36th Indian Engineering Congress

December 26-28, 2021

Theme

Engineers for Viable Technology and $ 5 Trillion Economy

Technical Volume

The Institution of Engineers (India)

8 Gokhale Road, Kolkata

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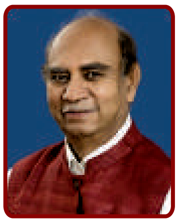

Er Narendra Singh, FIE
President
The Institution of Engineers (India)

Message

It gives me great pleasure to note that Technical Volume is being published on the occasion of the 36th Indian Engineering Congress held during 26-28 December 2021 at Vigyan Bhavan, New Delhi on the theme "Engineers for Viable Technology and USD 5 Trillion Economy".

The technical session was organized in online mode during December 15-16, 2021. During these two days, 55 papers were presented in 12 Technical sessions. The program was attended by 268 participants. Due to the unprecedented situation worldwide arising out of COVID-19 pandemic, we were compelled to organize the 35th Indian Engineering Congress last year in virtual mode. But with the gradual return of the normalcy we are fortunate enough to organize it in hybrid mode this year in which the Technical Session was organized in online mode and the main function of the Congress was organized in physical mode. I am overwhelmed by the response received from the authors and participants during the Technical Sessions.

I take this opportunity to congratulate and thank all those who have taken the initiative and put all effort to bring out this Technical Volume through meticulous planning comprising articles by eminent engineers.

I am sure that the articles in this technical volume will benefit scientist, engineers, technologists, policy makers, academicians and all concerned.

(Narendra Singh)

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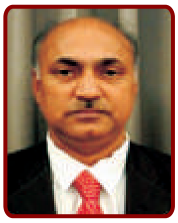

Prof (Dr) Swapan Bhaumik, FIE
Chairman
Committee for Advancement of Technology and Engineering
The Institution of Engineers (India)

Message

On behalf of the Technical Committee, I am honoured and delighted to present the prestigious Technical Volume of the 36th Indian Engineering Congress, which was held in hybrid mode during 26-28 December 2021 on the theme 'Engineers for Viable Technology and $5 Trillion Economy". The Technical Session was organized during 15-16 December 2021 in online mode and the main program of the Congress was organized during 26-28 December 2021.

On the occasion of this Prestigious Event of IEI during the two days of the Technical Session held during 15-16 December 2021. Out of 58 papers scheduled for presentation 55 were presented in 12 technical sessions. Total 76 papers were received out of which 73 were accepted after review and fulfilling the criteria for plagiarism. Finally authors of 58 papers registered for presentation.

We are thankful to the Reviewers for their kind evaluation of the papers received for 36th IEC, Session Chair and Co Chair of all technical sessions for their relentless effort to conduct the sessions successfully.

I also thank Director (Technical) of The Institution of Engineers (India) and his team for their dedicated effort to make the event successful and bringing out this Technical Volume.

(Swapan Bhaumik)

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Agricultural Engineering

Comparison of Data Driven Modelling Techniques for Rainfall Runoff Modelling of Kosi River

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***Abstract**: In the recent past, use of various machine learning techniques in predicting runoff from the catchment has become very popular. In this study, three empirical rainfall runoff models are employed to predict the discharge of the Kosi River for 11 years (2005-2015). The machine learning techniques such as support vector regression (SVR), multivariate adaptive regression splines (MARS) and random forest (RF) are employed for rainfall runoff modelling of Kosi watershed. The performances of all three prediction models have been successfully compared. Daily rainfall-runoff data for the period of 2005 to 2015 was collected for the Kosi River at Ramnagar barrage. It was seen that RF model outperformed over other two models. The gamma test was successfully applied in determination of the best input variables. The performance of the models is evaluated in terms of efficiency measures such as coefficient of determination (R^2), root mean squared error (RMSE) and Nash Sutcliffe Efficiency (NSE). The results revealed that random forest with R^2 value 0.95 in testing phase performed superior than other two models. The performance of MARS model was satisfactory while SVR model resulted very poor values. Therefore, RF model can be considered as most accurate model for prediction of discharge.*

***Keywords**: Rainfall-runoff Model; Gamma Test; SVR; MARS; RF*

INTRODUCTION

Rainfall-runoff models develop relationship between rainfall and runoff. The rainfall-runoff relationship is one of the most intricate hydrologic phenomena to comprehend due to its immense spatial and temporal variability of watershed characteristics and precipitation patterns, and the number of variables involved in the modelling of the physical process. For the decision makers, rainfall-runoff modelling produces a means of quantitative prediction. Modelling runoff helps to gain a better understanding of hydrologic phenomena and how changes affect the hydrological cycle (Xu, 2002). Modelling surface runoff can be difficult, as per as complex calculation is concerned and contain number of interconnected variables. The model add general components such as inputs, governing equations, boundary conditions or parameters, model processes, and outputs (Singh, 1995). The results of surface runoff modelling helps to understand catchment yields and response, estimate water availability, changes over time and forecasting.

Of the various models available, empirical or black box type models develop empirically identified statistical relationships between rainfall and runoff, without attempting to define and understand the physical processes invoked in the transformation. Empirical models are data driven models and are simple to use.These type of models do not consider physical processes involved in the system. The precision of model predictions is greatly subject to user’s ability, knowledge, and understanding of the model and of the watershed characteristics.

Machine learning based models are capable of providing a useful alternative to deal with the multivariate and complicated nature of the phenomena of rainfall and runoff.

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Support Vector Regression (SVM)

Support Vector Regression technique was firstly made known by Vapnik in 1992. Support Vector Regression (SVR) is a nonlinear regression method based on Support Vector Machines (SVM). It can be said as a sub part of Support Vector Machines (SVM). Support Vector Regression maps the data lower dimensional data into a higher dimensional feature space using various kernel functions and then attempts to solve a linear regression problem in the newly developed higher dimensional space. The SVR algorithm works with the goal to create the best line that can segregate n- dimensional space into classes.

Multivariate Adaptive Regression Spline (MARS)

Multivariate adaptive regression spline (MARS) model is a newer non-parametric regression method. It is a non-linear regression method that was first established by Friedman in 1991. The model records the nonlinear response between the inputs and the output of a system by constructing several splines and creates a number of knots between these splines (Friedman 1991). It works in two stages viz. forward stage and backward stage. In forward stage, MARS algorithm take the whole data and then takes the sub sample from the dataset and tries to fit linear regression line on those sample data set. When these lines are getting fitted on those sample data set, the algorithm just try to connect all those linear regression lines fitted by the algorithm. Thereafter, the algorithm joins all those regression line with knot. A knot marks the end of one region of data and the beginning of another. Number of knots are selected randomly in the model. These knots occurs in pairs and are called as basis function. In backward stage, the algorithm removes the basis function which does not contribute to model accuracy or removes the model error.

Random Forest (RF)

Random forest is very popular ensemble machine learning technique. It was systematically developed by Breiman in 2001. The algorithm of Random Forest are very stable, straightforward and flexible. Random forest classifier or regressor is basically a bagging technique. Number of models called as based learners or decision trees are created using some samples of rows and features from the complete dataset. Sampling with replacement method is used while performing sampling. Decision tree have two properties viz. low bias and high variance. Each decision tree gets trained on the particular dataset used thereby becoming able to give accuracy or prediction. In case of classifying problems, majority of votes given by various decision trees are considered as outputs. Whereas, in case of regression problems, mean of the outputs given by various decision trees is considered as output. Mean of the outputs of all decision tree causes conversion of high variance possessed by individual decision tree into low variance in overall decision trees.

This paper illuminates application of SVM, MARS and RF in rainfall runoff modelling. The purpose of this study is to evaluate the performance of machine learning techniques viz. SVM, MARS and RF in modelling the runoff using statistical indices such as root mean square error (RMSE), coefficient of determination (R^2) and Nash Sutcliffe efficiency (NSE) etc. for the Kosi watershed. Also, this paper compares values of statistical analysis. On the basis of values computed, the study puts forward the best model to use in rainfall runoff modelling among these three empirical models.

MATERIAL AND METHODS

Description of the Study Area and Data

The study area is located on the Kosi River, a Himalayan river which originates at Rudradhari in Almora district of Uttarakhand state. It confluences to river Ramganga river near village Chamraul (Uttar Pradesh). The study area spatially lies between 33°21′54″N to 34°27′52″ N latitude and 74°24′08″ E to 75°35′ 36″ E longitude with a total area of 3420 sq. km. It covers almost all the physiographic divisions of the Kashmir Valley and is drained by the most important tributaries of river Jhelum. The rainfall and runoff data at Ramnagar barrage gauging station from 2005 to 2015 was procured, comprising of 4013 days. The data sets for the years 2005 to 2013 were used for training the models and these models were validated for various data sets achieved for 2013 to 2015. The whole dataset were work out in Gamma test software for best input selection. Gamma test creates different models with

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combination of different inputs. Then it calculates gamma value for each model. The model having least gamma value is selected as best input model. The best inputs illustrated by gamma test were further used for modelling.

Support Vector Regression

The Support Vector Machine (SVM) is a nonlinear generalization algorithm used for classification and regression problems, introduced by Vapnik (1992). The rainfall-runoff phenomenon is itself non-linear in nature, thus creating non-linearly separable points in space. The regression model can be constructed by mapping non-linear mapping function. The nonlinearly separable problem can be converted into linearly separable by mapping the original input data into higher dimensional space. The goal of the SVR algorithm is to construct a function y = f(x) which represents the dependence of the output y_i on the input x_i. The form of this function is

$$y = \omega^T \Phi(x) + b \qquad (1)$$

Where, ω is weight vector and b is bias and Φ(x) is non-linear mapping function of inputs

Multivariate Adaptive Regression Splines (MARS)

Multivariate adaptive regression spline (MARS) models the nonlinear response between the inputs and the output of a system by constructing several splines and creates a number of knots between these splines. A knot marks the end of one region of data and the beginning of another. In a MARS model, there is no need for any specific assumption about the underlying functional relationship between the inputs and the output.

$$GCV = \frac{MSE}{\left[1 - \frac{(f+1) + pf}{n}\right]^2} \qquad (2)$$

Where, MSE= mean squared error, f = number of basis functions, p = basis function penalty and n = number of observations.

Random Forest (RF)

Random Forest model is a decision tree model which handle complex relationships of independent and dependent varaiable without any assumption. The algorithm deals well with overfitting of the data and they can operate in parallel computing mode (Dayal el al. 2021). Considering a training set $X = x_1, x_2, \ldots, x_n$, responses $Y = y_1, y_2, \ldots, y_n$, and B times repeated bagging, a random sample (X_b, Y_b) is selected replacing the training set, which is fitted to a regression tree (f_b), for b = 1, 2, . . ., B. After training, the unseen samples (say, x') can be predicted by averaging all the individual regression trees' predictions on x' as:

$$\hat{f} = \frac{1}{B} \sum_{b=1}^{B} f_b(x') \qquad (3)$$

RESULTS AND DISCUSSION

The least gamma value was found for the combination of seven inputs as following: R, $R_{(t-1)}$, $R_{(t-2)}$, $Q_{(t-3)}$, $Q_{(t-2)}$, $Q_{(t-1)}$ and Q where R and Q are the rainfall and runoff data calculated from t^{th} day. (t-1), (t-2) and (t-3) represents the lagging done from one, two and three days before t^{th} day, respectively. Minimum gamma value was computed to be 0.0959. These input variables were further used in SVM, MARS and RF model. The complete dataset were divided into two parts. First 80 % data i.e. for the period of 2005 to 2013 were used for training of the models and remaining 20 % dataset i.e. for the period of 2013 to 2015 were used for testing of the models. The maximum discharge for the Kosi River was recorded to be 2180.341 cumec. The values of statistical indices such as minimum, maximum, mean, first quartile, and third quartile of the training, testing, and the complete dataset is given in **Table 1**.

In case of SVR model, the value of Root Mean Square Error (RMSE) for training and testing phase was found to be 58.28 and 33.28, respectively. Also, NSE values were -1.28 and 0.00 for training and testing phase respectively.

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Coefficient of determination (R^2) of 0.66 was observed for testing phase. Overall, the performance of SVR model was poor as compared to MARS and RF model. The agreement between observed and predicted discharge is unsatisfactory.

The MARS model resulted better values than conventional SVR model. Root Mean Square Error (RMSE) value was 47.36 for training and 17.96 for testing phase. The NSE and coefficient of determination between observed and simulated discharge was found to be in the range of 0.49 to 0.88 and 0.66 to 0.89, respectively. Thus, big hike observed in R^2 value in testing phase. The performance of MARS model is intermediate between SVR and RF model.

Random forest model came up with superior values among all three models. The model performance during training and testing period is found to be very good. RMSE value for training and testing phase was found to be 28.52 and 12.98, whereas NSE value was found to be 0.81 and 0.92, respectively. Highest coefficient of determination is obtained by RF model is 0.95. The agreement between observed and predicted discharge is very satisfactory.

Table 1 Values of statistical parameters of training, testing and complete daily dataset R, $R_{(t-1)}$, $R_{(t-2)}$, $Q_{(t-3)}$, $Q_{(t-2)}$, $Q_{(t-1)}$ and Q of the study area. X_{min}, X_{max}, X_{mean}, 1^{st} Q, 3^{rd} Q are minimum value, maximum value, mean, first quartile, and third quartile

Statistical Parameters	**Input Variables** R (mm)	$R_{(t-1)}$ (mm)	$R_{(t-2)}$ (mm)	$Q_{(t-3)}$ (cumec)	$Q_{(t-2)}$ (cumec)	$Q_{(t-1)}$ (cumec)	Q (cumec)
Training (2005-2013)							
X_{min}	0.00	0.00	0.00	0.00	0.00	0.00	0.00
X_{max}	140.00	140.00	140.00	2180.341	2180.341	2180.341	2180.341
X_{mean}	3.012	3.012	3.012	27.864	27.868	27.872	27.876
Median	0.00	0.00	0.00	6.966	6.966	6.980	6.994
1^{st} Q	0.00	0.00	0.00	3.709	3.709	3.709	3.709
3^{nd} Q	0.00	0.00	0.00	21.606	21.606	21.606	21.606
Testing (2013 - 2015)							
X_{min}	0.00	0.00	0.00	2.379	2.379	2.379	2.379
X_{max}	142.400	142.400	142.400	731.198	731.198	731.198	731.198
X_{mean}	2.472	2.472	2.472	27.776	27.759	27.743	27.726
Median	0.00	0.00	0.00	11.383	11.383	11.355	11.298
1^{st} Q	0.00	0.00	0.00	6.173	6.159	6.145	6.131
3^{nd} Q	0.00	0.00	0.00	22.101	22.101	22.101	22.101
Complete Data (2005-2015)							
X_{min}	0.00	0.00	0.00	0.00	0.00	0.00	0.00
X_{max}	142.400	142.400	142.400	2180.341	2180.341	2180.341	2180.341
X_{mean}	2.958	2.958	2.958	27.846	27.846	27.846	27.846
Median	0.00	0.00	0.00	7.929	7.929	7.929	7.929
1^{st} Q	0.00	0.00	0.00	4.247	4.247	4.247	4.247
3^{nd} Q	0.00	0.00	0.00	21.634	21.634	21.634	21.634

Comparison of the performance values of RMSE, NSE and R^2 for both the models is shown in **Table 2**. From the comparison, it is clear that Random Forest model outperformed than SVR and MARS model.

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Table 2 Comparison of SVM, MARS and RF model using statistical indices

Models	Training			Testing		
	RMSE	NSE	R^2	RMSE	NSE	R^2
SVM	58.28	-1.28	0.57	33.28	0.00	0.66
MARS	47.36	0.49	0.66	17.96	0.88	0.89
RF	28.52	0.81	0.90	12.98	0.92	0.95

CONCLUSION

In this study, comparison of three empirical rainfall-runoff models have been successfully done. Random forest model outperformed the other two model and thus, it is best suited for the prediction of runoff. Decision trees present in random forest model learns better from the data, thereby creating good correlation between observed and predicted values. Due to tremendous variation in the data, regression line has limitation to fit well. It causes SVR and MARS model to perform in the range of poor to satisfactory.

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Power Characteristics of BLDC Motor for Design of e-Powered Agricultural Machine

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***Abstract**: Marginal and small farmers, having less than 2 ha land and size of plots, in India depend on animate power for various agricultural operations. There is a need of such prime movers in India to provide a clean source of power for light to medium farm operations which require power of 576 W to 1080 W. Power characteristics on various loads with two power packs was analyzed using frictional resistance mechanism. A 48 V BLDC 1.5 kW motor was studied for voltage and current drawn characteristics at varying loads (gradual and fixed load) with 24 Ah and 48 Ah capacities of deep rechargeable batteries power packs. It is observed from laboratory study that higher battery capacity (48 Ah) power pack provided stability in voltage and current drawn at varying loading condition. The maximum and sustainable power obtained from 1500 W BLDC motor suggests to have maximum speed of 5 km/h for designing a walk-behind electric prime mover as an electrimate source of power in agriculture. Optimum power was derived of 844 W at speed of 0.42 m/s for operation of having 700 mm operational width for designing small walkbehind electrical agricultural prime mover. Use of electrical energy through battery have great capability in reducing burden of global emissions in terms of 41.8 kg CO_2/ ha for one operation in a single pass.*

***Keywords**: Electrimate Source of Power; Smf Lead Acid Battery; Battery Power Pack; Power Characteristics; Electric Agricultural Prime Mover; Clean Technology*

INTRODUCTION

Agricultural machines are mostly operated in hard/loose soils for performing various mobile farm operations in the field. The soil condition affectspulling ability of traction device. At present the mobile farm operations are mostly performed byhuman beings, animate power (human and animal) and mechanical (tractor, power tiller and combine harvester) power source. There is very confined output withhuman beings and animate power in farm operation. Therefore, the share of mechanical power in farm operations increased to a tune of 86% (Mehta et al. 2019). Diesel is the main source of fuel for mechanical power. The power obtained with diesel fuelis considered as one of the largest contributors to environmental pollution due to exhaust emissions. This is also responsible for several health problems as well (Reşitoğlu et al. 2015). Exposure to pollution from fossil fuels also leads to around 490 million days of work absence due to illness (NDTV 2020; Farrow et al. 2020). The Automotive Industry Standards (AIS) suggested for reducing pollution with a viable option of electric vehicles and providing incentives to farmers (Pushkar 2019).World Health Organization also suggested the reduction in fossil fuel in India that can be achieved with liquid petroleum gas and electricity, along with biogas and ethanol, as these are the clean energy alternatives (WHO 2016). Considering these suggestions, attempt has been made to use electric power in mobile agricultural operations for primary and secondary tillage, furrow/ridge making, planking, sowing, interculture, spraying, harvesting and plucking.

The use of electric power using battery as energy storage system is being studied globally for its potentiality in mobile farm operations with tractor, solar powered electric tractor, orchard tractors, autonomous or self-drive agricultural machines, agricultural robots, precision agriculture, walk-behind electric machine for tillage,

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sowing/planting and plant care, interculture, harvesting, etc (Kiranet al. 2017; Shinde and Awati 2017; Mathan et al. 2019; Rycroft 2019; Singh et al. 2020; Singh et al.2019a &b; Sahoo and Raheman 2020). Electric vehicles were found better-quality than internal combustion engines with respect to its efficiency, endurance, durability, acceleration capability and simplicity (Juan 2010).

Brushless direct current (BLDC) motor or direct current (DC) motor was used to drive the agricultural machines for indented function at farm. Lead acid batteries are mostly used in these devices due to economy and low maintenance i.e.,less expensive than other energystorage alternatives (Juan 2010). It also adds weight to machine for better traction. Study has also been made to charge the batteries through solar for running battery power weeder (Govardhini and Reddy 2017). Peukert model of battery behavior described the drop of voltage at increased load and same time current drawn was also increased (Buchmann 2001; NPTEL).There is very limited information available on the use of electric power characteristics at various loads on low rpm as most of the work is for high-speed battery electric vehicle (Grunditz 2016). Electric motors used in electric vehicles are providing high torque at the time of initial acceleration and low power consumption (Hayrettin 2020). The important characteristics of wide available range of motor speed and torque provides a workable zone for operation in various fields (Yimin and Mehrdad 2006). BLDC motors are more advantageous in terms of usage compared to other electric motors with regards to high torque (Gökozan and Taştan 2019) because of its high magnetic rotor. Hence brushless DC motors has potential in designing the agricultural farm traction vehicle under electric vehicle (EV) impetus framework (Nanda and Kar 2006).

In Indian agriculture, small farmers are dependent on manual and bullock power for various farm operations. There is need to have electrimate source of power (human being and electric power obtained from battery, account for the bulk of the power used in agriculture particularly among small and marginal farmers) for them. Keeping this in view, study is planned to assess design parameters for electric powered agriculturemachine to increase their productivity.

MATERIALS AND METHODS

Laboratory Experiments

A frictional resistance mechanism was designed and developed for assessing characteristics of 1500W BLDC motor. Frictionalsurface was considered to load the BLDC motor through a flywheel using Prony brake dynamometer principle. A flywheel was coupled with a three-phase BLDC motor through a 1: 9 gear reduction unit. Motor wasdriven by 48 V sealed maintenance free (SMF) battery controlled by motor controller. Two battery power packs were used in the study. A 12 V 24 Ah valve regulated lead acid (VRLA) battery having 350 cycles was taken to make 48 V as per requirement of BLDC motor. For making 48 Ah, pack of 4 batteries were used in parallel. The weight of 24 Ah and 48 Ah battery power packs was 28 kg and 56 kg, respectively. Motor controller has provision to vary the speed in three levels i.ethe speed at transmission level of 1, 2 and 3 was 2000, 2550 and 3100 rpm, respectively. An energy meter wasconnected to the power transmission circuit for measuringreal time voltage and current during operation. The flywheel was loaded through a canvas belt. Belt was fixed at one end and other end was attached with a 998 N spring balance. The idle weight was 21.58N. Required load was provided by tightening nut and bolt on the setup. A 736 N S-type tension and compression load cell was attached with fixed end of belt to recorded tangential force on flywheel (**Figure 2**). Excitation power was provided to the load meter through 12 V 12 Ah lead acid batteries.

Total five experiments were conducted in laboratory in the Division of Agricultural Engineering, ICAR-Indian Agricultural Research Institute, New Delhi, India during the period July 2020 to December 2020. Tangential force on flywheel under static condition was recorded at no applied load condition, 49 N, 98 N, 147 N, 196 N, 245 N, 294 N, 343 N, 392 N, 441 N, 491 N, 540 N and 589 N applied load at T_1 side and was also recorded during dynamic condition at selected speed. The experiment was conducted at first transmission level of speed of motor. Out of five, two experiments were conducted for five minutes of experiment duration with both power packs. During first experiment, the flywheel was run at 397 N load (tangential force) and gradually load was decreased at the rate of 49 N applied load till no load condition. Second experiment was conducted at increased loads at similar load increments pattern from no load condition up to 397 N.In the first two experiments speed were allowed to change due to loading and unloading force. Third experiment was conducted at gradual increased load from no load condition by maintaining constant speed at 24Ah power pack. With same power pack, fourth experiment was also conducted at constant applied load of 245 N at speed of 100 rpm for analyzing battery discharge rate with voltage and current drawn behavior. Fifth experiment was conducted to evaluate the effect of online charging the 48 Ah battery power pack with solar power. Three solar panels (17.87 V of each panel) were attached in series to get 48 V and 6.06 current. Power was provided through maximum power point tracking (MPPT) controller to power pack. The flywheel was loaded at 232 N tangential forces at speed of 102 ± 2 rpm for 37 minute duration. The power characteristics was compared with and without charging power pack also on similar flywheel load (221 N) at speed of 100 ± 2 rpm.

Multi meter was also used to compare the voltage reading obtained from energy meter before start of experiment. Speed on flywheel was measured by a tachometer. Data obtained with these experiments were analyzed for power characteristics during different loading conditions. Power was calculated using a formula of multiplication of voltage and current. Whereas torque applied to the motor was calculated as,

$$T = \frac{P \times 60}{2\pi N}$$

Where, T = torque [Nm] P = power at tangential force on flywheel [W] and N= flywheel speed [rpm]

Data recorded during each experiment were analyzed and correlations are shown in **Figures 5** to **10**. Two tailed t-test were used to compare the data of voltage, current, power, torque and speed with both power packs.

Operational Parameter Optimization

The power requirement in selected farm operations lies between 0.0072 to 0.018 W/mm^2 based on the power requirement with human and animate power (**Table 1**). From this table,the power requirement for small prime mover of size 700 mm was analysed to a range of 576W to 1080 W for 800 mm width of cultivator In secondary tillage operation to 400 mm plough for primary tillage operation. The size of land with the marginal and small farmers are generally varying from 100 m^2 to 2000 m^2. Therefore, the requirements of machine is light weight and compact which enable to perform multi operation.

Table 1 Force requi1rement in different type of farm operations.

Power source	Farm operations	Equipment	Width [mm]	Depth/ Dia [mm]	Draft [N]	Speed [m/s]	Power [W/sq. mm or W]
Animal (Sharma and Mukesh 2013)	Tillage	Desi plough	120	150	588.6	0.55	0.018
	Secondary tillage	Tyne cultivator	450	100	588.6	0.55	0.0072
	Sowing	3 row seed drill	660	75	588.6	0.55	0.00654
Manual	Seeding (Sharma and Mukesh 2013)	Hand drill	200	50	196.2	0.55	0.0108
	Weeding (Singh et al. 2016)	Wheel hoe	150	40	147.2	0.55	0.0135

Multi-objective genetic algorithmic technique was employed in R software using “nsga2R” package for optimizing depth of operation and draft requirements with respect to electric power availability at pre-determined working width. Considering a multi-objective optimisation problem, the objective functions along with the constraints are given below

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Maximize $f_1(x) = x_1 x_2 x_3$, and

Minimize $f_2(x) = x_1 x_2 x_3 x_4$,

subject to $0 \le x_2 \le 200$ and $0.42 \le x_4 \le 0.97$

where, $f_1(x)$ = draft, N; $f_2(x)$ = power requirement, W; x_1 = operating width of the machine, mm; x_2 = depth, mm; x_3 = resistance force, N/mm^2, and x_4 = speed, m/s. The operating width of the machine x_1 was fixed at 700 mm keeping in view of the row to row spacing at the field condition. The resistance force, x_3 was fixed at 0.02 N/mm^2 as it remains constant at the 0-200 mm depth of the soil.

RESULTS AND DISCUSSIONS

Effect of Loads on Power Characteristics of BLDC Motor

The study carried out on frictional resistance mechanism setup to decide the variables for designing a small walk-behind electric prime mover in agriculture were analyzed in terms of tangential load, power and torque characteristics, and speed with load, battery performance and solar charging during operation at different type of loading conditions. The results are discussed in appropriate sections.

Effect of Gradual Decreased Load on Speed, Voltage and Current

A power pack of 48 Ah and 24 Ah battery charging capacities was used to observe the voltage and current for decreasing trend of tangential force (**Figure 1(a)**) on flywheel. Correspondingly flywheel speed was 85 and 66 rpm by setting acceleratorposition for the experiment. It was found that 1500 W BLDC motor could not be accelerated at initial load of 490.5 N with both power packs. The voltage of 48 Ah and 24 Ah power packs was 52.62 V and 52.71, respectively before start of experiments. In 48 Ah power pack, voltage was dropped from initial level to 48.5 V at load of 397 N tangential force. Voltage drop continued up to 172 N load on flywheel. While it was dropped from initial charge level to 47.6 V at 397 N tangential force with 24 Ah battery capacity and continued up to 217 N. Voltage was in increasing order after 124 N load of tangential force and continued till No Load condition with 48 Ah battery capacity of power pack while it was observed from 217 N load onwards with 24 Ah battery capacity. The decreasing and increasing of volatile voltage during run were due to requirement of varied current at reducing loads. This might be due to battery's internal resistance. The drop of voltage during run was 19.9 to 42% more with 24 Ah battery capacity of power pack than 48 Ah battery capacity of power pack. Two tailed paired t-test reveals the significant difference at $p < 0.05$ with 13.77964 value of t and < 0.00001 value of p. The drop of voltage may be called battery drop at varied current drawn depending on load. More stability in voltage drop during run was observed with higher Ah capacity of power pack. The voltage (stabilized) was 49.69 V and 48.75 V after experiment with 48 Ah and 24 Ah battery capacity, respectively. The current drawn was 26.85 A at flywheel load of 397 N with 48 Ah battery capacity of power pack while the current drawn of 23.4 A with 24 Ah battery capacity. Current drawn was in reducing trend with reduced load of flywheel at both power packs. T-test analysis reveals the significant difference at $p<0.05$ between current drawn at both power packs with t-value of 8.861187 at value of p of <0.00001. The significant difference between voltage and current drawn clearly indicates better stability with higher capacity power pack under this condition.

