors, such as its precision, sensitivity, detection range,

and speed of response. Each of these elements plays a vital role in determining how effectively the sensor performs in its intended application. Sensors serve as crucial tools in bridging the gap between real-world phenomena and machine-based analysis, converting data like temperature, pressure, or motion into actionable information.

HUMAN-MACHINE INTERFACE (HMI)

The human-machine interface serves as the crucial link enabling interaction and communication between a user and a machine or computer system. This interface facilitates the exchange of information, creating a cycle of interaction referred to as the loop of interaction.

Components of the Loop of Interaction

Visual Interaction: This is the most commonly studied and applied area of human-computer interaction (HCI). It includes visual components like screens, icons, and displays to facilitate interaction.

Audio Interaction: HCI systems also rely on audio-based communication, where sounds or voice commands serve as input and output mediums, enabling intuitive interaction.

Task Environment: This refers to the user's objectives and the conditions under which they interact with the machine.

Machine Environment: The context in which the computer operates, such as a student using a laptop in their dorm room, influences the interaction dynamics.

Input Flow: The user's actions generate an input flow, initiating the exchange of information from the task environment to the machine.

Output Flow: Information generated by the machine as a response to user input forms the output, providing feedback or actionable results.

Feedback Mechanisms: Feedback loops assess and refine the processes occurring between the user and the machine, ensuring clarity and accuracy in communication.

Fit: This involves optimizing the system design, user interaction, and task requirements to minimize the resources needed while maximizing efficiency and usability.

By seamlessly integrating sensors and human-machine interfaces, systems can deliver intuitive and efficient interactions in various fields, from healthcare to industrial automation and consumer electronics.



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TYPES OF SENSORS

Flexible Tactile Sensors

Flexible tactile sensors integrate seamlessly with the human body, enabling precise motion detection and posture evaluation. They monitor movements like walking, jumping, and squatting and assess muscle contractions and relaxation states.

Applications

- a. Health monitoring
- b. Athletic training
- c. Sports science

Types of Force Sensors in HMI Applications:

- i. Resistive Force Sensors: Detect changes in resistance when force is applied.
- ii. Capacitive Force Sensors: Measure changes in capacitance between conductive plates under force.
- iii. Piezoelectric Force Sensors: Generate electrical charges in response to mechanical deformation.



Fig 1 Force and Tactile Sensors [9]

Temperature and humidity sensor

Temperature and humidity sensors measure ambient temperature and relative humidity with precision.

Working Principles

- i. Temperature Measurement Techniques: Thermocouples and RTDs detect temperature changes.
- ii. Humidity Measurement Techniques: Capacitive, resistive, and thermal conductivity sensors measure moisture levels.

Proximity sensor

Proximity sensors are contactless devices that detect the presence or movement of objects within a defined range.

Working Principles

- i. Capacitive Sensors: Generate an electrostatic field and monitor capacitance changes.
- ii. Inductive Sensors: Create an electromagnetic field and detect metallic objects through eddy currents.

Infrared Sensors

Infrared (IR) sensors operate by emitting and detecting infrared radiation, allowing them to identify objects and monitor movement.

Types:

- a. Active IR Sensors: Use an IR source and detector.
- b. Passive IR Sensors: Detect natural infrared radiation emitted by objects.

CONCLUSION

In recent years, Artificial Intelligence (AI) and Human-Computer Interaction (HCI) have emerged as transformative fields, significantly advancing the way humans engage with technology. This paper provides a detailed exploration of the integration of Human-Machine Interaction (HMI) systems and sensor technologies, focusing on their potential to enhance interaction efficiency, user experience, and cross-industry applications. By leveraging advancements in flexible tactile sensors, proximity sensors, and AI-powered interfaces, the study underscores the development of intuitive, adaptive, and user-cantered systems.

The findings highlight the role of innovative sensors in improving motion detection, environmental monitoring, and data accuracy, with applications spanning healthcare, sports science, and industrial automation. Additionally, the paper emphasizes the importance of soft HMI designs, particularly in wearable technologies and robotics, to achieve seamless integration with human anatomy and movement. Addressing challenges such as energy efficiency, real-time data processing, and sensor reliability, this paper identifies key areas for future research and innovation. The convergence of HMI and AI is projected to lead to intelligent, adaptive systems that respond dynamically to user needs, fostering more natural and efficient humanmachine interactions. These advancements promise to redefine technology's role across industries, making it more inclusive, accessible, and aligned with human intent. By bridging the gap between human capabilities and machine intelligence, this study contributes to paving the



way for a future where technology acts as an extension of human intent, improving quality of life and driving innovation globally.

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Review on Real Time Monitoring System for Medical Treatment Using Smart Syringe Pump

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ABSTRACT

The real-time monitoring system for medical treatment using a smart syringe pump aims to improve patient care and ensure accurate drug delivery through continuous monitoring and control. The system integrates a syringe pump with sensors, microcontrollers, and wireless communication technologies to track the medication flow, dosage, and patient status in real-time. By leveraging IoT (Internet of Things) and data analytics, the system offers remote monitoring capabilities, allowing healthcare professionals to monitor multiple patients simultaneously and intervene when necessary. The smart syringe pump adjusts the infusion rate dynamically based on patient parameters, reducing the risk of over or under-infusion. It provides alerts for anomalies such as blockages, air bubbles, or incorrect dosage, ensuring patient safety. Additionally, the system can log patient data for further analysis and trend identification, enhancing treatment outcomes and personalized healthcare. This real -time monitoring system promises significant improvements in the accuracy, efficiency, and safety of intravenous medication administration, contributing to better clinical decision-making and optimizing patient care.

KEYWORDS : Smart syringe pump, Real-time monitoring, Medical treatment, IoT, Patient safety.

INTRODUCTION

The integration of real-time monitoring with smart syringe pumps is a major advancement in medical care. A smart syringe pump is an electronic device that delivers precise amounts of medication or fluids to patients. When combined with real-time monitoring, it improves safety, accuracy, and efficiency, benefiting both healthcare providers and patients.

Key Features

1. Precision Drug Delivery

Smart syringe pumps ensure accurate and consistent delivery of medications, minimizing the risks associated with under- or overdosing.

2. Real-Time Feedback

These systems continuously monitor parameters such as infusion rates, dosage, and patient response, providing instant feedback to clinicians. 3. Integration with IoT and Data Analytics Smart pumps can connect to hospital networks,

allowing data to be analyzed in real-time and shared with healthcare teams for informed decision-making.

4. Alarm Systems

Built-in alarms notify clinicians of any anomalies, such as occlusions, air bubbles, or deviations from programmed settings.

5. Remote Monitoring

Healthcare providers can monitor infusion status remotely, improving care in critical scenarios, such as ICUs or homebased treatments.

LITERATURE REVIEW

Health Monitoring System by Using IoT, G. Prakash, Ponkishore. K, Chermathdurai. S, Harish S, 2024, IEEE.



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• Health monitoring system using IoT is designed to remotely track and manage a patient's health by using interconnected sensors and devices.

• This system enhances preventive care, reduces response time in emergencies, and ensures better management of chronic diseases

Smart Infuse Dosing and Monitoring System, Epideny Nur Rachman, Fachmet Dwi Prasetyo, Fadhila Hilda Indriyani, Wahmisari Priharti, Hesty Susanti, 2024, IEEE

The system automated programming, patient-specific dose adjustments, and connectivity to EMR for seamless data tracking. It enhances patient safety, improves treatment efficiency, and provides clinicians with actionable insights through alerts and analytics, supporting better decisionmaking in critical care and routine medical practices.

Development and Evaluation of an IoT-Driven Auto-Infusion System with Advanced Monitoring and Alarm Functionalities, Chiang Liang Kok1, Tee Hui Teo2, Yit Yan Koh1, Yuwei Dai1, Boon Kang Ang1 and Jian Ping Chai1, 2024, IEEE

• The development and evaluation of an IOT driven auto infusion system with advanced monitoring and alarm is automates the delivery of intravenous fluids or medications, utilizing IoT technology to enhance accuracy, reliability, and patient safety. Key features include real- time data monitoring, remote access for healthcare providers, and alarms to detect anomalies like occlusions, air bubbles, or incorrect dosages. The study evaluates the system's performance in terms of precision, responsiveness, and usability, highlighting its potential to improve clinical outcomes and reduce manual intervention in medical settings.

A Smart Infusion Pump System for Remote Management and Monitoring of Intravenous (IV) Drips, Muhammad Raimi Rosdi, Audrey Huong, 2021, IEEE

- To enhance the precision, safety, and efficiency of intravenous therapy. The system integrates advanced technologies such as IoT and wireless communication to allow healthcare professionals to remotely monitor and control IV drips in real-time.
- It is designed to improve patient outcomes, optimize resource usage in healthcare facilities, and provide convenience for remote and home- based care scenarios.

Adaptive Drug Delivery to Control Mean Arterial Blood Pressure by Reinforcement Fuzzy Q-Learning, Rui Zhang, Zhichun Li, Xingzheng Pan, Zejun Ma, Ying Dai; Ardashir Mohammadzadeh, 2024, IEEE

- The system learns to deliver optimal drug dosages in real time by interacting with the patient's physiological model. The fuzzy logic component handles uncertainties in the dynamic MAP response, while Q-learning continuously improves drug delivery policies by trial-and- error based on feedback from the patient's MAP.
- This approach shows promise for personalized, precise blood pressure regulation, reducing risks of over- or under-medication and addressing individual variability. It highlights a significant step towards automation in critical care settings.

Determination of the Volume that a Syringe Pump can provide for Fluids Injection into Nanochannels, M. Flores-Reyes, J. H. Zepeda- Peralta, A. Vera-Hernández, L. Leija-Salas, 2024, IEEE

• This syringe pump helps to provide for fluid injection into a nanochannel to determine by the syringe's capacity, the pump's precision, and the nanochannel's dimensions which ensure accurate flow and compatibility with the channel's volume and pressure limits of the fluid.

A Wireless Implantable Closed-Loop Electrochemical Drug Delivery System, Max L. Wang, Pyungwoo Yeon, Mohammad Mofidfar, Christian Chamberlayne, Haixia Xu, Justin P. Annes, 2024, IEEE

• This wireless implantable closed-loop electrochemical drug delivery systems are the devices that release drugs precisely as per demand using real-time feedback and wireless control, which enables personalized and responsive by the system.

METHODOLOGY

Here's a conceptual flowchart for a Real-Time Monitoring System for Medical Treatment using a Smart Syringe Pump:

Start

Initialize System

• Power on the smart syringe pump.

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- Establish connection to the server or cloud for data storage.
- Initialize sensors and communication modules (e.g., Bluetooth, Wi-Fi).



Input Parameters

- Patient Information (ID, Name, Age, etc.)
- Medication Type and Dosage (Pre-programmed by healthcare provider).
- Rate of Infusion (Input required rate of flow, volume to be infused).

Pump Activation

Smart syringe pump begins to administer the medication based on the input parameters.

Real-Time Monitoring

- Flow Rate Sensor: Measures the actual rate of medication infusion.
- Pressure Sensor: Detects any pressure irregularities in the syringe pump.
- Temperature Sensor: Monitors temperature of the medication or surrounding environment.

Data Collection

- Real-time data from sensors is collected (flow rate, pressure, temperature).
- System logs data and timestamps for future reference.

Comparison with Predefined Parameters

- Compare the actual infusion rate with the desired rate.
- Compare the pressure and temperature values with the safe thresholds.

Alert/Warning Generation (if any issue)

- Alarm Triggered: If infusion rate deviates from the prescribed rate.
- Alert for Blockage: If pressure is too high or low (potential blockage).
- Temperature Alert: If temperature is out of range.

Feedback to Healthcare Provider

- Notifications/alerts sent to the healthcare provider or caregiver via mobile app or web portal.
- Real-time updates on the medication status.

Patient Monitoring

- Continuous monitoring of patient vitals (e.g., heart rate, blood pressure, oxygen levels) integrated with the system (optional, depends on the setup).
- Data from the syringe pump is synchronized with the patient's medical records.

Completion of Infusion

- When the prescribed dosage is delivered, the system stops the pump.
- The final data is stored in the system, and the healthcare provider is notified.

End

RESULTS

A real-time monitoring system for medical treatment using a smart syringe pump allows healthcare professionals to track and manage drug delivery precisely. It involves using sensors and IoT technology to continuously monitor the infusion rate, volume, and patient response. The system alerts healthcare providers of any deviations or potential issues, such as blockages or incorrect dosing, improving patient safety and treatment efficiency. Additionally, data can be accessed remotely, enabling continuous supervision and reducing the risk of human error. This system enhances the precision and reliability of medication administration.

CONCLUSIONS

A real-time monitoring system for medical treatment using a smart syringe pump improves the accuracy, safety, and efficiency of drug delivery. By integrating sensors, data analysis, and remote communication, the system ensures



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timely interventions and minimizes human errors. This is particularly beneficial for critical care environments where precise medication administration is essential.

FUTURE SCOPE

In the future, smart syringe pumps with integrated realtime monitoring capabilities will revolutionize patient care, providing more efficient, accurate, and personalized treatment while also improving healthcare accessibility and reducing costs.

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Review Paper on Embedded System Based Real Time Monitoring and Data Management System of Cutting Tools for Improving Efficiency of Machine Using IoT

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ABSTRACT

The development of an embedded system-based real-time monitoring and data management solution for cutting tools using the Internet of Things (IoT). Cutting tools are critical in precision machining, and their performance significantly impacts product quality and manufacturing efficiency. The integration of IoT with embedded systems enables advanced monitoring and data analysis, providing insights into count number of tools are cut in particular given time setup. This paper examines an applications of IoT-enabled systems for cutting tool monitoring, including data acquisition, fault diagnosis, and predictive maintenance. The system enables real-time tracking of CNC operations and parameters, leading to more efficient and smarter manufacturing processes. Additionally, it reduces the power consumption of the wireless sensors used to monitor the machines, contributing to cost and energy savings. By focusing on data collection and monitoring, this approach gives the way for intelligent manufacturing workshops that are more connected and efficient.

KEYWORDS : Cutting tools, IoT, Embedded system, Data management.

INTRODUCTION

Cutting tools are essential in machining processes, especially in industries like aerospace, where high precision and performance are critical. Monitoring the condition of these tools in real-time can help improve product quality, reduce downtime, and lower costs. With the rise of the Internet of Things (IoT), it is now possible to create smart systems that track and manage tool performance effectively.

This paper focuses on an embedded system-based realtime monitoring and data management solution for cutting tools using IoT. The system collects data on tool wear, temperature, vibration, and other factors to ensure better decision-making and predictive maintenance. By integrating IoT technology, manufacturers can enhance efficiency and reliability, gives way for smarter and more efficient machining processes. Some key features are Real Time Monitoring, IoT integration, Data Collection and Analysis, Embedded System Control, Fault Detection, Energy Efficiency, Scalability etc.

LITERATURE REVIEW

2.1. Internet of Things and Data Analytics for Predictive Maintenance in Industry 4.0, A Review, Mohsen Soori; 2024, Behrooz A Arezoo; 2023, IEEE.

The integration of Internet of Things (IoT) and data analytics for predictive maintenance within Industry 4.0. It highlights the role of IoT-enabled sensors, real- time data collection, and advanced analytics in predicting equipment failures, optimizing maintenance schedules, and reducing downtime. The paper also discusses challenges, current trends, and future opportunities in implementing predictive maintenance strategies.

Condition Monitoring and Remaining Useful Life Prediction for Tool Wear in CNC Machines Xing, Q., Zhang, X., Wang, S., Yu, X., Liu, Q., Liu, T.; 2024, IEEE.



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Condition monitoring and remaining useful life prediction are critical for managing tool wear in CNC machine. By using real-time sensor data such as vibration, force, and condition monitoring detect and identifies errors in it. These techniques improve machining efficiency, reduce costs, and extend tool life.

Machine learning for monitoring and predictive maintenance of cutting tool wear for clean-cut machining machines, Andrea Bonci., Alesandro Di Baise in 2022,IEEE.

This study explores the application of machine learning for monitoring and predictive maintenance of cutting tool wear in clean-cut machining processes. By leveraging realtime sensor data and advanced algorithms, the approach predicts tool wear patterns, enabling timely maintenance and reducing downtime. The system enhances machining precision, optimizes tool lifespan, and contributes to sustainable manufacturing practices by minimizing waste and operational disruptions.

Design of Intelligent Management System for NC Cutting Tools Based on Computer Tech Qingzhen Zhang; 2023, IEEE.

This paper presents the design of an intelligent management system for NC (Numerical Control) cutting tools, utilizing advanced computer technologies. The system integrates real-time monitoring, data analysis, and predictive maintenance to optimize tool performance and lifespan. By automating tool management processes, it enhances machining efficiency, reduces downtime, and supports intelligent decision-making in manufacturing operations.

Cutting Tool Wear Monitoring in CNC Machines Based in Spindle-Motor Stray Flux Signals Israel Zamudio-Ramírez, Jose Alfonso Antonino-Daviu; 2022,IEEE.

In this paper method for cutting tool wear monitoring in CNC machines using stray flux signals from the spindle motor. By analyzing variations in the motor's electromagnetic emissions, the system detects tool wear in real-time without additional sensors. The approach offers a cost-effective and non-invasive solution, improving maintenance accuracy, reducing downtime, and enhancing machining efficiency.

METHODOLOGY

Methodology can be describe into some following parameters:

System Design

- o Develop an architecture comprising embedded systems for edge processing, IoT sensors, and a cloud/ server for data storage and management.
- o Select appropriate sensors (Proximity sensor) for monitoring cutting tool conditions.
- o Design an embedded hardware interface for sensor integration and data acquisition.

Data Acquisition

- o Use IoT-enabled sensors to collect real-time data on tool parameters.
- o Implement microcontrollers or single-board computers (e.g., Arduino, Raspberry Pi) to process raw sensor signals.

Data Processing and Analysis

- o Preprocess the acquired data using filters and algorithms to remove noise and detect anomalies.
- o Apply predictive maintenance algorithms or machine learning models for tool condition monitoring.

Data Transmission

o Using GSM modem and wireless communication protocol like Wifi transmit data from embedded devices to a central server or cloud platform.

Cloud Integration and Management

o Implement cloud services for data storage, visualization, and analysis.

Real-Time Monitoring Interface

- o Using counter of Embedded system will count Number of tool cuts.
- o Provide features like notifications, alerts, and historical data visualization.

System Validation and Optimization

- o Test the system in various operating conditions to ensure accuracy and reliability.
- o Optimize algorithms and network settings for minimal latency and efficient data management.

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Implementation and Maintenance: Deploy the system in the operational environment and provide training to users. Regularly maintain hardware, update software, and refine algorithms for improved performance.



Fig. 1: Block diagram of Embedded System Based Real Time monitoring and Data Management System



Fig. 2: Overview of measurement quantities of whole life cycle of cutting tools

The Working of rod cutting machine is as follows:

Rod cutting machine: The physical machine that cuts the rod into pieces.

Sensor: Detects the cutting action (e.g., pressure sensor, optical sensor).

Processor/Raspberry Pi: Processes sensor data, counts pieces, stores data, and controls communication.

Memory: Stores real-time and historical data Communication module: Sends data to a designated phone number or cloud platform.

Display Output: In this block it display the result of the system.

RESULT AND ITS DISCUSSION

The result of implementation of an embedded systembased real-time monitoring and data management system for cutting tools using IoT demonstrated significant improvements in some parameters as follows:

Improving efficiency of machine

- Real-time Monitoring: Continuous tracking of tool parameters such as temperature, vibration, number of tools cut, and force enables operators to identify potential issues before they lead to breakdowns.
- Optimized Tool Utilization: Monitoring data allows operators to determine the exact life of a cutting tool, ensuring tools are replaced only when necessary, reducing downtime and costs.
- Reduced Downtime: It minimizes unexpected stoppages, improving overall machine uptime.

Enhanced Data Management

- Centralized Data Logging: IoT-enabled systems store data in a centralized cloud or local database, enabling easy access and analysis.
- Analytics and Reporting: The system generates insights such as trends in tool wear and correlations between operational conditions and tool performance, which assist in informed decision-making.
- Remote Access and Control: Authorized users can monitor cutting tool status and machine performance from remote locations, increasing flexibility and efficiency.

Cost and Resource Optimization

- Reduced Tool Replacement Costs: By monitoring the condition of tools, unnecessary replacements can be avoided, leading to cost savings.
- Energy Efficiency: Real-time monitoring allows adjustments to operating conditions, reducing energy waste and improving sustainability.

Scalability and Integration

- Integration with IoT Ecosystem: The system can integrate with other IoT-based manufacturing systems, enabling a seamless flow of data across processes.
- Scalability for Future Needs: The design of the system supports additional sensors and capabilities, ensuring adaptability to future requirements.

Operational Safety

• Early Fault Detection: Alerts for anomalies in tool



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performance reduce the risk of accidents or damage to the machine.

• Improved Operator Awareness: Real-time data visualization empowers operators to maintain safe and optimal machine operation conditions.

An IoT-enabled embedded system for real-time monitoring and data management of cutting tools significantly enhances manufacturing efficiency by enabling predictive maintenance, cost optimization, and improved tool utilization.

CONCLUSION

In conclusion, embedded system combined with IoT technology provide an efficient solution for real-time monitoring and data management to enhance machine efficiency. By integrating sensors, controller and IoT platforms, these systems enable seamless data acquisition, processing and communication. This approach not only improves operational accuracy and predictive maintenance but also reduces downtime and enhances productivity. The collaboration between embedded system and IOT fosters smarter decision-making and supports the optimization of industrial processes in real-time.

FUTURE SCOPE

The future of embedded system-based real-time monitoring and data management of cutting tools using IoT lies in advancing predictive maintenance through AI and machine learning, enabling more precise failure predictions. Integration with edge computing can enhance real-time processing and reduce dependency on cloud platforms. Expanding the system to include multiple tools and processes will improve scalability for industrial automation. Furthermore, leveraging 5G networks can enable faster data transmission, while integrating AR/ VR for visualization can revolutionize tool condition monitoring. These developments will make manufacturing smarter, more efficient, and highly adaptive to Industry 4.0 requirements.

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Anomaly Detection in Mobile Adhoc Network to Prevent Denialof-Service Attack

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ABSTRACT

The security strategy for Mobile Ad-Hoc Networks (MANET) must be complex because nodes have low energy and processing capacity. Dealing with denial of service (DoS) attacks is challenging because of their characteristics, including changing attack rates, a variety of targets, a large botnet, etc. MANET has characteristics of dynamic topologies, limited battery capacity, multicast routing, node transmission range, routing overhead, scalability, etc. which are susceptible to DoS attack. The analysis presented behavioral strategies of adversary nodes to breach availability and non-repudiation security services using DoS attack. This work presented authentication of genuine nodes using their trust level and blacklisting malicious nodes. Simulation is done on Ad Hoc On-demand Distance Vector (AODV) routing protocol with and without malicious nodes. The result analysis shows the impact of behavioral changes on the adversary node. Simulation results show average throughput is 51.57% and the packet delivery ratio is 73%. Also routing overhead is decreased to 18%

KEYWORDS : AODV, Black-hole, Gray-hole, Sink-hole, DoS, Anomaly detection, Intrusion detection.

INTRODUCTION

The MANET is based on the cooperative and autonomous behaviors of mobile nodes. All nodes in MANET maintain the ad-hoc routing information in the routing table which allows it to send data to other nodes. The network provides a self-organized topology, as well as a distributed multi-hop system of movable nodes. As a result, the network finds use in areas such as rescue operations, transport infrastructure, military science communications, and remote sensing [1].

MANETs seem to be susceptible in terms of functionalities. Attackers can disrupt network operations by targeting most of the physical, MAC, or internet protocols. Due to physical resource limitations like battery power, computational speed, trustworthiness, etc. of the mobile node, conventional wireless routing algorithms are appropriate to defend against black-hole, gray-hole attacks, etc. These attacks led to DoS attacks in MANET which breaches availability service [2].

A malicious node claims to have an optimal route and further it has dropped every packet that passes through it or forwarded fake packets to the destination node. Due to this situation, legitimate nodes are unable to reach the destination as shown in Figure 1. In the AODV protocol a destination node receives Route Request (RREQ) packets with a sequence number and several hops, then determines it has received another RREQ packet with a minimum hop count[3]. The destination node forward Route Reply (RREP), which follows the same route as the RREQ in returning to the source. After receiving RREP at the source node, communication is established between the source and the destination node. As a reactive protocol, AODV often has less overhead than a proactive one. A RERR message is issued through a node that detects the link interruption if the connection is lost and the path is no longer functioning, preventing messages from being sent[4].

Node energy, RTT, number of packets transmitted, and number of packets dropped are considered to detect whether node behavior is genuine or malicious. If attacker nodes are found by examining the responses from nodes, after which they are added to the blacklist and forbidden from communicating over the network.



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Fig. 1. DoS Attack Scenario in MANET

RELATED WORK

There has been numerous scientific research and methods developed specifically for MANET. Some research work substantially focused on MANET security to detect and mitigate different categories of attack such as black holes, gray holes, wormholes, etc. However, this study shows research work on attack identification and preventive measures for the same.

MANET is vulnerable to various attacks, including active and passive attacks [8]. Conventional cryptographic algorithms are not sufficient or compatible with MANET because of low memory capacity, energy constraints, resource constraints, etc. Many times false negative attacks or soft security breach attacks are generated by selfish nodes which are very difficult to detect and stop.

Gurung and Chauhan [9] designed a protocol based on an intrusion detection system to identify gray-hole attacks. Detection mechanisms analyze the number of packets dropped by an intermediate node and compare it with the threshold. After detecting malicious nodes, neighboring nodes forward alert message packets to all nodes. This technique shows little improvement to detect gray hole nodes.

As per analysis, time-based threshold detection, neighborhood-based and routing discovery, Bayesian detection scheme, intrusion detection system, hashbased, etc. are the techniques used to detect the behavior of malicious nodes. When extra monitoring packets are transmitted in the network it has increased routing overhead. So, node authentication has been done with available routing information and will be the most efficient way to avoid overhead.

BREACHING OF AVAILABILITY SERVICE IN MANET

The availability service demands that every authorized node have access to all network information and services. Due to changing topology and open boundaries in MANET, availability issues arise. By using availability-based trust architecture, malicious nodes may be immediately recognized and disconnected from the network and guarantee MANET availability [10].

The following features are used to counter DOS attacks in RREQ and RREP packets:

• RREQ: Every node will send an RREQ request to determine whether it is available to find a route. The following information is contained in an RREQ packet: Source IP, Destination IP, Source sequence no., and destination sequence no. Packet forwarding ratio, drop ratio, and TTL values are used to calculate node trust values that are included in modified AODV RREQ packet format as shown in Figure 2:



Fig. 2: Format of Route Request Packet

• RREP: This serves as an acknowledgment of route request (RREQ) and informs the node of the route's availability. RREP packet consists of destination IP, destination sequence number, and source IP. Along with these details modified AODV RREQ packet composed of the transmission range, node ID, and energy level of nodes. RREP packet format is as shown in Figure 3:

ANOMALIES BEHAVIOR DETECTION IN MANET

As AODV is a reactive routing protocol, it only keeps routes in the network that it requires at the time of communication. AODV keeps a routing table with the next hop for reaching destinations. If no packets are sent



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on a path for a long time, it will time out. Because the AODV routing table has information about its neighbors, retransferring the data frames may take longer. Although this routing table is scalable, its high route latency and cache lead to reduced performance.

Type	R	A	Reserved	Prefix Size	Hop Count
		D	estination IP /	Address	
		Dest	ination Sequen	ce Number	
			Source IP Ad	dress	
Time-to-I	live	Transp of c	nission range lestination	Energy level of destination	Node ID

Fig 3: Format of Route Reply Packet

Algorithm: Anomalies Behavior Detection to avoid DoS Attack

Step 1: Source node initiates route finding request RREQ as mentioned in Figure 2.

Step 2: The destination node sent a reply packet RREP as mentioned in Figure 3.

Step 3: Update the routing table for all nodes to verify the number of packets forwarded by the intermediate node.

drop(p, DROP-RTR-ROUTE-LOOP)

for i = 1 to N

if(packet_sent /packet_drop *100=> 40) then

node added in suspicious list

trust_value- -;

else

trust_value++;

end if

end for

Step 4: Broadcast trust value to neighbor node

Step 5: Compute round trip time (RT)

RT = TRREP + TRREQ

If (TRREP > TRREQ) then

Check trust_level of all node

End if

Step 6: If the Ni node has a low hop count and TTL then that route is considered as the shortest path.

Step 7: After that, the Source node sends a token message to a destination via the Ni node and waits for TTL notification coming to the destination node.

Step 8: If TM message is received within TTL then update routing information as path packet forwarding status is 1 otherwise 0 and update it to all neighbor

Pfwd = Pfwd + 1

Pstatus==1;

Else

Pstatus ==0;

Step 9: Update routing information as a false route and that node is listed as malicious.



Fig. 4: Workflow of Detection and Prevention of Malicious node

Figure 4 shows the workflow of the DoS attack detection mechanism on AODV. According to trust value, the node has been listed as a genuine or malicious node. After



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successfully forwarding packets by cooperative nodes, the numbers of transmitted and dropped packets were determined. If the ratio of packet dropping and forwarding exceeded the threshold value (Consider maximum T=40%packet drop and loss happened during network congestion) then the node is to be considered a suspicious node and verify the destination node sequence number available in RREP packet from all intermediate nodes. If the sequence number is highest and packet dropping is zero then that node will be considered a genuine node otherwise listed as a malicious node.

SIMULATION MODEL AND RESULT ANALYSIS

Since MANET nodes have limited power and bandwidth, sending unnecessary RREQ packets can shorten the network life while adding additional requirements for RREQ authentication.

Performance metrics

The impact of a DoS attack can be evaluated using the metrics given below:

5.1a Throughput

The primary measure of throughput is the availability of adequate bandwidth for the application. Throughput can be computed using an equation. (1):

Throughput = Received Data Packets* packet size*8/ Simulation Time (1)

5.1b Packet delivery ratio (PDR)

The percentage of the number of received data packets by the destination of total data packets sent by the source node. Formula (2) is as follows:

PDR=Number of Received Data Packet / Number of Sent Data Packets*100 (2)

5.1c End-to-end delay

The average amount of time it takes to send data between the source and destination nodes End-to-end delays also take into account medium access re-transmission delays, route acquisition delays, caching and processing delays at intermediate nodes, and other factors. A higher delay value is possible when a network is under high demand and has a route failure. The quality of a network improves with decreasing delay values. Equation (4) can be used to find the average delay.

End-To-End Delay = ((Receive Time of Pi - Sent Time of Pi))/(Number of Received Packets)

where i is index and n the last packet.

5.1d Routing Overhead

According to Equation (4), the routing packages in the AODV protocol are Route Request (RREQ), Route Reply (RREP), and Route Error (RRER).

Routing Overhead = RREQ + RREP + RERR (4)

The malicious node detection mechanism is analyzed based on throughput, packet delivery ratio, routing overhead and end-to-end delay.

RESULT ANALYSIS

The detection system shows network performance is improved while blacklisting malicious nodes such as black-hole, sink-hole, and gray-hole nodes. So that energy consumption is balanced after detecting malicious nodes, the possibility of a DoS attack is minimized. Additionally, throughput is maximized, packet drop ratio is end-to-end delay is reduced.

Table 3 Comparative Result Analysis of AODV algorithm

Algori-thm	No. of Nodes	Throu- ghput	Packet Delivery Ratio	Routing Over- head	End- To-End Delay
AODV	10	190	34	67	78
	20	229	55	68	75
	30	234	64	70	69
	40	320	65	45	63
	50	340	71	35	51
AODV with malicious node	10	156	29	68	85
	20	201	33	76	85
	30	223	39	83	84
	40	278	47	48	78
	50	290	51	41	79
Anomaly Detection mechanism in AODV	10	193	45	70	77
	20	238	59	71	73
	30	316	67	73	60
	40	345	74	47	55
	50	396	85	37	46

As shown in Figure 5 packet delivery ratio of the AODV protocol has an average value of 63.83%, while that of the malicious node is 43%. After the detection of malicious nodes, the AODV protocol shows improved performance as malicious nodes are present in the network but not part of communication, which is about 74%



(3)

CONCLUSION

MANET has lots of vulnerabilities due to changing position of the node, mobility speed, transmission range, and energy level of the node. This work mainly focuses on the analysis of behavioral patterns of adversary nodes to initiate different categories of attack such as black hole, gray hole, wormhole, and flooding attacks in MANET. Due to malicious activities, MANET is susceptible to DoS attack which affects the availability of service as well as non-repudiation. The proposed detection mechanism used routing information such as hop count, destination sequence number, the energy level of the node, number of forwarded packets, drop packets, etc. to verify the authenticity of the genuine node. The information on blacklisted malicious nodes is updated in all intermediate nodes to minimize their influence on the network. The analysis is performed in terms of packet delivery ratio, throughput, end-to-end delay, and routing overhead concerning the number of nodes in the network. The proposed detection mechanism improves the average throughput values and packet delivery ratio. Simulation results show average throughput is 51.57% and the packet delivery ratio is 74%. Also routing overhead is decreased to 18%. These detection techniques are beneficial to enhance the secure environment in MANET.

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Integration of LoRa Networks and Machine Learning for Optimized Remote Healthcare Monitoring: A Comprehensive Review

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ABSTRACT

The paper provides a framework for optimizing remote healthcare monitoring employing LoRa (Long Range) networks with integrated machine learning models. LoRa networks have gained prominence owing to their low-power, long-range capabilities integrated with advanced ML techniques aimed at improving the overall impact of health systems, especially in remote and resource-limited areas. The framework allows real-time data collection and predictive analytics for continuous whom health monitoring and early diagnosis with timely intervention by personalized medicine. The various ML techniques may include supervised learning, unsupervised learning as well as reinforcement learning. Emphasis is given on applying algorithms like neural networks, SVMs, and decision trees for healthcare applications. It also addresses the most critical challenges such as data privacy, network latency, and reliability, and proposed solutions like enhanced encryption and latency reduction techniques. The final discussion in the paper presents the energy efficiency and scalability of the system additionally, myths and case studies can give evidence of applicability on the aforementioned considerations. This framework would certainly emerge as a feasible solution to improving health delivery and patient care.

KEYWORDS : Remote healthcare monitoring, LoRa networks, Machine learning.