The power obtained with 48 Ah and 24 Ah battery capacity of power pack was 1302 to 200 W and 1114 to 139 W, respectively under reduced loading conditions at fixed accelerator positions (**Figure 1(b)**). Power reduction was higher (8.04 times) with 24 Ah battery power pack as compared to 6.52 times with 48 Ah battery power pack. Decreasing trend of power requirement was observed with both power packs at different loading conditions. The speed was increased 3.03 times (66 rpm and 200 rpm) from initial speed with 24 Ah battery power pack as compared to speed increment of 2.55 times (85 rpm and 218 rpm) with 48 Ah battery power pack at fixed accelerator position. The significant difference was observed in power and speed obtained with both power packs at

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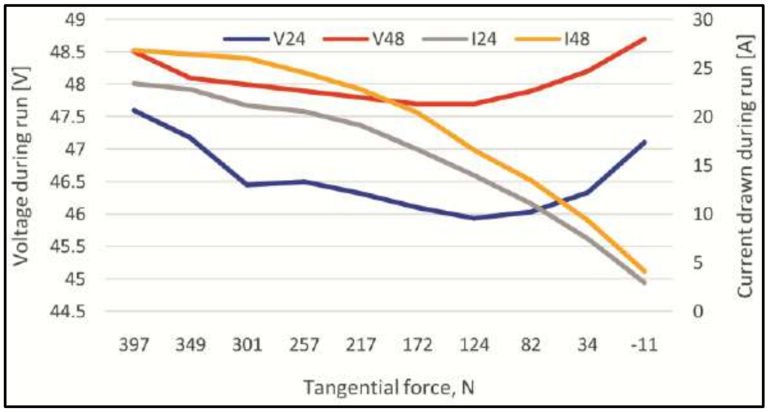
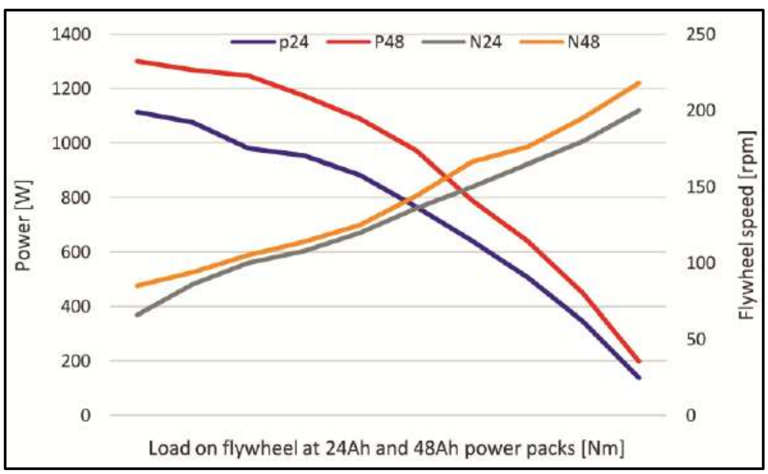
$p < 0.05$ with t-value of 8.934273 and p-value of 0.00001, and t-value of 6.421683 and value of p as 0.00012, respectively. It is clear from figure that 48 Ah battery power pack provides better stability during decreased flywheel loading conditions. From **Figure 1 (b),** it is clear that a sharp decline in power was observed for 129.07 Nm torque and 119.43 Nm torque for 48 Ah and 24 Ah battery capacity of power pack, respectively and thereafter stability was observed. It suggests for use of 24 Ah battery power pack for 980 W power with 94 Nm torque while 1248 W power at 113.6 Nm was with 48 Ah battery capacity.



a. Reduced force in contrast to voltage and current



Load at 22Ah	161.24	119.43	93.64	84.33	70.31	53.89	40.96	29.40	18.30	6.62
Load at 48Ah	146.37	129.07	113.56	98.35	83.30	64.56	45.57	34.84	21.96	8.75

b. Torque in contrast to power and speed at gradual decreased loading condition

Figure 1 Correlations between voltage, current, torque, speed at gradual decreasing load with 48 Ah and 24 Ah battery power packs.

Effect of Gradual Increased Load on Speed, Voltage and Current

The correlation between tangential force and current drawn clearly indicated the increasing trend with increasing tangential force on flywheel (**Figure 2(a)**) with both power packs. The initial charge level of 48 Ah and 24 Ah battery capacity power packs was 52.71 V and 49.96 V, respectively. The increase of load was up to 447 N with 48 Ah battery power pack at flywheel speed of 29 rpm while it was up to 349 N at flywheel speed of 39 rpm with 24

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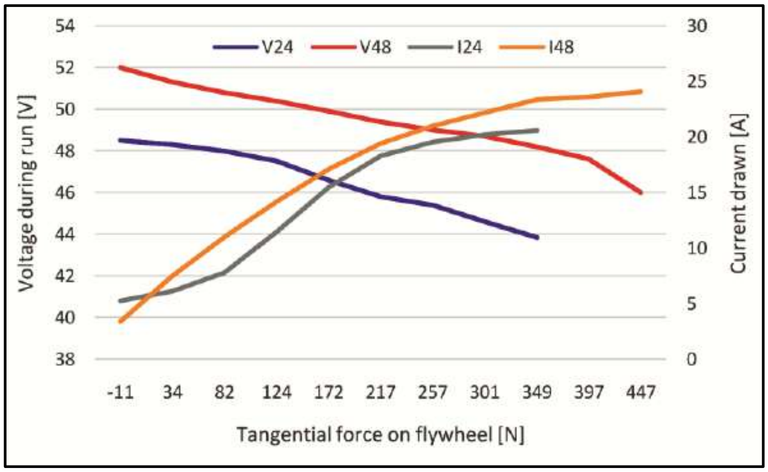
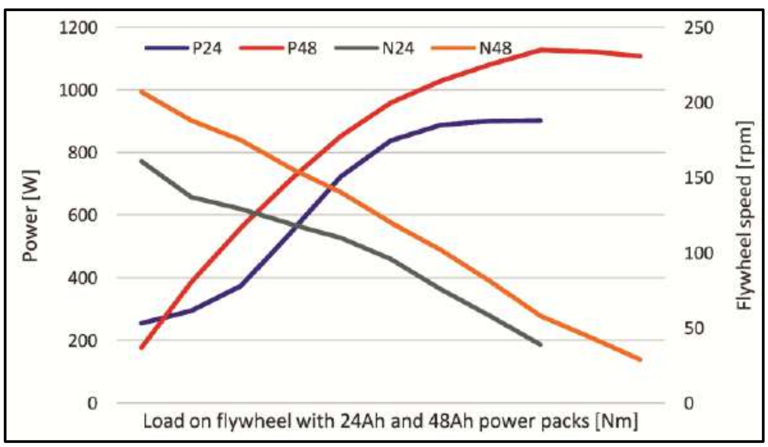
Ah battery capacity of power pack. Regarding loading of flywheel, it is observed that flywheel is loaded at 417 N tangential force when gradually increased loading condition while initial loading condition motor could not be accelerated at 397 N (**Figure 1(a)**). The voltage drop with 48 Ah and 24 Ah battery power capacities was 0.71 V from initial level of 52.71 V during idle condition at flywheel speed of 207 rpm and 1.46 V drop in voltage from initial charge at flywheel speed of 161 rpm. The voltage drop followed decreasing trend with increase in load on flywheel with both power packs. The current drawn followed increasing trend at increased load with both power packs. This follows similar trend of voltage drop and increase in current drawn with varying (speed) load (Buchmann 2001 and NPTEL). Consistency in voltage and current drawn was observed with 48 Ah battery capacity of power pack.



a. Tangential force in contrast to Voltage and Current drawn at gradual increasing loads



Load at 24Ah	15.16	20.55	27.73	43.82	62.74	83.41	111.58	148.66	221.29	-	-
Load at 48Ah	8.16	19.55	30.51	43.83	58.23	76.30	96.38	127.52	185.79	243.93	365.23

b. Torque in contrast to Power and Flywheel Speed at gradual increasing loads

Figure 2 Correlations between torque, speed, voltage and current drawn at gradual increasing load with 48 Ah and 24 Ah battery power packs

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Power obtained with both power packs showed increasing trend with increase in load (torque) on flywheel at fixed position of accelerator (Figure 2(b)). Power varied from 177 W to 1109 W at 8.16 Nm to 365.23 Nm torque on flywheel with 48 Ah battery capacity of power pack while it was 255 W to 903 W at torque of 15.16 Nm to 221.29 Nm. The flywheel speed follows decreasing trend at both power packs with increasing load on flywheel. The speed was reduced from 207 to 29 rpm at minimum to maximum applied torque with 48 Ah battery capacity of power pack while it was reduced from 161 rpm to 39 rpm with 24 Ah battery capacity of power pack. The torque-power characteristics curve indicates fragmented linearity of power at varied torque with 24 Ah battery capacity of power pack. However linear power was observed up to 838 W at 83 Nm torque and speed of 96 rpm

Effect of Constant Speed on Voltage and Current at Increasing Loads

The speed obtained (96 rpm) during gradual increase loading condition (**Figure 2(b)**) was assessed at constant load for power assessment. Voltage and current drawn at different torque levels at flywheel speed of 105 ± 5 rpm was presented in **Figure 3**. The drop of voltage was 1.7 V at No applied load condition (8.8 Nm torque) from initial charge level (51.2 V) of a 24 Ah battery power pack. The voltage was dropped to 46 V during run at torque of 198.1 Nm. Total voltage drop during the experiment was 6.9 V from its initial charge level. Current drawn at low torque (8.8 Nm) was 2.07 A and follow increasing trend with increase in torque at flywheel. The current drawn was found 46.15 A which was maximum with this battery pack. This study at constant rpm of 105 rpm clearly indicates the optimum obtainable torque of 112.9 Nm at power of 1241 W with 1.5 kW BLDC motor when voltage during run was 48.45 V and current drawn was 25.62 A. The study suggests utilizing maximum 82.7% of motor power.

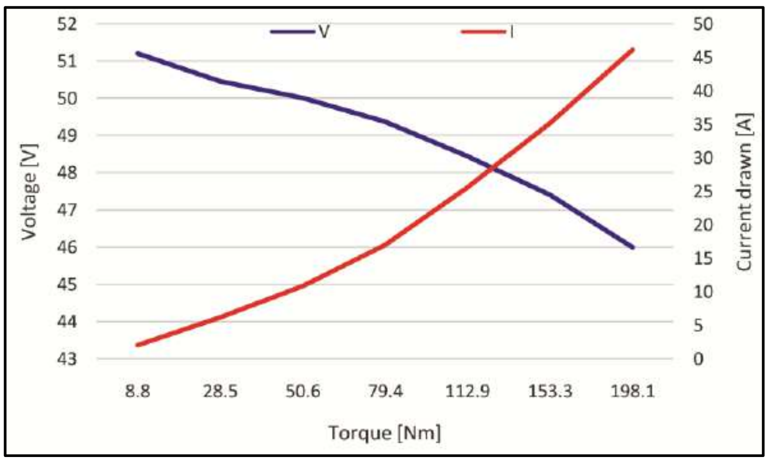

Figure 3 Correlations between voltage drop and current drawn with increasing torque at 105± 4.6 rpm with 24 Ah battery power pack.

Effect of Constant Load and Speed on Voltage and Current with Time

The speed obtained (96 rpm) during gradual increase loading condition (**Figure 3(b)**) was assessed at constant load for battery discharge rate. A graph was presented between voltage and current drawn behavior when the flywheel was loaded at constant load of 217 N at a flywheel speed of 101 ± 6 rpm with a 24 Ah battery power pack (**Figure 4(a)**). The voltage was dropped to 49.4 V at load of 217 N from initial charge level of 53.12 V. The voltage varied from 49.14 V to 41.2 V during 72 min run. After 65 minutes of run at this load, current drawn was 17-17.4 A at voltage of 42.6 to 41.2 V. The current drawn was 15.9 A to 16.6 A up to 60 minute when voltage was 49.4 to 43.4 V. This battery power pack completely exhausted in 72 minute under the condition. Battery performance at constant load and speed is analyzed and presented in **Figure 4(b)**. This will help in assessing the battery level at a time and also to finalize the storage battery capacity for the prime mover to be designed.

Effect of Solar Charging on Battery Power Pack at Load

Voltage and current drawn characteristics during with and without online solar charging of 48 Ah battery power pack was shown in **Figure 5**. Average tangential force was 232 N and 221 N with online solar charging and without

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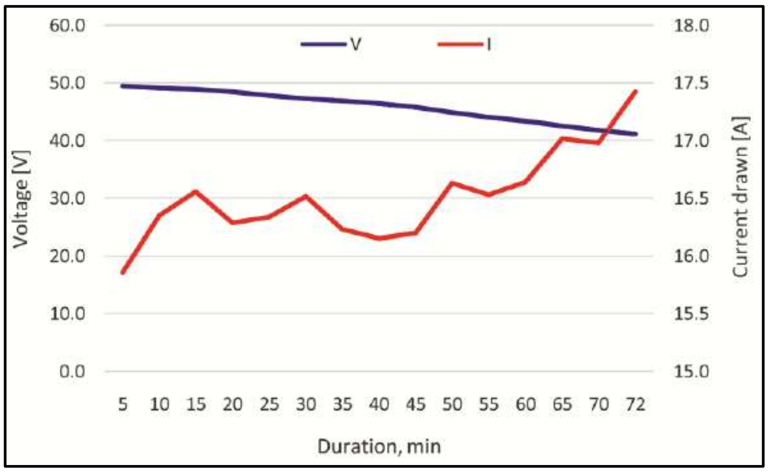
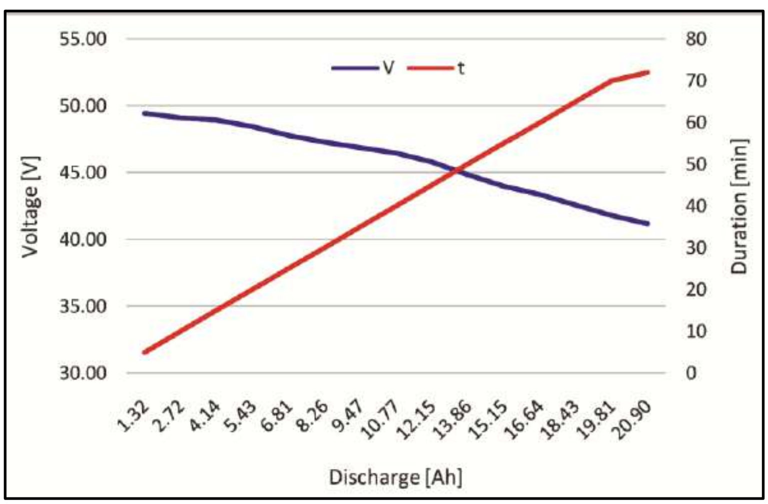
charging at flywheel speed of 102 rpm and 100 rpm, respectively. Voltage was dropped from initial 53.8 V to 49.42 V at 232 N load and voltage varied around 48.81 V to 50.04 V during the experiment when power pack was attached with online solar charging with 3 panels of 100W 6A attached in series. While voltage was dropped from initial 53.11 V to 50.37 V at 221 N load and voltage remained between 48.65 V to 50.73 V when the experiment was run with battery power pack only. After experiment the voltage was 51.5 V and 51.25 V of the power pack with and without online solar charging. No significant difference was observed in voltage drop during the experiment at $p < 0.05$ with t-value of -1.604853 and p-value of 0.12061. The current drawn at 232 N load was 20.93 A and varied between 17.71 A to 21.49 A during the experiment at average flywheel speed of 102 $\pm$2 rpm with power pack attached with online solar charging. The current drawn at 221 N load was 18.51 A and it varied between 18.36 A to 20.58 A at average flywheel of 100 $\pm$ 2 rpm with battery power pack only.



a. Voltage and current drawn



b. Discharge cycle of 24Ah battery at constant load and speed

Figure 4 Correlations between voltage and current drawn at load of 217N at 101±6 rpm with time through 24 Ah battery power pack

A significant difference was observed in current drawn at load of 232 N and 221 N at $p < 0.05$ with t-value of 3.497525 and p-value of 0.00185. The torque generated varied between 80.01 Nm to 101.98 Nm during online- solar charged power pack while it varied from 88.04 Nm to 98.6 Nm with battery power pack only. The power and torque

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obtained during experiment without charging the power pack was significantly higher (t-value of 3.625291and p-value of 0.00135, and t-value of 4.365496 and p-value of 0.00021) as compared to online charging the power pack with solar. This may be due to high requirement of current at this load while charging through solar might be fluctuating with maximum 6A current. This experiment clearly indicates more stability in voltage drop during run with power pack charged solar online while 21.5 % variation in torque was also observed with online solar charged power pack as compared to 10.71 % torque variation with battery power pack at 232 and 221 N loads. The study suggests increasing the current drawn by solar which may affect significantly during run at load.

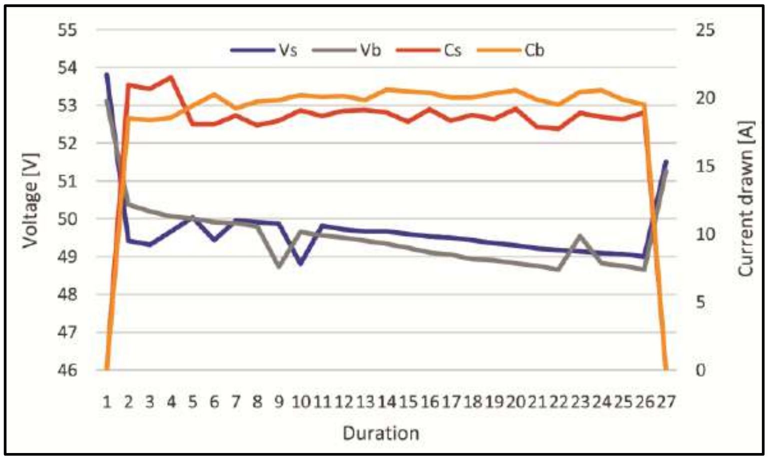

Figure 5 Voltage and current drawn characteristics with and without solar charging the power pack of 48 Ah

Comparative Performance of Battery Power Packs on Power, Torque and Speed

Power, torque and speed relationship with reference to tangential force on flywheel was presented in **Figure 6**. The load and power graph clearly indicates sustainability of power with increase in load on flywheel at full accelerator position for 48 Ah power pack as compared to 24 Ah power pack. The maximum power obtained with 48 Ah and 24 Ah battery capacity power packs was 74.9 % and 71.7 % of 1500 W BLDC motor, respectively. Linearity of power was obtained up to 853 W (56.8% of motor power) with 48 Ah battery capacity power pack at 58.2 Nm torque. There is no significant difference (t-value of 1.410095 and p-value of 0.19212 and t-value of 0.315063 and p-value of 0.7599) at $p < 0.05$ between torque and speed with both power packs but significantly higher power was obtained with 48 Ah power pack as compared to 24 Ah battery pack at t-value of 5.867323 and p-value of 0.00024. The results obtained with the experiment gave a clear-cut finding of power versus speed reduction. The speed reduction was 5.4 and 4.7 at power ratio of 6.32 and 6.35 with torque ratio of 30 to 34 for studied battery power packs. This reveals for having speed reduction of about 5 to get desired level of power and torque.

Optimization of Depth and Power

Multi-objective genetic algorithmic technique was employed in R software using “nsga2R” package to optimize the output of machine at minimum power consumption. In case of the secondary tillage operation, it is carried out at around 100-130 mm depth of the soil. Therefore, 102, 121 and 153 mm depth of soil are chosen as the optimal solution points in the Pareto front (**Figure 7**). These optimal solution points are marked as cyan, black and red coloured squared points, respectively. At thesedepths, the operating speed of machine is determined as 0.42 m/s. The draft and power requirement of the machine at 102 mm, 121 mm and 153 mm operational depth were found as 1424 N and 597.92 W, 1689 N and 709.43 W, and 2141 N and 899.19W, respectively. A set of optimal solutions, known as the Pareto front solutions is obtained from a set of non-dominated solutions, being chosen as optimal without sacrificing at least one other objective function. In case of multi objective optimization, the trade-off was identified since it gave multiple solutions across the Pareto front.

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The results obtained from **Figure 8** was matching with the optimization result given in **Figure 7**. The findings suggest to operate the machine at 144 mm depth for getting optimal performance with the equipment having 700mm operational width. The power requirement was observed to 844W at speed of 0.42m/s.

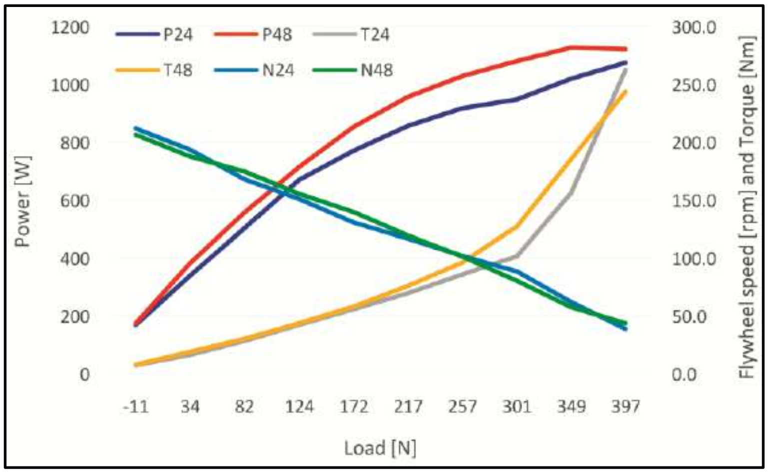

Figure 6 Power and torque characteristics with two different power packs at gradual increased load

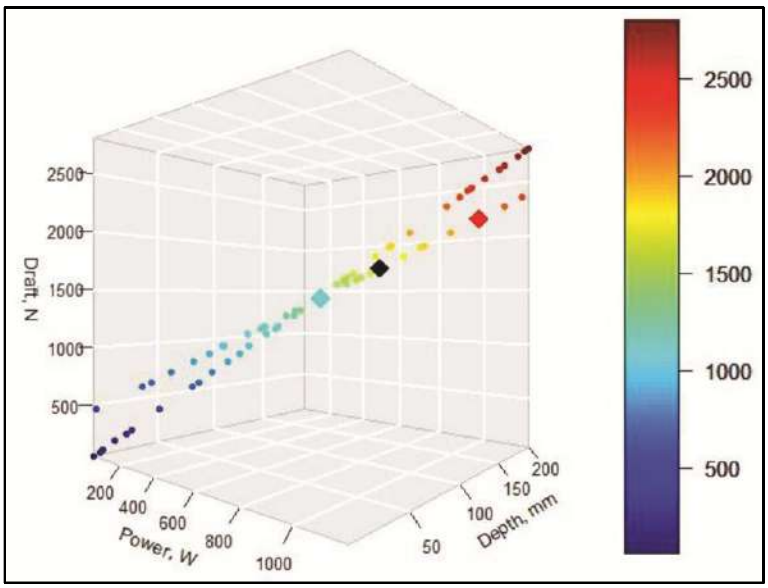

Figure 10 Optimization of operating depth and power for design of e-prime mover in agriculture

A 48 Ah battery capacity power pack is suitable for about 3 h duration at continuous current drawn of 16 Ah (800 W). Considering the speed reduction ratio obtained from **Figure 6**, the maximum speed of 5 km/h may be kept for walk-behind electric prime mover to achieve desired power and torque. This also confirms the finding of Grunditz (2016) about the time to accelerate can be achieved with various combinations of initial maximum force and maximum power. This small prime mover has potential to save 15.6 liter diesel per ha as compared to power tiller operation at 75% field efficiency for one operation in a single pass (Tewari et al. 1997). Hence, this prime mover would reduce burden of global emissions in terms of 41.8 kg CO_2/ ha. Use of electrical energy through battery may have great potential in mobile and stationary farm operations in developing and under-developed countries.

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CONCLUSIONS

Based on laboratory experiment conducted on frictional resistance mechanism setup with 1500 W three-phase BLDC motor, following significant conclusions are drawn,

1. 1500 W BLDC motor can develop power to sustain initially maximum tangential force of 397 N (441 N applied load) on flywheel shaft.
2. Online solar charging at varying loads on fixed accelerator position with both power packs have some effect on voltage stability.
3. Higher battery capacity (48 Ah) power pack provided stability in voltage and current drawn at varying loading condition.
4. The maximum and sustainable power from 1500 W BLDC motor was 75 % (1125W) and 56.8 % (853W) of its capacity with speed reduction of 1.47 and 4.7, respectively.
5. The study suggests to have maximum speed of 5km/h for designing a walk-behind electric prime mover as an electrimate source of powerin agriculture.
6. Optimization technic also suggested to have optimum power of 844 W at speed of 0.42 m/s for operation of having 700 mm operational width.

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Architectural Engineering

Preparing Architectural Education for Atmanirbhar Bharat

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***Abstract**: India is urbanizing at a rapid rate. This rapid urbanization is essential for the growth of economic opportunities but the built-environment is facing crucial challenges. Atmanirbhar Bharat Abhiyan coupled with the creative spirits of good architects will help to realize the true potential of urbanization for a sustainable and prosperous future for India. Architecture education and practice should transform and develop to accommodate the needs of an Atmanirbhar Bharat. Institutions in India should have reciprocal arrangements with other countries and thus expand the opportunities of the student to gain a broader experience in an increasingly globalized profession. Architecture education should also be internationally validated with direct evidence of student learning. There should be a paradigm shift in the design of Education towards developing professionals with the ability to understand and use local knowledge, traditional knowledge, and emerging technologies while being cognizant of critical issues such a climate change. Architectural practice requires becoming financially competitive and technologically challenging to keep up with the international standards of design and delivery.*

***Keywords**: Atmanirbhar Bharat; Architecture; Education; OBE; Practice*

INTRODUCTION

India has a population of 1.34 billion which is growing at a rate of 1.17% with an urbanization rate of 2.28%[1]. India's urban population has grown five-fold in the last half century to approximately 430 million inhabitants in 2015 and the number is expected to rise to 600 million by 2030, accounting for 40% of India's population[2]. 5 of the top 20 emerging cities in the world, namely, New Delhi, Mumbai, Bangalore, Kolkata and Chennai are in India [1]. This rapid urbanization is essential for the growth of economic opportunities but the built environment is facing important challenges such as outdated building regulations, poor spatial planning, urban sprawl, poor public transport, lack of investment in infrastructure and affordable housing, land shortage, and climate change. The New Urban Agenda, Habitat III, Ecuador, 2016 calls for government to ensure sustainable and inclusive urban economies by leveraging the agglomeration benefits of well-planned urbanization.

Atmanirbhar Bharat Abhiyan coupled with the creative spirits of good architects will help to realize the true potential of urbanization for a sustainable and prosperous future and will support in making India "a bigger and more important part of the global economy." The main goal of Atmanirbhar Bharat is for India to become self-sufficient though not a self-centered system. It will aid in pursuing policies that are efficient, competitive and resilient, thus making India a self-sustaining and self-generating country. An Atmanirbhar Bharat is necessary to fulfill the dream of making the 21st century an Indian century, i.e. a century dominated by India. It will help in creating an eco-system that will allow Indian companies to become competitive in the global market. It aims to make the country and its citizens independent and self-reliant in all senses. The five pillars of Atmanirbhar Bharat are Economy, Infrastructure, Systems, Vibrant Demography, and Demand. This will require research and development, and mindset to make a creative, innovative and learning society[3]. Architecture education and practice should transform and develop to accommodate the needs of the strong foundation for an Atmanirbhar Bharat.

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ARCHITECTURE

Architecture is a profession which has to be embraced very carefully as it allows the architect to transform the environment, built and un-built. It deals with everything that surrounds us, the Panchabhootas, the air, water, fire, earth and light.Architects in association with planners and engineers have an important role in the design of well-planned cities which can contribute to the economic, socio-cultural, civic, and environmental development of a nation[2]. The Guidelines for the UIA Accord on Recommended International standards of Professionalism in Architecture Practice Policy on Ethics and Conduct defines architecture as a liberal profession and architects being obligated to the highest standards of independence, impartiality, professional confidentiality, integrity, competence and professionalism and committed to provide the highest possible quality of design, and other deliverables. It also states that architects must bring to the society special and unique knowledge, professional skills, and aptitudes essential to the development of the built environment and to those societies and cultures in which such development take place" [4].

Architects such as Charles Correa, BV Doshi, Joseph Allen Stein, and Laurie Baker rose to become masters achieving international recognition, designing in a language which is modern yet rooted to the Indian context. An architecture which celebrates the spirit of India while competing globally will lead the way to an Atmanirbhar Indian Architecture.

Architecture Education

The UNESCO-UIA Charter for Architectural Education states that Architectural Education constitutes some of the most significant environmental and professional challenges of the contemporary world and that the educators must prepare architects to formulate new solutions for the present and the future.Social and functional degradation of many human settlements will create severe and complex problems[5]. Architectural education is not just a simple matter of information dissipation but it deals with the entire life and living of man and his societies, continuing traditions and his developmental progress[6]. Architectural education is an amalgamation of a myriad of studies, extending from materials, climatology, drafting, sketching, design, and services to history, sociology, and philosophy. An education which is embedded in the true Indian heritages and inculcates the need of the 21st century can pave a way forward.

A. Current state of Architecture Education in India

The Council of Architecture (CoA)is bestowed with the responsibility to regulate the education and the practice of the profession of architecture throughout India.There are 471 institutions imparting education in Architecture in India. The standards of education being imparted in these institutions is currently governed by the Council of Architecture's Minimum standards of Architectural education Regulations, 2020, which set forth the minimum requirements of eligibility for admission, course duration, standards of staff and accommodation, course content, examination, etc [7]. The significant increase in the number of architectural schools during the late 2000's without upholding the Council of Architecture's Minimum standards of Architectural education has lowered the overall quality of architectural education.

Table 1 shows the unprecedented increase in the number of new institutions and the consequent increase in the number of institutions closed/ put on zero intake. **Figure 1** shows the percentage of seats that are vacant in various institutions together. The Perspective Plan for Growth of Architecture Education approved and adopted by the Council of Architecture (2020) proposes only a check on the allotment of new institutions based on categories of states created on the basis of the average ratio of architects to inhabitants [8].

Very few institutions in India have reciprocal arrangements with other countries and thus limit the opportunities of the student to gain a broader experience in an increasingly globalised profession. Although a student can apply to study overseas for architecture education, but the tuition fees are very expensive and thus can be afforded only by the rich and prosperous.

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Table 1 Status of Institutions

Year	Number of Institution	New Institution Approved	Institutions Closed/ Zero Intake/ Restored	Total Number
2006-07	127	10	0	137
2007-08	137	4	2	139
2008-09	139	7	13	133
2009-10	133	25	6	152
2010-11	152	27	-7	186
2011-12	186	60	12	234
2012-13	234	67	-1	302
2013-14	302	35	0	337
2014-15	337	52	10	379
2015-16	379	64	20	423
2016-17	423	33	-2	458
2017-18	458	22	12	468
2018-19	468	20	11	477
2019-20	477	15	29	463
Source – Perspective Plan for growth of Architectural Education in India, Council of Architecture				

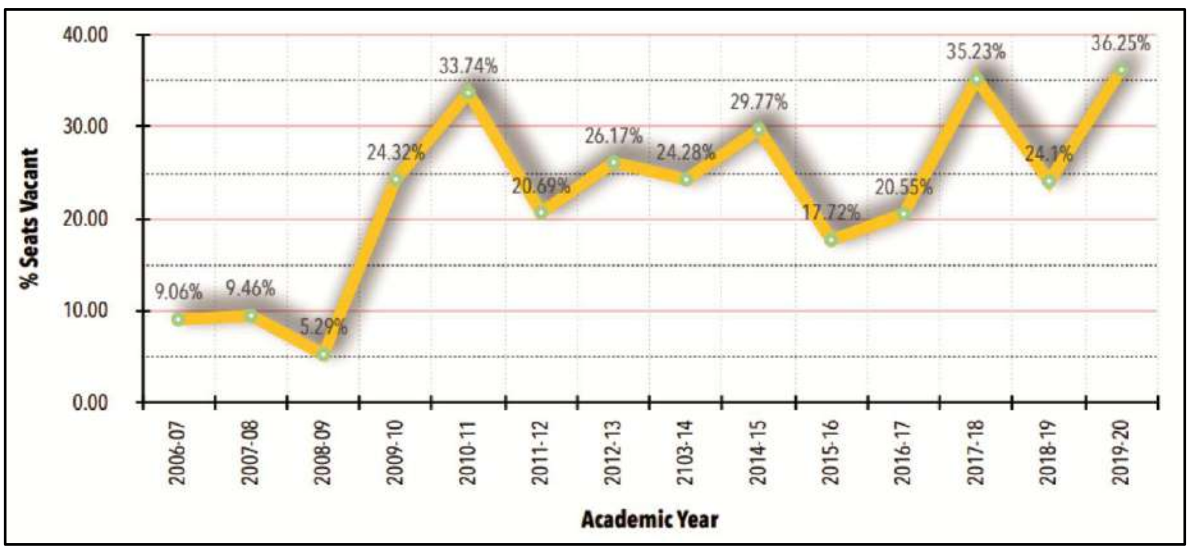

Figure 1 Percentage of seats vacant *(Source – Perspective plan for growth of Architectural Education in India, COA)*

B. International Validation / Accreditation

The Council of Architecture (CoA) oversees the maintenance of the architecture education standards for about 500 institutions in India, periodically by way of conducting inspections through committees of peer experts against a checklist prescribed by the document 'Minimum Standards of Architectural Education.' Even though the works of the students are also evaluated by the peer experts in addition to the checklist as prescribed by the Council of Architecture, there is no direct evidence of student learning and these need to be included for transparency and quality assurance but the methodology does not have an international recognition /validation. The Commonwealth Association of Architects (CAA) is a membership organisation for professional bodies representing architects in Commonwealth countries[10]. The association sets procedures for the validation of courses in architecture against

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set criteria. But neither the Indian Institute of Architects (IIA) or the Council of Architecture (CoA) is a member currently.

The UNESCO-UIA Charter for Architectural Education, the UIA Accord on Recommended International standards on Professionalism in Architectural Practice and the Canberra Accord on Architectural Education are documents employed by various accreditation/validation agencies in architectural education. The National Board of Accreditation, India, the only body which accredits programmes is only a signatory to the Washington accord responsible for accrediting undergraduate engineering programs. The various international accreditation agencies such as the National Architectural Accrediting Board in USA, the Canadian Architectural Certification Board, Royal Institute of British Architects, the Architects Accreditation Council of Australia, and the Korean Architectural Accrediting Board have various Performances Criteria for both the program and the student. Each accreditation agency has a formal evaluation process for assessment of student achievement, which is based primarily on the concept of outcomes based education. All agencies have a framework for the documentation and demonstration of the results of the assessment.India’s demographic dividend will be a key for its growth in the future. This can only be utilized effectively by the students of architecture if the B.Arch course is adept to the 21st Century skills, and is validated to international standards also.

C. National Education Policy (NEP) 2020

The aim of education in ancient India was not just the acquisition of knowledge as preparation for life in the world but for the complete realization and liberation of the self. The rich heritage of ancient and eternal Indian knowledge and thought has been the guiding light for the National Education Policy (NEP) 2020. The preparation of professionals must involve an education in the ethics and importance of public purpose, an education in the discipline, and an education for practice. It must centrally involve critical and interdisciplinary thinking, discussion, debate, research, and innovation [12].

The National Education Policy calls for a paradigm shift in the design of Education towards developing professionals with the ability to understand and use local knowledge, traditional knowledge, and emerging technologies while being cognizant of critical issues such a climate change for our rowing population. It needs to be competitive globally, adopting best practices and embracing new and appropriate technologies for wider access. It must reflect socio-cultural contexts in an evidence based manner. It should be re-envisioned to match the varied roles that an architect needs to address in the society. Indian Knowledge Systems, including indigenous and traditional systems are to be included.

D. The Way Forward

There needs to be a significant paradigm shift in the traditional output based education system. The traditional uniformity that was part of learning doesn’t any longer have the same power or sense of purpose. It won’t work effectively in order to educate people to their potential or enable them to be useful in society. But the current times require a new Learning, a Reflexive and Transformative pedagogy for the networked knowledge society[14]. The new learning needs to be dynamic with greater emphasis on learner engagement, with leaners acknowledged as knowledge constructors and as active knowledge makers. It should be passion driven. The society needs the students to understand about Knowledge, Skills, and Attitudes / Sensibilities. Architecture education should instill various skills and abilities such as creativity, critical thinking, collaboration, problem solving, leadership, cross-cultural communication, information management, and technology advancements. The diverse representation in classrooms, the students’ unique educational, cultural, linguistic and social backgrounds, and their multiple perspectives should help in the proliferation of Intercultural Competence. Cultural self-awareness, empathy, and openness can bridge the gap. All learners should be understood in their differences, in their own sense of identity, and the orientations that they bring to learning.

Outcome Based Education (OBE) begins with the end in mind with clearly defined educational goals or outcomes set for each course and program thatis aligned to the Graduate Attributes. The basic characteristics of OBE being remediation and enrichment for students would give every opportunity available to master the content, irrespective of their differences, and to meet the absolute standards. The design of the curriculum, learning strategies, and

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learning opportunities should be such as to ensure the achievement of the learning outcomes and to enhance student learning.

Architecture Practice

India is in a stage of development wherein huge amounts of investment are pouring into the building industry and opportunities of growth are increasing. Architectural practice requires becoming financially competitive and technologically challenging to keep up with the international standards of design and delivery[13]. **Figure 2** shows the ratio of inhabitants to architects. Very few States and Union Territories have low ratios, i.e. less than 10,000 persons/architect. The state with the highest ratio is Bihar, with 201792 persons/architect, which is also a backward state in terms of economic development. In developed economies such as the USA and the UK, the ratios are much lower, i.e. lesser than 2000 persons/architect. India is urbanizing rapidly with vulnerable issues. The lack of educational, institutional and professional capacity has important consequences such as weak policies, unsustainable development, unhealthy and ill-designed spaces, and loss of identity and cultural values.

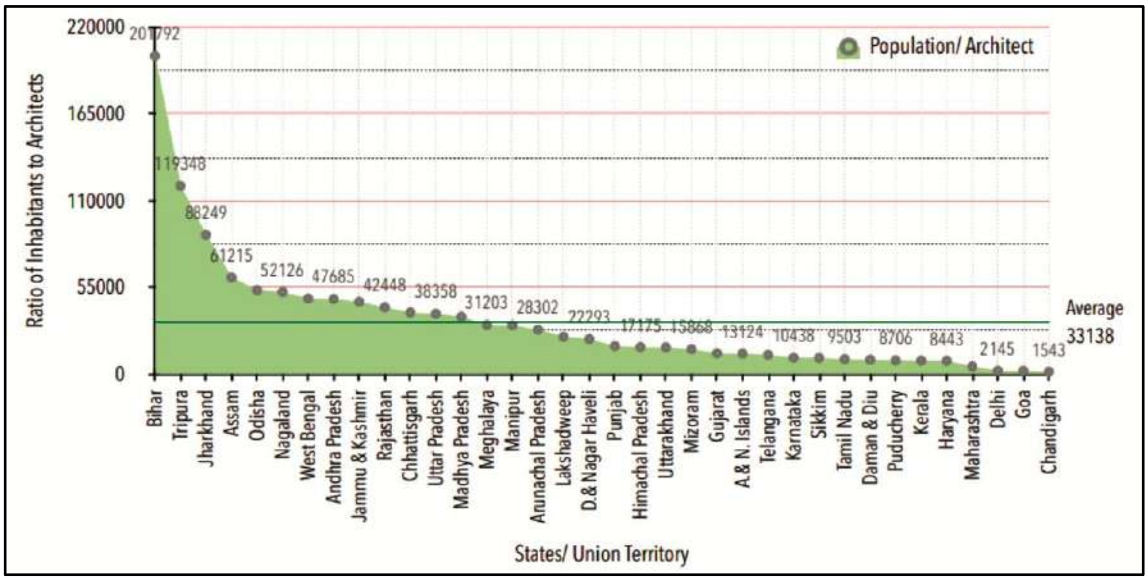

Figure 2 Ratio of inhabitants to architects *(Source – Perspective plan for growth of Architectural Education in India, COA)*

The architectural profession faces many challenges such as lack of respect, establishing standards of design, insufficient opportunities, outdated building regulations, corruption, poor enforcement of existing building codes and schedule of fees, and the understatement of the role of the architect in the community. Continuing Professional Development is essential as architects develop their career and need to be abreast with technological advancements, material innovations, and to learn new skills for higher expertise. But are our institutions equipped enough to take up this challenge and additional burden.

CONCLUSIONS

The profession of Architecture can only realize it's true potential for the development of the country when both the education and the practice are aligned towards the need of delivering international quality architecture that rejuvenates the essence of the varied culture and heritage of the sub-continent. There should be a proper connect between academic education and professional context. This transformation is fundamental for achieving full human potential for a diverse, equitable, and inclusive society and for the nation’s development. The minimum standards made mandate by the Council of Architecture, the apex body of the controlling the education scenario in the country is only the minimum bench mark to be attained by an institution to continue with education. While most of the institutions in India maintain only these minimum standards for obtaining extension of approval by the Council of

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Architecture, without exploring ways and means to go ahead of this minimum bench mark. New ways and means are to be discovered so that Minimum standards 2020 can embrace NEP2020 and take Architecture Education ahead to meet the global standards and thus attain the standards to meet the settings of Atmanirbhar Bharat.

ACKNOWLEDGMENT

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Chemical Engineering

Scientometric Analysis on Utilization of Agricultural Waste for Board and Panel Preparation

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***Abstract**: Agricultural wastes are widely distributed in the environment, creating a health and environmental risk. Because of their environmental and health benefits, natural insulating materials are becoming increasingly popular. The goal of this research is to provide a precise method for measuring science and technology development trends in agricultural waste panel and board production, with sustainability as the most important factor. The papers were gathered using a bibliographic approach based on the Scopus database. Using scientometric analysis, researchers can look at the trends in these articles, including keywords, journals, countries, and authors. The use of waste in energy-efficient architecture is an emerging research topic. The filter is applied based on the paper's keyword of panel and board, and the observed properties are detailed in the study. The research is being carried out to gain a practical understanding of the various materials that have been used in the preparation of boards and panels, as well as the tests that will be carried out, such as modulus of rupture, elasticity, thermal conductivity, energy analysis, small hot box test, and life cycle assessment to assess energy usage and CO_2 emissions. The future scope has alsobeen added in the conclusion.*

***Keywords**: Agricultural Waste, Board, Panel, Insulation, Thermal Conductivity*

INTRODUCTION

Many countries are now debating the use of organic residual biomass from urban, agricultural, and industrial sources. Dumping materials in landfills adds to the production of greenhouse gases, of which paper and cardboard account for a significant portion[1]. Agriculture produces trash, which is currently mismanaged in terms of both environmental and economic considerations[2]. Agricultural waste has the potential to play a key role as a sustainable alternative building material in the construction industry. New alternative sustainable insulating construction products, on the other hand, have been at the forefront of societal concerns[3]. Buildings use a lot of energy and have a lot of severe environmental effects. A structure's facade is a structural component that can help save energy while also mitigating negative environmental effects[4]. Pyrolysis is one of the processes that might be used to transform biomass into higher-value goods [5]. Nonetheless, administrations are passing regulations to prohibit the use of asbestos in a wide range of items due to a variety of health issues. Other advanced technologies are currently searching for more resistant and long-lasting materials[6]. The demand for energy is high, as are the prices of heating and cooling in the winter and summer, respectively. Building insulation, which is becoming increasingly popular, may help save money on these charges. The creation of acceptable materials has become equally important as a result of the rising use[7]. Manufacturing particleboards with agricultural waste as raw materials is a cost-effective and intriguing solution. Natural particleboards with low thermal conductivity might be used in a variety of applications, including ceiling and wall insulation. Furthermore, manufacturers, restaurants, and the food industry create a large number of agricultural peels each year, which are frequently discarded as trash[8]. Particleboard makers are now obliged to search for new, inexpensive, and readily available raw material sources. At the same time, the construction industry has concentrated on using healthier, safer, and ecologically friendly materials[9]. Particleboard is indeed an engineered wood-based panel made by heating and pressing wood particles with an appropriate adhesive. The major main material in the particleboard business is wood [10]. Vermicomposting, which uses worms to stabilize and modify compost into useable end-products, has been recommended as an alternate treatment strategy for high-moisture-content organic wastes from agricultural,

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industrial, and municipal sources[11]. A large research community has been paying attention to the ongoing search for better sustainable and cost-effective processing solutions throughout the world. Emissions CO_2 of to the environment, energy, and water usage are just a few of the variables that play a role in this scenario. Some approaches that have shown favorable outcomes in this context include reusing, employing green construction materials (which has to be sustainable, regional, and accessible), retrofitting, and adopting low-tech tools and approaches[12]. Concrete manufacturing has become one of the primary environmental problems in the construction sector because to the related emissions and contributing to natural resource depletion [13].

Using diverse types of agricultural waste for the board can help reduce CO_2 emissions while also being beneficial for soundproofing, insulation, and artificial ceilings[14]. Cork oak are long-lived trees (up to 200 to 250 years), and various life cycle assessments on cork material have highlighted the forest's sustainable environmental benefits, especially in terms of avoiding destruction in dry regions and long-term CO_2reduction[15].Buildings' environmental effect has been analyzed not just in terms of the energy used in their usage, but also in terms of the energy materials used in their construction. The prevalence of "sick building syndrome" is rising. The primary investigation was chemical contaminants from indoor sources such as building materials, poor ventilation, excessive use of heating, ventilation, and air conditioning, and volatile organic compounds[16]. Not only has the utilization of agricultural waste proven beneficial in terms of insulation, but so has bacterial farming, it is 20% stronger and has a larger density, a greensulate panel offers better structural qualities than a foam panel. It is less flammable than foam and can sustain fire for longer. It also creates no hazardous emissions when burned and may be broken down into little pieces and dispersed on the ground to give nutrients[17].The basic thermophysical characteristics used to describe the thermal behaviour of insulating materials are thermal conductivity, specific heat capacity, and density[18].

Sustainable development asks for lower-impact technology in all aspects of human existence; a circular economy approach attempts to keep a product's value by returning it to the manufacturing process at the end of its lifespan, reducing material intake, waste creation, and energy usage [19]. Waste management is the most essential issue in environmental preservation and natural resource protection.The fundamental causes of the numerous processes of deterioration that have harmed our planet's ecosystem, including the creation of municipal solid waste, are changes in the environment and population increase[20]. The increasing need for high thermal performance and "near-zero-energy" buildings, as well as present rising problems and possibilities in the domains of green manufacturing and low environmental effect, necessitate the use of organic relevant items rather than traditional methods [21].Thermal insulation is a low-cost, widely available, and well-proven method that saves energy and money while also decreasing emissions as soon as it is implemented. The originality of this research derives from the analysis done, which included a cross-comparative study capable of picking the best article from the scopus data source linked to panel and board preparation, as well as experimental investigations in terms of thermal performance and environmental effect.By merging VOS mapping technology with upgraded viewer software, the VOS viewer application was born. The VOS viewer works with almost any hardware and operating system. It may also be launched directly from a web page on the internet [22].

The utilization of agricultural waste will be focused in this study. Agricultural waste is a good building material since it is renewable, inexpensive, lightweight, and has a high specific strength and stiffness.

METHODOLOGY

While document structure is important in many fields, it is especially important in information inspection. Bibliometrics is the study of document structure via the use of tools, goals, frequency classification, ranking, and reference analysis.The details about the various level done to carry out the review study is represented in the **Figure 1** that consisting of six levels.

Data Analysis

Bibliometric analysis, a methodology for mapping identified published records, is now widely recognized as a new way to evaluate academically complex themes in library and information science [23-24]. VOS viewer is a publicly accessible computer software for creating and viewing bibliometric maps. The VOS viewer is used to produce co-citation maps of authors or journals, as well as co-occurrence maps of keywords[25].

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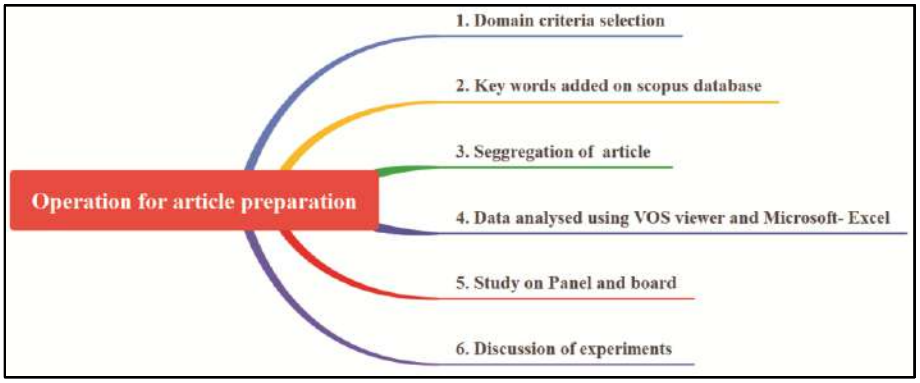

Figure 1 Levels for analytical study

Data Retrieval

The Scopus database was used as it gives users access to journal articles as well as the references in those papers allowing them to go back and forth in time. The database may be used for both research and collection development [26]. A total of 675 articles were used to do research on board made from farm waste.

PUBLICATIONS

Annual Publication using Agricultural Waste

Agricultural waste utilization is one of the important topics to be analyzed as it creating a disturbing impact on the environment. From 1974 to 2021, **Figrue 2** shows publications published on the subject of "agricultural waste utilized in civil engineering" for construction applications.

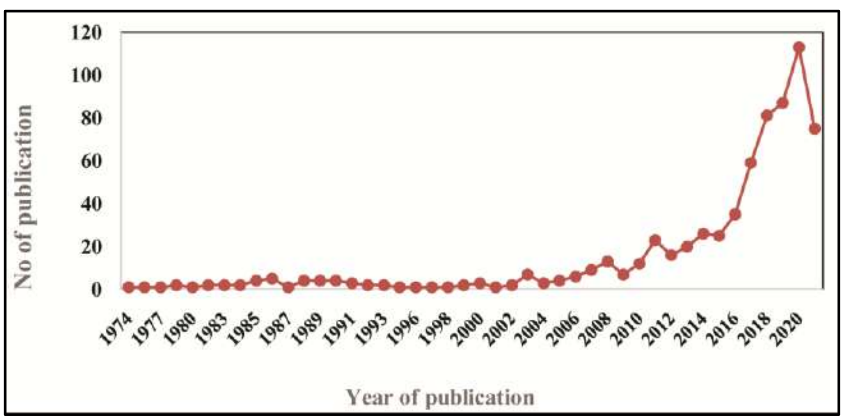

Figure 2 Chronological order of agricultural waste publication

From the above figure, it is observed that the study on agricultural waste has been done from early years but from 2010, the study has been increased exponentially each year. In 2020 it has reached the highest and it continuous increasing in 2021.

TYPES OF PUBLICATION

The publication is divided into three areas, document type, language, and publication access. **Figure 3** shows the number of different sorts of publications over the same period (1974 to July 2021). The language in which the

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publications were published is shown in **Figure 4**. The graph clearly shows that more than 63% of papers were written in the English language. **Figure 5** depicts the paper's publishing access where 75% of the papers are published in the paid journal.

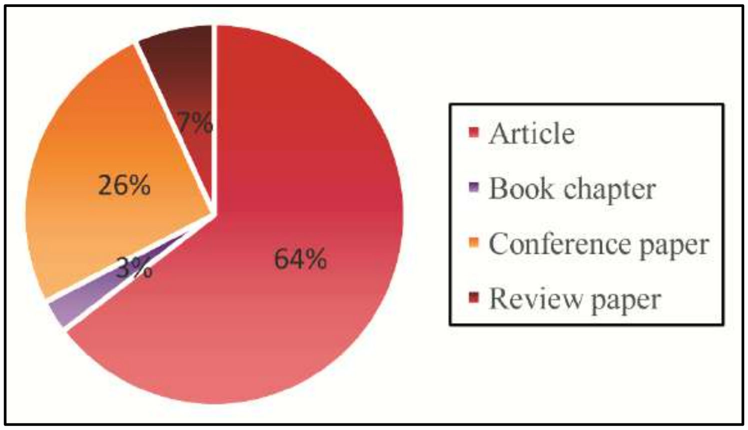
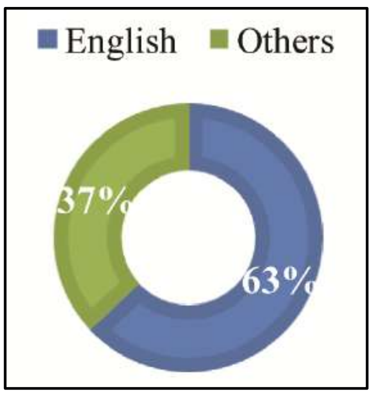


Figure 3 Publication based on document type



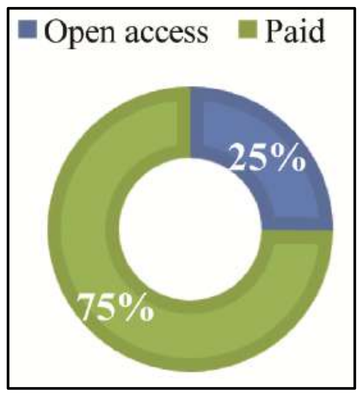


Figure 4 Publication based on language

Figure 5 Publication based on access

Keyword Analysis

The review of the paper is on the area related to agricultural waste and the most prevalent keywords linked with agricultural waste in the building were analyzed. The minimal number of keyword co-occurrences has been kept at five. Using these conditions as a guide, 72 out of 1640 met the requirements. Following that, the mapping was used to document the co-occurrences of terms, total occurrences, and total bond strength. **Figure 6** depicts a keyword-based collaborative network. The clusters of the keyword that has been taken in various studies are shown in **Table 1**.

Source Analysis

Readers may receive the finest information available and quickly choose the ideal journal for publishing by assessing the influence of journals in a given subject. **Figure 7** shows the source occurrences map using the bibliography as an analysis tool. The minimum number of documents of a source given was 8 and out of 331 sources, 15 meets the threshold. The clusters of the source that has been taken in various studies are shown in **Table 2**. A cluster is a collection of nodes that are linked in some way. In a network, each node is allocated to a single cluster.

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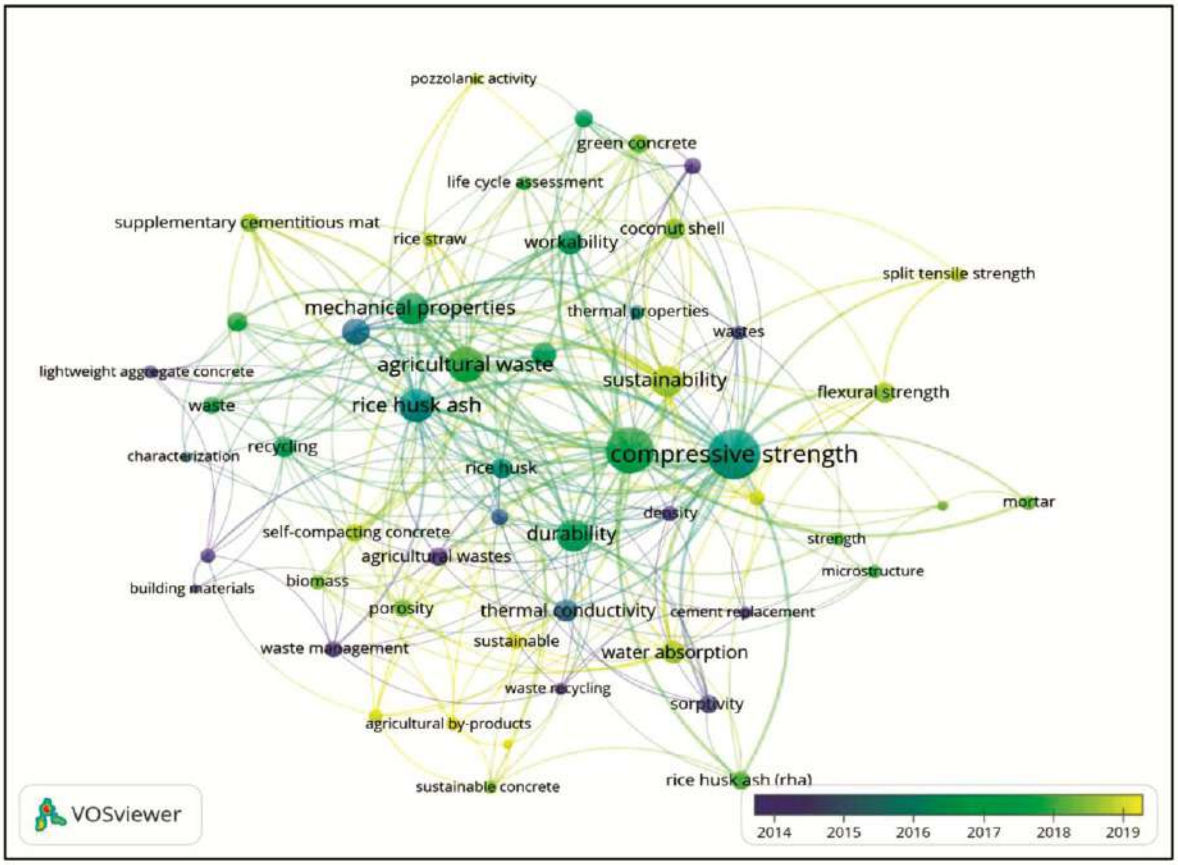

Figure 6 Occurrences map of keywords

Table 1 Clusters of keywords

Cluster no	Keywords
1	Agricultural by- products, agricultural wastes, biomass, building materials, porosity, recycling, rice husk, self-compacting concrete, sustainable, sustainable concrete, sustainable developer, sustainable materials, thermal conductivity, waste management, Waste material waste recycling.
2	Agriculture waste, agricultural waste materials, environmental impact, green concrete, life cycle assessment, pozzolanic activity, rice husk ash, rice straw, thermal insulation, workability.
3	Characterization, coconut shell, lightweight aggregate, lightweight concrete, mechanical properties solid waste.
4	Agricultural residues, cement replacement, concrete, durability, microstructure, mortar, strength, sustainability, wastes.
5	Compressive strength, density, flexural strength, foamed concrete, rice husk ash, sorptivity, split tensile strength, water absorption.

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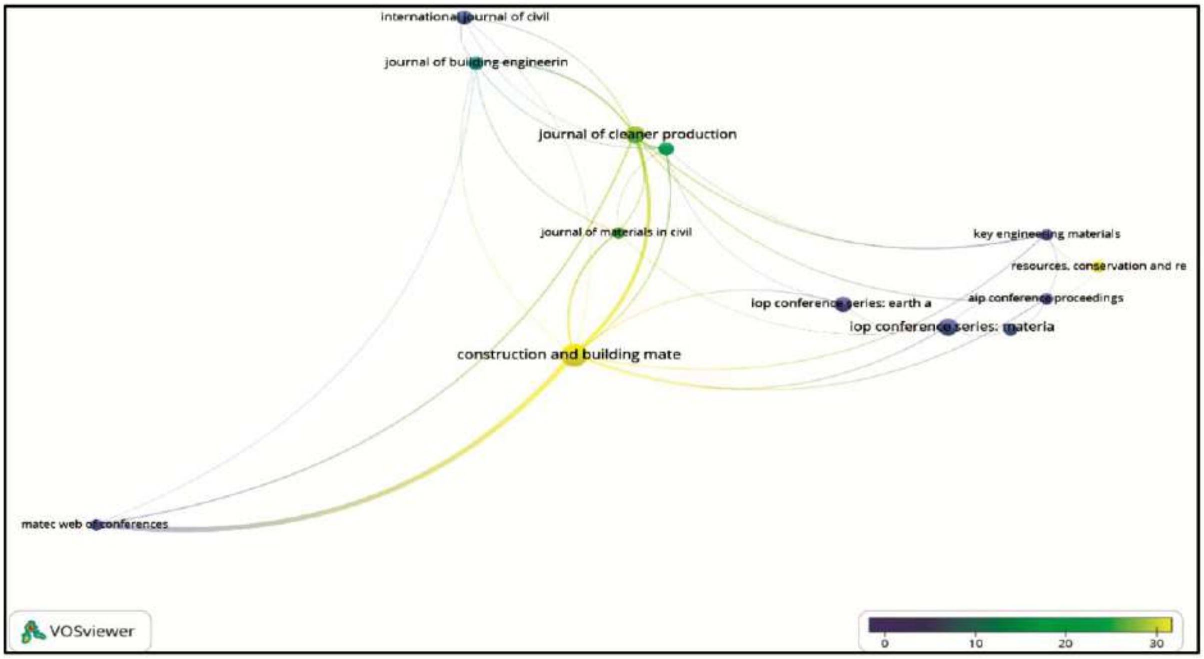

Figure 7 Occurrence'smap of source

Table 2 Clusters of Source

Cluster no	Source
1	AIP conference proceedings, IOP conference series: earth and environmental science, iop conference series: material science and engineering, key engineering materials. Materials today: proceeding, resources, conservation and re.
2	International journal of civil, journal of building engineering, journal of cleaner production, materials.
3	Construction and building, matec web of conference

Regions Analysis

According to the research, the minimum document was 5. Computing the overall strength of co-production groups with other nations and choosing the country with the largest total bandwidth among the 152 countries, 35 meet the threshold that fulfills the criterion. **Figure 8** depicts a network of collaboration based on national cooperation. The highest document was 134 from India and the lowest was 5 from Taiwan. The clusters of the region that has done similar studies are shown in **Table 3**.

PANEL vs BOARD

A panel is a rectangular portion of a surface covering, wall, fence, and other structure in architecture, a recessed compartment with elevated borders, as in ceilings, wainscotings, etc. While a board is a long, broad, and thin piece of any material, generally wood is similarly used in building or furniture manufacturing. But likely to be used as a word for similar meaning.