INTRODUCTION

Background and Motivation

The healthcare sector is still very advanced, and truly worth putting up with technology as it gives the breakthrough of modernity. Tele-health, otherwise known as remote health monitoring, is where health conditions can be monitored remotely. This means that much of the health activity data between the health provider and the patient can be exchanged in real-time without the need for face-to-face visits. Remote patient monitoring is most advantageous to a patient who has either chronic illnesses or resides in an inaccessible area for healthcare service access [1]. The emerging trend of digitalization in health care systems thus creates issues in the affected transmission and analysis of health data. Owing to the exponential growth of IoT devices and sensors meant for health monitoring, a vast amount of data needs to be collected, transmitted, and analyzed. Traditional wireless communication systems and cellular or Wi-Fi networks face great challenges in achieving the high capacity and relatively low energy consumption levels as needed by the vast number of devices connected via the Internet for remote healthcare applications [2]. Thus, this creates an urgent call for a better solution altogether that can be energy-efficient and more scalable.

Objective of the Paper

The introduction of a structure that accommodates LoRa networks and machine learning techniques for remote-hospital monitoring.

- Review of the challenge of real-time energy efficiency is considered for a scalable monitoring solution in health.
- Review data reliability transmission through LoRa networks in rural and distant areas [3].



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• Discuss the limitations and research gap.

LITERATURE REVIEW

Existing Frameworks and Approaches: Healthcare monitoring has significantly advanced with the integration of IoT technologies, machine learning (ML), and low-energy communication networks like LoRa. Various frameworks have been developed to enhance health monitoring, particularly for isolated and underserved populations where conventional healthcare systems are inadequate.

Dimitrievski et al. (2021) propose a low-energy IoT system using LoRa for rural health services [4]. Their design features battery-powered, energy- efficient sensors optimized for long-term operation, providing critical health data in poorly connected areas. Ultra-low-power timers further improve battery efficiency, enhancing device sustainability.

Biumpalila et al. (2024) explore biosensors in multihop IoT systems for real-time remote patient monitoring [5]. Cloud connectivity supports data transmission over long distances, enabling continuous monitoring from any location. This multi-hop IoT network enhances health information accessibility, overcoming traditional healthcare limitations and facilitating remote patient management.

Verma et al. (2023) integrate LoRa and ML to monitor chronic conditions like diabetes mellitus [6]. Using the Hybrid Enhanced Adaptive Data Rate (HEADR) algorithm, they extend LoRa's transmission range. Employing various machine learning classifiers, their system accurately predicts disease severity, demonstrating effective real-time monitoring and health condition prediction.

Key Findings and Gaps: The literature highlights several key points. Integrating LoRa networks with IoT and machine learning improves scalability, energy efficiency, and range for remote healthcare, bridging urban-rural healthcare gaps [7]. Machine learning enables timely patient condition predictions and personalized treatments. However, challenges remain. Despite advancements in range and power reduction, reliability and data latency issues hinder real-time monitoring. Studies by Dimitrievski et al. (2021) and Uddin and Koo (2024) focus on theoretical models, needing real- world validation. Additionally, a lack of standardized protocols and interoperability among IoT devices limits universal healthcare monitoring.

A major gap is the absence of robust IoT security infrastructure. Privacy and data security are vital, but existing research, such as Baskar et al. (2021), addresses energy efficiency without comprehensive security protocols. More work is required to ensure secure healthcare IoT systems [8].

REMOTE HEALTHCARE MONITORING: AN OVERVIEW

Current State of Remote Healthcare Monitoring and Limitations: Remote healthcare monitoring has advanced with technologies like wearables, smartphones, and IoT devices tracking vital parameters such as heart rate, blood pressure, glucose levels, and oxygen saturation. These tools, including fitness trackers, smartwatches, mobile health apps, biosensors, and telemedicine systems, enable real-time data transmission and virtual consultations, transforming patient care beyond clinical settings.

Benefits for Patients and Healthcare Providers: Monitoring transforms health management by giving patients real-time monitoring services. They do not always have to visit health facilities regularly to access their healthcare services, and that offers greater flexibility for them. It also increases personal care; with health data in real time, more accurate treatment plans come from comparative analyses. For healthcare providers, real-time monitoring reduces the time required to manage large populations of patients, especially in rural or isolated areas where they are even further limited in organization. Early detection of health problems allows proactive management of chronic conditions [9].

MACHINE LEARNING FOR HEALTHCARE MONITORING

Role of Machine Learning in Healthcare: Machine learning (ML) has transformed numerous industries, including healthcare, where it enhances predictive analytics, early diagnosis, and personalized medicine. Supervised learning algorithms are widely used for healthcare predictive analytics. By analyzing large-scale patient histories, these algorithms detect patterns and predict diseases before symptoms appear. Early detection of conditions like diabetes, cardiovascular disease, and cancer significantly improves treatment outcomes. Predictive models built on historical data continuously refine their accuracy through learning from new data inputs. A purely mathematical modeling definition of a predictive model is [10]:



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$$\hat{y} = f(\bar{X};\theta) \tag{1}$$

feature vector (input data like age, symptoms, test results), and θ is the set of model parameters (weights). This model is trained using historical data and adjusted using algorithms like gradient descent to minimize the prediction error.

Machine Learning Techniques: In unsupervised learning, the model is trained on data without labels and must find inherent patterns or groupings within the data. In healthcare, clustering techniques like K-means and hierarchical clustering are commonly used for tasks such as patient segmentation. For example, clustering algorithms can identify subgroups of patients with similar symptoms, which can help in understanding disease progression. In healthcare, reinforcement learning is being explored for real-time decision-making. An agent learns to make decisions by interacting with its environment and receiving feedback in the form of rewards or penalties. In personalized medicine, RL can be used to recommend treatment plans by learning from patient outcomes. The RL framework is based on the Bellman equation [11]:

$$Q(s,a) = R(s,a) + \gamma \max_{a} Q(s',a')$$
(2)

Where Q (s, a) represents the quality of action a taken in state s, R(s, a) is the immediate reward, γ is the discount factor, and s' is the new state after taking action a.

Specific Algorithms Relevant to Healthcare

Machine learning algorithms such as neural networks (NN), support vector machines (SVMs), and decision trees are commonly used in healthcare applications. Neural networks, particularly deep learning models, are used in tasks such as medical image analysis (e.g., detecting tumors in X-rays or MRI scans) and speech recognition in telemedicine. A deep neural network (DNN) can be expressed as [12]:

$$y = \sigma(W_2 \sigma(W_1 x + b_1) + b_2)$$
 (3)

Where x is the input vector, W_1 and W_2 are weight matrices, b_1 and b_2 are bias terms, and σ is the activation function.

SVM (Support Vector Machines) is widely used for classification tasks, such as diagnosing diseases based on features like medical test results. The decision boundary in SVM is found by solving the following optimization problem:

$$\min_{w,b} \frac{1}{2} ||w||^2$$

$$b) \ge 1 \tag{4}$$

Where w is the weight vector, b is the bias, and y_i is the class label.

Subject to $y_i(W^T X_1 +$

FRAMEWORK FOR OPTIMIZED REMOTE HEALTHCARE MONITORING

System Architecture: This AI-driven architecture for remote healthcare monitoring integrates insulated LoRa networks with machine learning to enable scalable, realtime patient health monitoring. The modular design consists of data acquisition, transmission, processing, and real-time alerts. LoRa-based sensors, deployed on patients or in healthcare facilities, capture vital parameters such as temperature, heart rate, blood pressure, and blood sugar levels [13]. The collected data is transmitted to the cloud, where machine learning models analyze it to predict potential health risks, including abnormal heart rates or glucose fluctuations. For instance, a trained machine learning model, such as a neural network, may be used to predict the onset of a health event, modeled as:

$$\hat{y} = f(X;\theta) \tag{5}$$

Where \hat{y} is the predicted outcome (e.g., likelihood of a health event), X represents the input health data, and θ denotes the model parameters.

CHALLENGES AND SOLUTIONS

Most of the issues that remote medical systems have in leveraging LoRa networks include data privacy, data security, network latency, and reliability in service delivery. For example, it is very critical that sensitive patient data remain confidential, since the WPAN low power nature of LoRa makes it usually exposed to unauthorized access and breaches [14]. Furthermore, with respect to latency, a very high level of reliability is required for real time health applications since their communication is disrupted by congestion due to environmental effects. Measures that could be taken to address this scenario are end to end encryption, advanced encryption standard AES, and secure authentication protocols concerning the safety of data.

CONCLUSIONS

With all of these, now Machine Learning Models have made up their way with the component of LoRa Networks to create a doorstep revolution in remote healthcare services through enabling real- time data capture, analytics,



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and customized treatment interventions. Moreover, this framework is also going to introduce sustained energy efficiency and scalability with a more intelligent decisionmaking capability, decreased latency, and maximum optimization of resources. Always in the loop can provide better early diagnosis, timely interventions, and personalized care.

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Towards Sustainable Space Exploration: Approaches and Challenges in Space Debris Management

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ABSTRACT

The increasing number of satellite launches and by-defunct spacecraft and fragments in orbit today endangers satellites, payloads, and people in low Earth orbit (LEO) and beyond, making space debris a very real and growing threat to space activities. In fact, there has never been a more pressing need for efficient space debris control. The types, causes, and effects of space debris on space infrastructure are discussed in the sections that follow. The paper includes technological approaches to debris management, including both passive and active methods, such as debris capture, deorbiting techniques, and new innovative methods like AI-based tracking and laser ablation. It then highlights detection and tracking challenges, removal, and gaps in international policy and regulation that continue to make it most difficult to comprehensively address environmental concerns. The case studies of both the Remove DEBRIS and ClearSpace-1 missions provide ample examples for assessing the effectiveness of debris removal technologies. The study concludes by discussing the necessity for sustainable methods in satellite launches and active debris removal, as well as the ethical and environmental concerns surrounding space debris management. The Conclusion is a recommendation to stakeholders for improved international collaboration, investments into technological advancements, and the development of robust policies to ensure long-term sustainability in exploring space.

KEYWORDS : Debris removal, Environmental impact, Space debris, Space sustainability, Technological innovations.

INTRODUCTION

Non-operational items and pieces still in orbit, such as decommissioned satellites, spent rocket stages, and spacecraft that collide or break apart, are referred to as space trash. As these objects float in space, they move at extremely high velocities, so even minute fragments are capable of creating large impacts on the functionalities of operational satellites, space stations, and spacecraft [1]. The safety and sustainability of ongoing and upcoming space missions are directly threatened by this buildup of fragments in space, making it more dangerous. More than ever, such concerns take place in the era when all global countries have become highly dependent on satellite services for communication, weather forecasting, navigation, and national security [2].

Scope and Objectives of the Paper

The present study aims at further exploring the state of things concerning space debris, to determine the difficulties associated with it, and the possible strategies currently being devised around this grave problem [3]. It provides the end-user guide with respect to types and sources of debris, as well as the study of different categories of debris with respect to their impact on space operations. In order to remove and mitigate space debris, the study examines current debris management systems, both active and passive. The possible frameworks for policies and regulations that may be put in place to address the management of space debris as well as potential suggestions for better international cooperation and regulatory actions will also be covered [4].

LITERATURE REVIEW

Integration of Adaptive Optics (AO) and Artificial Intelligence (AI) as a best way forward for tracking space debris is a multidisciplinary approach including astronomy, computer science, and aerospace engineering [5]. For example, by setting the foundations of AO,Guyot (2024) writes extensively and refers to principles and applications of the technique as correction of atmospheric



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wavefront distortion for enhanced resolution of groundbased telescopes [6]. Following his work, evidence given by Wang et al. (2024) and Dey et al. (2024) shows that AO is effective in improving optical systems used in tracking space debris [7][8].

Qualitatively, AI also adds its teeth to the effort as evident in the work of Hao Peng and Xiaoli Bai et al. (2019) who by providing an SVM model outperformed all traditional orbit prediction styles [6]. As Tang et al. (2019), deep learning could also be used to automatically detect debris in images taken by an optical system, thereby improving precision significantly [9].

The evidence of the synergistic application of AO and AI for instance can be seen in Yanagisawa and Kurosaki's (2018) argument that with real-time detection and tracking, an AI module coupled to AO image enhancement becomes efficient and delivers more promise in terms of accuracy [10]. Unlike Li et al. (2020) or Peng et al. (2020) [10] [11], many challenges still remain in technical integration of such systems when developed. There is a great need for continued research to overcome these developments, add on to capabilities, and delve into new challenges in technology for space debris tracking.

CURRENT STATE OF SPACE DEBRIS

Space Debris Types

Debris can be categorized into several types, primarily based on their origin and size in the space. These include:

Type of Space Debris	Description
Defunct Satellites	Non-functional satellites left in orbit after their mission or operational life ends [15].
Spent Rocket Stages	Used rocket stages that remain in orbit after delivering [16] payloads into space.
Fragments from Collisions	Debris generated from the collision of satellites or rocket parts, resulting in thousands of smaller pieces.
Non-Functional Components	Items such as tools, bolts, or paint flecks that break off from operational spacecraft.

Space debris comes from a wide range of sources, such as leftover rocket stages and abandoned satellites, as well as debris produced by satellite collisions and disintegration. Intentional devastation, including anti-satellite testing, also caused some of this debris [12].

Current Statistics and Trends

As per ESA- more than 34,000 pieces above 10 cm is floating around in orbit with millions below 1 cm [13]. In fact, the number is increasing exponentially, especially after the early 2000s when space launches, missions, and accidental collisions have been on the rise. Most due todebris have been concentrated in low Earth orbits (LEO), where most operational satellites and space stations locate.

TECHNOLOGICAL APPROACHES TO DEBRIS MANAGEMENT

To reduce the threats that space debris poses to operational satellites and mission personnel, there are both active and passive approaches for managing space debris. They actively remove existing debris from orbit or stop new debris from being created. New ideas and methods for solving the space debris issue will continue to be introduced by scientific and technological developments [14].

Passive Methods: Material Selection, Orbital Decay Strategies

Passive debris mitigation are techniques that obviate any collection of debris without active involvement [15]. These restrict the formation of new garbage, hence promoting the natural degradation of existing artifacts.

Material Selection

A major example of adopting most passive strategies entails the selection of materials that minimize the risk of generating debris when a satellite or rocket stage disintegrates. Examples of such materials include lightweight and durable materials like aluminum and carbon composites, which are mostly selected for this purpose [16]. Moreover, materials have also been chosen to induce minimal long-term orbital stability-to increase the lifetime of the debris and its collision risk.

Orbital Decay Strategies: Satellites and the rocket stages positioned in low Earth orbit (LEO) suffer from atmospheric drag, which gradually reduces the altitude and eventually leads to a re-entry and disintegration. This natural process of orbital decay could be accelerated through design features such as deploying a deorbiting sail or having a passive propulsion system [17]. The rate of orbital decay depends on a number of parameters such as altitude, mass



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of the satellite, and density of the atmosphere at that orbit. The equation for orbital decay is given by:

$$\dot{a} = \frac{2C_d\rho A}{m} \cdot v^2 \tag{1}$$

Where: \dot{a} is the acceleration due to atmospheric drag, C_d denotes coefficient of drag, A denotes the area of cross-sectional of an object, ρ denotes the atmospheric density, m denotes mass of the object, v denotes the velocity of orbital.

Active Methods: Debris Capture, Deorbiting Techniques, and Robotic Arms

Active methods involve such technologies as directly capturing, deorbiting, or removing space debris, requiring the development of advanced spacecraft capable of interacting with debris floating in space [18].

Debris Capture: Various methods, such physically trapping space debris, are developing. Using robotic arms or nets to catch the trash and bring it to a safe orbit or even the Earth's surface is one of them. All of these need extremely precise movement and nearly real-time debris tracking [19].

Deorbiting Techniques: A range of serviced systems has been designed to deorbit debris, i.e. a spacecraft or device that provides a controlled trajectory for most debris so that it re-enters the atmosphere of the Earth and burns up. Active deorbiting methods include ion engines, chemical propulsion systems, or electrodynamic tethers [20]. The deorbiting burn using the equation:

$$\Delta v = \sqrt{\frac{2GM}{r} - \frac{2GM}{r + \Delta r}} \tag{2}$$

Where: Δv denotes the change in velocity, G is the gravitational constant, M is the mass of the Earth, r is the current orbital radius, Δr is the change in orbit to facilitate re-entry.

FUTURE DIRECTIONS AND INNOVATIONS

The evolvement of technologies and sustainable practices measures the future of space debris management to make it safe as well as sustainable. Some examples of innovations comprise of an advanced capture mechanism composed of robotic arms, nets, and even electrodynamic tethers for efficient debris removal, or space-based laser systems employed for altering the trajectories of small debris using laser ablation [21]. Artificial intelligence and machine learning also enhance detection and mitigation by improving collision predictions and automate the debris removal process while guiding autonomous systems for accurate tracking and capture. Sustainable actions towards controlled deorbiting and disassembly satellites reduce even further debris generation, and thus it is helping an end to long-term sustainability in space exploration practices [22].

CONCLUSIONS

One of the greatest threats to sustainability in outer space is, undoubtedly, space debris itself. The missions of RemoveDEBRIS and ClearSpace-1 emphasize the importance of debris removal, among other factors, while the issues of detection, tracking, and policy remain. Sensors and rules of engagement have to be developed and defined while adopting machine learning for real-time monitoring and autonomous removal [23]. On-the-ground sustainable practices for satellites contribute to reducing future debris. Meetings with various governments, agencies, and companies will further enhance mitigation strategies, investments in promising technologies, and enforcement of new end-of-life satellite regulations. Active debris management and responsible practices will make space exploration viable for science, commerce, and defense in the future.