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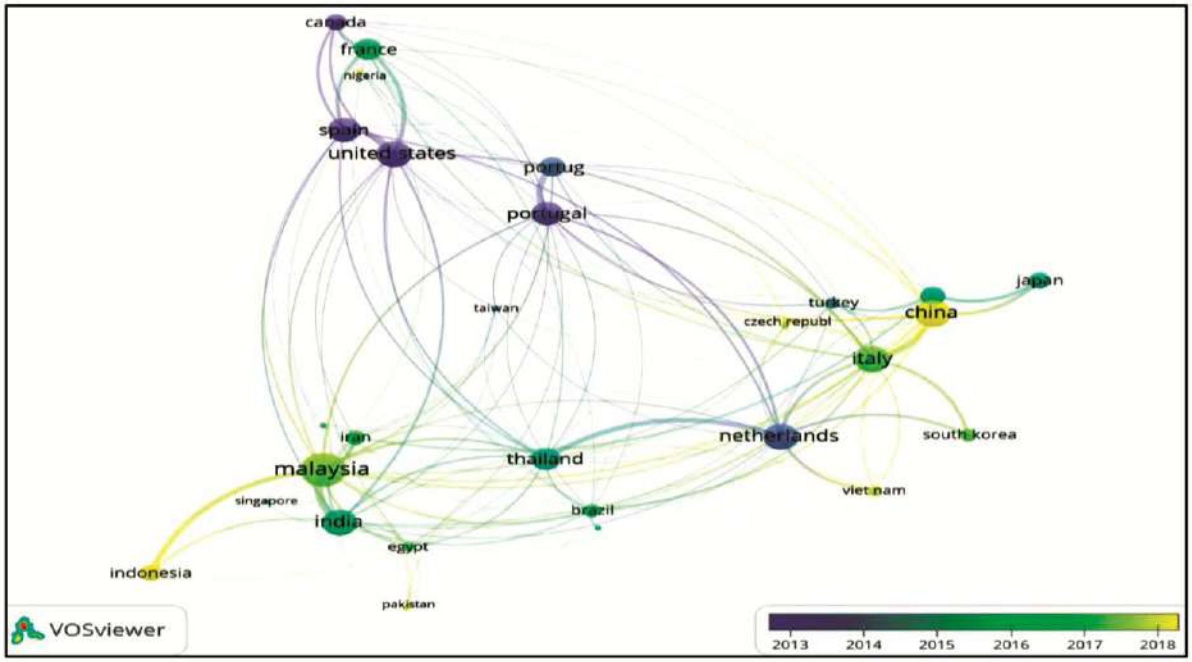

Figure 8 Occurrence'smap of country

Tables 3 Clusters of country

Cluster no	Country
1	Australia, Canada, France, Nigeria, Spain, United States
2	India, Indonesia, Iran, Malaysia, Mexico, Singapore
3	Brazil, Egypt, Germany, Pakistan, South Africa, Thailand
4	Italy, Netherlands, South Korea, Vietnam
5	China, japan, Turkey, United Kingdom
6	Portugal, Taiwan
7	Czech republic

Study on the Board Preparation using the Farm Waste

The data collected for the research on agricultural waste was further separated, and then the studies prepared on the board were taken. Corn curbs, agriculture debris, rice husk, and coconut husk, have high insulating properties. The filtering procedure in the title of the article using boards as a search phrase was used to separate the 675 articles.

Figure 9 depicts the article about the board that was published each year. It can be observed that the study in the area of board preparation for insulation has been increasing from 2020.

Study on the Panel Preparation using the Farm Waste

The data gathered for the agricultural waste study was divided further, and the studies prepared on the panel were then taken. Mostly used waste for the study was cork, granulated tires, rice husk, coffee chaff, wood shavings, straw,

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and maize stalks **Figure 10** depicts the article about the panel that was published each year. It can be observed that the study in the area of panel preparation for insulation has been continuing in 2021.

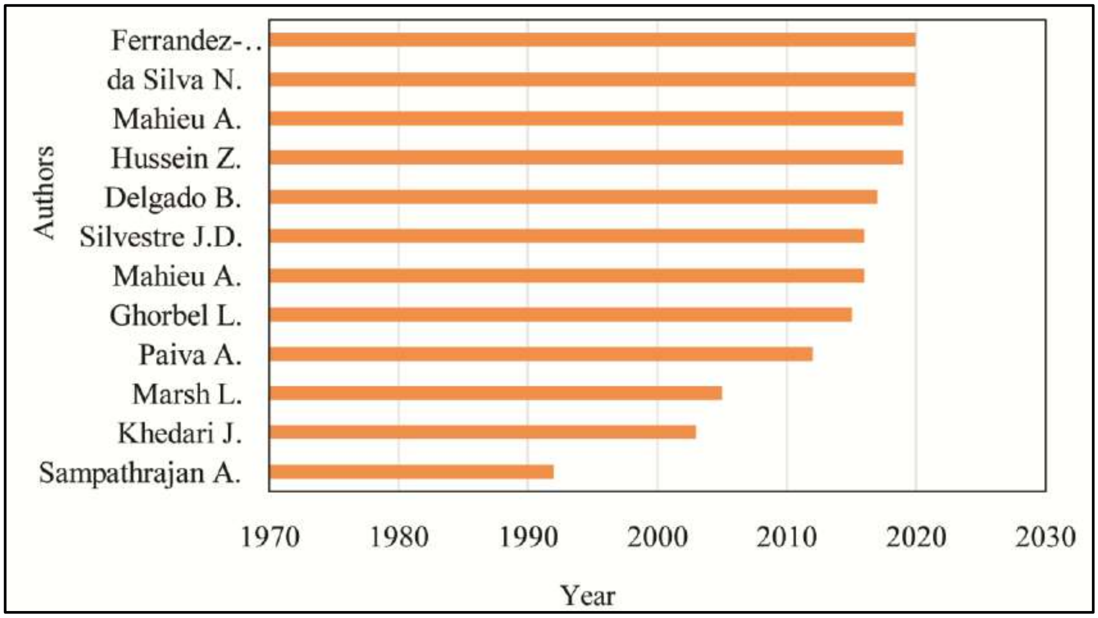

Figure 9 Chronological order of board publication

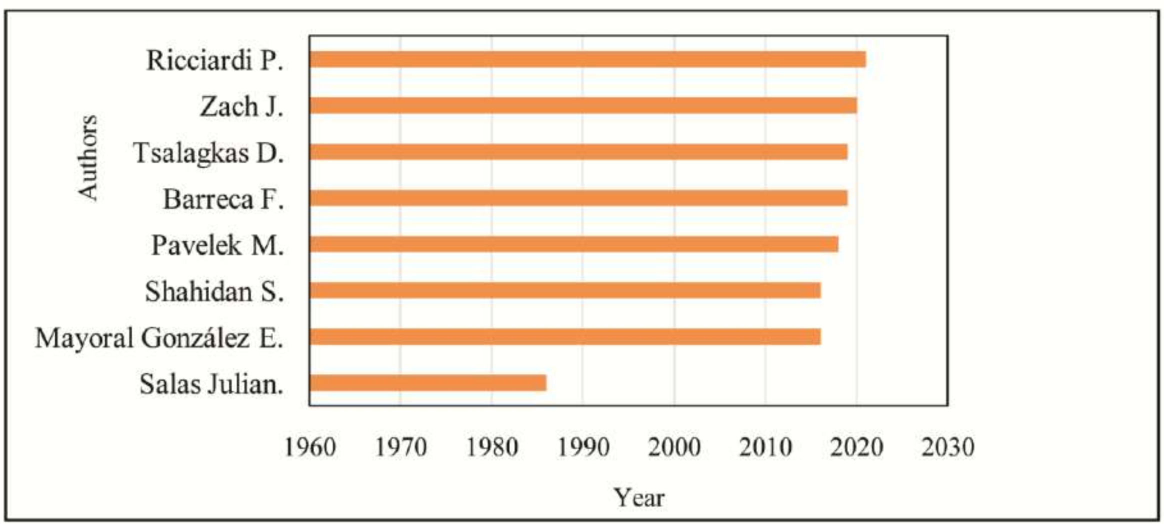

Figure 10 Chronological order of panel publication

TEST TO BE DONE FOR BOARD AND PANEL

The four main parts of this technique include mixing the components, starting with the particles and glue, molding, natural curing, and unmolding. The sample preparation technique is depicted in **Figure 11** [7].

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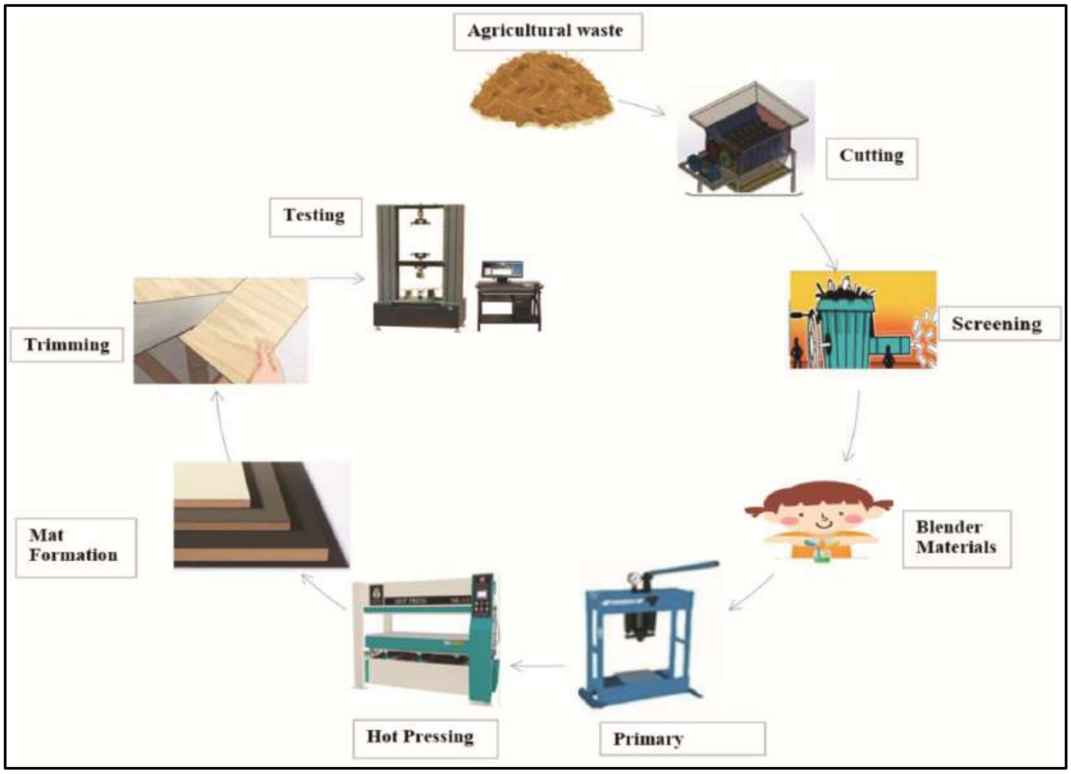

Figure 11 Particleboard production process

Classification of Board

Particleboards are divided into seven categories based on their characteristics. The SFS-EN 312 [27] standard is used to define the characteristics of particle board classes across Europe. Particleboard classes are denoted by the letter 'P' followed by a number from 1 to 7 [28]. **Table 4** shows the classification of board grades.

Table 4 Board grade and its uses

GRADE	USES
P1	Boards for interior construction
P2	Interior usage furniture boards
P3	Non-load-bearing usage
P4	Interior-use boards that can endure stress
P5	board that withstands moisture better, that must tolerate tension
P6	For internal usage, floor boards that can resist a lot of pressure
P7	For applications that must bear a lot of pressure

Flexural Strength

Flexural parameters such as modulus of rupture (MOR) and modulus of elasticity will be evaluated using static bending tests (MOE) section 9 of ASTM D1037-06[20] is used for the samples that are subjected to static bending testing [7]. The results are shown in **Table 5** for various materials.

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Table 5 MOR and MOE of board from various farm waste materials [2,7,9,10,14]

Material	MOR (MPa)	MOE (MPa)
Vine pruning	6.58- 16.5.	743 – 1810
Flax	13.85	1722
Durian particleboards	25.177	28.407
Rubber wood Medium Density	3776.100	2947.234
Tea oil camellia shell	13.4	1840
Maize husk	427	5.2
Paddy straw	193	4.9
Coconut Pith	282	5.8
Groundnut shell	523	6.3

Most common boards used for studies are grade P1-P4 and the values of MOR and MOE of those grades are shows in the **Figure 12**.

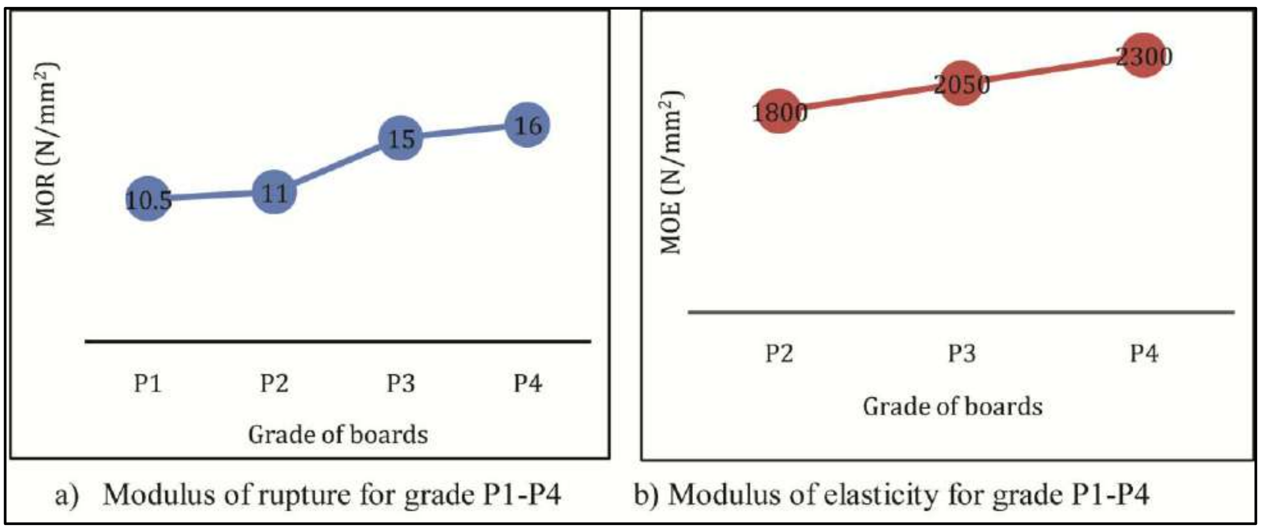

Figure 12 MOR and MOE of Grade P1-P2

Thickness Swelling and Water Absorption

According to European rules, particleboards certified as Grade P3 must have a maximum thickness swelling value of 17% after 24 hours in water. The findings of the thickness swelling values and water absorption values using natural fiber are shown in **Figure 13** [2].

Water absorption can be assessed with a precision of 0.1 mg by weighing the samples before and after immersion. To get an accurate average, the measurements must be repeated five times for each particleboard[9].

Sound Insulation

Boards with thicknesses of 3, 2, and 4 cm are utilized for sound insulation boards made from natural waste. Impact sound insulation tests must be carried out following NP EN ISO 140 [30], and impact sound insulation ratings were determined following ISO 717-2 [31]. The equipment to measure sound insulation is shown in **Figure 14**. The basic

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tools for testing sound insulation are a sonometer and a percussion machine[3]. **Table 6** shows the values of the various average sound absorption coefficients for agricultural materials.

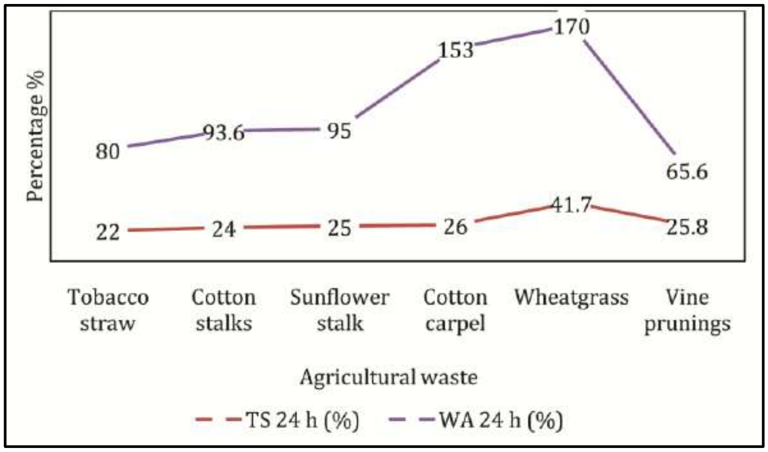

Figure 13 Thickness swelling (TS) andwater absorption (WA)

Figure 14 Sound insulation test equipment

Table 6 Sound absorption coefficient of materials

Product	**Average Sound Absorption Coefficient**	**References**	**Product**	**Average Sound Absorption Coefficient**	**References**
Flax	0.5–0.85	[34]	Rice	0.02–0.8	[38]
Hemp	0.45–0.95	[35]	Oak	0.9	[36]
Reed	0.25–0.6	[36]	Coconut	0.5–0.9	[39]
Bagasse	0.15–0.9	[37]	Palm	0.38	[40]
Sunflower	0.86–0.99	[35]			

Thermal Conductivity

A Netzsch Heat Flow Meter (HFM) 436 Lamda was used to measure the thermal conductivity of the bulk plant particles and particle boards[9]. As the porosity of the boards grew, the thermal conductivity decreased as the particle size rise [2]. The HFM is a calibrated device that is used for testing thermal conductivity. A specimen is

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placed between two plates, one hot and the other cold, and the heat flow induced by the temperature differential is measured using a heat flux sensor[32]. The schematic diagram is shown in **Figure 15** and the thermal conductivity (λ) value for various materials is shown in **Table 7**.

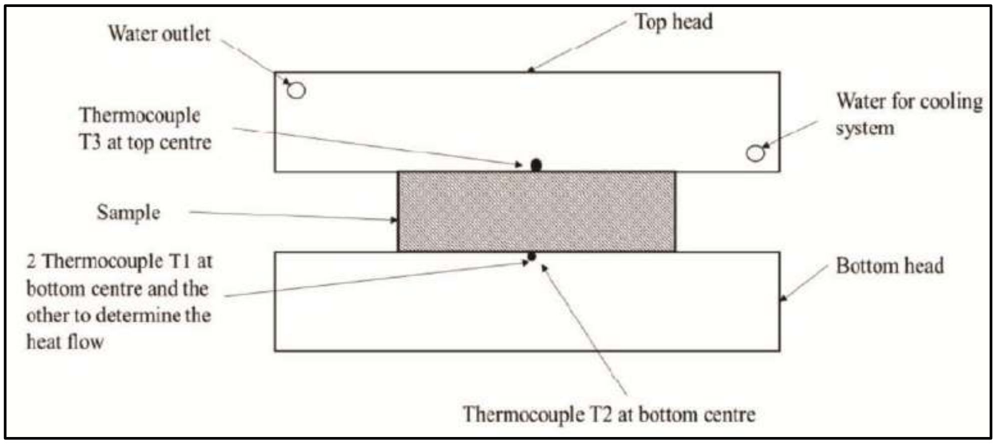
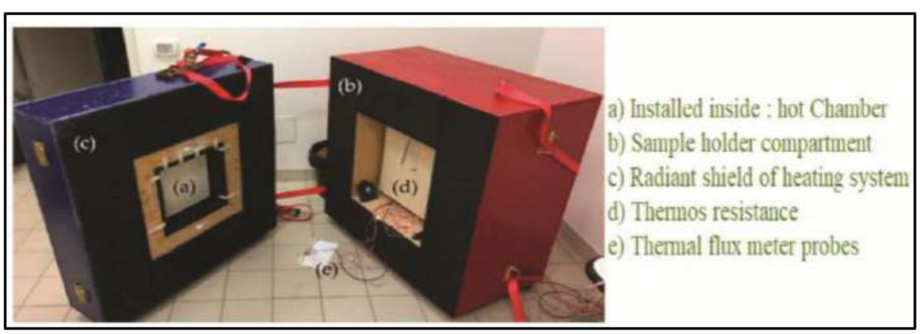


Figure 15 Schematic of thermal conductivity test [6]

Table 7 Thermal conductivity coefficients of different organic fibers [2]

Material	Thermal Conductivity λ (W/m K)
	0.111
Hemp	0.040 to 0.094
	0.038 to 0.075
Flax	0.042
Cotton	0.040 to 0.069
Date palm rachis	0.083
Rice straw	0.076 to 0.091
Sisal	0.070
Sugarcane bagasse	0.079 to 0.098
Wood particleboards	0.070 to 0.180
Wood fiberboards	0.050 to 0.140
Vine prunings	0.064 to 0.068

The hot box design is the method that was used by Milos Pavelek and Paola Ricciardi to measure the thermal conductivities. **Figure 16** shows the apparatus of the small hot-box [19].



Figrue 16 The small hot box apparatus

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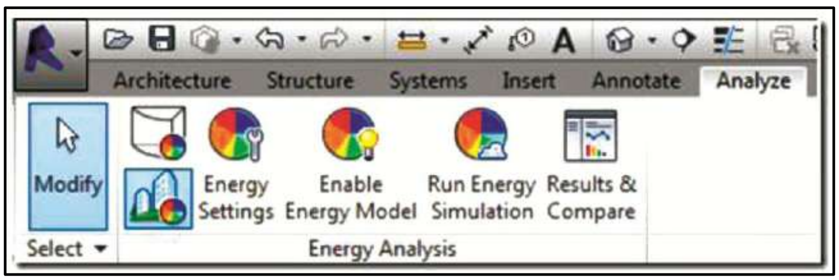
The specimen is sandwiched between two compartments, one for metering and the other for environmental conditions [42]. The climatic chamber represents the outside climate (cold side), whereas the metering chamber represents the inside environment (hot side). The panel thermal resistance is estimated using the observed heat flow from the metering chamber side to the climatic chamber side passing through the specimen, as well as the recorded temperature differential between the hot and cold sides [41].

Energy Analysis

The software mostly used is “energy plus”. This activity includes the physical or chemical processing of materials, as well as the transfer and conversion of energy.The innovative panels in giant reed for buildings with the “chimney effect” and the cork were used to make the panel in the wall the panel was compared with the normal brick wall for the energy analysis of heating and cooling. For heating and cooling, the predicted CO_2 emissions for brick walls were 2517 kg, 623 kg for agglomerated cork walls, and 1905 kg for giant reed walls [16].



Figrue 17 Energy Analysis for Autodesk Revit

As shown in **Figure 17**, Energy Analysis for Revit is a tool that allows users to execute a cloud-based whole-building evaluation using Autodesk® Green Building Studio® (GBS) directly from Revit.Revit now provides an integrated Energy Analysis workflow that incorporates both Architectural Building elements such as walls, roofs, floors, and windows, as well as Conceptual Massing components formerly known as Conceptual Energy Analysis.

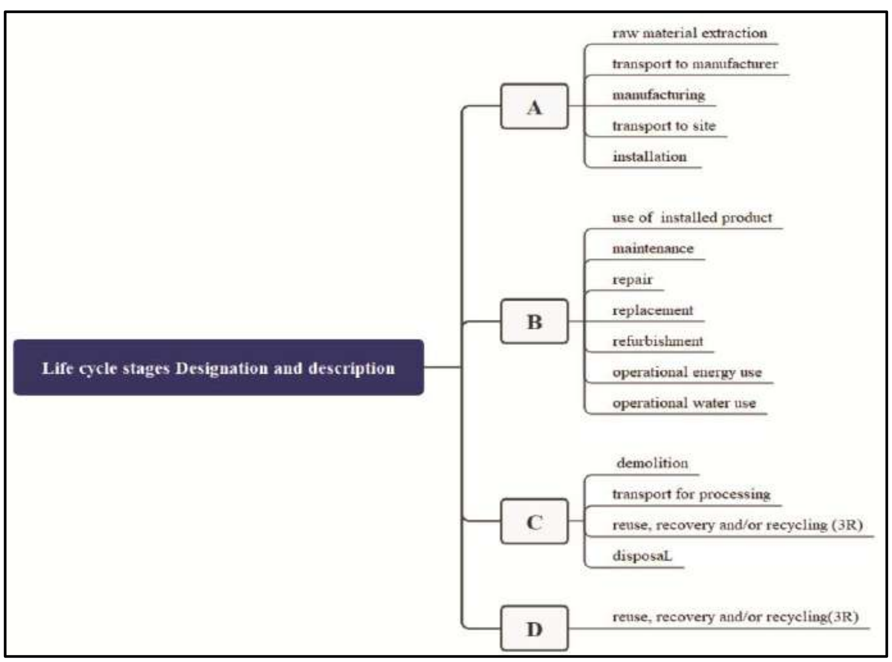


Figure 18 Detailed life cycle stages of building materials [15]

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Life Cycle Assessment (LCA)

The analysis and valuation of a given item's natural impacts is known as a life cycle assessment [1]. An LCA investigation of a building material or collection can be classified as cradle-to-grave (the extraction and handling of raw materials and creation), cradle-to-cradle (vehicle cost, appropriation, and assembly, use, upkeep, and final removal), or cradle-to-cradle (reuse, recovery, and recycling). The details of 4 stages (A, B, C and D) considered in LCA are discussed in **Figure 18**.

The importance of conducting a life cycle assessment of particleboard production is that it provides information on critical parameters such as fossil fuel based primary energy consumption, renewable primary energy consumption, Eutrophication potential, climate impact over a period of 100 years, depletion of the ozone layer.

CONCLUSION

- The monetization of these agricultural byproducts could thus give farmers with a new source of income.It contributes to the removal of agricultural waste from the environment in such a way that even waste is turned into a commodity.
- Applying water repellent chemicals during the board's manufacture would improve these metrics significantly if the thickness swelling and water absorption values were very high.
- When compared to cork and granulated tyres, rice husk and coffee chaff have the lowest global warming potential and cumulative energy requirement, especially when considering thermal studies.
- Coconut shells can withstand temperatures of up to 800°C while losing just a small percentage of compressive strength. Less than 10% was the ideal proportion to use as an admixture or replacement. The thermal characterization can be done using the small hot box apparatus.
- Cork, rice husk, and coffee chaff were some of the finest sustainable panels discovered, with similar thermal conductivities of 0.063–0.068 W/mK and reduced environmental effects.
- As the agricultural waste is used on the panel and board preparation the binding agent must be used and binder types urea-formaldehyde, phenol-formaldehyde resins, isocyanate.
- Consequently, particleboards manufactured from agricultural waste are feasible choices to employ in building insulation walls and ceilings, even for the improved aesthetic features making it affordable and also decrease in CO_2 emission and the problem of waste disposal.
- The greater the value of the average sound insulation capacity, the better the sound insulating capability.
- This review paper would help in understanding the different test values of agricultural waste as well as the experimental procedure for the thermal conductivity test. Making it useful for the researcher.
- The study of life cycle assessment aids in analyzing the environmental consequences of practical boards and panels' manufacture, usage, and end-of-life processing. This aids in the reduction of toxic waste utilization as well as pollution in the environment.

FUTURE SCOPE

Future studies on the impact of various binding material ratios for thermal and mechanical characteristics can be done. Furthermore, most of the studies are done using the hot-pressing process, and fewer binders are used, further research on the binder and alternative agricultural waste for the sustainable solution can be an intriguing and better approach in the construction of sustainable solutions.

DECLARATION OF COMPETING INTEREST

There are no conflicts of interest declared by the authors.

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Civil Engineering

Conceptual Model of Quality Management based on Blockchain in Construction Industry

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Abstract: *Poor quality in construction could lead to the cash flow disruption, project delays, profit loss in projects due to rework, and some time to the property damage or human loss due to accidents. In order to ensure the quality of work, quality control (QC) departments inspect the construction work compliance with best practices, defined procedures, and specifications. These inspections rely on manual procedures, post-construction evaluation, document-based, and are carried out through a supervisory manner approach from top-down. However, this topdown control-oriented approach does not provide enough motivation for quality control managers, operators, and workers to voluntarily follow quality procedures and specifications. Besides, document-based quality specification compliance assessments have limitations that are difficult to determine whether the required specifications have actually been implemented and are not reliable to measure their real performance as well. In this regard, this study proposes a conceptual framework for Blockchain-based quality management at construction sites, which could ensure security and reliability of information generated through while implementing quality-related specification and procedures by managers and workers using Distributed Ledger Technologies (DLT) and also to encourage them by establishing a compensation structure through performance assessment for activities of each task. The Block chained quality management approach would greatly help shift the traditional top-down and passive quality control process to bottom-up and voluntary manner. It might open a new innovative value-chain structure in the construction quality domain which provides securing reliability of activities required for quality assurance procedures and specification implementation.*

Keywords: *Blockchain; Distributed Ledger Technologies (DLT); Construction Quality; Defect Management*

INTRODUCTION

Rework of poor-quality construction work is regarded as a non-value adding activity that is utterly affecting the productivity and performance in construction projects that spend inessential enormous costs, materials, time, and manpower [1]. Many researches have extensively focused on construction defect management to enhance the poor quality in construction. Previous studies revealed that 5% to 15% of costs in construction projects are caused due to poor-quality work [2].

The rework does not only costs but might charge additional expenses due to delay in the project, and sometimes consume those resources which are allocated to other parts of the project. Poor quality does not only affect costs but also severe accidents. In the case of Korea, accidents due to poor quality of construction work have been reported in many projects such as the collapse of Pyenogtaek international bridge and the fall of the exterior wall of the National University Museum, both of which cause many deaths. Also, the number of dispute related to defects in apartment buildings are increased from 69 cases in 2010 to 3,880 cases in 2016.

Generally, in construction, to make sure the quality of work and prevent defects, the manager inspects the completed work, identify the defects if any, and records them with information of drawings and locations or in the form of documents such as checklist and punchlist. After identifying defects in the field, they discuss the quality of work with the subcontractors and instruct them for actions such as repair or rework. This cycle of rework and quality

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inspection continue until to gain the defined level of quality conformance advised by the agreed quality specification document between stockholders.

On the contrary, documentary evidence of events, activities, and tasks carried out to ensure the quality of work are often prepared for the purpose of responding to quality inspections by the management, and it is difficult to determine the authenticity of the actual acts and events being done to make sure the quality of work. Previous studies revealed that the capacity of government agencies responsible to ensure the quality of construction work is limited to 400,000 sites per year in Korea, which is unable to cover the total projects.

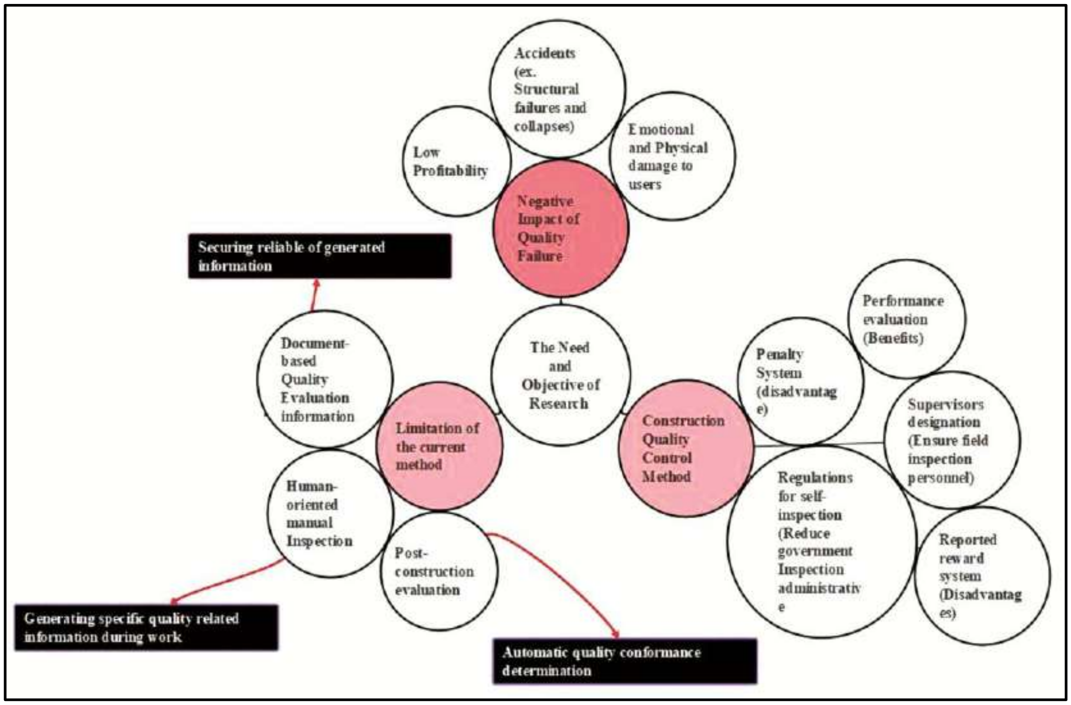

Figure 1 Limitation in Current Quality Management System and research objectives

Moreover, the data shows that 67% of projects had experience in missing inspection work due to excessive workload or shortage of personnel, even if professional quality control personnel are deployed to inspect the sites. It is practically impossible to inspect all work steps for the required quality conformance events at each site, thus, there is high probability to have post- work inspection in a supervisory manner (top-down approach).

Even though various quality management systems are currently in practice to ensure the quality of construction work. However, there are several inherent limitations in the current practice such as physical inspection of work, manually observing and recording the quality-related events and activities, data loss during communication between the office and field, reactive approach for rework. The top-down approach, in which the quality inspector/auditor enforce the standards and specification to achieve certain quality conformance level using supervisory manner is another significant limitation of the current practice.

To address this, the following systemic approaches are required:

1) The construction information related to quality conformance of work can be produced at the worker level performing the actual work.

2) The quality-related information generated during the course of work is automatically determined by the system, not by inspector.

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3) The reliability of the generated information can be secured at the same time. Therefore, this study aims to propose an innovative quality management system model that utilizes blockchain technology, which has a lot of interest in the construction field.

Issues in Current Quality Management Systems

One of the critical components in a successful construction project management is quality management [3]. In construction, the occurrence of quality non-conformance is comparatively high and can negatively affect the firm's profit and its competitiveness [4]. Poor quality is the consequence of non-conformance to the quality standards and specifications during construction work, which results in additional time and cost to all in a project [5].

In order to sort out the issue, this area is being extensively studied by many researchers. However, the problem of data loss, reactive approach, and substantial workload still exist. For instance, the process of manual observation and recording the non-conformance or defect information at the site and re-putting to the computer in the office for discussion is cumbersome and could be less accurate due high chance of data errors, omission and miswrite [6]. Quality conformance inspection consumes a major portion of construction manger's work efforts, which is accounted for around 38 percent of their total work [7]. To reduce the workload of the construction managers in checking quality conformance, radio frequency (RF) technology [8], personal digital assistant (PDA) [9] and laser scanner [10] have been developed. However, these systems work with reactive approaches after non-conformance already been happened, and it is vital to control and apply all the required events and activities for quality conformance during the construction process so that to ensure the specified quality before the defect occurs.

Over the last decade, many researchers have devoted vital attention to enhance the quality management system in construction. Several concepts and their enabling technologies such as building information modeling (BIM) and augmented reality (AR) have been investigated for proactive and automatic quality inspection during the construction work. The augmented virtuality (AV) based tele-inspection system for non-conformance detection has been developed by Wang and Chen [11]. Similarly, Dong et al proposed a mobile-based telematic digital workbench system for construction quality management that integrates the location of visual information on the job site with the 3D model [12]. However, a categoric, transparent, and reliable approach is inevitable to solve the before mentioned issues in the current quality management system.

Blockchain Technology Applications in Construction

Blockchain technology also known as distributed ledger technology (DLT) is considered to be capable of transforming many global industries, and the construction has no exception. Blockchain was introduced in 2008 as an underpinning technology for the verification tool of world's first cryptocurrency (bitcoin) transactions[13].

The significant features of block chain technology are:

(i) immutability (once blocks are chained then cannot be modified);

(ii) a peer-to-peer network made up nodes (computers) for decentralized operation;

(iii) reliability (all nodes have an same copy of the same blockchain in all nodes which is verified through an algorithm for any anomalies;

(iv) authentication (a Proof-of-Work mechanism validate transactions in the Blockchain) [14].

Previous research already been carried out to explore blockchain technology for multiple domains can be classified in seven use-categories:

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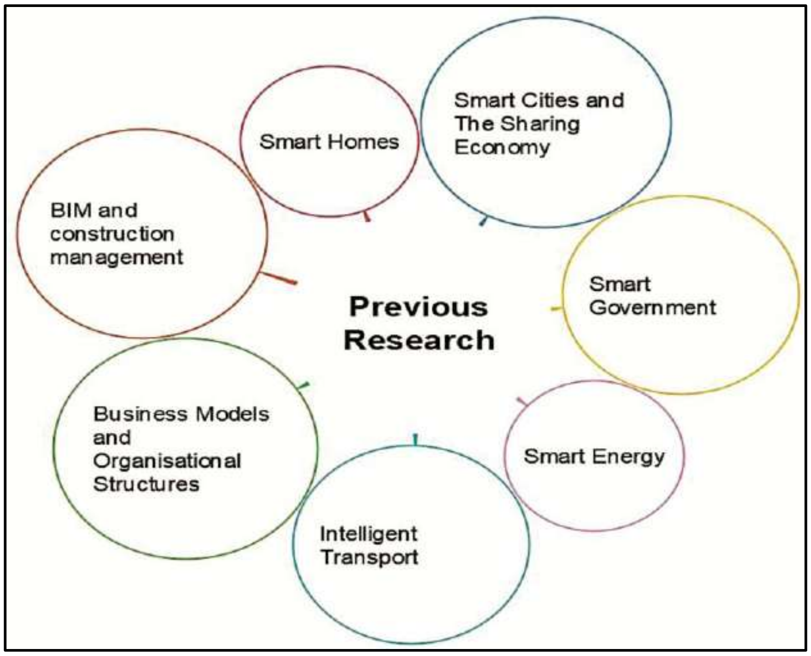

Figure 2 Previous research on blockchain technology for multiple domain

The scope of the derived literature in this paper is limited to the previous efforts related to the buildings, energy and construction. Currently, many researchers are focusing on the applications of Blockchain technology in various construction industry areas such as energy transactions using distributed fields, Integration of IoT technologies with blockchain, BIM and blockchain-based approaches, and resolution of delayed payment to subcontractors' problems through a smart contract. Castellanos investigated the energy transactions generated from wind or solar sources using distributed ledger technology (DLT)[15]. To measure the inside temperature in the building using IoT based smart home devices, a hybrid approach of BIM and blockchain technology is applied for energy management and saving [16]. Wang proposed a smart contract-based blockchain method to solve the problem of wage payment to the construction worker [17]. Previous efforts regarding the blockchain in the construction domain revealed that most of the research was focused on smart contracts to enhance the transactions of payments. However, some web articles have focussed on the conceptual adoption of blockchain in safety compliance and quality conformance in construction.

Blockchain-based Quality Management System Framework

This study intends to develop an innovative system framework that utilizes blockchain technology for effective construction quality management. The main functions and utilization effects of this system includes three main attributes: (1) Implementing text mining, computer vision, internet of things (IoT), and augmented reality (AR) technology to determine the appropriate information generated by quality conformance activities, (2) Leveraging Distributed Ledger Technologies (DLT) in blockchain to ensure security and reliability of information generated during the specific quality-related events, tasks, and activities (3) Based on the report of on-site quality conformance activities being done by worker level, granting the contractor/partner quality conformance level assessment.

The proposed framework enables the categoric generation of construction information related to the quality of work at the bottom worker level that performs the actual work. However, the system instead of the person automatically determines the generated information and controls the reliability of the generated information.

The quality management-related stakeholders in a construction project can be grouped into four classes. Quality conformance events and activity information produced during the construction work is mainly generated by contractors and suppliers, and the generated information is stored in the quality management events and activities

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database (DB). The verification of the quality conformance of the stored information is evaluate d in rules-based or algorithm-based systems. To allow access of relevant participants to the project's information, the proposed system framework would adopt licensed blockchain protocols to only allow authorized participants to the network.

In the process of creating quality conformance events and activities information, checking and verifying the ledger, Hyperledger consensus algorithm can be used to check the author or viewer's authority to ensure the reliability of stored data and prevent unauthorized users from accessing the ledger. Unlike, other specific platforms to a particularbusiness- models, Hyperledger can be universally adopted in several fields of industries. The Hyperledger is an open-source community of Linux foundation project focused on developing tools and libraries for blockchain deployments.

These tools and libraries are open source and can be written or modified based on requirements using common programming languages such as Java, Golang, Node.js, and could be further integrated with construction industry tools for BIM such as Revit, dynamo, grasshopper, as well as to other technologies such as IOT, image recognition, and text-mapping. The configurable module structure allows users to easily select and replace the functions they want to fit the business model of the desired company. In order to reduce data overload in a Blockchain network, the raw data in large amount with more size such as images, BIM files, sensor data, etc. could be stored in a separate database outside the blockchain, however, the generated hash and URL against each transactions would be recorded in a distributed ledger. Through channel separation and MSP (Membership Service Provider) function in Hyperledger, general contractor can access the ledger of subcontractor’s CH.2, but sub-contractor cannot be accessed by general contractor’s CH.1.

In addition, the audit agency, and supervisor can grant the participation access to CH.1 and CH.2 for reviewing the quality conformance level of construction companies recorded on the blockchain.

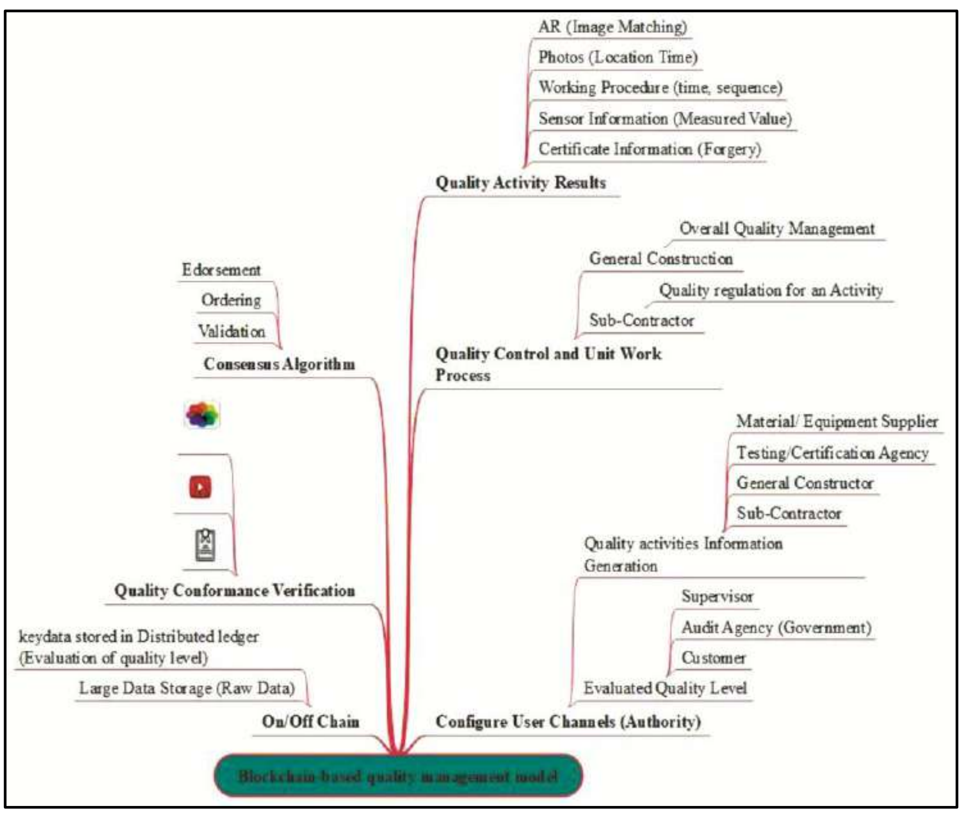

Figure 3 Process of proposed Blockchain-based quality management model

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IMPLEMENTATION SCENARIOS

In order to ensure quality of work, the quality conformance events and activities needs to be checked for each work step, and the generated information during each step is automatically checked by the system, not the person, for compliance with quality-related regulations and procedures.

To further elaborate the idea of the study, four case scenarios are selected and detailed as under. Missing struts when install shoring system: For instance, inspecting the struts when installing the shoring or shielding system in an excavated site, the manger takes images of each job-step during work progress. The augment reality (AR) based image matching techniques check the installation status and accuracy of the struts, any discrepancies could be recorded and sent to the database.

The blockchain system could generate a hash for each generated record and will save on the server. Checking waterproofing work procedures: In waterproofing work, there are various layers of different materials to be painted and finished on the surface with specific time intervals. The manger captures the images after finishing the primary layer and before starting the second layer, the rule-based engine analyzes the images with corresponding time reference and record the hash against each transaction in the blockchain.

Testing Compressive Strength of Concrete: Calculating compressive strength of concrete is very critical in construction of structural works. Initially, the quality inspector in the lab take image of concrete molds during curing under water. Then the inspector captures the compressive strength results after 3, 7 and 28 days by doing experiment on universal testing machine (UTM). The system can then generate the hash against both the images and will be saved in the block chain, other data such as images or documents will be stored in the external database.

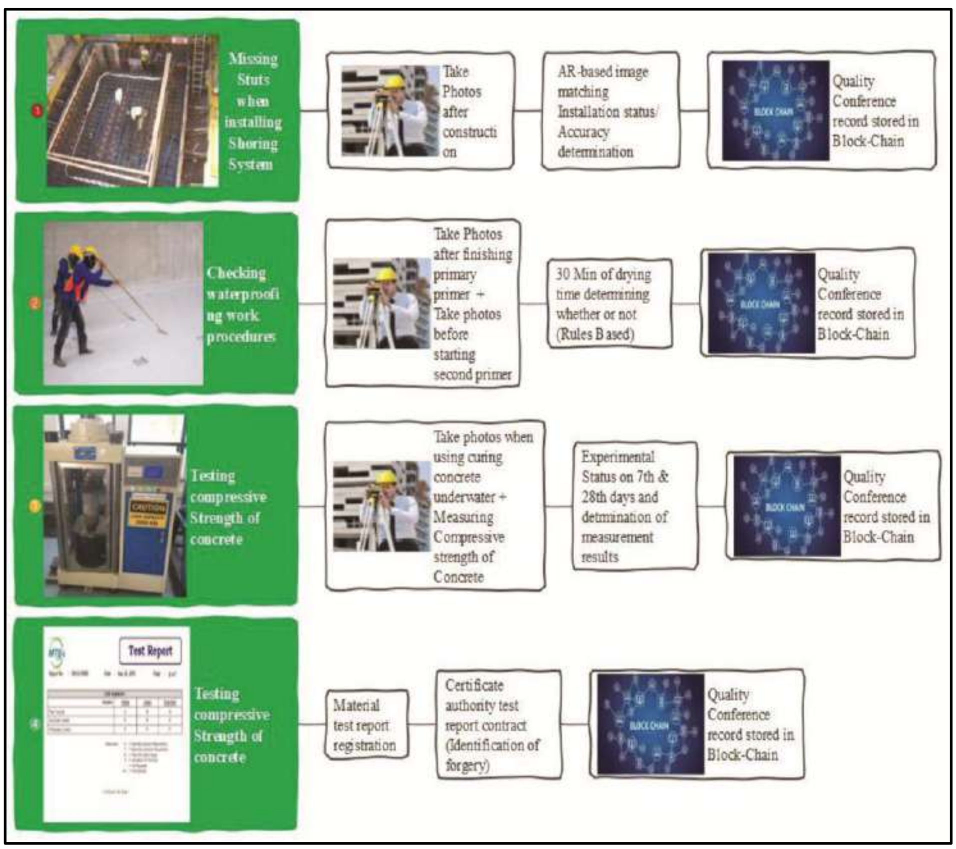

Figure 4 Implementation scenarios for the proposed Quality Management Model

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Material test report Registration: Similarly, equipment or machinery fitness and material quality is also significant to ensure quality of work. In order to have reliable quality and fitness to use information, the document certificate made against each particular inspection for the concerned equipment or materials could be uploaded to the blockchain system.

The images of the documents can be converted to the text using optical character recognition technology (OCR) or text mining, then the required relevant important information such as date, time, location and fitness etc. can be extracted, and their corresponding hash along with URL could be stored in the blockchain.

DISCUSSION ON EXPECTED RESULTS

The core intention of the study is to develop a framework for a system that automatically evaluate and examine the quality conformance events and activities grading level based on the information generated during the process of performing quality control events, activities and tasks by the manager or workers. The system based on the proposed framework is expected to be beneficial and alternate for Inspection agencies and prospective users or occupants (considering apartments case), as it provides reliable, transparent, and verified information required for quality conformance, without even physically visiting the site.

The rules for quality conformance can be defined from quality management regulations and quality inspection cases. The integration of advance technologies with blockchain such as image recognition, image matching and IoT based sensors could determine the accurate and secure information pertaining to quality conformance. In addition, the determined qualityrelated information and verification data can be recorded on the blockchain to gain security and reliability, and using channel-specific access rights, users can be provided with reliable quality management activity information at any time.

Additionally, this study proposed a quality management process innovation for shifting the traditional quality management process from top-down approach to bottom-Up approach that can efficiently measure the quality conformance level during the actual work (proactively) before the failure occurs, rather than detecting the defect after the completion of entire work, which is reactive approach.

CONCLUSION

To ensure the quality of work in construction, the quality control (QC) departments inspect the work compliance with best practices, defined procedures, and specifications. These inspections rely on post-construction evaluation, document-based, and are carried out through a supervisory manner approach from top-down.

Apart from that, the traditional quality management system is unable to acquire the job step events/activities information pertaining to the standard and best practices required to produce a qualitative work. To address this issue, this research proposed a conceptual framework for Blockchain-based construction quality management system.

This proposed framework utilizes Hyperledger fabric protocols to store key information of quality related events and activities using blockchain technology. It also proposed the application of various technologies, including image recognition, image matching, text mining, and IOT sensors, to verify the suitability of safety activities. It is expected that the Block chained quality management approach will contribute to shift the traditional top-down to passive quality control process to bottom-up and voluntary manner. It might open a new innovative value-chain structure in the construction quality domain which provides securing reliability of activities required for quality assurance procedures and specification implementation.

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Evaluation of Energy-Efficient Office Building through Glass Thermal Properties, Shading Devices and Window-wall Ratio

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Abstract*: Sustainable development is a more concerning topic due to rapid urbanization, population growth, and comfort in building services. As India is a developing country it consumes almost 30% of energy in lighting, cooling, and heating form, in the commercial building sector. By implementation or adopting energy-efficient codes could provide lead to a sustainable future. In India, BEE has introduced ECBC (Energy Conservation Building Code) 2017 to optimize energy use by using passive strategies and providing comfort levels to occupants in a commercial building. This paper will present the energy performance of the building, for developing process data needed for modeling a new commercial office building was collected from past research related to energy-efficient building. By adopting ECBC prescriptive compliance approaches the reference office building was model through simulation software Design Builder along with the Energy Pulse engine. Using energy-efficient code as a guideline further evaluation of the same building is done by changing 3 building parameters via window glass with increase WWR and shading devices. After simulating the model the results were analyzed for annual total energy consumption and all summer energy consumption. Making use of ECBC's prescriptive compliance approach and simulation software will help in easy implementation and imposing. The use of such codes will lead to a reduction in future barriers and using software will lead to a reduction of manual calculation barriers. After that lastly, the Discount payback period analysis was done for 10% and 6% rates.*

Keywords*: ECBC 2017; Glazing; Shading Devices; WWR; Design Builder*

INTRODUCTION

India consumes almost 30% of energy in the commercial building sector [5, 12]. The primary energy consumes in form of heating, cooling, ventilation, lighting, and equipment’s and the secondary energy is consumed by domestic hot water and other loads [15]. A previous study observed that windows help save energy consumption by using glass as a major material and using glass with its thermal properties as lower U-value and high solar heat gain coefficient for passive solar heating applications [10]. The building window design is the major part that affects the received natural light across the building, so for this reason the window must be designed in such a manner that it allows most of the natural sunlight to enter with the required amount into the building and it should balance the light need and heat gain inside the building. So this will help to achieve balance in heat gain and natural daylighting[14]. Among the building envelope glass is the main element that influences the thermal performance of the building, therefore it is essential to study the thermal behavior of the glass for balancing the day lighting and heat gain inside [5]. However, the glazing technologies can help provide sufficient daylight to the building and save energy Moreover, it also enhances the architectural appearance of the building [9]. Using a glass of different types such as single, double, and triple and also affect the energy performance of the building. Shading devices can also contribute to the energy performance of the building, using shades for the facades with large portions glazed. As the provision of glaze is to provide natural lighting and aesthetic appearance to the building but providing glass at large portion can cause heat gain inside the building which would lead to occupant/employee discomfort to overcome this property of glass the application of shades would help provide better energy performance of the building. There are different shading elements such as fixed and movable shading devices that are used to improve the energy performance of the building [6]. The shading design impact and its control on building energy performance are not taken into account at the design stage, eventually, the cooling and lighting energy balance between fenestration

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design and lighting are to be identified [16]. BEE (Bureau of Energy Efficiency), a government body of India with United States AID, has done a study based on the actual performance of the building for conditioned and non-conditioned buildings for all commercial building sectors. The ECBC (Energy Conservation Building Code) was developed for the same aspect by BEE; on 27th May 2007, ECBC was launched for the first time to design or to construct new commercial buildings with minimum efficiency standards. The ECBC in June 2017 was updated which introduced additional new requirements, lighting, HVAC, electrical, building envelopes, and renewable systems [12,15]. In this paper evaluation of the model would be done with ECBC guidelines by using DesignBuilder version 7.0.0.093 along with EnergyPluse Engine 9.4 and then changing three parameters such as different types of glass, WWR, and shading devices for the same ECBC model to make energy performance better and the results were analyzed for annual total energy consumption in kWh/m^2, and all summer energy consumption in kWh/m^2. Then lastly a simple discount payback period analysis was performed for 10% and 6% for providing guidelines for selecting the project [11].

METHODOLOGY

In this evaluation, the office building is simulated for energy usage which is in form of heating, cooling, and lighting energy loads, by using the simulation tool — Design Builder. The use of the software will help in easy analysis of the model at the initial design stage and with an excuse for any manual calculation. The reference building is a model by using ECBC as a guideline [12]. The glass mandatory value is inputted, then by replacing three glass types-single, double and triple glass are consider with it four different shades are coupled with a 60% increase in WWR [19].

Design of Reference Building is Developed Which Complaints to ECBC 2017

The building is a commercial office building with a rectangular shape [17] with a two-story office building and the design of the building complaints to ECBC 2017. By assumption of the building are done from the previous study, such as 2-story building, the shape of the building is kept rectangular, lighting controls are on and are LED lighting, cooling appliances are to be 5-star rating, remaining data is prescriptive values from the code.

Table I Base building details summary

	Activity template		
Occupancy Schedule	Working Profile (days in a week)	Metabolic Factor	
8:00 – 16:00	6	0.90	
	Construction template		
External wall (u-value)	Roof (u-value)	Floor (u-value)	Infiltration in air change
0.4	0.33	2.16	0.5ac/h
	Opening template (ECBC)		
Glazing (u-value)	SHGC	VLT	WWR
3.3	0.27	0.561	40%
	Lighting template		
Lighting	Lighting Controls	LPD	
LED	On	9.5 w/m^2	
	HVAC		
Mechanical vent	Heating	Cooling	DHW
On	On	On	Off

Design of Proposed Building is Developed by Altering Glass Type, Shades and 60% WWR

For making the office building energy-efficient, alternate glass types were selected concerning its thermal properties, shading devices and 60% WWR selected from past research studies and were used for evaluation and they were considered for the same ECBC model. Further evaluation was carried concerning alternate 3 building parameters.

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Table 2 Glazing types

Sr. No.	Types of Glass
1	Sgl. LoE (e2=.2) Clr. 6mm
3	Dbl. LoE SPEC. SEL. Tint 6/13 Argon
5	Dbl. LoE Spec. Selc. Clr. 3/13/6 Arg.
6	Dbl. Sage glass Climaplus Green No Tint
7	Dbl. SGG XT 60-28 6/16/4
9	Trp. LoE Film (66) Br. 6/13 Air
10	Trp. Sage Glass Climatop Green No Tint

Table 3 Shading devices

Sr. No.	Types of Shading Devices	Dimensions
1	Overhang, Sidefins	1.5 m
2	Overhang, Sidefins, Louvre	0.5 m
3	Louver	1 m
4	Sidefins	0.5 m

RESULT AND DISCUSSION

Calculation of Annual and All Summer Energy Consumption for Reference Model

Simulating the office building in the DesignBuilder software the following results were obtained, the model was simulated for annual total energy consumption in kWh/m^{2}and all summer energy consumption in kWh/m^2. From **Table 4** it is observed the building consumes 72.7 kWh/m^2 of energy annually and 47.4 kWh/m^2 of energy all summer. This value would be used as a benchmark for the project and alternate glass; shades would be used to make the energy performance of the building best.

Table 4 Results ECBC Model

Results ECBC Model	
Annual total energy Consumption kWh/m^2	All Summer energy Consumption kWh/m^2
72.7	47.4

Calculation of Annual and All Summer Energy Consumption for Propose Model

Results for Annual Total Energy Consumption of Office Building

As the simulation of the reference model is carried on, the same building would be used for further evaluation with different glass types, shading elements, and WWR. So after simulating the building with alternate parameters following results are obtained. From **Table 5** it is observed that evaluation of building is done for single, double, and triple glass type with four different shading devices.

The single glass shows a poor performance than that of double and triple glass types. Double layer saint global glass along with overhang + sidefins show more efficient performance than ECBC mode. As for annually, the office building consumes 63.23 kWh/m^2 of energy, and all the triple glass shows the best energy performance of 61.86 kWh/m^2 annually. And so on it is observed that overhang+ sidefines 1.5 are more energy-efficient shading devices

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that save more energy than that of outer shades. **Figure 1** helps in understanding the energy performance of the building through various parameters consider for the building.

Table 5 Annual total energy consumption kWh/m^2 of proposed building

	Description	Overhang +Sidefins 1.5	Overhang, Sidefins, Louvre 0.5	Louver 1	Sidefins 0.5	No Shade
Case 0	ECBC Glaze	-	-	-	-	72.7
Case 1	SglLoE (e2=.2) Clr 6mm	91.52	97.29	181.0	132.97	-
Case 2	DblLoE Spec Sel Tint 6/13mm Argon	67.95	70.64	80.93	84.89	-
Case 3	DblLoE Spec SelClr 6/13mm Arg	72.49	76.15	77.41	97.64	-
Case 4	Dbl. LoE Spec. Slec. Clr 3/13/6mm Argon	72.82	76.33	77.46	98.35	-
Case 5	Dbl. Sage glass Climaplus Green No Tint	64.37	66.78	75.6	80.39	-
Case 6	Dbl. SGG XT 60-28 6/16/4	63.23	65.57	70.21	79.44	-
Case 7	Trp. LoE Film (66) Br. 6/13 Air	69.69	72.41	85.06	84.97	
Case 8	Trp. Sage Glass Climatop Green No Tint	61.86	63.98	74.98	74.72	

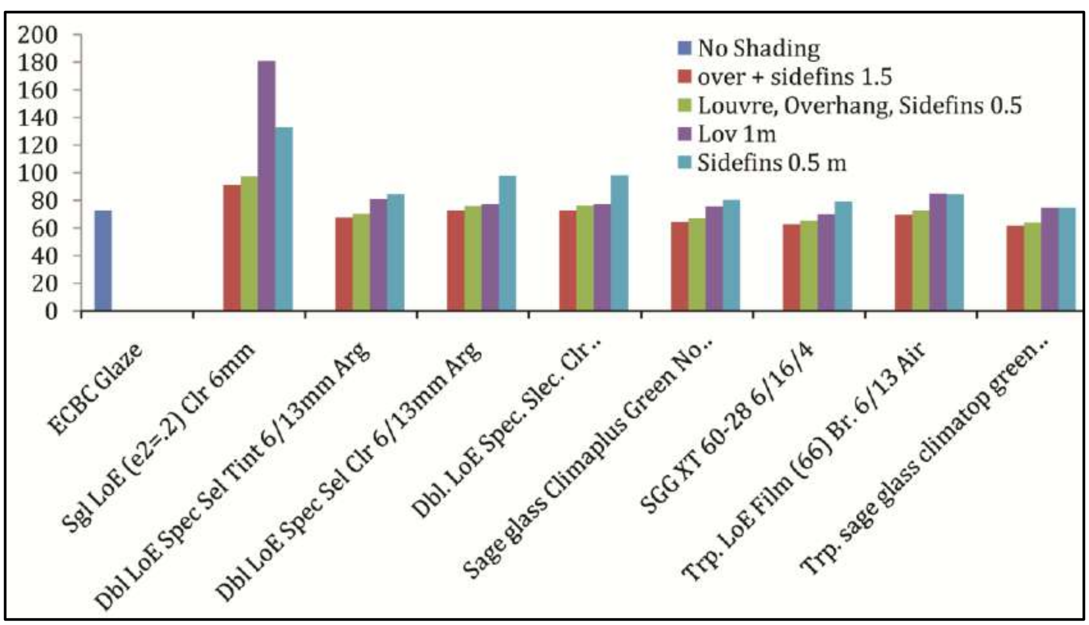

Figure 1 Graphical presentation of annual consumption in kWh/m^2

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Results for All summer Total Energy Consumption of Office Building

As the simulation of reference model is carried on, the same building would be used for further evaluation with different glass types, shading elements, and WWR. So after simulating the building with alternate parameters following results are obtained. From **Table 6**, it is observed that evaluation of building is done for single, double, and triple glass type with four different shading devices.