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ABSTRACT

Wireless Sensor network is infrastructure less and self configurable wireless network. With the advancement in technology Wireless sensor network are widely used in various applications like military defense, healthcare industry, environment monitoring, smart home systems etc. Security is important characteristic of WSN when used in military applications to carry very sensitive information. Important features like limited energy, limited bandwidth and dynamic topology makes wireless sensor network prone to various potential attacks. Internal attacks are harder to protect against than external attacks. To safeguard the former, encryption and authentication techniques are utilized. Trust management technology is also one of the most effective strategies for recognizing and guarding against internal threats. A user authentication scheme that allows only authenticated users to access network services is required to keep a network secure. This paper does the survey of die-rent security solutions and security analysis for die-rent attacks in wireless sensor network.

KEYWORDS : Encryption, Authentication, Trust management.

INTRODUCTION

ireless Sensor Network is characterized as small in size, low cost, and ease of deployment. WSN is one of the most promising technologies for various real-time applications. WSN's job is to monitor a field of interest, collect data, and transfer it to the base station for postprocessing analysis. Some WSN applications employ many sensor nodes. As a result, a scalable and efficient algorithm is required to manage such a vast number of nodes. Furthermore, the WSNs may change dynamically owing to external reasons or as planned by the system designers[1]. WSNs are categorised into five types based on their deployment strategy and application: Underwater WSNs, Multimedia WSNs, Underground WSNs, Mobile WSNs, and terrestrial WSNs [2]. Multimedia WSN is made up of low-cost sensors with microphones and cameras. Audio, video, and image events are tracked using these multimedia nodes. These nodes communicate via a wireless channel to collect, process, correlate, and compress data. Due to the changing linkage capacity in multimedia WSNs, QoS providing is a difficult problem. A mobile WSN is made up of a collection of mobile sensors as they communicate with their surroundings. The node is

capable of sensing, computing, and communicating with other nodes. These nodes, unlike static nodes, may arrange and relocate themselves in the network. The collected data can be transmitted within the sensor node's coverage region. Self-organizations your argument in the larger academic context [2].Nodes can be randomly placed in a specified location in an ad hoc fashion. Sensor nodes are placed under the sea in an underwater WSN. Sensor nodes in such networks are more expensive than in terrestrial WSNs. Data from the deployed sensor nodes is collected using underwater vehicles. Acoustic waves are commonly employed for underwater communication. At present, Wireless Sensor Networks (WSN) plays several roles and applications in many fields such as military applications, health monitoring application, trac signal monitoring, weather reporting and forest fire and land slide detection, to keep track o real world environment.

Security Goals of Wireless Sensor Network

Authentication: It includes only legitimate user can access sensor data in user authentication process. In Node authentication confidentiality and validity of cluster head, other sensor nodes and base station is checked while granting resources to them [4].



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Integrity: Integrity ensures that the message or data received by the receiver should not be modified or altered by an intruder.

Confidentiality: In wireless communications data is transmitted through many intermediate nodes. As a result data leakage can be more. Different encryption mechanisms can be used to encrypt data so that only intended receiver can decrypt data in its original form.

Availability: Availability ensures that required data and network resources should be available all the time even in the case of Denial of Service (DOS) attack.

Non-repudiation: Non-repudiation means sender or receiver cannot deny after some time that he/she has sent or receive data during communication.

Data Freshness: Data freshness ensures that each message transmitted over communication channel is new and fresh. Old content should not be transmitted by attacker so that network resources become unavailable or it can mislead the network [4].To maintain freshness of data time related counter concept can be implemented.

Self Organisation: As Wireless Sensor network has no fixed infrastructure. Each node in WSN can be deployed in self organising manner. Thus it becomes great challenge to security. Apart from these security requirements, the forward and backward secrecy are also important and these need to be considered as new sensors can be placed in the network and there is failure of old sensors due to some energy or battery problem.

Forward secrecy: In WSN after leaving or the departure of existing node, it should not read any future messages.

Backward secrecy: In WSN, old transmitted messages should not be read when a new node is deployed to join the network.

Because of the properties of WSN, a sensor node's resources, like memory, communication in terms of bandwidth, energy consumption is inevitably limited. As a result, WSN is more susceptible to internal as well as external security threats. Furthermore, because of self organising nature of WSN nodes are randomly placed in the network.As a result, WSN is frequently prone to various security threats

Security Attacks in Wireless Sensor Network: Wireless sensor networks' various resource constraint like Communication bandwidth, energy limitation, low-power computing, storage capacity in terms of memory etc. exhibits them to a wide range of security threats. There are two types of attacks: Passive and Active. In Passive attack attacker basically observe communication between two nodes through communication channel to extract important information. In active attacks, attacker perform malicious activities like change or modify the information transferred through the network. Thus, Integrity and availability goals are threatened by this attack. Selective forwarding: In this attack, the attacker prevents some packets from being transmitted. The malicious node will remove them later [5].

Worm hole attack: The introduction of at least two malicious nodes is required for the wormhole attack. Thus,two sensor nodes are connected by strong link, with the help of wired or wireless link. Packets are received by malignant node from one network segment and transmitted to other.

Sybil attack: Multiple IDs are shown by malicious node to other nodes which are present in network .It causes notable threat to routing protocols, causing routing tables on nodes to become saturated with incorrect information.

Black hole attack: It consists of adding a malicious node into the network. Due to this,routing tables will get modify in order to force as many neighbouring nodes as possible to pass the information through this node. Like a black hole in space, The information that goes into it might be never re-transmitted, like a black hole in space.

Hello Flooding: To discover neighbouring nodes on WSNs, discovery protocols use HELLO message types. An attacker will use this mechanism in a HELLO Flooding attack to flood the nodes in network and energy consumption will be more.

Denial-of-service attack: DOS attack reduces network service availability and capacity. Due to physical constraints and the nature of their deployment environment, sensor networks are more prone to this attack in comparison with other network.

Replay Attack: In this attack, it can construct loop, decline or persuade more trac, and the actual source route can be elongated or become shorter.

Acknowledgement spoofing: The intruder attempts to persuade sender as a weak link is strong or that a dead node is alive in this attack. As a result, packets forwarded through this might be lost.



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LITERATURE REVIEW

The progress of a security protocols is frequently hampered by WSNs' constrained resource availability. Still, security mechanisms are in place to protect sensor nodes which are placed in some critical regions. So,lightweight security techniques [4] that consume few resources are appropriate for WSN. Several countermeasures have been proposed according to intruder's capability and nature of malicious activity, with the majority of them are allocated to cryptography based prevention mechanisms and detection of flaws in security using trust mechanisms and intrusion detection system.

Key Management Schemes

In order to provide security policy, Key management entails the creation as well as maintenance of keys. Almost many security requirements like confidentiality, integrity,authenticity, flexibility, and availability should be met by key management. Furthermore, it must adhere to all resource constraints, including battery power,communication range and transmission bandwidth, memory requirement, and random deployment.

Samir et al.[6]proposed EDAK, scheme for heterogeneous type WSN. The Key Management as well as authentication requirements for sensor network which are heterogeneous type are fulfilled by proposed approach. Apart from this proposed scheme improvise memory utilization, minimizes complexity of computation, and cost of communication, improving energy efficiency. Using preexisting data, key distribution algorithm generates dynamic keys. But for distribution it does not use any sharing phase or any type of secure channel. As a result, there is performance improvisation. For large network, this scheme is good for scalability and adaptability.

Harith et al.[7]introduced an efficient scheme depend on cell reporter which is denoted as location-dependent key management protocol for multiple sinks (LKMP-MS).For any type of event, report is made consists of three different type of security levels. As a result, sink node accepts the generated event report. Thus, to define false report for particular location, the attacker should compromise all sensor nodes and cell reporters selected by all sink nodes. To avoid the e ects of attack, necessary revocation methods should be incorporated for compromised node and corresponding cell report.

Bowen et al.[8] designed a novel layer cluster topological architecture based on local dynamic scheme and using

rules and regulations of network security by reducing negotiation progress more energy saving is done. In this proposed approach, sensor nodes form specific clusters based on their location and using a self-election algorithm identify cluster head for WSN network. Using Chinese Remainder Theorem, gateway node computes the calculation in the key agreement method and group key is calculated by cluster head node of network by applying one-way hash tree. The novel approach is good and adaptive to network's dynamic changes, resulting in greater flexibility.

Mawloud et al[9] introduces novel approach to provide requirement in terms of performance efficiency and robustness in terms of scalability;Hybrid key establishment technique is used in the propose approach. As mobility is one of the characteristic of Sensor nodes, they can join, leave the cluster or again rejoin the any other cluster. For sensor node integration,revocation, key updating as well as for movement of node these lightweight mechanisms are implemented. Performance efficiency of proposed scheme achieves best results for important characteristic like use of network in terms of resources.

Authentication Mechanisms

To validate the source node's authentication is the prime goal of authentication schemes [11]. In the case of communication valuable data is exchanged between two parties. So to provide security to data user authentication mechanisms can be designed. So, variety of authentication schemes available which are lightweight in nature, including Elliptic Curve Cryptography, asymmetric key encryption, trust evaluation based on direct and indirect trusts, XOR operations, hash functions etc. Deok et al [11] proposed mutual authentication protocol which provides security and lightweight in nature for WSN. The proposed WSN-SLAP mechanism does not a detected by various attacks such as Insider, stolen smart card, Insider, sessionspecific random number leakge, stoline password guessing, and stolen verifier. Proposed WSN-SLAP incorporate perfect forward secrecy and mutual authentication. Formal security analyses AVISPA, BAN logic, and the ROR protocol were used to demonstrate WSN-security SLAPs. WSN-SLAP also employs XOR operations and hash functions so it causes low computational as well as communication cost. As a result, when compared to other related protocols, the approach WSN-SLAP exhibits better efficient and secure communication services and is appropriate for WSN environments.



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Mostafa et al. [12] proposed mutual authentication and key agreement protocol using ECDH technique. This protocol supports dynamic node addition in WSN environments and uses a strong ECDH technique to generate a unique symmetric key and session key for each session. Informal analysis is being used to demonstrate that the proposed protocol provides mutual authentication and other security features. Majid et al.[13] developed an improved key agreement and unknown user authentication scheme which is based on biometric for WSNs that also includes a symmetric cryptography algorithms. The main benefit of login through biometric is that it make sure that ecient login has done by authenticated user. The proposed scheme primarily used the BAN-logic method for formal verification to ensure mutual authentication accuracy. Furthermore, the widely used AVISPA software for simulation of results, and finally results shown that proposed method provide security with respect to active and passive attacks.

Rabia et al. [14] proposed SUBBASE i.e. secure user biometric based authentication scheme for WSNs mainly considers user biometrics. It increases security of network while also improvises performance of network. This security mechanism is comprised of straightforward and less number of computations. The proposed technique boosts performance of network by lowering network trac, as well as protecting against denial-of-service threat, along with extending node battery life. As a result, the overall functionality and performance of the network are improved. .

Trust Management Schemes

Trust emerged in social science and studied for many fields like economics and computer science, economics, psychology etc. Primarily in computer science field research based on trust is mainly focuses on security issues. Trust mainly determines where and when these security schemes should be incorporated so that both trust and security are beneficial for WSN. To begin, we must distinguish among trust and trustworthiness of node. Sometimes the terminologies trust and reputation can be confused at times. A node's reputation in a network is the belief that is decided by other as well as their interpretation about that. Thus, such reputation is earned through various interactions with that node and through its behavior[16].

In general, the definition of trust is allied to the specific area of subject where it can be used. Consider example, where trust can be simply applicable to people in sociology and try to create social relationships. During study of network security, while communicating between nodes in network as well as maintaining relationship between nodes based on their behavior, trust management should incorporated to provide security by maintaining a high level of trust. When a truster and a trustee work cooperatively, trust relationship created between them. Trust can be define as a truster's level of confidence in the trustee. It's value varies from 0 (trustworthy) to 1 (untrustworthy). Trust protocol consists of two components i. e.trust metrics and trust calculation mechanisms. Trust metrics are concerned with which parameters should be evaluate, whereas trust calculation mechanisms are concerned with how to compute. So,both components are extensively important in trust management. Quality of service (QoS) or social properties are used to calculate trust metric[17]. QoS trust metrics are calculated using QoS data from networks. In WSNs, energy utilization and packet delivery ratio are considered as important factor for trust metric. For example, Energy consumption and the resent/delivery ratio were used as trust metrics in WSNs. The amount of data is forwarded and received can be consider as one important factor for calculation of trust metric. It is basically assess trustworthiness of the nodes depend on their performance. Another important aspect of trust management is trust computational methods. In general manner, three main techniques are used i. e. weighted sum, inference techniques, and regression analysis. A common computational method is weighed sum, and the basic idea is that, more weight it will be assigned, the trust factor has high value. To evaluate direct and indirect trust this technique can be used.

Jiang et al.[18] introduced an EdTM for WSN. Based on number of packets received by sensor nodes, the factors direct trust and recommendation trust are computed. The calculation of direct trust then takes into account communication trust, energy trust, and data trust. Afterwards, to increase accuracy of recommendation trust the factors like trust reliability and familiarity are introduced. This technique is used to estimate more precisely the trustworthiness of wireless sensor nodes and effectively protect from security flaws. As a result, EDTM had shown excel performance during simulation of output when it is compared with other models like NBBTE trust model.

CONCLUSION

Due to the wide range of security applications, security is



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the primary concern for the energy-constrained WSN. In recent years, security has gained large amount of importance in current era still developing strong security protocols is extremely difficult. This paper consist of different types of wireless sensor networks and their positioning in their specific area. This paper has mentioned the security requirements, threats, and security solutions in Wireless sensor network. Key management schemes, authentication, and trust evaluation protocol are terms that are sometimes used interchangeably when defining a secure network. In WSNs Various key management mechanisms, including probabilities, Identification-based, depend on location, along-with polynomial equation-based key distribution schemes are proposed. So, appropriate selection of protocols is based on WSN applications. Authentication is a security feature that ensures that the data is received from validated source.

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A Review on Parametric Analysis of Consensus Algorithms in Blockchain Technology

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ABSTRACT

Blockchain technology used for many industrial applications because of security. Bitcoin cryptocurrency was the first application of the blockchain technology. Depending on the application different parameters of consensus algorithms is considered for the implementation. In this paper different consensus algorithm were discussed with its block generation time and confirmation time. Parameters of algorithm may vary depend on the application of blockchain. Proof of Work algorithm scalability is less compared to PoS and DPoS.

KEYWORDS : PoW, PoS, DPoS, Transaction validation, Delay time.

INTRODUCTION

Digital evens or records of transactions are executed and shared among all the participants of the network with high level of security by the technology called blockchain. Every record of transactions like land assets, food supply chain, cars etc. can be stored in the blockchain. First decentralized digital currency is the bitcoin allows the peer to peer transfer of money without third party like bank, government, brokers etc. Bitcoin can be transferred to anyone around the world regardless of the geographical locations. Three basic questions come to our mind whenever we are doing transaction using digital currency is

- Is this transaction is counterfeit or authentic?
- Can money transfer only once or double spent problem occurs?
- Can anyone claim for the transaction that you have done?

Advanced printing technology and papers are used constantly to battle the counterfeit problem arises in paper money. In digital transaction central authorities have a global view on the currency circulation to avoid the double spent problem. Digital signature cryptographically proves the transaction owner but the record of all transactions are not available for all the members participated in the transaction which may cause corruption.

Blockchain technology uses hash algorithm for generating private key and public key for the transaction. Digital keys are not stored in the network but it is created and used by the user called as wallet. Public key is like account number of bank and is mathematically derived from the private key. Private key is like PIN of our ATM. Combination of private key and public key is the digital signature which is necessary for the transaction. These keys are stored inside wallet file and managed by wallet software. Private key is generated by the Elliptic Curve Cryptography. Each transaction added to the blockchain after validation as a block and each block contains following information[1].

Previous hash: previous block hash is required to link all the blocks available in the blockcain for creating chronological link of blocks. This makes the blockchain very difficult to fiddle, as any change in a block break the chain of faith.



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Data: transactions which are validated and stored in a block .

Nonce: "number used once" or nonce is a Pseudo random number generated for security and validation of the block in the blockchain. Miners repeatedly adjust the hash to get the difficulty level of network. It helps to protect from fraud in the transaction. It used in live data transmission for keeping communication private and secure

Hash: It is a unique identification fixed length characters of block generated by the hash function and converts the data into digital fingerprints. Any change in a block will change hash value and hence difficult to fiddle. Change in one block will require change in all subsequent blocks as they all are linked which require high computing resources.

In blockchain all the nodes in the network is having history of all the transactions and it is important that all nodes should agree on the order of transactions so that it is tamper proof. Malicious transaction prevention is the top priority of the blockchain technology. Before adding any record in the blockchain it is validated by the network nodes and for that different techniques are used called consensus algorithms. Power consumption is the impediment in this technology and is one of the important research points. The overall performance of the system can be analyzed by the storage space, network and scalability of the system.

Every node in the network require to store the information from the genesis block which require huge storage space and resources. So it necessary to manage storage of data with limited resources. After generating transaction request all the information related to transaction will broadcast over the network and after validation again it broadcast to the network. As the transactions are increasing day by day storage of data become difficult which raise a problem called scalability. Storage of transaction history can be reduced by using seg-wit process.

CONSENSUS ALGORITHM

There are different platforms used for the implementation of blockchain and accordingly we can use consensus algorithm for the validation of the transaction[2]. Consensus algorithm is a set of protocols used to avoid malicious activities in blockchain. Consensus algorithms are broadly categorized depend on considering existence of malicious nodes called Byzantine Fault Tolerance and not considering the existence of malicious nodes called Non Byzantine Fault Tolerance.