The single glass shows a poor performance than that of double and triple glass types. Double layer saint global glass along with overhang + sidefins show more energy-efficient performance than the ECBC model. As for all summer, the office building consumes 42.12 kWh/m^2 of energy and from all the triple glass show best energy performance of 40.82 kWh/m^2 for all summer. And so on it is observed that overhang+ sidefines 1.5 are more energy-efficient shading devices that save more energy than that of outer shades. **Figure 2** helps in understanding the energy performance of the building through various parameters consider for the building.

Table 6 All summer total energy consumption kWh/m^2 of proposed building

	Description	Overhang +Sidefins 1.5	Overhang, +Sidefins, Louvre 0.5	Louver 1	Sidefins 0.5	No Shade
Case 0	ECBC Glaze	-	-	-	-	47.35
Case 1	SglLoE (e2=.2) Clr 6mm	60.56	62.9	61.16	78.59	-
Case 2	DblLoE Spec Sel Tint 6/13mm Argon	44.98	46.42	52.85	53.32	-
Case 3	DblLoE Spec SelClr. 6/13mm Argon	48.26	49.94	51.02	60.11	-
Case 4	Dbl. LoE Spec. Slec. Clr 3/13/6mm Argon	48.49	50.13	51.33	60.26	-
Case 5	Dbl. Sage glass Climaplus Green No Tint	42.62	43.87	51.71	50.56	-
Case 6	Dbl. SGG XT 60-s28 6/16/4	42.12	43.27	46.75	50.32	-
Case 7	Trp. LoE Film (66) Br. 6/13 Air	46.03	47.56	54.96	53.4	-
Case 8	Trp. Sage Glass Climatop Green No Tint	40.82	42.01	49.02	47.44	-

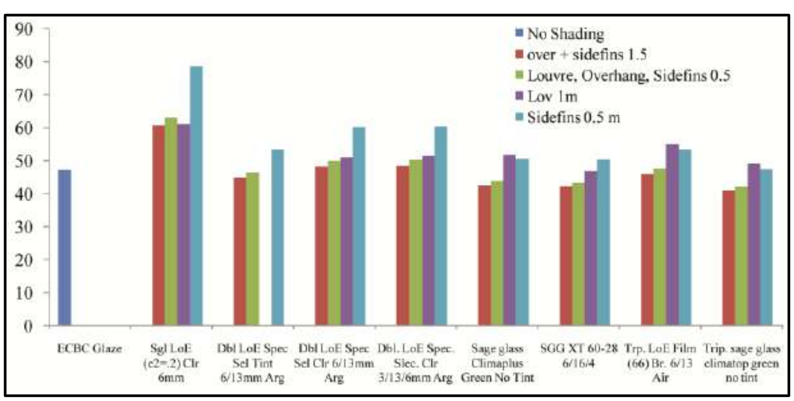

Figure 2 Graphical presentation of all summer consumption in kWh/m^2

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Variations in Energy Save for Annually and All Summer

Evaluating the model for 3 types of glass, 4 types of shading devices, and increased window-wall ratio gave the result with annual energy consumption and all summer energy consumption in kWh/m^2. From **Table 7** the energy save for both annual and all summer energy consumption is calculated with respect to ECBC model, the percent saves in energy is calculated and the following results are accounted single glass consumes more energy in form of heating, cooling, and lighting which is -25.89% annually and -27.89% all summer. Double glass consumes moderate energy which is 13.03% annually and 9.99% all summer. And triple glass saves almost 14.91% of energy annually and 13.79% of energy all summer; this shows the triple glass with overhang &sidefins is more energy-efficient than other two glass types.

Table 7 Energy save for annually and all summer

Type of Glass	Annual Energy Consume kWh/m^2	All Summer Energy Consume kWh/m^2	Energy Save in Percent (Annually)	Energy Save in Percent (All Summer)
ECBC Glaze	72.7	47.35	0%	0%
Single Glass	91.52	60.56	-25.89%	-27.89%
Double Glass	63.23	42.62	13.03%	9.99%
Triple Glass	61.86	40.82	14.91%	13.79%

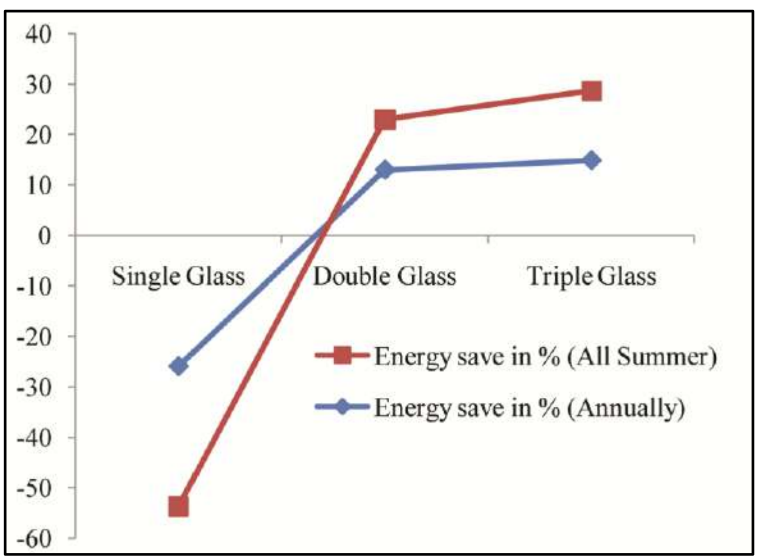

Figure 3 Variation in energy save for annually and all summer

DISCOUNT PAYBACK PERIOD ANALYSIS

The cost of the project was estimated from the DesignBuilder software which shows 254877587.3/- INR for ECBC, 259451577.2/- INR for Double glass saint globin glass, and 333280262.1/- INR for triple-layer sage glass. The payback period is the period required for the initial investment of a model to be recovered by the accumulated savings. It’s a simple method to calculate the period of time the project will recover the cost. A simple calculation was done for the office building with triple-layer glass and shading elements.

The discount payback period was calculated for triple glass as this glass shows more energy-efficient performance of the building. The discount rates were assumed to be 10% and 6% [11]. It was taking 4.86 years for a 10% discount rate and 4.32% for a 6% discount rate. This simple calculation will help to select the project at its initial stage.

CONCLUSIONS

In the present paper, the ECBC model is as reference model 3 parameters are changed to evaluate the energy performance of the building, single, double and triple types of glass with different thermal properties and different gap gas, 4 types of shading elements are used which are of fixed type and increased window-wall ratio of 60% is used.

From the results conclusion are made:

- Case 0- ECBC model is provided as a benchmark for minimizing energy standard and it consumes 72.7 kWh/m^2 of energy for annual total energy and 47.35 kWh/m^2 of energy for all summer consumption by an office building.

- Case 1- Single glass shows poor energy performance even after coupling with shading elements as its least energy consumption is 91.52 kWh/m^2 for annual total and 60.56 kWh/m^2 for all summer.

- Case 2, 3, 4, 5, and 6- Shows the performance of double glass type with all 4 different shading elements out of which Saint Globin Glass shows good energy performance with overhang &sidefins 1.5 shading element i.e. 63.23 kWh/m^2 for annual total energy consumption and 42.12 kWh/m^2 for all summer energy consumption.

- Case 7 and 8- Triple glass-sage shows best energy performance than the rest of the glass with overhang &sidefins shading element and 60% WWR.

- Triple glass when coupled with overhang &sidefins, and 60% WWR, it performs better than other glass as it saves 14.91% of energy annually. The single clear glass performs the worst with -25.89% of energy annually; negative sign represents the overuse of energy concerning the ECBC model. The double glass shows moderate performs as compare to all of 13.03% save in energy annually.

- By performing simple calculation as discount payback period analysis, this helps as a guideline for selecting the project at the initial stage it is not accurate, more variations can be performed but this is a simple calculation for roughly analyzing the project budget. So the calculation for 10% discount rate 4.86 years is observed and 6% discount rate 4.32 years is observed.

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Applications of Geo-textiles for the Stabilization of Soil: A Review

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Abstract: *Soil serves as a support for the construction and effectively distributes load. If the soil is unable to bear load effectively, the structure fails in a variety of ways, including settlement, fractures, and other types of structural collapse. If soil is not properly stable, it sometimes creates a lot of problems for construction engineers, mostly due to the lower bearing capacity of the soil and its high compressibility. Therefore, to increase the load bearing capacity and engineering properties of subsoil (known as Soil Stabilization), a wide range of methods and reinforcing materials are available, such as: geo-textile sheets, geo-grid, metal strips, bar mats, etc. The strength and stability of soil mass can be improved and increased with the help of the stabilization process, and the settlement of structures built on it is reduced. Geo-textile (Geo-synthetic) is a reinforcing material made of thin permeable sheets of synthetic fibres that are widely used in modern engineering practice to strengthen foundations, slopes, crushed stone columns, road pavements, etc. From the various studies done by many researchers in recent years, it is determined that the geo-textile used in all the projects or research work has a significant impact on the properties of the soil. In this paper, before and after putting in the geo-textile, dry density, shear strength, permeability, and CBR values have been compared, and an effort has been made to collect information about soil stabilization using geo-textiles, which includes a brief summary of their procedure and their applications and identifies the different areas that need further attention or improvement.*

Keywords: *Soil Stabilization; Geo-textile; Reinforcement; Sub-grade; Geotechnical Tests*

INTRODUCTION

In olden times, a substantial role in the development of structural engineering was made possible only by parallel developments in building material technology. For the construction of large and elaborate structures, man initially used wood, then limestone, and then cement concrete, reinforced cement concrete, and more recently, pre-stressed reinforced concrete. Whereas, soil and rock are commonly used as geotechnical materials. Whereas, soil and rock are commonly used as geotechnical materials. It is difficult to expect a similar development in geotechnical construction. In geotechnical engineering, a variety of materials are taken to improve the quality of the soil, one of which is geosynthetics (Geotextiles). The use of geotextiles has been described through this research paper. Use of geotextiles increased the tensile resistance capacity of soils. Due to this, the load-carrying capacity of the soil and stability of the soil increased [1].

The soil which has contained silt and clay particles exhibits significant distress signs, including shrinkage and strength loss during the rainy seasons throughout the summer. Because of its expansive behavior, black cotton soil loses its strength during the rainy season. The following are some of the issues with soil expansion (N.B.O. 1962).

When soil is saturated, expansive soils exhibit high plasticity and are compressible. These soils have a high dry strength but become mushy after being saturated. Filling pores and cracks with water accelerates the softening process, reducing shear strength and resulting in limited bearing capacity

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Differential heaving of structures created in the dry season as an outcome of soil swelling throughout the subsequent wet season. Swelling restrictions create swelling pressure, which makes the structures unstable. As a result of the formation of fractures, structures supported on soil lift up. During the dry season, structures constructed at the end of the rainy seasons, when high natural water content, display shrinkage cracks and settlements. Through skin friction, shrinkage causes downward pressure on the foundation, increasing the foundation pressure [2].

Because of these factors, expansive soils must be treated before being used as an engineering material. Soil modification and soil stabilization are the two processes that these treatments are grouped into. The technique of blending and combining things with soils to enhance the specific features of soils is termed "soil stabilization". Blending soils with commercially existing admixtures which affect the texture, stage, or plasticity, or function as the binder of soil cementation, may be part of the process (IRC: SP: 89-2010). Soil modification is a stabilizing procedure by which a change in one or more soil properties occurs without a considerable gain in soil strength or durability.

Various soil stabilization and modification procedures can modify soil qualities such as strength of the soil, compressibility features, its workability, swelling potential, and tendencies to volume change.

Thermal, mechanical, chemical, and electrical methods are used to achieve stabilization. Because thermal and electrical energy are rarely used, there is less information available on them. The use of mechanical energy to densify soil is known as mechanical stabilization or compaction. Densification causes air to be evacuated from soil cavities without any significant changes in the moisture content. This technique can be used to stabilize soils with low cohesion where the compaction energy can promote particle interlocking and the rearrangement. However, if soil is exposed to considerable moistness fluctuations, then procedures are ineffective. Efficiency of compaction might be reduced if the fine content of the soil (fraction less than 75 micron) increases. Because of interparticle connection and rearrangement during compaction, this is the case. For the fine-grained soil to change the physio-chemical properties, chemical stabilization, rather than densification, is a more effective way. Chemical stabilization of the non-cohesive and coarse-grain soil by more than 50% by weight at a grain size greater than 75 microns can be profitable if a significant stabilization response is accomplished in the soil (Dallas and Syam 2009)[2].

Therefore, Geotextiles are expected to be cost-effective, long-lasting, and simple to use. Geotextiles are becoming increasingly important in geotechnical engineering. In this review paper a brief summary of the research work done on soil stabilization using geo-textile.

Geo-synthetic materials are made up of synthetic fiber and polymers used as geotextiles such as polypropylene, polyethylene terephthalate, polyethylene, polyamide etc. Synthetic fibres are utilised in contact with soil, rock, or other geotechnical materials to improve soil engineering properties. Geo-textile, geo-grid, geo-cell, geo-net, geo-membrane, erosion control mat, geo-synthetic clay liner, and geo-composite are some of the most common geo-synthetics [1]. The most extensively utilized geo-synthetics are geo-textiles. The nylon bags filled with sand employed in the Dutch Delta Works in 1956 can be regarded as the first known application of geo-textiles.

For the past 60 years, geotextiles have been frequently utilized in geotechnical engineering. Geotextiles can help with separation, filtration, drainage, reinforcement and stabilization, barrier, and erosion protection in geotechnical engineering [3].

Every year, more than 1.4 billion square metres of geotextiles are utilized, and this tendency is expected to continue. Approximately 98 percent of geotextiles are made of non-biodegradable polymers from the polyester, polyolefin, or polyamide families. Long-term use of geo-textiles may result in the breakup of synthetic polymer, results in the form of accumulation of microplastics in the surrounding environment, due to a variety of environmental conditions such as friction, wind, moisture, and UV radiation.

Furthermore, when geotextiles are used in geotechnical engineering, they raises the performance requirements of geotextiles [3].

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As a result, geo-textiles are thought to be cost-effective, long-lasting, and simple to utilize. Geotextiles are becoming increasingly important in the field of geotechnical engineering. The main objective of paper is to deliver a quick overview of the research on soil stabilization using geotextiles which have been done by many researchers.

MATERIAL AND METHODOLOGY

Materials and methodology for 'Application of Geotextiles for the stabilization of soil' used by different researchers are given below-

Talal o. AI-Refeai (1999) worked to understand the resilient behavior of a weak subgrade soil with the geotextile reinforcement which is laid on the soil subgrade. The effect of deviator stress and confining stress on the resilient behavior of a base subgrade arrangement provided with a nonwoven geotextile reinforcement layer has received special attention. They studied the influence of nonwoven geo-textile on the resilient and plastic behavior of a sub-grade geo-textile base system by conducting a series of cyclic triaxial tests on two different soils (coarse sand as a base material and clayey silty sand as a sub-grade material) [5].

E.A. Subaida et al. (2010) conducted an experimental investigation to determine the benefits of using fabricated coir geotextiles in place of reinforcing material in the pavement section. A robust circular plate in acres was used to put on monotonic and consistent loads on both the reinforced laboratory road sections and unreinforced road sections. The impacts of estimated geotextile position and stiffness were examined with the help of using dual base courses and 2 types of woven coir geotextiles[12].

Abhijith R.P. (2015) The natural coir fibers' importance on approved roads is presented through an experimental study. The coir fibres provide a reinforcing action on the subgrade soils. Coir fibre is a natural material derived from coconut husk. Coir fibre is commonly found in many places in India. Use of coir fibre improves the strength of sub grade soil. Coir fibres of varying lengths from 0.5 to 3 cm and 2 to 8 per cent of the total soil weight are mixed and a correlation is made by the CBR test. As a result, the introduction of soil at two-thirds of the depth appears to be more effective. Reinforcement action is necessary during the initial phase; thereafter, reinforcement action is achieved by consolidation of subgrade soil [13].

Sugandini and Madhuri (2017) worked on soil geo-synthetics (including geo-textile) interaction properties for four types of soils (Red laterite, Marine clay, Black Cotton Soil, and Sandy soils) were used with the geo-composite reinforcing materials and CBR tests were conducted to find out the density of the soil samples and the mechanical strength of the sub-grade soil. The main objective of the work is to study the effect of the strength of the soil after the application of geo-synthetics [8].

D.A. Ogundare et al. (2018) explored the use of non-woven geotextiles in sub-grade material as a road building reinforcement. They assessed two soil samples for sub-grade suitability based on their geotechnical qualities. According to the AASHTO, virgin soil samples A and B, which are classified as A – 7 – 5 and A – 7 – 6, respectively, are weak sub-grade materials.

Compaction experiments were conducted by using a hard metal mould with a height of 175 mm and an interior diameter of 150 mm for this experiment. Soil samples were compacted into three layers, each with 25 blows of a 2.5 kg rammer falling from a height of 310 mm.

The CBR tests were carried out in a single layer of soil (compressed soil) in unsoaked conditions without reinforcement and placed at a depth h/4 from the top surface and base surfaces of the soil sample in a mould with reinforced non-woven geotextiles. Load values corresponding to the results were noted at 0.25, 0.5, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.5 and 8.00 (all values in millimetre) [4].

Vivek et al. (2018) stabilized the soil by using coir geo-textile and described its use, which provides knowledge about the enhancement of soil properties with the results of CBR and shear tests carried out before and after the treatment [7].

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Prasad and Satyanarayana (2018) In his study examined, to improve the soft marine clay, silica-manganese slag mixed with sand was used as stone column material, and geo-textile material was employed to support the stone columns as reinforcement. This geo-textile was cut into circular discs and placed horizontally within the stone column at a 50 mm interval (equivalent to the stone column's diameter "D").

Marine clay, Silica-Manganese slag, Sand and Geo-textile were used in his study. For the preparation of the geo-textile reinforced stone column, after the clay bed was prepared to a depth of 100 mm at the bottom, a PVC pipe of 5cm in outer diameter and 1mm thick was located at the centre of the tank, and the clay bed was prepared to the outside of the pipe in 50 mm layers up to the remaining height of 200 mm, which is prepared similar to the procedure used to prepare the plain stone column. The reinforced stone column was constructed for different reinforcement lengths and was prepared in two stages, i.e., the unreinforced and reinforced portions. To construct the fully reinforced (D) stone columns, the geo-textile discs were placed at specified intervals of "D" within the stone column trial and the compaction was done similar to the unreinforced column. To construct the partially reinforced stone column (D/2D/3D), the bottom unreinforced portion was constructed similar to the unreinforced portion and the upper reinforced portion.

After completion of the stone column, it was kept for 24 hours for moisture equalization and to improve the bonding between the aggregates and the clay bed. After the load tests were conducted for the clay bed, unreinforced and reinforced stone columns, load settlement graphs were drawn and the ultimate load and corresponding settlements were determined by drawing double tangent method [9].

G.G. Janakiraman et al. (2019) focused on better understanding of natural and artificial geo-textiles for strengthening of subgrade soil and evaluated the effect of reinforcement of geo-textiles on subgrade soil. For this, they took five dissimilar geo-textiles (composite geo-textile, Geo-bag geo-textile, Hot Bound geo-textile, Coir geo-textile, non-Woven geo-textile) and the load-penetration performance of granular soil reinforced with geotextiles was examined in the laboratory by the California Bearing Ratio test. Granular soil specimens of various gradings are selected and tested for lack of reinforcement.

A field CBR test was conducted on soil filled with a ground grid in test pits. Test pits of a size of 0.5 m × 0.5 m × 0.5 m were excavated and filled with moisture-retaining soils having moisture content and density. In order to ensure the density and moisture after filling, the core cutter test is carried out on the loaded soil.

The field density and moisture content have been measured. The soil filling with and without geogrid was subjected to a CBR test. For all testing on geo-grid reinforced soil beds, a single layer of geo-grid is laid at the mid-height of the soil in the pit. The experiment is repeated with different geo-grids and soil fill levels. The load is applied via the response loading technique, which is aided by the truck [11].

Tanvi Singh et. al. (2020) examined the strength enhancement with the help of experimental investigation. The main objective of their investigation was to decrease the pavement thickness and to rise the strength of pavement structures by using geo-textile as reinforcement material and in their experiments they also included the study on the effect of type of geo-textile used for reinforcement, effect of position of reinforcement layer, effect of number of layer of reinforcement, prediction of CBR values using ANN and M5P, Prediction for woven geo-textile, prediction for non-woven geo-textile [6].

RESULTS AND DISCUSSIONS

Based on the above materials and methodology used by researchers, they came to results as given below:

Talal o. AI-Refeai (1999) according to the results of the experimental investigations, the resilient modulus of the sub-grade geo-textile base system increases as the confining stress grows and drops as the deviator stress increases. In contrast to the very little influence of geo-textile inclusion on k3, the influence of geo-textile on k2 is significant, implying that the relative sensitivity of the sub-grade geo-textile-base system to changes in deviator stress is lower than that of the sub-grade base system.

Behavior of Geo-textile Reinforced Sand on WeakSub-grade231. Because of confining and deviator stresses, the AASHTO models (equations 1 and 2) may be unable to predict the change in resilient modulus of sub-grade geotextile-base systems. The addition of nonwoven geotextile to the sub-grade geotextile base system resulted in just a minor increase in the system's resilience modulus of around 14%. The presence of geotextile improved the plastic behaviour of the sub-grade geotextile-base system and reduced permanent deformation by almost 50%.

The findings indicate that the use of the geotextile had no significant effect on the resilient modulus (increase of only 14 percent). Permanent deformation, on the other hand, was significantly reduced (by 50%). [5].

E.A. Subaida et al (2010) By use of coir geotextiles improved the bearing capacity of thin sections, according to E. A. Subaida et al. The load-carrying capability of geotextile applied at the interface of the subgrade and base course was significantly increased during major deformations. When coir geo-textile placed within the base path at all stages of deformations, there was a significant increase in bearing capacity. The coir geotextile was developed to be installed one-third of the plate diameter under the surface in the base course. [12]

Abhijith R.P (2015) The results of Abhijith R.P (2015) concluded that introducing Geo-textiles at a depth of two-thirds from the bottom was more successful. The initial reinforcing activity is required, and later reinforcing action is produced through the consolidation of subgrade soil. [13]

D.A. Ogundare et. al. (2018) It is observed that when the two soil samples were reinforced with non-woven geo-textile, there was an increase in their CBR values in unsoaked condition (15% and 21%) than when equated with their CBR values (4% and 7%) without reinforcement which shows that the soil sample reinforced with nonwoven geo-textile are suitable for sub-grade as established under the specification of the Federal Ministry of Works (1997) criteria for sub-grade soils.

Table 1 Summary of preliminary test results

Classification (BIS)	**G M**	**G C**	**G W**
Liquid-limit (%)	35.50	43.50	23.00
Plastic-limit (%)	20.20	29.40	-
Plasticity-index (%)	15.30	14.10	-
Specific-gravity (g)	2.70	2.63	1.98

Table 2 CBR values under Soaked Condition

Soil samples	**Without nonwoven geotextile**		**C B R value (%)**	**With nonwoven geotextile**		**C B R value (%)**
	2.5mm	**5.0mm**		**2.5mm**	**5.0mm**	
Samples A	2.8	3.2	3.2	9.6	9.7	10.0
Samples B	5.2	6.0	6.0	15.8	13.8	16.0
Samples C	1.4	1.5	2.0	2.8	2.6	3.0

According to their experimental data, the application of non-woven geo-textile at various depths, as measured by the California Bearing Ratio (CBR), generally increases the strength of the sub-grade soil, irrespective of the level at which the non-woven geo-textile is installed within the thickness of the sub-grade.

Prasad and Satyanarayana (2018) from their study, following conclusions were derived-

Load carrying capacity of the soft clay can be increased by introducing the stone column and also by adding the sand to the stone column by minimizing the voids between the aggregates. Load carrying capacities are increased to

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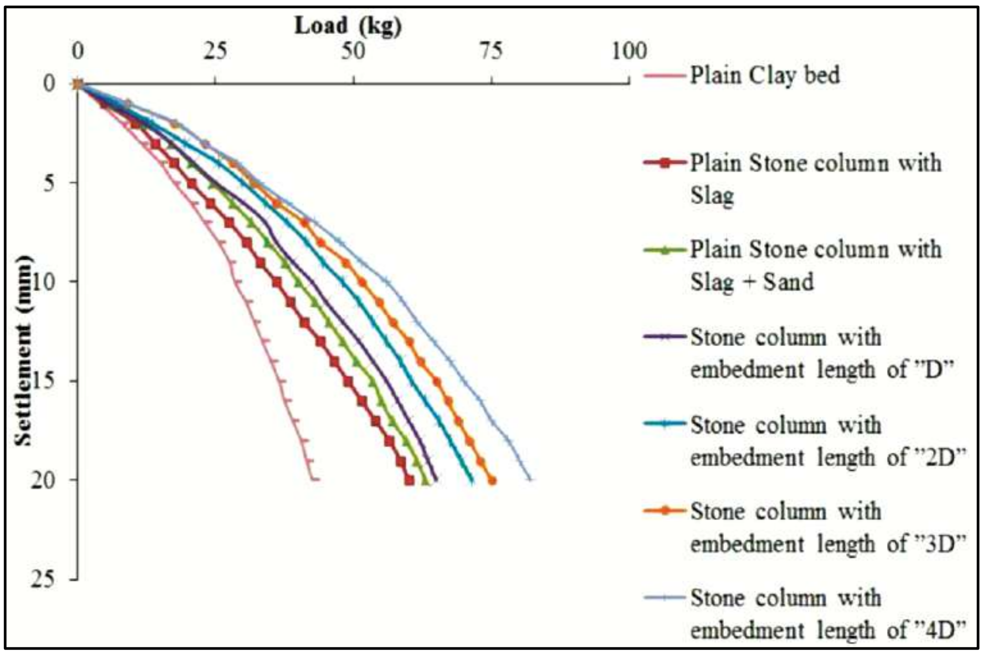
32% and 43% by improving the soil with the Slag column and Slag Sand column respectively. Stone column performance can be increased by introducing the lateral geotextile discs within the column.

Load carrying capacity can be increased by increasing the embedment length of reinforcement.

Settlements can be reduced by improving the soil with stone column and also with the reinforcement length. Settlement of the clay bed was reduced from 10 mm to 4.0 mm by reinforcing the soil with the reinforcement length of 4D. Bulging of the stone column can be reduced by introducing the reinforcement and also with the reinforcement length. Bulging of the plain stone column was reduced from 7.5 mm to 5.5 mm by reinforcing with geo-textile to a length of 4D. The maximum bulging for the unreinforced stone column was found at the middle of the column. Whereas for the reinforced columns, the maximum bulging found below the end of thereinforcement. The results indicate that the soft soil can be improved with the stone column and can be further stabilized with the geo-textile reinforcement [9].



Graph 1 Source- Prasad and Satyanarayana, 2018

BULGING ANALYSIS OF STONE COLUMNS

After the load testing, the slag aggregates were removed, and the hole created in the clay bed was filled with plaster of Paris paste and allowed to set for one day before the surrounding clay was removed to get the deformed shape. The bulging behaviour of the columns was investigated after measuring deformations at 2.5cm intervals throughout the length of the stone columns. The column's depth vs bulging is displayed on a graph.

Graph 2 depicts the bulging curves of unreinforced and reinforced stone columns with different reinforcing depths. The core of the stone columns that were not reinforced had the largest bulging of 10 mm. The maximum bulging of the stone column was reduced to 8.1 mm using slag+sand. The addition of reinforcement lowered this even more, resulting in maximum bulging of 7.0 mm, 6.5 mm, 6.0 mm, and 4.0 mm for reinforcement lengths of D, 2D, 3D, and 4D, respectively.