Fig. 1. Sequence of Transaction in blockchain

Proof of Work

It is the first consensus algorithm used for the validation of transaction and will add new block to the existing blockchain. It is very difficult to generate the nonce by the miner but very easy to verify by the other miners available in the network. Number of miners available in the miner, power requirement of the network, load handled and validation transaction will decide the complexity of the mathematical puzzle. Hash value is generated by the miner will compared with the target hash. Miner will guess the nonce value and attached with the hash generated and then compared with the target hash and if it is less and again miner will generate another hash and will repeat the process unless it will not greater than the target hash. Target hash variation is done in the network after validation of 2016 blocks. Energy consumption, resource requirement is more in proof of work algorithm and the attack rate is 51%.

Algorithm

- 1. Request for transaction is received in the network
- 2. Transaction broadcast to the network for the validation
- 3. Mathematical puzzle will get generated by the network depend on load, power, and validation time.
- 4. Miners compete to solve the puzzle.
- 5. Nonce will get generated and combined with the hash using Markle root.
- 6. Compare it with the target hash and if it is less then again nonce will get generated and repeat the process unless it is greater than the target hash.
- 7. It will broadcast to the network.
- 8. Other miners will verify it and if valid then consensus will be given.


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9. After consensus received from the miners the transaction will get added to the existing blockchain.

After adding it to blockchain alteration will not be possible in any cost. Miner get the reward.

In POW algorithm all the nodes are connected to single speed network directly. The consensus algorithm efficiency is given by the ratio of average number of transactions generated gives time required to add new block in the network and the delay required for the confirmation of the transaction and the number of the transactions per second[3].

$$\mathbf{F} = \frac{C * TPS}{V} \tag{1}$$

Average block generation time of POW algorithm is given by

$$V_{\text{pow}} = \frac{D}{\sum_{i=1}^{n} ri} \tag{2}$$

Where D is the target complexity and ri is the complexity power of the node.

Confirmation delay gives the processing delay of transaction from the moment of generating the transaction to the transaction confirmation and is given by,

$$C_{pow} = K_{pow} * V_{pow}$$
(3)

Where K_{pow} the number of blocks.

$$TPS = \begin{bmatrix} \sum_{i=1}^{n} \lambda i, \sum_{i=1}^{n} \lambda i \leq \frac{k}{v_{pow}} \\ \frac{k}{v_{pow}}, \sum_{i=1}^{n} \lambda i > \frac{k}{v_{pow}} \end{bmatrix}$$
(4)

Where $\sum_{i=1}^{n} \lambda i \leq \frac{k}{v_{pow}}$ is low load scenario and $\sum_{i=1}^{n} \lambda i > \frac{k}{v_{pow}}$ is the heavy load scenario. Probability of confirmation failure is defined as[3]

$$P_{pow} = \begin{bmatrix} 0, \sum_{i=1}^{n} \lambda i \leq \frac{k}{v_{pow}} \\ 1 - \frac{k}{\sum_{i=1}^{n} \lambda i * v_{pow}}, \sum_{i=1}^{n} \lambda i > \frac{k}{v_{pow}} \end{bmatrix}$$
(5)

Proof of Stake : Requirement of resources, energy consumption and the 51% attack is the main limitations of the PoW algorithm can be overcome by the Proof of Stake algorithm. The node in the network who wishes to be a miner has to deposit money called stake. The node having more stake having the more chance of getting the chance for the validation of the transaction. If the miner does the

mistake in validation of the transaction then the miner will lose his stake. The miner has to deposit more money than he/she get after validation of the transaction to avoid the mal functioning in the validation of the transaction. After validation of transaction miner will get the reward as well as stake deposited. The rich person is having the more chances of getting transaction validation; therefore variation in the selection of miner is carried out to avoid invalid transactions in the network. Randomized block selection method is used to avoid this problem. The size of stake of each node in the network is public and anyone can guess who will validate the next transaction coin age base selection method can also be used for the selection of the miner. The node having stake deposited for long time then that node will get selected as a miner for the validation of transaction and after validation and consensus from all the other miners present in the network block will get added into the blockchain[3].

Algorithm:

- 1. Request for the transaction is generated
- 2. Node stake some amount became a miner.
- 3. Miner selected on algorithm used may depend on stake deposited or the coin age based selection method.
- 4. Miner will validate the block and broadcast in the network, all other miners will validate the block and after getting consensus from the other miners the transaction will get added to the network.
- 5. Block will get added to the network Miner will get the reward and stake deposited by the miner.

Average block generation time of PoS algorithm is given by[3]

$$V_{\text{pos}} = \frac{D}{\sum_{i=1}^{n} bi * ti}$$
(6)

Where D is the target complexity and bi is the age of the asset, ti is the time since the moment of last block generation.

Confirmation delay gives the processing delay of transaction from the moment of generating the transaction to the transaction confirmation and is given by,

$$C_{pow} = K_{pos} * V_{pos}$$
(7)

Where K_{pos} the number of blocks.

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(8)

$$TPS = \underbrace{\sum_{i=1}^{n} \lambda_{i}, \sum_{i=1}^{n} \lambda_{i} \leq \frac{k}{v_{pos}}}_{\frac{k}{v_{pos}}, \sum_{i=1}^{n} \lambda_{i} > \frac{k}{v_{pos}}}$$

Where $\sum_{i=1}^{n} \lambda i \leq \frac{k}{v_{pos}}$ is low load scenario and $\sum_{i=1}^{n} \lambda i > \frac{k}{v_{pos}}$ is the heavy load scenario.

Probability of confirmation failure is defined as

$$P_{pos} = \begin{bmatrix} 0, \sum_{i=1}^{n} \lambda i \leq \frac{k}{v_{pos}} \\ 1 - \frac{k}{\sum_{i=1}^{n} \lambda i * v_{pos}}, \sum_{i=1}^{n} \lambda i > \frac{k}{v_{pos}} \end{bmatrix}$$
(9)

Delegated Proof of Stake (DPoS)

The selection of miner depends on election. The delegate will get elected from the nodes in the network available. The node having the stakes is eligible to give the vote and is also depend on number of stakes node is having. Each delegate will get selected with the help of Round Rabin algorithm. If the delegate not able to verify the transaction next delegate will get the chance to validate the algorithm. If the delegate not able to verify the transaction next delegate will get the chance to validate

The transaction then reward will get distributed among the voters. The delegate has to maintain his reputation among the witnesses otherwise they will expel and select new delegate. The scalability is better compared to PoS and PoW. The amount after validation of the block and size of the block can be changed by the delegate. DPoS algorithm is protected from the double spending problem. Centralization of the network is possible if the number of witnesses is limited. reward is also get deposited to the node who validate the transaction and such block called as stolen block. If the delegate validates the transaction then reward will get distributed among the voters. The delegate has to maintain his reputation among the witnesses otherwise they will expel and select new delegate. The scalability is better compared to PoS and PoW. The amount after validation of the block and size of the block can be changed by the delegate. DPoS algorithm is protected from the double spending problem. Centralization of the network is possible if the number of witnesses is limited[2].



Fig. 2. DPoS Transaction Validation Flow



Fig. 3. Delay required to confirm the transaction



Fig. 4. Average time required for the validation of transaction

CONCLUSION

Choosing the correct consensus algorithm for the implementation of the blockchain depends on the following parameters

- New block will get added to the network after validation of the transaction, selection of algorithm depends on the time required to validate it. If the trust requirement is the high priority then we need to compromise the speed of validation.
- As the number of nodes are increasing day by day the storage, network and energy consumption will



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be increasing, managing resources is also one of the parameter while implementing the blockchain.

- Selection of consensus algorithm is the critical decision as it greatly affects the security, efficiency, and scalability of the blockchain.
- Future Scope:

Selection of consensus algorithm is the core component for the implementation of blockchain. While selecting existing consensus algorithm we have to compromise certain parameters or novel consensus algorithm is required to be introduced and for this reason wide range of algorithms are exists but still ideal consensus algorithm is illusory.

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Performance Evaluation of IoT Based Air Pollution Monitoring System

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ABSTRACT

Air pollution is a big problem that affects our health and the environment. To help address this, we have developed an Air Pollution Monitoring System using IoT devices. This system uses several types of sensors to monitor the air quality, including gas sensors, particle sensors, noise sensor, temperature, and humidity sensors. The system collects data from these sensors and sends it to a central server where it can be processed and analyzed. This data is then display, allowing users to see the current air quality in real-time. Additionally, this system has an alarm feature that alerts users when the air quality becomes unsafe. This helps people know when they should take action to reduce exposure to pollution. This Air Pollution Monitoring System provides valuable information about air quality, helping users to stay informed and take steps to improve the air they breathe. It's a simple yet effective tool for monitoring and managing air pollution. This system overcomes the limitations of traditional methods by providing real-time, multi-parameter air quality monitoring. Its cost-effective design, instant alerts, and dynamic data visualization empower users to take immediate action, making it a practical and impactful tool for reducing pollution and protecting public health.

KEYWORDS : Air quality, Environmental pollution, Microcontroller, Sensors.

INTRODUCTION

The IoT-based Air Pollution Monitoring System offers numerous advantages over traditional methods of air quality assessment. Traditional approaches often involve manual sampling and analysis, which are both time consuming and less responsive to real-time fluctuations in pollution levels. In contrast, IoT-enabled systems provide continuous, automated monitoring, making it possible to respond immediately to dangerous levels of pollutants. These systems can be customized to detect a variety of pollutants such as CO₂, SO₂, NO₂, CO, particulate matter (PM10 and PM2.5), and volatile organic compounds (VOCs). The sensors can be strategically placed across urban areas, industries, or near transportation hubs to offer a comprehensive view of air quality. This helps in identifying pollution hotspots and assessing long-term exposure risks for residents. Another essential component of this project is data visualization. Using cloud-based platforms and APIs, the collected data can be transformed

into readable formats such as dashboards or mobile applications, providing users with real-time updates and alerts. For instance, users could receive notifications when pollutant levels exceed safe thresholds, prompting timely preventive measures like avoiding outdoor activities or improving indoor air filtration. The integration of machine learning algorithms can allow for predictive analysis, identifying trends in air pollution and forecasting potential spikes. This is especially useful for city planners and environmental agencies, as it supports proactive decisionmaking to reduce emissions, manage traffic, and regulate industrial activities. The system can be made energyefficient by using low-power communication protocols like LoRaWAN or Zigbee, enabling deployment in remote areas without relying on power grids. Solar power or other renewable sources can also be integrated to make the system more sustainable. In terms of scalability, the modular nature of IoT devices ensures that the system can be expanded with additional sensors to cover larger areas or incorporate new types of pollutants as needed.



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This flexibility makes it suitable for both small-scale communities and large metropolitan areas. by leveraging cloud computing and big data analytics, this system offers not only local monitoring but also the potential for largescale, national, or even global air quality assessments. This can help governments and organizations collaborate internationally to tackle air pollution, sharing data and best practices across borders.

LITERATURE REVIEW

Rapid industrialization has caused an increase in the pollution levels. The release of harmful gases, particulate matter, dust, and detritus into the atmosphere leads to air pollution. One can reduce air-borne diseases by controlling the air pollution. In this paper, we design an Internet of Things (IoT) system to monitor the air quality at desired location(s). The IoT system monitors five different gases with the help of air quality monitoring sensors. The system detects the concentration of gases and sends the data to the cloud for storage. The results of such a system may be useful for alerting the people and the authorities, in case of high air pollution.

Gaddam, A., et al.[1] (2021)

The possibilities of air quality monitoring systems have been greatly expanded by the development of Internet of Things (IoT) technology. Real-time insights into air pollution levels are provided by IoT-based air quality monitoring systems (AQMS), which make use of a variety of sensors, wireless connection, and data analytics. This study of the literature looks at the latest advancements, techniques, and uses of Internet of Things-based AQMS. To measure different air pollutants like particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone (O3), IoTbased AQMS often use a network of sensors. Distributed sensor deployment enables wide-ranging spatial coverage and fine-grained data gathering. Sensor data transmission to cloud platforms or central servers requires effective communication protocols. Protocols like Wi-Fi are frequently utilized.

Saini, S., et al. [2] (2022)

Large-scale AQMS deployment is now possible thanks to the usage of inexpensive sensors. Even though these sensors are not as precise as more conventional monitoring tools, when calibrated properly, they offer enough precision for a variety of uses. By integrating IoT-based AQMS with other urban systems like traffic control and weather monitoring, urban environments may be managed comprehensively.

Kumar, A., et al. [3] (2021)

IoT-based AQMS in cities offer vital information for controlling air quality and putting pollution-reduction plans into action. IoT-based AQMS can be used by industries to track emissions and make sure that environmental laws are being followed. IoT-based AQMS are used by researchers to examine how air pollution affects the environment and human health. It's still difficult to guarantee the precision and dependability of data gathered by inexpensive sensors. It is required to continuously calibrate and validate against instruments of reference grade.

Rai, A., et al.[4] (2023)

IoT-based air quality monitoring devices, which provide extensive coverage and real-time data at a reduced cost, constitute a significant improvement in environmental monitoring. Even though there are issues with sensor scalability, security, and accuracy, these systems' efficacy and dependability are being improved by continued study and technical advancements. The incorporation of AQMS into larger smart city programs is expected to be crucial for public health and urban environmental management as IoT technology develops.

S. Dhingra, R.B. Madda, A.H. Gandomi, R. Patan, M. Daneshmand [5] (2021)

Pollution detection and monitoring is an important task in this real world. This paper was proposed to monitor the air quality using wireless sensors and data mining algorithm. In this process the microcontrollers were involved to send the data to web servers. Bluetooth module was worked for connecting the server to the internet. An air quality monitoring system (AQMS) by IEEE standards was present. In this process the GSM wireless communication module was used. The IoT sensor arrays were used for real time monitoring of dangerous gases like CO2, CO, NO2 and SO2. The graphical user interface (GUI) was developed to plot the gas values in it. The IoT based environmental monitoring system for smart cities was enabled to check the air quality, humidity levels and weather conditions. The data sent from the transmitter was received at the receiver and then the received data is monitored and recorded using web application.

Pradyumna Bapat Karthikeyan Sengunthar Krishna Shenvi Anindita Khade [6] (2021) The purpose of this



project is to identify the harm caused by the air and sound pollution to the environment. Pollution in simple words can be explained by, the presence of an foreign object in the environment which has harmful effect, we as a society have to ensure that all the pollution levels are maintained to the minimum, In today's world, pollution is the biggest concern, pollution has a lot of harmful effects on the well being of the people.

Pal, P., Gupta, R., Tiwari, S., Sharma, A. (2017) [7]

The use of Internet of Things-based air pollution monitoring systems has become a viable option for the continuous, scalable, and real-time monitoring of air quality indices. This review of the literature examines the state of the art in this field, highlighting the difficulties and potential paths forward while delving into the different elements, techniques, and technologies that go into IoTbased air pollution monitoring systems.

N. Maisonneuve and M. Stevens and M. E. Niessen and L. Steels. Noise Tube (2021) [8]

Environmental pollution detection and its potential effect on human health has become one of the major topics of research over the last few decades. But the involvement of modern technology in this area has moved to it's peak in the current decade. In the year of 2009, a project named Noise Tube was used to detect source of noise, personal exposure to noisy areas and henceforth to create a record of noisy areas for 241 cities around the world.

Kennedy Okokpujie, Etinosa Noma- Osaghae, Odusami Modupe, Samuel John and Oluga Oluwatosin (2022) [9]

Air and sound pollution monitoring system for a particular locality of Croatia named Zagreb was projected in late-2022, which used both a wearable sensor for air quality measurement and a mobile crowdsensing application for sound noise level detection. But the proposed model seemed very challenging while calibrating different brand mobile phones for accurate collection of data (noise level). Another air pollution measurement system was designed in 2022 by the researchers from Covenant University, Nigeria.

B. Predic, Zhixian Yan, J. Eberle, D. Stojanovic, and K. Aberer (2013) [10]

The literature has identified a large number of projects utilizing low-cost air pollution sensing devices that can be carried by individuals or by flexible vehicles. In the study, an environmental sensing technique has been shown to reinvigorate citizens' attention and sympathy for pollution. Exposure Sense is a portable framework for participatory sensing that is used to track one's daily activities.

METHODOLOGY

The development of an IoT-based air pollution monitoring system follows a structured approach that ensures accuracy, real-time data collection, and ease of use. The first step is designing the system architecture, where a microcontroller, such as Raspberry Pi, serves as the core component for managing and processing data. Various sensors are connected to this microcontroller, including gas sensors like MQ135 for detecting pollutants, as well as temperature and humidity sensors to measure environmental conditions. These sensors are selected based on their sensitivity and compatibility with the microcontroller, ensuring they provide reliable data. After integrating the sensors, the system begins continuous data collection, measuring air quality in real-time. The collected data is transmitted wirelessly using communication modules such as Wi-Fi, GSM, or Bluetooth to a cloud server or a local database. This allows the system to store large amounts of data, which can be accessed remotely for monitoring and analysis. The real-time data is processed, where pollutant levels are analyzed against pre-set safety thresholds or by using algorithms to identify trends and patterns in pollution levels. For better usability, the system includes a user interface that displays this data in a visual format, accessible through web or mobile applications. The interface provides detailed information on gas concentrations, temperature, and humidity, with clear indicators of whether the air quality is good, moderate, or hazardous. In cases where pollution levels rise beyond safe limits, the system can automatically send alerts or notifications to users via text messages, emails, or in-app notifications, prompting immediate actions to mitigate exposure to poor air quality. In addition to real-time monitoring, the system can be equipped with predictive models that use historical data to forecast air quality trends, providing users and authorities with proactive insights. The system is also designed to be scalable, making it suitable for integration into larger smart city infrastructures, where multiple sensors can be deployed across various locations for comprehensive environmental monitoring. Rigorous testing is conducted to ensure the system's reliability in various environmental conditions, including urban, industrial, and rural areas. The data collected during these tests is validated to guarantee that the system accurately



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detects pollutants and responds appropriately to changing air quality levels. This ensures the monitoring system is dependable and can provide actionable insights into environmental pollution.

Microcontroller: The brain of the system that collects data from the sensors, processes it, and sends it to the internet. Examples include Raspberry pi. The central processing unit of the system, the microcontroller, manages data collection from all sensors, processes this data, and communicates with other modules.

Sensor's Gas Sensor: Measures the amount of gas (like smoke or carbon monoxide) in the air. Dust Sensor: Measures how much dust or particulate matter is in the air. Noise Sensor: Measures the sound levels to check for noise pollution. Humidity and Temperature Sensor: Measures the humidity and temperature in the environment.



Fig. 1: Block Diagram of Air Pollution Monitoring System

IoT Platform: A cloud service that stores and processes the data sent by the ESP8266. It helps analyze and visualize the data. Examples include Thing Speak. The platform receives data from the ESP8266 module, processes it, and makes it accessible via a user-friendly interface.

End User: The person who uses the website to monitor environmental data and receive alerts. They can see realtime and historical data. The target audience who uses the system to stay informed about air quality and take necessary actions to protect their health and the environment.

RESULTS AND DISCUSSION

The proposed model is used for measuring the air pollution/ intensity level near educational institutions, hospitals and corporate offices. Before taking final data, the sensor was calibrated at the beginning. For measuring the pollution level, we chose schools, colleges, corporate offices and hospitals where traffic is busy all the time. To demonstrate the effect of sound pollution on these places, we took two set of measurements with the proposed model, one set in the early morning and another set in the busy hours.



Fig. 2: Gas level measurements in Thing Speak platform

The histograms depict the distribution of air quality and environmental factors, including AQI, CO2, PM10, PM2.5, humidity, and temperature. The AOI (Air Ouality Index) is predominantly low, with most instances below 50, suggesting good air quality, though occasional spikes up to 175 indicate temporary pollution events. CO2 levels concentrate around 400-500 PPM, representing standard atmospheric conditions, with a few instances exceeding 1000 PPM, likely from localized sources. PM10 and PM2.5 levels remain under 50 µg/m³ and 40 $\mu g/m^3$ respectively, indicating manageable particulate pollution, though occasional peaks highlight specific pollution incidents. Humidity levels are centered near 55%, with most readings ranging between 50% and 60%, reflecting a relatively humid environment. Temperature data reveals a dominant range of 25°C to 32°C, indicating warm ambient conditions, with minimal fluctuations. The combined analysis indicates overall favorable air quality with occasional pollution surges due to external factors. This data is crucial for identifying pollution hotspots and designing mitigation strategies.

The smoothed temperature graph for 2024 provides a clearer visualization of long-term seasonal patterns. It shows a gradual rise in temperature from January, peaking mid-year during summer, and a steady decline toward the end of 2024, consistent with winter conditions. The maximum temperature curve remains higher than the minimum, with the largest gap observed in the summer months, indicating significant day-night temperature differences. Minimum temperatures consistently drop



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below 10°C during winter, while summer minimums stay above 20°C, highlighting distinct seasonal variations. The smoothing curve removes short-term fluctuations, emphasizing long-term trends specific to 2024. This data is crucial for understanding climate stability over the year and supports agricultural planning, energy optimization, and weather forecasting for 2024.



Fig 3: Temperature level measurements in Thing Speak platform

CONCLUSIONS

In conclusion, the development of an IoT-based air pollution monitoring system offers a practical and efficient solution to the growing problem of air pollution. By using sensors to detect harmful gases and environmental factors like temperature and humidity, the system provides real-time data that can be accessed remotely through a user-friendly interface. It not only allows for continuous monitoring but also sends alerts when pollution levels become unsafe, enabling timely actions to reduce health risks. With the ability to scale and integrate into larger infrastructures, such as smart cities, this system is a cost-effective and reliable tool for both individuals and authorities to track and manage air quality. Through rigorous testing and validation, it ensures accuracy and reliability, making it a valuable asset in combating air pollution and protecting public health.

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Integrated Lean-Green Framework for Small Scale Manufacturing Industry: A Substructure Synthesis Model Approach

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ABSTRACT

Small-scale industries (SSIs) are vital to India's economy, contributing significantly to employment. Lean manufacturing enhances operational efficiency by minimizing waste, while green manufacturing promotes sustainability by reducing environmental impacts. Integrating Lean and Green practices can help SSIs achieve both economic and environmental goals. This research presents a four-phase framework—Assessment, Planning, Implementation, and Evaluation—designed for easy adoption by SSIs, fostering long-term sustainability and efficiency.

KEYWORDS : Lean manufacturing, Green manufacturing, Integrated framework, Small-scale industry.

INTRODUCTION

SIs play an important role in India's economic and social landscape. Despite their significance, they face challenges such as inadequate resources, poor inventory control, and outdated technology [34, 35]. Implementing Lean-Green practices can address these issues by reducing waste, enhancing resource efficiency, and improving environmental performance.

Lean manufacturing eliminates the non-value-added activities, increasing productivity and reducing costs. Techniques like 5S, Kaizen, and Just-in-Time (JIT) are commonly used [1, 4]. Studies show Lean practices improve inventory turnover [2], productivity [3], and operational efficiency [6, 7].

Green manufacturing aims to minimizing the environmental impacts throughout a product's lifecycle, emphasizing resource conservation and waste reduction [10, 11]. Strategies include using recyclable materials, reducing energy consumption, and eliminating toxic substances [12, 13]. Adopting these practices can save resources, reduce emissions, and offer competitive advantages [13, 14].

LITERATURE REVIEW

Lean Manufacturing and Its Practices

Lean manufacturing, introduced by the Toyota Production

System, has objective to eliminate non-value-adding activities. Techniques such as Value Stream Mapping (VSM), 5S, and Total Productive Maintenance (TPM) have demonstrated improvements in productivity, quality, and inventory management [1, 2, 4]. For instance, Singh et al. (2013) showed that JIT principles in supply chain management reduced costs and improved quality [1]. Hemanand et al. (2012) highlighted a 12% productivity boost in the automotive sector using Lean tools [3].

Key Benefits:

- Cost reduction [1]
- Waste minimization [3]
- Improved operational performance [4, 7]
- Enhanced productivity and efficiency [6]

Green Manufacturing and Its Practices

Green manufacturing considers the entire product lifecycle, focusing on reducing environmental impacts. Strategies include using recyclable materials, minimizing resource use, and reducing emissions [8, 10]. Sarkis (2003) emphasized that JIT and TQM contribute to resource efficiency [10]. Luttropp et al. (2006) provided guidelines for eco-friendly product design, stressing minimal energy use and resource consumption [11].

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Advantages

- Resource conservation [10]
- Reduced emissions and waste [12, 13]
- Competitive advantage and energy efficiency [14]

Linking Lean and Green Manufacturing

While Lean focuses on efficiency and waste elimination, Green emphasizes environmental sustainability. Integrating both approaches can enhance profitability without compromising environmental responsibility [20, 22]. Studies show significant performance improvements when Lean and Green are combined, reducing resource usage by up to 50% [15, 16]. Pampanelli et al. (2014) found that applying Kaizen alongside Green practices reduced resource use and environmental impact [15].

Key Outcomes

- Cost savings and productivity gains [16, 19]
- Reduced environmental impact [17, 18]
- Enhanced sustainability performance [20]

FRAMEWORK DEVELOPMENT FOR LEAN AND GREEN INTEGRATION

The framework involves creating a structured approach that aligns with the goals of improving efficiency, reducing waste, and enhancing environmental sustainability.

Literature related to the Lean and Green (LnG) Framework

Several studies have explored the integration of Lean and Green (LnG) practices in small and medium enterprises (SMEs). Siegel et al. (2019) identified challenges such as a lack of metrics and measurement tools for implementing Green-Lean strategies. Their review highlighted 5S as the most commonly applied tool and presented a systemic model for addressing LnG determinants in SMEs [45]. Rafique et al. (2019) developed a framework combining Value Stream Mapping (VSM) with the Technology-Organization-Environment (TOE). This approach integrates technological advancements with Lean practices to enhance implementation success [46]. David et al. (2016) suggested a methodological framework for Lean-Green adoption but noted obstacles due to low organizational

maturity, which complicates implementation [35].

Cherrafi et al. (2017) highlighted barriers such as limited environmental awareness, inadequate government support, and financial constraints, suggesting that overcoming these issues is crucial for successful LnG integration [36]. Duarte and Cruz Machado (2017) have developed a conceptual framework for integrating Lean and Green within supply chains. They faced challenges related to the complexity of aligning these models effectively [37].

Similarly, Belhadi et al. (2018) applied Lean-Green strategies in SMEs and found that cultural change and resource limitations were key obstacles, despite the positive impact on the operational and environmental performance [38]. Jamwal et al. (2019) identified critical barriers such as high implementation costs and resistance to change in small industries. Their study used Total Interpretive Structural Modeling (TISM) to map these challenges and propose strategic solutions [39]. Choudhary et al. (2019) developed an integrated framework emphasizing Lean-Green synergy, with tools like Green Integrated Value Stream Mapping (GIVSM) to simplify carbon footprint analysis and waste visualization [40].

Overall, these frameworks and studies underscore the benefits of combining the Lean and Green practices but also highlight the challenges, particularly for resourceconstrained SMEs. Effective integration requires addressing technological, financial, and cultural barriers to achieve sustainable performance improvements [41, 42].

Development of the Lean and Green Framework

The development of an integrated Lean and Green (LnG) framework for small-scale manufacturing industries requires a structured approach. This framework aims to enhance operational efficiency while promoting environmental sustainability.

Siegel et al. (2019) emphasized the importance of addressing implementation challenges by creating systematic frameworks tailored to SMEs. They noted that tools such as 5S, Kaizen, Total Productive Maintenance (TPM), and Value Stream Mapping (VSM) are crucial for LnG integration [45]. Rafique et al. (2019) proposed a technology-linked Lean framework, highlighting the need for aligning technology with organizational and environmental considerations to optimize resource usage [46].



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Phase	Assessment Phase	Planning Phase	Implementation Phase	Evaluation Phase
	Continuous Improvement		\leftarrow	
Objective	Process Mapping, Identification of Problems Identification & selection of LnG tools	Setting of Goal Setting of KPIs Develop plan of implementation	Implement Lean and Green tools to eliminate/ reduce the problems & improve sustainable performance	Expediting, Standardization, Performance measurement and Continuous improvement
Tools	 SWOC analysis PISTEL analysis SHPOC analysis Shoo process characteristic analysis Boto process characteristic analysis Boto cance analysis Boto cance analysis Canse and effect analysis Pitrick Analysis PICK analysis 	LGG awareness Training about LaG LoG lease formation LoG lease formation Kalese teams formation Softing of RPIs Mainteninese planning Print Layout Planning Print Layout Planning Lorivounnental Management System (ILS) Insission Control (ILS) Insission Control (ILS) Divulopment of Genuba bouch	Green Integrated VSM Kizen implementation Si miplementation Simplementation Make reduction Soft implementation Soft implementatimplementation Soft implementation Soft implementation	Lxpodiing Sundardization Sundardization Incformation mathematicion regular internal Audio Respiral functional Audio External and/s LarG Scoreboard
Procedure	Evaluate current manifesturing processes, resource, and performance or physics, management, and customers. Specify materials, internation flow, and end products for each site, statistical statistics, and performance of the statistics of the performance of the statistics of the performance of the statistics of the bettieneds within processes. Conduct SWOC, PESTEL, SIPOC, VOC, rest cause, and cusse and effect analyses.	Eutablish clear goals for the Lean and Gener ministrue. Determine KPAs and set becklop a supely-step lark implementation plan. Conduct awareness and training seconds. Form a Lean-Gener toma responsibilities. Schoolae Kaizen events and regular ministrance checks. Develop new plant loyouts and create visual boards.	Follow the detailed molyconcatacies plane KPM, and track propress agams KPM, and track propress agams KPM, Value Stream Magyong, Implement Katzers, SS, 347, SOP, EMS, and other Learn- Green tools. Laubhish system conclusions maintenance, and Just-In- Time practices.	Expedite and streamline processes. Sandharkar, 2003b based on Sandharkar, 2003b based on Measure effectiveness against KPBs and gather feedback. Implement regular review cycles for continuous Conduct internal and thirds party andia. Develop visual scorebards to track performance.
Expected Outcomes	 To understand existing processes, resource utilization, and performance mettics. To Pripont areas of inefficiency, waste, and production hortlenecks. To analysis of futurnal methods external factors affecting the cognitization, and root assess of mefficiencies. 	To define objectives and targets for the Lean-Green initiative. To Improve employee understanding and commitment to Lean-Green preferes. To optimume plant layouts and visible performance tracking systems.	 To steamline processes, organized workspaces, reduced resource usage, standardized operations, and onvoronmental management. To develop efficient plant layouts, reliable engineent maintenance, and operimize invontory management. 	To accelerated production cycles and robused process delays. To establish consistent, high- quality operations across the organization. To identify further improvement opportunities.

Fig. 1: Integrated Lean & Green Framework

The framework involves four key phases:

Assessment Phase

Evaluate current processes, identify waste, and analyze performance. Tools such as SWOC and PESTEL analyses are used to assess internal and external factors. Stakeholder input is also critical at this stage.

Planning Phase

Set clear goals and define key performance indicators (KPIs). Develop detailed implementation plans and form Lean-Green teams with defined roles. Regular training sessions and workshops ensure all staff understand LnG concepts and their responsibilities.

Implementation Phase

Apply Lean tools such as 5S, Kaizen, and Kanban alongside Green practices like 3R (Reduce, Reuse, Recycle) and Environmental Management Systems (EMS). Standard operating procedures (SOPs) are established to ensure consistency, and techniques like Single-Minute Exchange of Dies (SMED) improve efficiency [36, 39].

Evaluation Phase

Monitor performance against established KPIs and conduct regular audits. Tools such as PDCA (Plan-Do-Check-Act) cycles ensure continuous improvement. Internal and external reviews help identify areas for refinement, while feedback mechanisms engage employees in the improvement process [37, 38]. This framework offers a step-by-step guide to effectively integrate Lean and Green practices in SSIs, fostering both operational excellence and environmental responsibility [41, 42].

CONCLUSIONS

Integrating Lean and Green practices offers SSIs a structured path to enhance efficiency and sustainability. This framework addresses common challenges, enabling SSIs to improve resource management, reduce environmental impact, and strengthen their competitive edge. Implementing these practices fosters sustainable growth and operational excellence in the small-scale manufacturing sector.

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Analysis on Behavior of Reinforced Concrete Structures under Considerations of Explosive Loads: A Review

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ABSTRACT

Reinforced concrete structures are renowned for their strength and durability, making them integral to modern construction projects. While they are designed to withstand routine loads from occupants and environmental conditions, they face considerable vulnerabilities when subjected to explosive forces from events like terrorist attacks, industrial accidents, or military conflicts. The intense shock waves generated by explosions can lead to severe damage, including cracking, spalling, and, in extreme cases, catastrophic structural failure. This project aims to analyze the behavior of reinforced concrete structures under explosive loads to improve their resilience against such threats. Utilizing advanced computer simulations alongside a thorough review of existing research, we will explore the dynamic response of these structures to blast forces. This investigation will identify critical failure points and assess the effectiveness of current design practices. Ultimately, the study will provide recommendations for design enhancements that can bolster the strength and safety of buildings made of reinforced concrete in the midst of explosives threats. By improving our understanding of structural behavior under extreme conditions, we can contribute to the development of more resilient construction practices, ensuring better protection for occupants and assets in vulnerable settings.

KEYWORDS : Reinforced concrete structure, Collapse, Progressive Collapse, Analysis, Explosive loads, Etabs, etc.

INTRODUCTION

Reinforced concrete structures are prevalent in construction due to their remarkable strength and durability. These structures consist of steel reinforcement embedded within concrete, allowing them to endure everyday loads, include the weight on the building itself, people, and environmental elements like wind and rain. However, in extreme situations such as terrorist attacks, industrial accidents, or military conflicts, they may be subjected to explosive loads.

Explosive loads represent sudden and powerful forces that can inflict significant damage in a short period. When

an explosion occurs near or within a reinforced concrete structure, it generates a shock wave that propagates through the air, exerting intense pressure on the building. This pressure can lead to severe damage, including cracking, spalling (where concrete pieces break off), or, in extreme cases, the collapse of the entire structure.

Understanding how reinforced concrete structures behave under such extreme conditions is crucial for enhancing their safety and resilience against explosions. Engineers must consider various factors when designing buildings to withstand explosive loads. For instance, the type and magnitude of the explosion are critical, as different



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blasts can yield vastly different impacts on a structure. Additionally, the distance between the explosion and the building plays a significant role; closer blasts result in greater damage. The materials utilized in construction also influence the structure's response; stronger materials may withstand explosions better than weaker alternatives.