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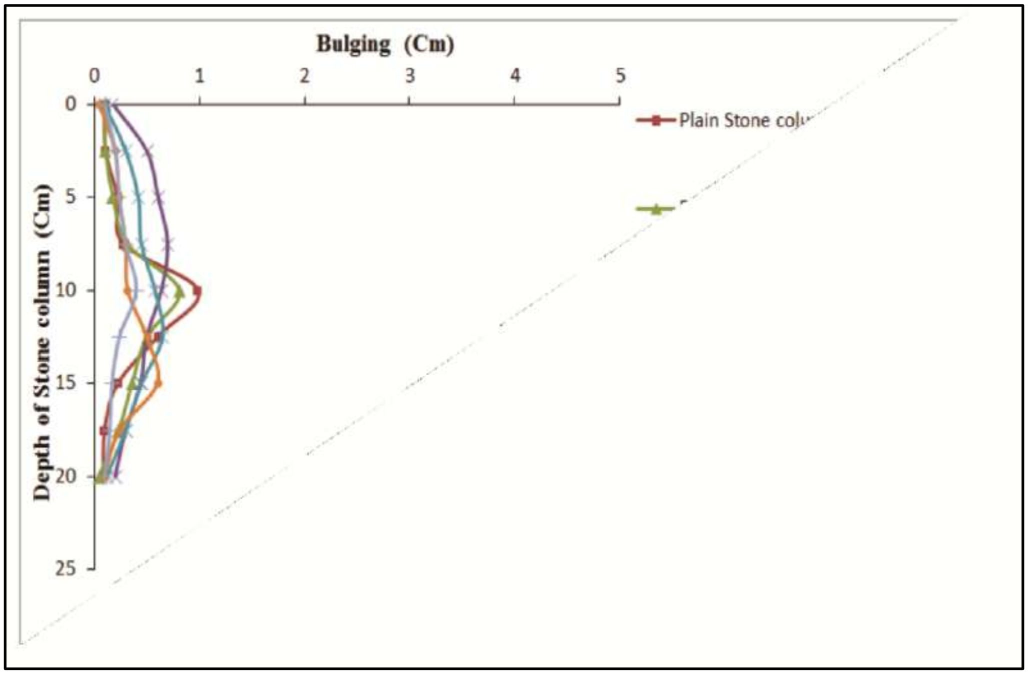

Graph 2 Source- Prasad and Satyanarayana, 2018

G.G. Janakiraman et. al. (2019) from their study, following conclusions were derived-

Soil that has been reinforced with geo-synthetics (natural or synthetic geotextiles) becomes stronger and stiffer than soil that has not been reinforced. Placing geotextile material in soil enhances the soil's bearing ability and load carrying capacity, extending the pavement's service life. Experimental tests revealed a significant increase in subgrade strength, verifying the theoretical aspects. When geo-synthetics are utilized in pavements, they provide a variety of purposes such as strengthening, separation, drainage, and filtering. Grain size analysis, Atterberg, compaction, and the California bearing ratio test were all recognized as geotechnical tests. To determine the strength of the soil, CBR tests were carried out by inserting geo-grids at varied depths and in a single layer under unsoaked conditions. As a result of incorporating geo-grids into the soil, the strength of the subgrade has also been significantly increased. It was discovered that geo-grids located 3/5 of the way from the base had a higher CBR value than those placed 2/5 and 4/5 of the way from the base. As the number of layers of geo-grids increases, changes in the behavior of the soil under unsoaked conditions emerge. It has showed a significant effect of improvement as a subgrade stabilizer. It has a quick preservation time, is corrosion resistant, and extends the road pavement's service life. The results of these studies show that adding geotextile to reinforced granular soils raises the bearing ratio. As a result, geotextile should be used as a more current approach of enhancing road construction on weak subgrade materials.[11].

Tanvi Singh et. al. (2020) were examined the effect of reinforcing woven and non-woven geo- textile at different depth of reinforcement in single and double layer in terms of CBR value in their research work. Further for prediction of CBR, ANN and M5P modeling approaches were used. Vital outcomes of their research are listed below: Strength of sub-grade soil was enhancing upon reinforcement with both woven and non- woven geo- textile. Rise in strength with reference to parent soil was noticed from 19.79% to 188.23% depending on the position of reinforcement, type of geo-textile laid and number of layers ofreinforcement.

Sub-grade soil reinforced with woven geo-textile gives better result when reinforced with to nonwoven geo- textile for all position of reinforcement and for both single and doublelayer. Optimum benefit of reinforcement was marked only if position of reinforcement of geo- textile layer is at M/3 and M/2 for both woven and non-wovengeo-textile.

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Increment ratio of double layer of reinforcement for both woven and non-woven was greater than of respective single layer. Performance of M5P predicts the CBR value for woven was better thanANN. Performance of ANN to predict the CBR value for non-woven was betterthanM5P.

S. Ramjiram Thakur et. al. (2021) In the laboratory, they performed California bearing ratio (CBR) tests and came to the following conclusions- The addition of nonwoven geotextile materials to soils improves CBR and, as a result, soil strength. In many earthen structures, geotextile-reinforced soils will perform unreinforced soils, increasing load-carrying capacity.

CONCLUSIONS

Different articles and journals reviewed above tell us about the different properties and uses of geo-textiles when used in different fields and areas of civil work. It is concluded that the geo-textile used in all the research work or projects has an important impact on the enhancement of soil properties.

Shear strength, permeability, dry density, and CBR were determined before and after the geotextile was installed. Shear strength, dry density, and CBR enhanced by the addition of geotextiles, whereas permeability and penetration (check for settlement) decreased, indicating a significant improvement in engineering behaviour. As a result, geo-textiles serve a critical role in improving soil qualities by lowering compressibility and boosting strength. Because the future of geotextiles is very dynamic and will be motivated by different aspects such as cost, performance, and resource availability, there is a lot of need for more research in this area. Today, there are various competing philosophies in the field of geotextile use. On the one hand, there is an increasing demand for environmentally acceptable geotextiles, and on the other hand, there is a continuing need to make use of natural resources. The following is a list of potential research topics for future work.

The current study could be expanded to include other types of geotextiles and soils. More advanced technology, precise application procedures, and maintenance can be used in investigations including soft soil reinforcement. Field tests can be conducted to obtain more useful results. Degradation aspects and their impacts are frequently addressed in studies.

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Consequence of Removal of Arbitration Clause from Engineering Contracts — A Discussion

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Abstract: *The arbitration clause which was an integral part of the Engineering Contract in India is presently a matter of considerable debate. This is because of the obvious reason that there are many instances where abuse of the arbitration clause in the Engineering contract has been made. There is an well-established legal system in India and any plaintiff who is a party to Engineering contract can bring a suit to a court of law if he feels that injustice has been performed and contractual clauses has not been adhered to. The legal system is very formal and substantial time is consumed before the issue is settled through the intervention of the court of law. As time being the essence of contract, especially engineering contract where delayed decision for contractual dispute resolution may actually affect infrastructural development and overall well being of the citizen of the country, alternative dispute resolution system through an arbitral mechanism is preferable practise. However some long drawn and costly arbitration proceedings for dispute resolution of Engineering contract has become one of the major reason for discouraging arbitration in engineering contracts. To facilitate arbitration, an arbitration agreement should executed between the contracting parties. The agreement is generally in the form of an arbitration clause in the Engineering contract. But various Government and Semi Government Engineering departments who invite tenders for large Engineering projects has either done with the arbitration clause by introducing departmental dispute resolution committee or have issued conditional arbitration clause fixing financial ceiling of tender amount for taking arbitration proceedings. In this article it is proposed to discuss the consequences which shall fall due to discouraging or removal of arbitration clause from engineering contracts.*

Keywords: *Engineering Contract; Contract Act; Engineering Arbitration; Alternative Dispute Resolution*

INTRODUCTION

The first major mile stone in the professional Engineering field of India was the formation of the largest professional body of Engineers called the Institution of Engineers (India) (IEI) way back in 1921, which was subsequently incorporated by a Royal charter issued by the British crown in 1935, granted by King George –V. The institution was formed with the intention "to promote and advance the science, practice and business of Engineering in all its branches in India". As per provisions of clause no. 2(i) of the Royal Charter reads "to arrange and promote the adoption of equitable forms of contracts and other documents used in the Engineering and settlement of disputes by arbitration and to act as or nominate arbitrators and umpires on such terms and in such cases as may seem expedient". The Royal charter awarded to the IEI the only Engineering institution of the Indian Engineers even before independence of India clearly reflected the intention of the Indian engineering community to resolve matters of disputes arising in Engineering Contract through process of arbitration rather than going to the Civil court for disposal of the issue. It is beyond doubt that the rationale for adopting arbitration process for resolving disputes relating to Engineering contracts provides a cheap and quick final settlement of the dispute of civil nature without direct intervention of the court. Building and Engineering contracts usually involve various technical points which can be speedily resolved by appointing competent and experienced arbitrators who have Engineering background and have retired from higher capacity such as that of Superintending Engineer or Chief Engineer of various works department of Government. Arbitration proceedings also have the added advantage of privacy and a less formal atmosphere then a Court of Law. The efficacy of arbitration provision over the general legal procedure may be

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categorised into (i) less time consuming (ii) less costly than proceeding through law courts (iii) more convenient method of disposal of disputes in Engineering Contracts. Time being the essence of Contract, if the contract is delayed due to dispute between client and the contractor or the client and the consultant, then the progress of the Engineering project is adversely affected. Arbitration here acts as an effective vehicle for delivery of speedy, effective and less formal form of dispute resolution mechanism. But it is often reported that the effective instrument of alternative dispute resolution, is not effectively applied and arbitration proceedings takes long time to conclude sometimes even for years together making it costly and frustrating the very objective for adopting arbitration for dispute resolution. It is also observed that certain arbitration minded contractors has the sole purpose to misuse the provisions of arbitration agreement in the contract document to extract more financial benefit from the client (often Government client) without actually executing the desired performance embodied within the engineering contract in terms of work specification. Such incidents have raised much questions about the actual benefits obtained out of arbitration. But inspite of some stray incidents of misuse of arbitration provision the overall benefit of arbitration in dispute resolution in engineering contract is manifold and cannot be undermined in any way.

SUITABILITY OF ARBITRATION FOR ENGINEERING CONTRACTS

(i) The procedure of a Civil suit in a Court of law is very formal (guided by provisions of Civil Procedure Code1908 with amendment 2002). Every fact will have to be pleaded in the plaint or the written statement. This makes the written statement very voluminous. However there are certain obvious facts in Engineering which need not be specifically stated. For example reinforced concrete work cannot be cast without shuttering or reinforcement. Again excavation below the ground cannot be done without dewatering arrangement. But even these obvious facts are required to be clearly stated in the statement of facts. This would require a proper and effective co-ordination between the Engineer and the advocate while preparing the legal document. Any omission of terminology in the written statement shall provide benefit to the unscrupulous and litigious document. Thus the case may be lost merely due to weakness of technical representation in written statement. However if the arbitrator is from Engineering background obvious technical facts may not be required to be stated explicitly as the individual is well acquainted with the technicalities due to wide experience in the concerned field.

(ii) During arbitration the time and place of sitting is habitually settled through mutual consent. The civil court will not permit such freedom. Thus if a Superintending Engineer failed to attend the court for oral evidence because the Chief Engineer had called for an urgent meeting the court may take “adverse presumption”. The honourable Court may interpret that had the Superintending Engineer appeared before the Court the evidence may not have gone in favour of the Government or the Government official is not co-operating with the Court in the matter of the legal proceedings. Thus the court may issue a punishment order against the Government official. But such problems could be avoided in case of an arbitration.

(iii) If there is provision for arbitration in an engineering contract it shall be possible to argue about various issues before an experienced Engineer arbitrator in a relatively informal ambience.

(iv) In many of the Engineering contracts related matters if the disputes are directly brought to the honourable Court sometimes there are possibilities that miscarriage of justice may happen due to want of proper interpretation of technical terminologies. In such case it is the honourable Justice may invite the opinion of a technical expert. Thus the judgement is much influenced by the conclusion drawn by the technical expert. Engineering is a practical subject, the interpretation given by a technical expert would actually be limited to the expertise of the individual in the particular field of Engineering. It is often difficult to obtain an expert with exact technical knowhow. Such as it is well known that in deep excavation it is required to provide earth retaining structure to prevent the caving in of the deep excavation. Earth retaining structure may be of various forms, such as sheet pile, brick retaining wall, Cantilever retaining wall, Reinforced Concrete diaphragm wall etc. Now the type of the retaining wall to be provided at the site depends on the design consideration and nature of the site. An expert may be experienced with deep excavation, but the technology used for execution of sheet pile work is quite different from that required for the work of diaphragm wall. Although the basic function of both this type of earth retaining structure is the same but the utility of the particular type of construction is site specific. Hence the expert testimony of an individual having experience with sheet pile wall

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construction may not be at all useful it the work actually requires diaphragm wall construction. However if the arbitrator is a civil engineer himself with wide experience and professional knowledge then it would not be difficult for him to enquire into the exact technicalities of the Engineering work to be executed. The stated example highlights the efficiency and beauty of the arbitration process for efficient dispute resolution in engineering contracts.

IMPLICATION OF REMOVAL OF ARBITRATION CLAUSE

Any valid Engineering contract in India should be defined as per provisions of the Indian Contract Act 1872. As per section 28 of the Indian Contract act any contract agreement to be valid should not contain any restrictive clause or provision which shall prevent any party involved in the agreement from suing the other party if the party feels that he has been deprived as per provisions of the agreement. Removal of arbitration clause in a way restricts the parties involved in the contract agreement to avail the instrument of dispute resolution through arbitration. Time being the essence of any engineering contract long drawn trials at the court in many cases virtually hampers the progress of the Engineering projects.

MODIFICATION IN ARBITRATION PROVISION IN GOVERNMENT CONTRACTS

Understanding the fact that the arbitration clause in the tender documents of Engineering works, especially in Government departments has been misused many a times by ligation minded contractors, authorities of many works department of the Government across the country has decided to cause removal of the clause or have placed restriction in tenders before taking recourse to arbitration. We may state as an example the standard bid document of the Kerala PWD[1]for works of value above Rs. 5.0 Crores, which under clause no. 79.1 reads "Arbitration shall not be a means of settlement of any dispute or claim out of this contract. All disputes and differences arising out of the contract may be resolved through discussion between the employer and the contractor within the preview of the contract agreement. If such discussions are not fruitful the disputes shall be settled only by the civil court in whose jurisdiction the work covered by the contract is situated or in whose jurisdiction the contract was entered into in case the work extended to the jurisdiction of more than one court". The above paragraph clearly indicated that the Kerala PWD has totally done with the arbitration clause in tender documents.

The CPWD in the clause number 25 of the contract agreement provides for settlement of contractual dispute through arbitration. But clause 25 of CPWD contract agreement[2] provides for conditional arbitration. As per provision the aggrieved contractor/agency should first approach the Superintending Engineer of the concerned Circle for redressing the dispute. If the Superintending Engineer fails to give decision within 15 days from receipt of the prayer concerned the contractor should now approach the Chief Engineer concerned who shall give decision within 30 days of receipt of the prayer, failing which the contractor may appeal to the dispute redressal committee for redressal of the dispute. If the dispute redressal committee fails to give decision then the aggrieved party may within a period of 30 days give notice to the Chief Engineer for appointment of arbitrator in the prescribed form. Thus the terms of contract clearly indicates that the aggrieved contractor should exhaust the entire mechanism of settlement of claims/disputes prior to invoking arbitration. Hence in other words arbitration is critically observed.

In the similar line the Maharastra PWD[3] vide section 3, clause number 24 of the standard bidding document requires for referring the contractual dispute to the departmental dispute review expert within 14 days of notification of the Engineer's decision, if such decision appears to be wrongly taken as per provisions of the contract agreement. The Departmental review expert in this case has been defined as the Superintending Engineer of the Circle whose decision shall be binding. However if the aggrieved contractor is unhappy with decision given by the Superintending Engineer, the contractor may appeal to the Chief Engineer within thirty days. If the contractor is not satisfied with the order passed by the Chief Engineer, he may again appeal within 30 days of receipt of such order to the Secretary of PWD. If he is convinced prima facie that there is substance in the claim of the contractor and that the claim rejected by the Superintending Engineer and The Chief Engineer is not frivolous the matter shall be put upto the standing committee of the Government for suitable decision. For works of value above Rs 5.0 Crores the procedure for arbitration shall be as per Government rules and procedure drawn up by the law and judiciary department of Government of Maharastra regarding "Institutional Arbitration Policy".

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In the state of Bihar[4], arbitration for engineering contracts are under the preview of the Bihar Public works contracts dispute arbitration tribunal Act 2008. The act provides for the constitution of a tribunal to arbitrate into disputes arising from works contracts to which the state Government or public sector undertaking is a party. The tribunal was formed in the interest of expeditious dispute resolution for speedy execution of projects. The tribunal consisted of a Chairman and such number of members who may be appointed by the State Government. The Chairman should be a judge of the High court or a District Judge with atleast 5 years of experience. The member should be or have been either a secretary to the Government of Bihar for atleast 3 years or Engineer-in-Chief or Chief Engineer for atleast 2 years of Superintending Engineer for atleast 3 years. The tenure of Chairman and members are renewed after every 3 years. The tribunal is vested with the powers of a civil court.

As per provisions of notification no. 558/SPW dated 13/12/2011[5] the PWD West Bengal has omitted the arbitration clause i.e clause no. 25 from the tender forms of contract. The Government in the said notification indicated that “Whereas the matter of dispensing with the resolution, through arbitration, of disputes arising out of the contracts entered into by this department with the contractors for the purpose of carrying out execution of public works has been under active consideration of the Government for some time past in order to get rid of the complicacies being encountered in the process;

Now, therefore the Governor after careful consideration of the matter is pleased hereby to say that there shall henceforth be no provision for arbitration for resolution of disputes that may arise out of the contracts to be entered into by this department with the contractors for the purpose of carrying out execution of Public Works and hence the West Bengal Form no. 2911/2911(i)/2911(ii) shall stand amended in the following manner:-

Clause 25 of the Conditions of Contract of the West Bengal Form No. 2911/2911(i)/2911(ii) shall be omitted”. The tender forms have been subsequently modifiedin PWD WB[6] by formation of dispute redressal committee vide provisions of Government G.O.No.8182-F(y) dated 26/9/2012 of the Finance Department. The clause number 25 reads “Except where otherwise provided in the contract. All questions and disputes relating to the meaning of specifications, designs, drawings and instructions, herein before mentioned and as to the quality of workmanship of materials used on the work or as to any other question, claim, right, matter or thing whatsoever, in any way arising out of relating to contracts, designs, drawings, specifications, estimates, instructions, orders or these conditions or otherwise concerning the works, or the executions or failure to execute the same, whether arising during the progress of the work, or after the completion or abandonment thereof shall be dealt with as mentioned hereinafter: If the contractor considers any work demanded of him/her to be outside the requirement of the contract, or disputes any drawing , record or decision given in writing the Engineer-in-charge or any matter in connection with or arising out of the contract or carrying out of the work to be unacceptable, he/she shall promptly within 15 days request the chairman of the Departmental dispute redressal committee formed by the Government, in written for written instruction or decision. Thereupon, the Dispute redressal committee shall give its written instruction or decision within a period of three months from the date of receipt of the contractor’s letter. Above provisions will be applicable irrespective of the value of the works to which the dispute may relate.” The Dispute redressal committee in the works department shall be constituted with the following officials as members:-

(i) Additional Chief Secretary/ Principal secretary/ Secretary of the Department concerned as Chairman,

(ii) Engineer-in-Chief/Chief Engineer or any officer of the equivalent rank of the Department as member,

(iii) One designated Chief Engineer/Engineer of the Department to be nominated by the Department as Member Secretary and Convenor,

(iv) One representative of the Finance Department of the Government not below the rank of Joint Secretary or Financial advisor in Case of works department as member.

This clause has been introduced by replacing the previous version of the clause 25 which runs as, “Except where otherwise provided in the contract. All questions and disputes relating to the meaning of specifications, designs, drawings and instructions, herein before mentioned and as to the quality of workmanship of materials used on the work or as to any other question, claim, right, matter or thing whatsoever, in any way arising out of relating to contracts, designs, drawings, specifications, estimates, instructions, orders or these conditions or otherwise concerning the works, or the executions or failure to execute the same, whether arising during the progress of the work, or after the completion or abandonment thereof shall be referred to the sole arbitration of the Chief Engineer of the department. Should the Chief Engineer be for any reason unwilling or unable to act as such arbitrator, such questions and disputes shall be referred to an arbitrator to be appointed by the Chief Engineer. The award of the arbitrator shall be final conclusive and binding on all the parties to this contract. The award shall be a speaking one, i.e the arbitrator shall recite facts and reasons arising in support of the award after discussing fully the claims and conditions of the parties." The above clause was valid only for works of value above Rs 100 Lakhs.

AMENDMENT TO ARBITRATION AND CONCILIATION ACT 1996

The Arbitration and Conciliation act 1996 which is the principal act has been recently amended recently twice once in 2015 and again in 2019. The amendment act has brought various significant changes to the 1996 act. The amendment act seeks to establish and incorporate under section 43A[7] Arbitration Council of India. The council has been defined as a body corporate having perpetual succession and common seal. The council shall be established by the Central Government through notification in the official gazette.

As defined under clause 43C(i) (a)[7] the council shall consist of a chairperson who has been a Judge of the Supreme Court of India, Chief Justice of a High Court or a Judge of the High court or an eminent person having specialized knowledge in the administration of arbitration. A member who shall be an eminent practitioner of arbitration and an eminent academician having experience in research and teaching of arbitration and alternative dispute resolution system. The Chairperson shall be appointed by the Central Government in consultation with the Chief justice of India. The member shall be nominated by the Central Government. An eminent academician shall be appointed by the Central Government in consultation with the Chairperson. Beside this there shall be ex-office members from the Ministry of law and Justice, Ministry of Finance department of Expenditure not below the rank of joint Secretary, and one part time member from recognised body of commerce and industry on rotational basis to be chosen by the Central Government. The Chief Executive Officer shall be the ex-officio Member Secretary. The Chairperson, Member of the council shall hold office for a term of three years only.

The duty of the council as defined under section 43D(1)[7] shall be to promote and encourage arbitration, mediation and conciliation or other alternative dispute resolution mechanism the council shall also frame policy and guideline for establishment of professional standard for arbitration. The duties of the Arbitration Council of India (refer section 43 D(2)[7]) includes the following:-

- Framing policy for grading of arbitration institutions;
- Recognition of professional institutions for accreditation of arbitrators;
- To promote institutional arbitration;
- To hold training, workshops and courses in arbitration in collaboration with law firms and institutes;
- To conduct examinations on various subjects related to arbitration;
- To make recommendations to the Central Government in the matters of arbitration; and several such other important functions.

The 1996 version of the Act specifies that the minimum required qualification of a person to be an arbitrator should be one who is competent to contract provided that the person should be of sound mind and shall not have any relationship with the parties involved in arbitration. However the amendment act specifically indicates and binds the qualification of the arbitrators. As per provisions of section 43J[7] of the amendment act the qualification, experience and norms for accreditation of arbitrators are mentioned under the eight schedule. The person shall not be qualified as an arbitrator unless he is an advocate or Chartered accountant or Cost Accountant or Company Secretary with ten years of experience or an Officer of Indian legal service or Government officer working in Government or Autonomous body or Public Sector Undertaking or at Senior level managerial position with ten years of experience with Law degree or Government officer working in Government or Autonomous body or Public Sector Undertaking or at Senior level managerial position with ten years of experience with Engineering degree or

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self-employed or an officer having administrative experience in Central or State Government. Above all the Arbitrator should have general reputation as an honourable individual with integrity and impartiality.

Model fee for the arbitrator depending on the money value of the claim which has risen the dispute has also been fixed in the amendment Act of 2015 as per provisions laid down in the fourth schedule[8] of the act.

CONCLUSION

Arbitration is a powerful methodology of alternative dispute resolution without the direct involvement of Civil Court of law. But certain incidents of long drawn and expensive arbitration process especially in Engineering contracts has led many government bodies to drop the arbitration clause or adopt conditional arbitration. Now in engineering contracts arbitration process is being replaced by empowered departmental dispute resolution committees. Finally when all the channels of dispute resolution committee are closed the aggrieved contractor has no other means left but to take recourse to the Civil Court for dispute resolution through formal trial as per civil procedure code, which is formal and hence time taking. However realising the obvious difficulties the Indian legislature has amended the principal act for good. The new amendments in the principal act of 1996 shall go a long way to encourage the process of adopting arbitration for speedy disposal of disputes in engineering contracts.

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Comparative Study of Concrete made using Rice Husk Ash, Rice Straw Ash and Bamboo Leaf Ash

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***Abstract**: In order to negate the effect of cement production, many researchers are studying the use of different industrial and agricultural wastes to develop sustainable concrete. Among them, Rice husk ash (RSA), Rice straw ash (RSA) and Bamboo leaf ash (BLA) are used for partial cement replacement. This paper gives the comparative study of the specific gravity, chemical compositions, compressive strength, tensile strength and sorptivity of concrete made using RHA, RSA and BLA. A few papers have been referred where the cement contents in concrete have been replaced by 5%, 10%, 15% and 20% of its total weight by RHA, RSA and BLA. The values of compressive strength, tensile strength and sorptivity developed at 28 days of curing are used for this study. Highest value of compressive strength is observed when 15% of the total weight of cement is replaced by RHA, followed by 10% BLA concrete and then by 5% BLA concrete. Highest value of tensile strength is observed at 15% RHA concrete, followed by 15% RSAconcrete and then by 10% BLA concrete. Lowest value of sorptivity is observed when 15% of the total weight ofcement is replaced by BLA.*

***Keywords**: Concrete; Rice Husk; Rice Straw; Bamboo Leaf Ashes.*

INTRODUCTION

Cement production is one of the main contributors of environmental pollution. The process of cement production leads to the emission of greenhouse gases. It also requires a lot of energy for fuel consumption. Even by changing the typical process of fuel consumption, cost of production can be reduced significantly and it can also help in reducing the negative effects of cement production. Therefore, different industrial and agricultural waste materials should be adopted for fuel in cement production [1].

Rice husk ash, rice straw ash and bamboo leaf ash are the residues of burning rice husk, rice straw and bamboo leaf respectively. The energy produced while burning can also be used as fuels in cement production. The residues can also be used as partial replacement of cement in concrete. This will greatly help in the environment by saving energy and lowering the carbon footprint.

Rice husk, which is one of the most common agricultural wastes, is a by-product left during rice milling process. It is the outer, non-edible part removed from the rice grain. It is mostly produced in rural areas of developing countries like India. When rice husk is burned, the ash left behind is known as rice husk ash. RSA is around 20% of the total weight of rice husk. This RSA contains high amount of silica, which makes it a suitable pozzolanic material for cement replacement [2].

Rice straw is also one of the most abundantly available agricultural wastes. It is produced during the process of harvesting paddy. This waste is usually disposed and burnt. It gives negative impacts to the environment.

Rice straw is burnt to give rice straw ash. This residue is a pozzolanic material which is suitable for partial cement replacement. The energy produced from burning rice straw can also be used as a fuel for cement production [3].

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Bamboo is one of the fastest-growing plants in the world. It is one of the best low-cost materials used for constructing houses especially in rural areas. Using bamboo leaf ash for partial cement replacement will be beneficial to the environment. BLA contains essential chemical compositions which makes it a suitable pozzolanic material [4].

Studies on RHA, RSA and BLA for using them as pozzolanic materials have been done by many researchers. These ashes are mixed at different percentage in concrete as partial replacement of cement. Their physical properties, chemical compositions, compressive and tensile strength developments have been studied. But, only few studies are available where the comparison of chemical composition, compressive and tensile strengths of concrete made with RHA, RSA and BLA at different percentage of cement replacement is done.

In this review paper, a few papers have been referred where the cement contents in concrete have been replaced by 5%, 10%, 15% and 20% of its total weight by RHA, RSA and BLA. Then, their compressive strengths, tensile strengths and sorptivity values are compared. These comparisons are made easier by converting the values in terms of percentage change.

A. Specific Gravity

Specific gravity of RHA [5], RSA [6] and BLA [7] are given at **Table 1**.

Table 1 Specific Gravity of RHA, RSA and BLA

	RHA	RSA	BLA
Specific gravity	2.06	2.10	2.64

B. Chemical Compositions

Chemical compositions of RHA [5], RSA [3,6] and BLA [8,9] are given at **Error! Not a valid bookmark self-reference.**.

Table 2 Chemical compositions of RHA, RSA and BLA

Chemical Compositions	RHA	RSA	BLA
SiO_2	87.2%	76%	69.11%
Al_2O_3	0.15%	0.69%	2.52%
Fe_2O_3	0.16%	0.63%	1.74%
CaO	0.55%	4.96%	10.81%
MgO	0.35%	2.65%	1.73%
SO_3	0.24%	1.90%	3.31%
Na_2O	1.12%	1.36%	0.26%
K_2O	3.60%	9.89%	4.81%
P_2O_5	-	-	1.52%
Loss on ignition	6.55%	9.71%	8.15%

C. Compressive Strength

The 28 days compressive strength of RHA concrete [10], RSA concrete [10] and BLA concrete [8] at different percentage of cement replacement is given at **Table 3**.

D. Tensile Strength

The 28 days tensile strength of RHA concrete [10], RSA concrete [10] and BLA concrete [8] at different percentage of cement replacement is given at **Table 4**.

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Table 3 Compressive strength of RHA, RSA and BLA concrete at different % content for 28 days of curing

% Content	Compressive strength (N/mm^2)		
	RHA Concrete	**RSA Concrete**	**BLA Concrete**
0%	38.88	38.88	26.90
5%	36.36	31.42	27.60
10%	37.80	33.37	28.50
15%	42.80	38.63	25.50
20%	38.47	34.35	24.10

Table 4 Tensile strength of RHA, RSA and BLA concrete at different % content for 28 days of curing

% Content	Tensile strength (N/mm^2)		
	RHA Concrete	**RSA Concrete**	**BLA Concrete**
0%	2.62	2.62	2.46
5%	2.24	2.32	2.67
10%	2.66	2.63	2.76
15%	2.90	2.85	2.41
20%	1.98	1.93	2.18

E. Sorptivity

Sorptivity in concrete is its ability to absorb and transmit water through it via capillary action. It determines the permeability, durability and water resistance of concrete [9].

For RHA and RSA concrete, the test was done using a plastic container with steel bar of diameter 18 mm kept on the bottom of the container. After the concrete cubes were oven-dried at 105°C for 24 hours and wetted, the test was carried out. The sorptivity values given at 120 minutes were considered [10]. For BLA concrete, the sampled cubes were oven-dried for 24 hours at 110°C, tarried for 72 hours at 50°C and then kept airtight for 15 days. Five faces of each of the cubes were coated and the other side was kept open to the water. Then, the samples were submerged in water [8]. Sorptivity values were taken after 28 days of curing.

RESULTS AND DISCUSSION

Compressive Strength

To compare the compressive strengths of RHA concrete, RSA concrete and BLA concrete at different percentage of cement replacement, the percentage change in their compressive strengths are calculated and given at Table 5. The comparison is done for 28 days of curing. Illustration of this change is also given at **Figure 1**.