Fig. 1. Bomb attack on Building in before and after the attack

This project focuses on these factors to inform the design of more resilient buildings. By analyzing the reaction of reinforced concrete structures to explosive loads through computer simulations and a review of existing research, the study aims to identify potential failure points and suggest design improvements. The findings will enhance safety and security, particularly for buildings at higher risk of explosive threats, such as government facilities, embassies, and industrial sites. Ultimately, this research contributes to the development of stronger, safer structures that better protect lives and property in the event of an explosion.

PROBLEM STATEMENTS

- Reinforced concrete structures are widely utilized in construction due to their strength and durability; however, their performance under explosive loads remains a critical concern.
- Events such as terrorist attacks, industrial accidents, or military conflicts can expose these structures to intense shock waves, leading to severe consequences, including cracking, spalling, or complete structural failure.
- Understanding the response of reinforced concrete to such explosive forces is essential for ensuring the safety and resilience of buildings, particularly those housing critical infrastructure.

- Current design standards often overlook the unique challenges posed by explosive loads, resulting in inadequately protected structures.
- This research aims to investigate how reinforced concrete structures behave under explosive conditions by employing computer simulations and reviewing existing literature.
- The findings will identify potential failure points and provide insights enabling design improvements, eventually contributing to the creation of more secure and resilient structures able to withstanding explosive threats.

LITERATURE REVIEW

Literature Survey

Jain and Prasad (2021) investigate the impact of reinforcement ratios on the blast resistance of reinforced concrete structures. Their findings reveal that higher reinforcement ratios significantly enhance resistance to explosive forces, emphasizing the importance of careful reinforcement selection in design practices. This study serves as a critical foundation for future safety-focused designs in explosive scenarios, guiding engineers in developing resilient structures capable of withstanding blast loads.

Kumar and Singh (2019) present a finite element model designed to predict damage patterns in reinforced concrete beams subjected to explosive loads. Their research confirms the efficacy of finite element analysis (FEA) as a reliable assessment tool for structural integrity. The model provides valuable insights into the behavior of beams under explosive conditions, paving the way for further investigations into explosive impacts on diverse structural elements. This study contributes significantly to the understanding and analysis of reinforced concrete structures facing explosive threats.

P., & Singh L. (2019) validate finite element analysis (FEA) models to assess the performance of reinforced concrete slabs subjected to close-range explosions. The research confirms the predictive capabilities of FEA, demonstrating its effectiveness in evaluating structural responses under explosive conditions. By establishing the role of FEA in understanding slab dynamics, this paper contributes to the broader field of structural analysis and reinforces the importance of numerical methods in blast resistance research.



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Gupta and Patel (2020) explore the behavior of highstrength concrete subjected to explosive loads, revealing that it performs exceptionally well due to its enhanced strain rate capacity. Their findings underscore the importance of material selection in blast-resistant design, advocating for high-strength components in critical applications. This research is significant for engineers looking to optimize materials for structures exposed to explosive forces, offering valuable insights into improving overall structural performance and resilience.

Ali and Khan (2021) provide a comprehensive review of reinforcement strategies aimed at enhancing the blast resistance of reinforced concrete (RC) structures. Their compilation of data on various approaches highlights key design principles and effectiveness, offering valuable insights into the current state of research. This paper serves as a critical resource for engineers and researchers, informing future studies and practical applications in the design of structures that can withstand explosive threats effectively.

Singh and Agarwal (2020) enhance existing models to predict the response of concrete structures to blast loads. Their research focuses on improving the accuracy of blast load modeling techniques, thereby contributing to a better understanding of structural behavior under explosive impacts. This work supports advanced analytical approaches in engineering design, paving the way for improved methodologies in assessing structural resilience against explosive threats and informing future design practices.

Verma and Das (2015) analyze the contrasting behaviors of reinforced concrete structures under seismic and explosive loads. By highlighting the distinct responses to these dynamic forces, their study provides valuable insights that can guide engineers in developing targeted design strategies. This comparative analysis contributes to a nuanced understanding of the different load types, ultimately enhancing the resilience of structures designed to withstand both seismic and blast loads.

Reddy and Rao (2019) demonstrate that incorporating steel fiber reinforcement significantly enhances the blast resistance of reinforced concrete. Their findings advocate for exploring alternative reinforcement materials, emphasizing the critical role of material selection in optimizing structural performance under explosive loads. This research adds to the understanding of how specific materials can improve resilience, guiding engineers in making informed decisions for blast-resistant designs in concrete structures.

Kumar and Sharma (2017) investigate the effects of dynamic loads on the flexural performance of reinforced concrete beams during explosions. Their study provides crucial insights into the structural integrity and safety of beams under explosive forces, informing the development of more resilient designs. This research is vital for engineers focused on enhancing the performance of concrete beams in blast- prone environments, ultimately contributing to safer structural designs.

Patel and Shah (2020) document case studies that illustrate common failure patterns in reinforced concrete buildings following explosions. The collected data serve as a valuable resource for validating analytical models and understanding real-world impacts. This paper aids in informing design improvements aimed at enhancing blast resistance, making it an important contribution to the field of structural engineering focused on safety and resilience against explosive events.

Verma and Sharma (2021) propose modifications to design practices aimed at enhancing the blast resistance of reinforced concrete buildings. Their recommendations are pivotal for developing practical guidelines that can significantly improve safety and resilience against explosive threats. The study emphasizes the necessity of integrating blast-resistant principles into standard design protocols, providing valuable insights for engineers focused on ensuring structural integrity and security in potentially hazardous environments. This work serves as a foundational reference for future research and design efforts in blast- resistant construction.

Kumar and Thakur (2020) validate the accuracy of numerical simulations in predicting the behavior of reinforced concrete walls subjected to blast loads. Their research demonstrates the reliability of computational methods in structural analysis, confirming that numerical simulations can effectively model explosive impacts. The findings support the project's approach of utilizing simulations to enhance understanding of blast effects on structural elements. This study contributes significantly to the growing body of knowledge regarding numerical techniques in assessing and predicting structural responses under dynamic loading conditions.

Jones and Black (2017) present advancements in blast load modeling techniques that enhance predictive



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capabilities for structural responses to explosive events. Their work emphasizes the necessity of accurate modeling in the design of resilient concrete structures, laying the groundwork for future research endeavors. By improving the understanding of how concrete structures behave under blast loads, this study provides engineers with essential tools for developing structures capable of withstanding explosive forces. The findings encourage the adoption of refined modeling approaches in structural design practices.

Patel and Mehta (2019) investigate the residual strength and stability of reinforced concrete frames following explosions. Their study provides critical insights into postblast structural integrity, highlighting the need for effective assessment strategies to evaluate damage. The findings inform strategies for repairing and reinforcing damaged buildings to ensure continued safety and usability. This research is vital for engineers involved in disaster recovery and structural rehabilitation, as it emphasizes the importance of understanding the behavior of structures after explosive events.

Zhang and Chen (2018) offer a comprehensive review of the spalling phenomena in concrete structures subjected to blast loads. Their analysis discusses various mitigation methods and highlights the critical importance of understanding spalling mechanisms to enhance the blast resilience of reinforced concrete designs. The review identifies gaps in current research and suggests avenues for future studies, ultimately aiming to improve the safety and performance of concrete structures under explosive conditions. This study is a valuable resource for scholars and practitioners alike.

Clark and Evans (2020) evaluate various blast- resistant design approaches and their effectiveness in real-world applications. This comparative study provides valuable insights into selecting optimal design strategies that enhance structural resilience against explosive forces. By analyzing different methods, the authors highlight the strengths and weaknesses of each approach, contributing to the broader understanding of how to achieve effective blast resistance in concrete structures. The findings serve as a guide for engineers seeking to implement robust design solutions in potentially hazardous environments.

Sharma and Gupta (2019) analyze the effectiveness of various blast-resistant designs in reinforced concrete structures. Their comparative assessment offers guidance for selecting the most effective strategies to enhance structural integrity under explosive loads. The study evaluates multiple design approaches, highlighting their impact on performance and resilience during explosive events. This research aids engineers in making informed decisions regarding the implementation of blast-resistant features, ultimately contributing to the development of safer and more resilient concrete structures.

Tan and Liu (2017) correlate experimental results with numerical models to improve the accuracy of predicting concrete panel behavior under blast loading. Their research emphasizes the importance of experimental validation in enhancing the reliability of simulation results. By integrating both experimental and numerical approaches, the study contributes significantly to the understanding of blast effects on concrete structures. The findings support the advancement of predictive models that can inform design practices aimed at improving blast resilience in concrete panel systems.

Rogers and Collins (2016) evaluate various mitigation techniques, including external reinforcement strategies, to improve the blast durability of reinforced concrete structures. Their findings are relevant for recommending design improvements aimed at minimizing damage from explosive events. The study highlights the effectiveness of different mitigation approaches and provides a framework for implementing these techniques in practice. This research is essential for engineers focused on developing blast-resistant designs that ensure safety and structural integrity in explosive scenarios.

Morgan and Taylor (2018) investigate the residual strength and repair strategies for reinforced concrete bridges following explosions. Their research provides vital insights into maintaining structural integrity after blast events, which is crucial for developing effective repair and rehabilitation methods. The findings contribute to a better understanding of how bridges respond to explosive loads, offering practical solutions for ensuring the safety and functionality of these critical structures. This study is significant for engineers involved in the maintenance and repair of infrastructure.

Sharma and Singh (2019) explore the impact of varying explosive charges on reinforced concrete beams, identifying Failure modes include cracking and spalling. Their research enhances the understanding of failure mechanisms, which is crucial for improving design strategies aimed at resisting explosions. By investigating different charge levels, the findings provide insights that can inform the development of more resilient beam



designs, ultimately contributing to enhanced safety in structures exposed to explosive forces.

Verma and Bhargava (2020) employ finite element modeling to simulate the impact of blast loads on columns made of reinforced concrete, identifying critical stress points and potential failure mechanisms. Their findings emphasize the effectiveness of simulations in accurately predicting structural responses under explosive conditions. This research supports the application of advanced numerical methods in assessing the vulnerability of concrete columns, contributing to the development of design practices that enhance blast resistance and structural safety in civil engineering applications.

Research Gap

There has been a lot of research on how reinforced concrete structures behave under normal conditions, less attention has been given to how these structures react to sudden, extreme forces like impact or explosive loads. Most existing studies focus on specific parts of the structure, such as columns or beams, but they don't consider the whole structure together More research is needed to determine how different materials and reinforcement techniques may enhance a structure's stability in the face of severe loads. This project intends to fill this gap through investigating the general conduct of reinforced concrete buildings under contact and explosive loads with simulation data.

Summary of Literature

The literature on reinforced concrete structures predominantly emphasizes their performance under normal conditions, leaving a significant gap in understanding their response to sudden, extreme forces such as impact and explosive loads. Most existing research tends to focus on isolated structural components, like columns or beams, without analyzing the holistic behavior of the entire structure under these conditions. This narrow scope limits insights into the overall stability and safety of reinforced concrete structures in critical situations. Additionally, there is a notable lack of exploration into the effects of varying materials and reinforcement techniques on enhancing structural resilience against extreme loads. Recognizing this deficiency, the proposed project seeks to address these gaps by employing simulation data to comprehensively study the behavior of reinforced concrete structures under impact and explosive loads. The findings aim to contribute valuable insights for improving design methodologies and material selection, ultimately enhancing structural safety

in high-risk scenarios.

RESEARCH METHODOLOGY

Criteria for selecting studies

The blast resistance of reinforced concrete structures, several key criteria should be considered. Firstly, the relevance of the research to the specific aspects of blast resistance, including material properties and reinforcement techniques, is crucial. Secondly, the methodology employed, particularly the use of reliable analytical tools like ETABS, ensures accurate predictions of structural behavior. Thirdly, the publication date should be considered to ensure that the findings reflect current practices and technologies. Lastly, studies that provide comprehensive insights or comparative analyses of different reinforcement strategies will enhance understanding and guide effective design practices.

Method of Analysis

Analysis of strengthened concrete buildings under impact and explosive loads involves a multi-faceted approach, primarily employing ETABS as a computational tool. ETABS allows for detailed modeling of the structural components, accounting for the dynamic behavior of materials when subjected to extreme forces. The first phase is to define the shape and material attributes of the construction, which includes the type of cement and reinforcing employed. Load cases simulating blast and impact scenarios are then applied to assess structural response.

Dynamic analysis techniques, such as time-history analysis, are often utilized to capture transient effects and time-dependent behaviors. Additionally, sensitivity analyses may be conducted to evaluate how variations in reinforcement ratios and material properties influence performance. The data are examined for crucial aspects like structural deformation, stress shipping, and possible failure modes, providing insights into the overall resilience of the structure and guiding design improvements for enhanced blast resistance.

Blast Phenomena

A blast is a sudden discharge of energy from mechanical, chemical, or nuclear sources, leading to the generation of a high-pressure shock wave. Structures designed to resist blast loads must endure loads much higher than those from storms, with shock waves exerting immense pressure. Blast loads are characterized by overpressure—an abrupt



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increase in pressure—Both impulse and duration can cause catastrophic damage. The effect of the blast waves decreases as the standoff distance between the exploding source & the structure grows. The damage caused by the blast depends on the intensity of the shock wave, the type of explosive, the weight of the charge, and standoff distance. The complex nature of blast-induced loads on structures makes the analysis of their effects on reinforced concrete frames highly challenging due to the nonlinear, high-intensity pressures generated over a short duration.

General Recommendations on Planning Blast Protected Buildings

IS Standard 4991-1968 Appendix C offers guidelines to enhance blast resistance in buildings. Small rooms can effectively limit blast damage, as partition walls help contain the impact within a confined area. Long, narrow hallways should be avoided since they intensify the explosion effect with many reflections, extending the damage. Projections such as balconies and parapets, especially when made of brittle materials, are particularly vulnerable and should be decreased. Masonry chimney in factories and boiler buildings pose significant hazards and should be avoided in blast-prone areas.

Brittle roofing supplies, such as tiles and corrugated asbestos sheets, can suffer substantial damage in a blast. When utilizing galvanized iron panels for roofing and cladding, additional attention needs to be given to properly anchoring them to the building to reduce the danger of damage. Flammable materials like timber should be avoided in areas where fire risk is high, such as strategic buildings that could be targeted by incendiary attacks.

For electrical safety, using conduit wiring is recommended over open wiring, as conduits provide protection in the event of wall movement, reducing the risk of short circuits and subsequent fires. Glass windows are highly susceptible to breakage from blasts, and the resulting shards can pose a threat to occupant safety. It is better to use non-shattering glass in such cases. Doors should be designed to withstand frontal blast pressures, while adequate wall thicknesses should be maintained to protect against splinters from bomb blasts, following the specifications given in the code for splinter protection.

Blast Load Parameters

According to IS Code 4991-1968: The requirements over blast immune design of structures for explosions above ground, the use of TNT (Trinitrotoluene), a pale yellow, solid nitrogenous organic compound used primarily as an exploding, is considered a reference for determining blast parameters for various charge weights as well as standoff distances. The blast parameters determined for the research project are identical to the examples in the IS Code.

Sample of IS Standard 4991-1968, annex A, for determining blast properties for a rectangular structure above ground.

Blast parameters resulting from the explosion of a 0.1 tonnes explosive are examined on an elevated rectangle framework, 3 m substantial, 10 m wide, and 8 m long, located 30 m above ground zero.

Blast characteristics: Scaled distance. x = 30/(0.1)1/3 = 64.65 m

From the first table of IS Code, assuming $pa = 1.00 \text{ kg/cm}^2$ Pressures are directly derived by interpolating linearly from 63 m to 66 m for the scaling distance of 64.65 m:

 $Pso=0.35\ kg/cm^2,$ $Pro=0.81\ kg/cm^2,$ and $qo=0.042\ kg/\ cm^2.$

The scaled times and td derived from Table 1 with IS Code with scaled distances 64.65 m are divided by (0.1)1/3 to obtain the values for the respective quantities with the real explosions with 0.1 tonne load to = 37.71 (0.1).1/3 equals 17.5 minutes; td = 28.32 (0.1).1/3 equals 13.15 milliseconds.

$$M = 1 + 6 \text{ pso} / 7\text{pa} = 1.14$$

a = 344 m/s; U = 1.14 * 344 = 392 m/s = 0.392 m per millisecond.

Pressures on the Building

Here H = 3 m, B = 10 m, and L = 8 m Then S = 3 m

tc = 3S/U = 3x3/0.392 = 23.0 milliseconds > td Tt = L/U = 8/0.392 = 20.4 milliseconds > td.

tr = 4S/U = 4*3/0.392 = 30.6 milliseconds > td

As tr > td No pressure upon the back face is considered. For front face:

Pro = 0.81 kg/cm2 for roof and sides: Cd= -0.4; pso+ Cd*qo = 0.35-0.4 * 0.042 = 0.33 kg/cm2

Here, 0.1 Tonne TNT explosive is proposed for a distance of standoff 30 meters.

Pa represents ambient atmospheric pressure, pso is peak side-on overpressure, pro is peak reflected overpressure, and qo is peak dynamic pressure.



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to = Positive component duration; td = length of the comparable triangular pulse.

M = mach no. = 1+6 pso / 7pa a = velocity of sound in air

U = shock front velocity = M*a S = H or B/2 whichever is less.

Cd = drag coefficient, taken from the second table of IS Code.

COMPARISON AND ANALYSIS

Comparison of key studies and findings

Reinforcement Ratios: One study emphasizes that higher reinforcement ratios significantly improve resistance to explosive forces, highlighting the importance of selecting appropriate reinforcement in design practices for enhanced structural resilience against blasts.

High-Strength Concrete: Research indicates that highstrength concrete exhibits superior performance under explosive loads due to its enhanced strain rate capacity, underscoring the importance of material selection in blastresistant designs.

Reinforcement Strategies: A comprehensive review highlights various reinforcement strategies aimed at improving the blast resistance of RC structures, providing key design principles and insights that inform future research and practical applications.

Dynamic Load Effects: Studies focusing on the effects of dynamic loads reveal critical insights into the flexural performance of concrete beams during explosions, contributing to safer and more resilient structural designs in blast-prone environments.

Evaluation of methodologies used in the reviewed studies

Many studies utilized ETABS to simulate and predict the behavior of RC beams, slabs, and entire structures under explosive loads. ETABS proved highly effective for analyzing damage patterns, material deformations, and dynamic responses. This method's strength lies in its ability to provide detailed insights into localized damage and structural response under different load conditions. However, its accuracy depends on the precision of the input parameters and assumptions, which can sometimes oversimplify real- world conditions. Experimental Testing: Some studies combined ETABS with physical testing to validate the models and predictions. These experiments often involved scaled- down or full-scale RC components subjected to controlled explosions. While experimental testing offers a realistic assessment of structural behavior, it can be limited by high costs, logistical challenges, and safety concerns, which restrict the range of testing conditions.

Material Property Analysis: Several studies focused on evaluating the material properties of RC under explosive conditions, particularly high-strength concrete and steel fiber reinforcement. These studies highlighted the importance of strain rate sensitivity and the material's ability to absorb energy. While they provide crucial data on material behavior, isolating material performance from overall structural dynamics can be challenging, leading to incomplete conclusions about real-world performance.

Comparative Analysis (Seismic vs. Explosive Loads): A few studies compared the behavior of RC structures under seismic and explosive loads. This methodology helped in understanding how different dynamic forces affect structures differently. However, these comparisons often used generalizations rather than direct experimental correlations, potentially oversimplifying the differences between load types.

Reinforcement Strategy Evaluation: Research on different reinforcement methods, such as steel fiber and high reinforcement ratios, provided insights into optimizing designs. This methodology primarily relied on parametric studies, where various reinforcement configurations were modeled to evaluate their performance under blast loads. The limitation of this approach is that it assumes ideal conditions, which might not capture the complexity of actual blast scenarios.

Highlighting trends, advancements, and challenges

Trends

- Increased Focus on Resilience: There's a growing emphasis on designing reinforced concrete structures that can withstand extreme loads, including explosive and seismic forces.
- Material Innovations: Advances in high-strength concrete and fiber-reinforced materials are enhancing blast resistance, leading to more resilient designs.

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Advancements

- Refined ETABS Analysis: Improved ETABS techniques offer more accurate simulations of structural behavior under explosive loads, enabling better predictions of damage patterns.
- Integration of Experimental Methods: Combining ETABS with physical testing enhances model validation and provides a deeper understanding of real-world performance.

Challenges

- Data Limitations: A lack of comprehensive data on various materials and reinforcement methods under explosive conditions hampers optimization efforts.
- Cost and Safety Concerns: High costs and logistical challenges of experimental testing limit the breadth of research on blast-resistant designs, constraining practical applications.

DISCUSSION

Synthesis of findings from literature

The literature highlights the critical need for enhanced understanding of reinforced concrete (RC) structures under explosive loads. Key findings indicate that higher reinforcement ratios and innovative materials, such as high-strength concrete and fiber reinforcements, significantly improve blast resistance. ETABS Analysis emerges as a reliable method for simulating structural behavior, though its accuracy is contingent on precise input parameters. Comparative studies of seismic versus explosive loads reveal distinct structural responses, emphasizing the necessity for tailored design strategies. Overall, the synthesis underscores the importance of integrating material properties, advanced modeling techniques, and experimental validation for developing resilient RC structures.

Implications for Study

- Explosions typically generate pressure. This can be investigated utilizing pressure loading methods or explosion simulation approaches.
- According to the recommendations for BIS: 4991-1968 (15) "Criteria for blast load immune design of buildings for explosions above ground," it is noted that, because of the static a lot i.e., dead weights and live loads, structural components are subjected

to detonation pressure that are required to resist the forces that are applied by means of the internal emphasizes developed in them.

- Nonlinear features of members affect their ability to withstand blast loads and produce self-resistance. The longer the member's natural time period, the lower the design's effective load.
- The study focused on blast stimulation at a setback distance, also known as the standoff distance, as shown in the figure above.



Fig. 2. Surface Blast Wave and Standoff Distance

- Real-life terrorist assaults cannot anticipate the standoff distance or measure the weight of the bomb deployed. The standoff range of explosion, also known as the setback of ground commercial buildings, is taken into account as recommended by building codes.
- Over expansion at the blast center creates a vacuum and reverses gas velocity. The negative pressure zone spreads outward, creating an opposite pressure (below atmospheric) that follows the positive phase.
- Negative phases often have lower pressure but longer duration than positive phases. Burst phase load are significantly more strongly charged than negative phase coherence.

Earth blast or gust that destroys hardened buildings such as bunkers, missiles silos, locks, springs, and so forth. They generate a mushroom cloud. Because the detonation occurs at ground level, several facilities must be insulated from one another from the prior damage, which is less severe than the air blast.



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Fig. 3. Pressure - time history graph

The explosion is an abrupt release of potential energy within explosive materials with a high capacity of producing gases under circumstances involving high pressure as well as high speed, as it exposed the environment around it for powerful and efficient dynamic pressure. To comprehend and comprehend how buildings behave under explosive loads, it's so important to be familiar with the main exploding factors such as:

-Shock wave.

- -High temperatures.
- -Flying shard.

-The sound wave.



Fig. 4. The primary repercussions of the explosion

- The project begins with an overview of the impact and explosive loading effects on reinforced concrete structures, setting the stage for understanding the context and significance of the research.
- Next, existing research on the behavior of these structures under impact and explosive loads is summarized to provide a foundation for further investigation.

- The model's behavior is analyzed under impact or explosive loads to assess structural performance. Results and discussion involve presenting simulation findings and analyzing the response of reinforced concrete structures, with an emphasis on implications for design practices.
- Finally, conclusions are drawn, summarizing key findings and offering recommendations for future research and practical applications to enhance structural resilience.

Methodology for future research directions

A multi-faceted methodology that integrates advanced ETABS Analysis with experimental validation to enhance predictive accuracy for reinforced concrete (RC) structures under explosive loads. Investigating innovative materials, such as ultra-high- performance concrete and advanced composite reinforcements, can provide insights into improving blast resistance. Additionally, conducting comparative studies on various reinforcement strategies will identify optimal configurations. Implementing realworld blast testing scenarios, combined with numerical modeling, will bridge the gap between theoretical predictions and practical applications. Lastly, developing a comprehensive database of material properties under dynamic loading conditions will support more robust design methodologies for resilient structures.

CONCLUSION

The paper focuses on key advances towards comprehending the behavior of RC buildings under explosive loads. Key findings show that larger reinforcement ratios and new materials, including high- strength steel and concrete fiber replacements, enhance blast resistance. ETABS Analysis is established as a reliable tool for predicting structural responses, though it must be validated through experimental testing. Comparative studies underscore the differing impacts of seismic and explosive forces. Overall, the synthesis emphasizes the need for comprehensive methodologies that combine numerical modeling and real-world testing to inform future design practices and improve structural resilience against explosive threats.

This project emphasizes the critical need to enhance the resilience of reinforced concrete structures against explosive loads, given their widespread use in modern construction and their vulnerabilities to such threats. Through advanced computer simulations and a comprehensive review of existing literature, we aim to



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deepen our understanding of how these structures respond to explosive forces, identifying key failure points and evaluating the effectiveness of current design practices. The insights gained will inform targeted recommendations for design improvements, ultimately contributing to safer and more robust construction methods. By prioritizing the analysis of structural behavior under extreme conditions, we can develop strategies that significantly bolster the integrity and safety of reinforced concrete buildings, ensuring better protection for occupants and assets in high-risk environments. This research not only addresses immediate safety concerns but also paves the way for innovative design approaches that can adapt to emerging threats in an ever-evolving landscape of construction challenges.

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Investigation of Thermo Acoustic Refrigeration System with Polynamide Nylon 6 Stack

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ABSTRACT

Recent advances in thermal acoustics potentially revolutionize several electronics. Manage longitudinal wave temperature changes to build a machine that can replace refrigeration and air conditioning. Space heaters, hot water heaters, refrigerators, and coolers can have these devices. Thermal acoustic devices don't include dangerous chemicals or environmentally hazardous materials like modern refrigeration systems. In thermo acoustics, heat is converted to sound and vice versa. Thermo acoustic equipment includes prime mover and refrigerators. A thermo acoustic engine converts heat into sounds that can be used for production. Instead, a thermo acoustic refrigerator absorbs heat from a low-temperature medium and rejects it to a high-temperature medium using acoustic power. This study examines the performance coefficient of a thermo acoustic refrigeration system with helium gas as working fluid, parallel plate stack geometry, and polyamide nylon 6 stack material. The performance of thermo acoustic refrigeration systems depends on stack geometry: spiral, parallel, or honeycomb. Different stack shape, stack material, and working fluid are needed to increase thermo acoustic refrigeration system performance.

KEYWORDS : Helium, Parallel plate, Polyamide nylon, Stack, Thermo acoustic.

INTRODUCTION

With pressure changes, acoustic waves suffer temperature and displacement oscillations. Gas oscillations near a solid surface allow heat transfer to or from the surface, creating a thermo acoustic effect. A stack of closely spaced parallel plates inside the thermo acoustic device provides a solid surface. Gas particles and stack plates interact to generate thermo acoustics. Large temperature differences across the stack produce sound waves and acoustic power (creating a thermo acoustic engine). Heat pumping or refrigeration produces heat when the wall gradient is very modest or zero.

Modern lifestyles require refrigerators. The vapor compression refrigeration technique, used in most modern refrigerators, is highly efficient but employs toxic refrigerants—once chlorofluorocarbons (CFCs), now hydro fluorocarbons (HFCs), which deplete the ozone. Moving parts diminish its service life and lengthen its maintenance life. Here, the goal is to replace the old refrigeration system, make it more environmentally friendly, and deliver effective, cheap, and maintenancefree refrigeration at its best.

Only environmentally friendly inert gases are used instead of refrigerants. Thermo acoustic freezers have an advantage over traditional freezers because to the international ban on CFCs and the lack of confidence in CFC alternatives. These devices use air, helium, and xenon, which have no greenhouse effect and are ozonesafe. Greenhouse gas regulations are expected to tighten. Due to CFC restrictions and knowledge of its ozonedepleting consequences, researchers had to find an alternative approach. Thermo acoustic refrigerators may be the greatest replacement for standard refrigeration systems. In addition, the thermal acoustic cycle is better suited to proportional control than binary control utilized in traditional freezers. These considerations make thermo acoustic refrigerators desirable for general use.



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METHODOLOGY

Basic of Refrigeration

A refrigerator transfers heat from a low- temperature to a high-temperature medium using external work. Refrigerators work with refrigerant. Refrigeration follows the first and second laws of thermodynamics. Most refrigeration uses the vapour-compression cycle. Most air conditioners, refrigerator heat pumps, and other refrigeration systems use the vapour compression cycle.

Acoustic Effect

Thermo acoustic wave oscillations include temperature, displacement, and pressure fluctuations. Gases with these three phenomena are predicted to oscillate near solid surfaces to cause thermal acoustic effects. In huge temperature differences other than the surface of a solid, these oscillations produce persistent sound waves. Acoustic theory studies long-distance waves. Compression and expansion of gas produce longitudinal acoustic waves. Particle displacement in a longitudinal wave is parallel to wave propagation, therefore particles oscillate around their equilibrium positions.

Parts of Thermo Acoustic Refrigeration System

The stack is the major component of a thermal acoustic device, where the phenomenon occurs. Thus, stack parameters affect thermo acoustic device perforce. Stackable material should have high heat capacity and low thermal conductivity. This design uses polynamide nylon 6 for parallel plate stacks.

The working fluid significantly affects the operation of the thermo acoustic refrigeration system. High sound speed, heat capacity ratio, and inert gases are used for efficiency and power. The thermo acoustic power increases with sound velocity in the working fluid, therefore lighter gases with high sound velocity can be employed. Working mediums include helium, neon, and argon.

A long tube with a certain geometry stack and two heat exchangers is used. It might be glass or acrylic. Resonator material should tolerate high frequency.

DESIGN PROCEDURE

In the assessment of the thermoacoustic refrigeration system conducted by MEH Tijani [1], various parameters must be predetermined with fixed values for specific justifications, which might be articulated as follows: The mean pressure determines the mechanical strength of the resonator. The elevated average pressure mitigates the risk of leakages. The elevated frequency chosen for sound prolonging and enhanced driver efficiency. This is the cooling effect achievable from the thermoacoustic refrigeration system. The working fluid must facilitate high efficiency, elevated power, and increased sound speed throughout experimentation. The stack material must possess low thermal conductivity and high specific heat capacity. Hence considering the design aspect of above following parameters have fixed for designing:

- 1. Average pressure $(p_m = 10 \text{ bar})$
- 2. Frequency 500Hz (Optimized Value)
- 3. Cooling load
- 4. Working fluid (Helium gas)
- 5. Mean Temperature. $(T_m = 27^{\circ}C)$
- 6. Stack material with high specific heat capacity and low thermal conductivity, so Polyamide Nylon 6 material is selected.

Stack Design

In half a cycle of oscillations, heat can permeate through a gas layer with a thickness of δ_{κ} , which is the thermal penetration depth.

The depth at which the viscosity effect becomes noticeable close to the boundaries is known as the viscous penetration depth (δ_v) .

The δ_{v} and δ_{v} will be showing in Figure 1.

$$\delta_{k} = \sqrt{\frac{2K}{\rho_{m}xC_{p}x\omega}}$$
$$\delta_{W} = \sqrt{\frac{2\mu}{\rho_{m}x\omega}}$$

Stack Spacing

It is the air channel or plate distance (2yo)

$$2y_0 = 3 \ge \delta_k$$

Stack plate thickness

$$2l = 2yo\left(\frac{1}{B} - 1\right)$$

It can be calculated as:

The value of plate thickness will be 2mm.



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Stack Position

Position the stack at $\lambda/20$ of acoustic wavelength from the close end of the resonator for optimal cooling power.

$$x_s = \frac{\lambda}{20}$$

Resonator Length

The minimum L resonator length is generally for the closed tube side is $\lambda/4$.

$$\lambda = \frac{a}{f}$$
 $L = \frac{\lambda}{4}$

Drive ratio

High average mean pressure and drive ratio are desired because power density is proportional to them. The percentage is 3%.

$$D = \frac{P_0}{P_m}$$

Blockage Ratio

Total area between solid and gas will be shown by this parameter, known as stack porosity. Increased porosity reduces thermo-acoustic area.

Normalized thermal penetration depth:

$$\delta_{kn} = \frac{\delta_k}{y_0}$$

Normal Stack Position: $X_N = K_v \times X_s$

Normal Stack length: $L_{sn} = K_v \times L_s$





EXPERIMENTAL SET UP



Fig. 2 Experimental Set Up of Thermo Acoustic Refrigeration System



Fig. 3 Parallel plate stack geometry

PROCEDURE

An acoustic driver, a stack, a resonator filled with operating fluid, a heat exchanger for both the hot and cold sides, and an acoustic driver housing make up the experimental setup. A pressure transducer detects the amplitude of a pressure wave generated by an acoustic driver. A pressure gauge used in the Bourdon tube is used to measure the charging pressure. Thermocouples are used in heat exchangers to measure the temperature of hot and cold fluids. After you plug it in and adjust the frequency on the signal generator, it will begin to work and, with the aid of the acoustic driver, produce standing acoustic waves. The cold side and the hot side of the heat exchanger are used to record the temperatures, which are formed by the temperature



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difference on both sides of the stack. Acoustic drivers are tested at different charging pressures for 60–70 minutes to avoid overheating. Turning off the power allows the cold end to cool down to room temperature after each run.

RESULTS AND DISCUSSION



Graph 1 Charging pressure vs Heat exchanger temperature



Graph 2 Charging pressure vs Coefficient of performance

A decrease in charging pressure results in a lower displacement of the working fluid, which subsequently leads to a diminished heat transfer rate. Elevating the charging pressure results in an increase in the displacement of the working fluid, which subsequently enhances the heat transfer rate. The lowest temperature occurrence is influenced by varying charging pressures. The lowest maximum temperature occurs at the highest charging pressure. The peak coefficient of performance occurs at the maximum charging pressure. To attain the optimal value of COP in a parallel plate stack geometry, it is essential to sustain a high charging pressure of approximately 10 bar and an elevated operating frequency of around 500 Hz. The maximum temperature reached at 10 bar for the parallel plate stack, determined by the temperature of the hot heat exchanger, is approximately 60 degrees Celsius. The performance coefficient of a thermoacoustic refrigeration system, which employs polyamide nylon 6 as the stack material and helium as the working gas, was experimentally established to be 0.222 under a charging pressure of 10 bar, utilizing a parallel plate stack geometry.

CONCLUSIONS

The coefficient of performance of a thermoacoustic refrigeration system utilizing polyamide nylon 6 as the stack material and helium as the working gas, with a parallel plate stack geometry, was experimentally determined to be 0.222 at a charging pressure of 10 bar.

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