The compressive strength of RHA concrete decreases at 5% RHA content, then it increases when cement is replaced by 10% and 15% of its weight by RHA. Then, it again decreases at 20% RHA content. The compressive strength of the concrete at 15% RHA content is higher than the normal concrete i.e. when the RHA content is 0%.

The pattern of percentage change in compressive strength of RSA concrete for its different percentage is almost similar to that of RHA concrete. But, the compressive strengths of RSA concrete at different percentage content of cement replacement are lower than the normal concrete i.e. when the RSA content is 0%.

For BLA concrete, the compressive strength increases till 10% BLA content and then decreases. The compressive strength of the concrete at 10% and 5% BLA content is higher than the normal concrete i.e. when the BLA content is 0%.

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Table 5 Percentage change in compressive strength of RHA, RSA and BLA concrete at different % content

% Content	Percentage Change in Compressive Strength		
	RHA Concrete	RSA Concrete	BLA Concrete
0%	0	0	0
5%	-0.94672	-2.86344	0.1883
10%	-0.388	-2.10684	0.4304
15%	1.552	-0.06596	-0.3766
20%	-0.12804	-1.7266	-0.7532

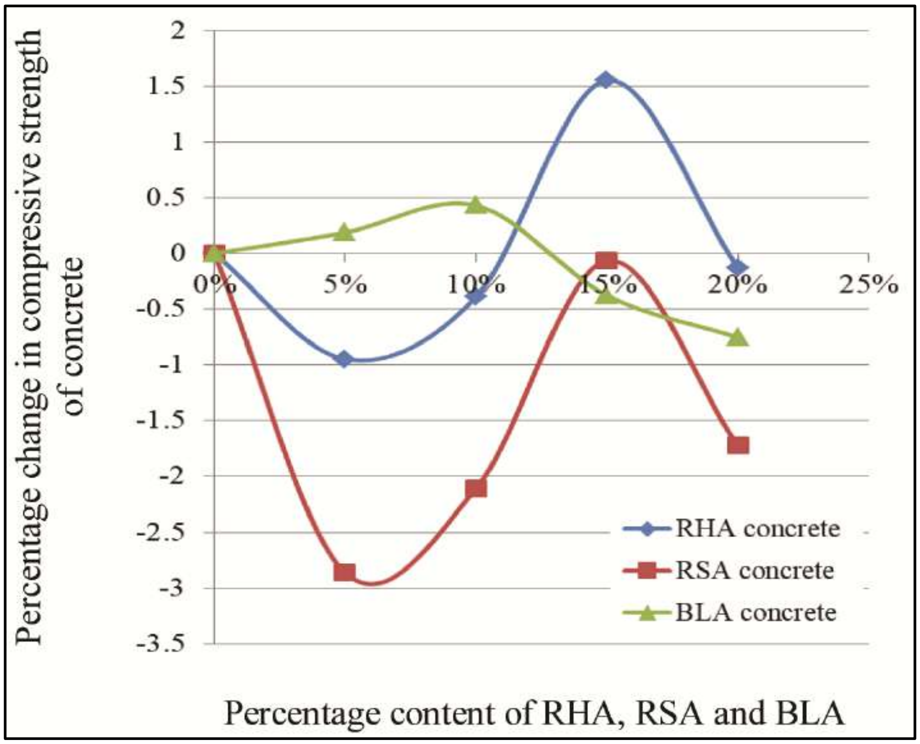

Figure 1 Percentage change in compressive strength of RHA, RSA and BLA concrete at different % content

From **Figure 1**, it is observed that the compressive strength of RHA concrete with 15% content is the highest. It is followed by 10% BLA concrete and then by 5% BLA concrete. Other mixes give the compressive strengths lower than that of the normal concrete mix.

Tensile Strength

To compare the tensile strengths of RHA concrete, RSA concrete and BLA concrete at different percentage of cement replacement, the percentage change in their tensile strengths are calculated and given at **Table 6**. The comparison is done for 28 days of curing. Illustration of this change is also given at **Figure 2**.

The tensile strength of RHA concrete decreases at 5% RHA content, then it increases when cement is replaced by 10% and 15% of its weight by RHA. Then, it again decreases at 20% RHA content. The tensile strength of the concrete at 15% RHA content is higher than the normal concrete i.e. when the RHA content is 0%. The pattern of percentage change in tensile strength of RSA concrete for its different percentage content is also similar to that of RHA concrete.

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Similarly, the tensile strength of RSA concrete decreases at 5% RSA content and then increases till 15% RSA content.

Table 6 Percentage change in tensile strength of RHA, RSA and BLA concrete at different % content

% Content	Percentage Change in Tensile Strength		
	RHA Concrete	**RSA Concrete**	**BLA Concrete**
0%	0	0	0
5%	-0.14744	-0.1164	0.05649
10%	0.01552	0.00388	0.0807
15%	0.10864	0.08924	-0.01345
20%	-0.24832	-0.26772	-0.07532

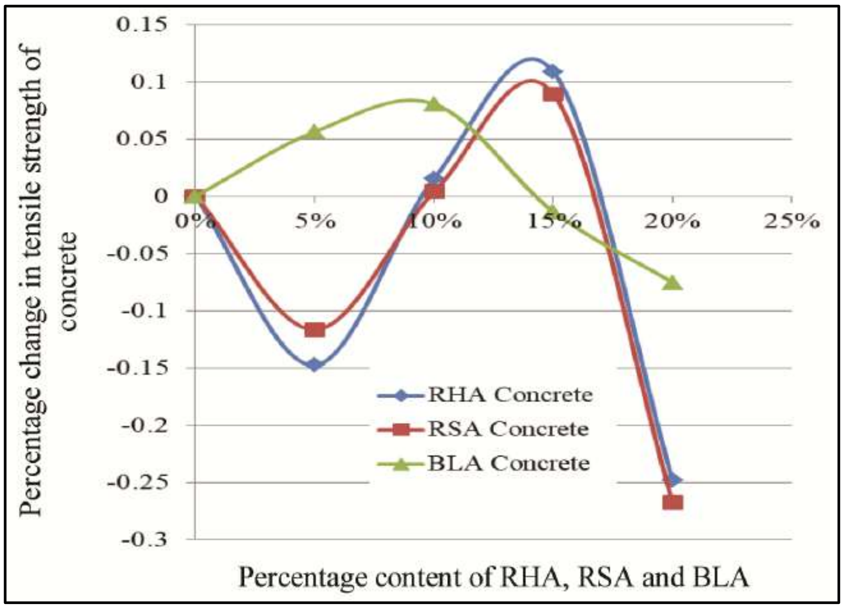

Figure 2 Percentage change in tensile strength of RHA, RSA and BLA concrete at different % content

It again decreases at 20% RSA content. The tensile strength of the concrete at 15% RSA content is higher than the normal concrete i.e. when the RSA content is 0%. It is also observed that the tensile strengths of 10% RHA concrete and 10% RSA concrete are slightly higher than that of the normal concrete mix.

For BLA concrete, the tensile strength increases till 10% BLA content and then decreases. The tensile strength of the concrete at 10% and 5% BLA content is higher than the normal concrete i.e. when the BLA content is 0%. This pattern is similar to its percentage change in its compressive strength.

From **Figure 2**, it is observed that the tensile strength of RHA concrete with 15% content is the highest, followed by 15% RSA concrete and then by 10% BLA concrete.

Sorptivity

To compare the sorptivity of RHA concrete, RSA concrete and BLA concrete at different percentage of cement replacement, the percentage change in their sorptivity values are calculated and given at **Table 7**. Illustration of this change is also given at **Figure 3**.

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The sorptivity value of RHA concrete decreases till 10% RHA content. It then slightly decreases and then increases

Table 7 Percentage change in sorptivity value of RHA, RSA and BLA concrete at different % content

% Content	Percentage Change in Sorptivity Value		
	RHA Concrete	RSA Concrete	BLA Concrete
0%	0	0	0
5%	-0.01402	-0.03079	-0.03623
10%	-0.03079	-0.03639	-0.03643
15%	-0.03079	-0.01782	-0.03722
20%	-0.02911	-0.00832	-0.03564

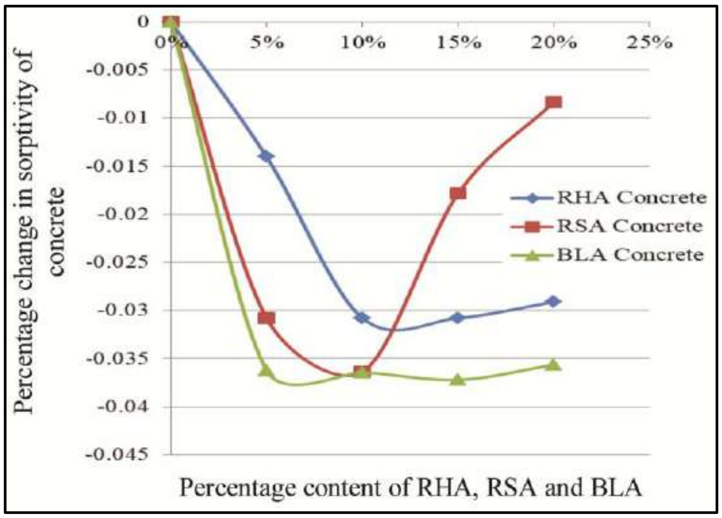

Figure 3 Percentage change in sorptivity value of RHA, RSA and BLA concrete at different % content till 20% RHA content.

For RSA concrete, the sorptivity value decreases till 10% RSA content and then it increases till 20% RSA content.

The sorptivity value of BLA concrete decreases at 5% BLA content and then it slightly decreases and then increases till 10% BLA content. This value decreases at 15% content and then increases again at 20% BLA content. Compared to the normal concrete, sorptivity decreases for all of the different mixes of RHA, RSA and BLA. From **Figure 3**, sorptivity of BLA concrete at 15% of its content is the lowest.

CONCLUSIONS

Based of this study, following conclusions can be drawn:

1. The compressive strength of concrete replaced with 15% RHA content is higher than the rest of the concrete with different percentage of RHA, RSA and BLA. It is followed by 10% BLA concrete and then by 5% BLA concrete. Other mixes give the compressive strengths lower than that of the normal concrete mix.

2. The tensile strength of concrete replaced with 15% RHA content is higher than the rest of the concrete with different percentage of RHA, RSA and BLA. It is followed by 15% RSA concrete and then by 10% BLA concrete.

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3. The sorptivity value of concrete replaced with 15% BLA content is lower than the rest of the concrete with different percentage of RHA, RSA and BLA.

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Challenges in Respect to Skill Development Initiatives for 5 Trillion Dollar Economy by 2025 — A Case of Construction Sector

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Abstract*: In the development of an economy, skill development occupies a dominant place and appropriate policies are required for the same. Performance of an economy is dependent on its human resources. The parameters driving the economic growth and socioeconomic stability of any country are skills and education. In the short term policy, reducing unemployment forms the basis the framing of the skills issue and in the long term policy, skill requirement are broadly seen whether the skilled and trained work force for a given Industry meets the requirement with the demand imposed in a particular sector of the economy based on the economic growth which is projected to be 5 trillion dollars by 2025 for India. The trend that is visible today and is expected to last atleast for another 2 decades is that the proportion of the workforce in the working age group is well in excess of those dependent on them. Acceleration of economic growth can be achieved by way of huge labour workforce through skill development thereby making the best use of the demographic dividend. The accelerated economic growth has fuelled the demand for skilled manpower which has resulted in woeful shortage of skilled manpower in the country in general and construction sector in particular. Based on the path for a 5 trillion dollar growth by 2025, will India be able to match or slip this growth considering a humble 5% contribution of the construction sector to the GDP Growth and where India could stand in an accelerated growth path. The paper also provides suggestion to meet the challenges of construction Industry needs for skilled man power with an attempt to meet the skills demand in Indian Construction sector.*

Keywords*: Socioeconomic Stability; Demographic Dividend; Accelerated Economic Growth; Key Drivers*

INTRODUCTION

Overall effectiveness and empowering of an individual for working more efficiently can be achieved by skill Development. This results in economy becoming more productive, innovative and competitive by way of having skilled human potential. Globalization and technological changes has provided both challenges and growing opportunities for economic expansion and job creation. Countries which have higher and better levels of human skills get adjusted more effectively to the changes that are taking place at a rapid pace. Apart from access to vocational and technical education, access to secondary and tertiary education is also equally important. Attention should also be focussed on informal learning on the job, structured apprenticeships and other enterprise based training, along with government and non-governmental training programs.

Skills development is a much broader concept involving a diverse community and as a result it is quite difficult to monitor this development. Skills development in construction sector is a good example and difficult to monitor and update the numbers being skilled at a given level due a diverse agency involved in skills training and updating the statistics is also difficulty as only those training being done under NSDC franchise for Construction sector skills centre and available within a reasonable accurate figure. There are a number of informal bodies providing skills training in construction trades and these are restricted to only the company employees and the details of trained workers are not publicly shared.

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CONSTRUCTION SECTOR SIZE AND MANPOWER

Construction is an important activity that drives emerging economies like India, which are yet to develop large network of Infrastructure and Real Estate Assets. The estimated size of construction industry is about Indian rupees 2.1 trillion in the year 2008. After agriculture sector in India the construction sector second largest contributing to the economic activity and it is providing employment opportunity to around 33 million workforces. The Compounded Annual Growth Rate (CAGR) of India's Construction industry has risen to around 11.1% in eight years (from 2001 to 2008). This is the result of increased housing demand and massive investment in infrastructure. The infrastructure sectors spending in Projects like Roads, Ports, power plants, Airports is projected at more than Rs 2.5 trillion on annual basis for the next six years, and will demand 92 million hours of labour.

Construction sector accounts for investment of around 53% of the Gross Fixed Capital Formation in the country. This has resulted in immense development of the economy and ensured that the supply chain movement goes at a brisk pace. The construction sector is linked to various industries like steel, cement, paints, chemicals, tiles, fixtures, accessories and fittings. In the short term this my have serve as a demand booster, while in the long term it has contributed to boosting the infrastructure capacity (NSDC 2012), **Table 1** shows the size and growth of the construction sector GDP in India.

Table 1 Growth and size of Construction Industry in terms of GDP at constant prices(Indian Rupees in Billions)

S.No	Year	GDP Growth (Indian Rupees in Billions)
1	2001	1,084
2	2002	1,127
3	2003	1,217
4	2004	1,362
5	2005	1.500
6	2006	1,839
7	2007	2.055
8	2008	2,263
Average CAGR is 11.1%		

Source: Economic survey 2008-2009 and IMaCS Analysis 2

A broad Classification of The Construction sector can be depicted into two segments (NSDC 2012). Infrastructure [Transportation, Urban Development, Utilities] and Real Estate [Residential, commercial, Industrial and Special Economic Zones (SIZ's)]

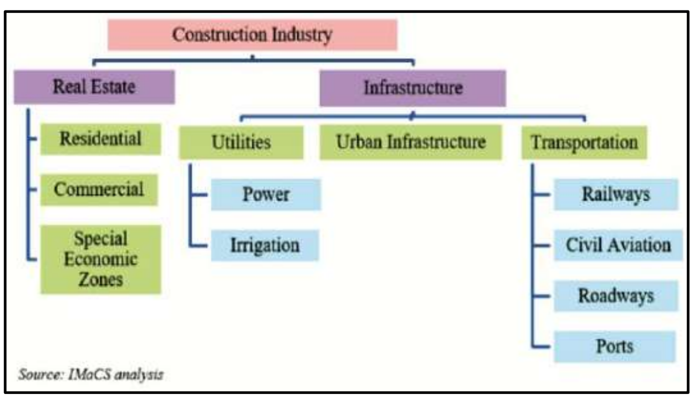

Figure 1 Landscape of Indian Construction Industry

The Real Estate sector contributes to around 24% of the Construction Gross Domestic Product of country where as the Infrastructure sector contributes to about 76%. Depending on the expected growth in the Real Estate sector and

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Infrastructure sectors, it is anticipated that about 83 million people would be engaged in the Construction sector by the year 2022. The increment construction workforce demand between the year 2008 and 2022 is projected to around 47 million. The composition sector wise is as follows:

Table 2 Projected Human Resources Required

Const Industry	2008 (in 000s)	2012	2018	2022	Increment
Infrastructure	25177	33868	48280	5,289	33,111
Real Estate	10790	14515	20692	24981	14,191
Total	35968	48383	68972	83270	47,302

Source: IMaCs Analysis

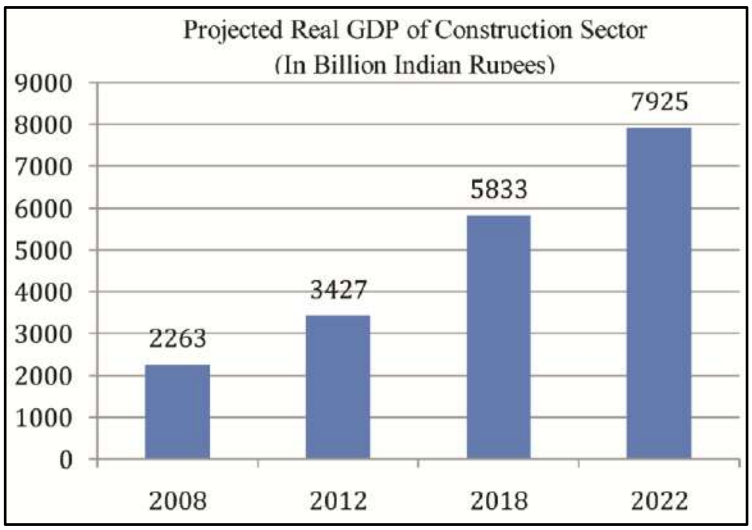

Figure 2 Projected figures in Billions of Rupees from2008 to 2022 with a Cumulative Aggregate growth rate of 9.5 to 10%

Projected Real GDP of Construction Sector (in Billion Indian Rupees)

Table 3 India: GDP in Current Prices

S.No	Year	GDP (billion USD)
1	1986	252.75
2	1990	326.61
3	1995	399.79
4	2000	466.84
5	2005	834.25
6	2010	1300
7	2015	2000
8	2020	2500
9	2022	3312.95
10	2024	3884.73
11	2026	4534.34

Source: STATISTA, Economics & Politics- International

Table 4 Segmentation of Work Force in Construction Industry

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S.No	Occupation	% (Percentage)
1	Engineers	2.65
2	Technicians and foremen	1.80
3	Clerical	2.50
4	Skilled workers	10
5	Unskilled worker	83.1
	TOTAL	100

SIGNIFICANCE OF STUDY

This paper is intended to highlight the proportion of skilled worker in relation to total manpower in the construction sector. Going by the present way the skilled worker is inducted despite having skill council for construction, adequate skilled and trained worker are not being generated to meet the demand going by the various studies made by study groups based on the secondary data collected. The man power projected by 2025 will be around 90 million and the skilled man power would be around 9 million. With the existing skilled man power generation we can hardly reach 0.5 million per year. Hence there is going to be a mismatch between availability and requirement by end of 2025 when our economy will be reaching a 5 trillion US Dollars.

LITERATURE REVIEW

Rubvita Chadha et al (2014)

"Industry's requirement for employability of Management students in Present scenario". The study has suggested and concluded that skill development can be achieved by way of offering more practical training, developing conversational skills, improving employability skills, organizing frequent personality development workshops and encouraging academia-industry interaction.

Hari Prasad. N et al (2014)

In his study titled "alarming employability skills deficiency a month budding engineering graduates and Diploma holders" – a study on Engineering and Diploma holds in Chittoor district" has concluded that in developing skills, impact of peer group and personal experiences play key role. Quick employment can be attained by focussing on group discussions and professional networking. Answering updated questionnaires related to technical aspect and continuous interview attempts a helps to sustain corporate employment.

FICCI skill report by Ernst and Young (2012)

In this research paper on "Skill Development in Construction Industry in India" development of skill wass one of the prime agenda of the Government of India for the 12th Five Year Plan. (2012-2017). This is very much highlighted in a research paper titled "Skill development in construction industry in India". The government plans to prepare standards required for training programs by setting up sector skills councils. Skills Development is a important initiative for achieving India's ambitious growth targets as envisaged by captains of industry and it was decided to work with dedication by involving stakeholders, namely the industry, government and academia to develop sustainable and scalable skills propositions which will promote the youth of the country from different sections of the society. The industry is attempting to reduce the skill gap by taking proactive measures to partner with the government. One example of this initiative is the Establishment of Rural Development and Self-Employment Training Institutes.The government as a incentive measure is exempting payment of service tax for all skills training institutes who are involved in vocational education training there by making skills training more affordable to public in large. Companies like L&T, Hindustan construction Corporation (HCC) etc have taken the following initiatives in enhancing the skills of construction workers.

A Report of the Working Group on Construction for the Eleventh Five Year Plan (for the Period-2007 to 2012)by BMTPC

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The size of Construction Industry is estimated at Rs.310,000 crores (includes Private & Public stakes), providing an employment standing at 31 million man-years per year of which unskilled category at 82.45 % occupies the major share. The manpower in construction industry is growing at a constant pace of 8 to 9 % resulting into annual addition of about 25 lakh individuals in addition to existing manpower. This is a huge task given that they required to be trained in order to have quality, safe and durable structures.

With the advent of innovative building materials, advancement in technology and the need for construction of disaster resistant structures to diffuse the effect of natural disasters, it is very imperative that working professionals update their knowledge and understanding of subjects periodically. Understanding need for capacity building, BMTPC is organizes structured training programmes for working professionals for updating their skills and knowledge in areas of Green Construction Practices, Sustainable Construction, Earthquake Resistant Design and Construction etc

OBJECTIVES OF THE STUDY

- To study about the proportion of skilled workforce over the total work force deployed in the construction industry.
- The present level of the total work force in the construction industry.
- Projected work force up to 2022 for the industry.
- Whether Indian construction industry would be able to meet the requirement of skilled workforce by 2025 when GDP is projected for a 5 Trillion US Dollar economy and suggested measures to be taken.

PRESENT STATUS OF SKILL DEVELOPMENT IN CONSTRUCTION INDUSTRY AND THE CHALLENGES FACED

The construction industry in India which is the index of country's progress and its economic development has a huge task in that efforts should be stepped up for training and upskilling its workforce thereby unlocking the growth opportunities in the construction sector and contributing to the nation's development in an optimal manner. In this fast paced era, the Indian construction industry needs more skills to be imbibed by an individual. Around 60 million people are employed in construction industry in India and 9% of the country's GDP is contributed by this sector. This sector also creates more than 45 million jobs either directly or indirectly. By 2022, the Indian construction sector will become the largest employer by employing around 76 million people. This means jobs for an additional 16 million people in the coming years. Notwithstanding the rosy predictions,, the construction industry is bogged down by poor productivity relative to other sectors as it is handicapped by intractable problems. Labour-productivity growth globally in construction has averaged only 1% annually in the past two decades as against 2.8% and 3.6% per year growth of the world economy and manufacturing respectively.

According to the McKinsey Global Institute's Construction Productivity Survey and Report, 2017, severe underperformance of the construction sector is attributed to high amount of regulation, dependence on public-sector demand and fragmented, cyclical nature of the industry.

The percentage of service-cost to the overall project-cost is 12-15%, whereas the global standard is higher at more than 40%. Indian companies face the problem of tough competition and lack of recognition for quality work. Constant changes brought about by technology upgradation and rising workplace expectations have fuelled the demand for a skilled work by appreciating safety regulations, working at optimum efficiency and at the same excelling in their trade. Concentrating on multi-skilling their workforce and improving the working environment at project sites for attracting the bright talents in this sector is the need of hour for countries like India if it is to catch with rest of the world.

CHALLENGES TO MEET THE FUTURE NEED

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Construction workers in India continue to be trained by the traditional master craftsmen owing to lack of an institutional mechanism for skill development. Absence of utilisation of new technologies or work methods in traditional methods has made the situation quite challenging as it is necessary that the next generation of workers need consistent and continual upskilling and not just confined to training by giving sustainable value to the entire ecosystem.

A remarkable example of how governments across the world can contribute to training future construction workers is shown by Government of United Kingdom by setting up the Construction Skills Fund (CSF), in 2018.The £22 million CSF is funded by the Department for Education aims to provide training to individuals looking to get into the construction industry through the Construction Industry Training Board for filling the skill gaps and make more people 'site ready'. by enhancing their skills. It has endeavoured to provide training to unemployed and those planning to have a change their career, for entering into construction sector. Similar initiatives are also taken by Construction Industry Development Council in India to for improving the productivity of construction workers. The construction industry too on its part has stepped up its efforts for increasing the sustainability of the sector. However, much more needs to be done by the sector if it is to t capitalise on the growth opportunities in future

Based on the fore going the challenges faced by the construction industry are:

- Changing market environment, technological progress besides disruptive entrants have triggered industry overhaul
- Value being added by multiple interventions from multiple stakeholders is at stake as they differ in objectivity, focus and framework
- Transformations have taken time but COVID is accelerating the same
- Industry has to prepare itself for new normal

SUGGESTIONS FOR ENHANCING THE CAPACITY OF SKILLED MANPOWER IN CONSTRUCTION INDUSTRY FOR MEETING THE DEMAND

1. Various ministries under Government of India dealing with housing, labour employment, skill development, rural development will have to amend changes appropriately to facilitate skill development.
2. Private players should be given incentives by the government to provide training to the construction workers. At the same time, the industry must collaborate on a massive scale for use of scarce capital resources for skill training
3. Skilling, Re-skilling and Up- skilling is required to endeavour to the needs of future
4. Offering of variety of diploma and vocational programmes and strengthening the industry-academia interaction.
5. There exists already more than 500 Pradhan Mantri Kaushal Kendra in addition to the training centres being run by the industry. The need is to realign and integrate all of them to collectively deliver in uni-direction which would make a paradigm shift in the way the industry conducts itself.
6. There is complete absence of primary research in the industry. There exists no mapping of demand clusters, supply clusters and traditional clusters which needs to be done
7. Move the entire workforce from ‘Informal’ to ‘Formal’ as being part of ‘Formal’ drives lot of inherent advantages.
8. Deploy and ensure that ‘Recognition of Prior Learning’ (RPL) becomes a mandatory part of the industry before construction workers moves in to a construction site.

All this can be expedited with the right kind of technology which will be vitalto the success. In short, numbers can be achieved but provided the right framework, delivery mechanism and technological support are present.

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Study of Methodology for Removal of Arsenic Contamination from Public Water Supply Projects — West Bengal Perspective

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***Abstract**: Water supply projects utilize surface water, sub-surface water and ground water as sources. The most economical alternative is to use ground water as source, because it will not require construction of water treatment plant for surface or sub-surface based water supply schemes, which involves high capital cost. However for areas which are far away from the river, it is not viable to utilize river water for source for such areas ground water is the only preferable source to feed the water supply scheme. If the area receives substantial rainfall throughout the year the ground water reserve in the aquifer is easily replenished and hence abstraction of ground water through production tubewell shall be a sustainable approach to provide drinking water supply to the population. As ground water is generally abstracted from confined aquifer, the water quality of ground water is free bacteriological contamination. However the main evil in ground water is chemical contamination. One of the most significant chemical contaminant in ground water is Arsenic, which is a cumulative poison in human system. Prolonged intake of arsenic laden water in relatively higher concentration, results in manifestation of toxic effects of arsenic in human body, various health related problems develop due to arsenic poisoning which is broadly termed as "Arsenicosis". Arsenic contamination in ground water is observed across the globe, the problem is very wide spread in West Bengal. In this paper a time tested methodology for effective removal of arsenic from drinking water is discussed. The methodology incorporates oxidation followed by coagulant assisted precipitation, and finally applying adsorption technique using polishing agent for removal of residual arsenic so that the treated water has arsenic below detectable limit. The method is easily implemented at the field and the operation and maintenance of the plant is less. The process has been indigenously developed for field application for public water supply schemes and provides potable water to the population in reliable quality.*

***Keyword**: Arsenic Removal; Ground Water; Aarsenic Contamination; Water Quality*

INTRODUCTION

Arsenic contamination in ground water is observed widely across the globe. The problem is prevalent in India and is very significantly observed in the state of West Bengal. As per assessment arsenic contamination is most prominent in the 8 districts of West Bengal including North 24 Parganas, South 24 Parganas, Hooghly (part), PurbaBurdwan (part), Nadia, Murshidabad, Maldah and only few scattered villages of Howrah (**Figure 1**). In these 8 districts about 84 blocks, 3319 villages and 8153 habitations are affected from arsenic infestation in ground water and about 16.5 million rural population of West Bengal are at risk due to this arsenic contamination. All the 84 blocks are located by the bank of the river Hooghly and its adjoining areas. The analysis of ground water sample in this areas indicated higher arsenic concentration in ground water. The contamination is mostly observed at a depth of 20m-80m below G.L. prolonged ingestion of arsenic through food and drinking water causes accumulation in the human body, arsenic can be traced in hair, nail, urine and other body parts. Due to the toxic effect of arsenic lesions develop in the palms and the foot (**Figure 2**). Diarrhea and other abdominal problems may occur, in severe cases kidney may be affected and cancer may develop. If the problem is detected at an early stage and the patient is removed to a location where drinking water is free from arsenic contamination, thepatient is found to improve in health, due to flushing out of accumulated arsenic from the system. It has been found that the effect of arsenic toxicity is manifested significantly in case of individuals suffering from malnutrition i.e. among the poor people. In the late 1980s water testing reports revealed higher concentration of arsenic in water beyond the tolerable limit of 0.05mg/l in shallow

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tubewells. Later arsenic in higher concentration was also observed in India Mark-II head fitted deep water pump type tubewell. Initially it was thought that stray cases of arsenic contamination was due to the activity of the farmers who spray fertilizers of arsenic based compounds to the crops, but later on realizing the huge extent of the problem it was concluded that detection of higher level of arsenic is possibly due to geological causes. So far the reason for extensive infestation of arsenic contamination is unknown. The question of delivery of arsenic free drinking water to the population was a very compelling question to the water supply Engineer of West Bengal. The issue was a big concern which led to the formation of arsenic Task force in 2005 by the Govt. of West Bengal a technical committee with the terms of reference to explore and give approval to such technologies for arsenic removal after appropriate evaluation and proper pilot study at the site. The Public Health Engineering Department, Govt. of West Bengal, has taken the most significant initiative in the aspect of provision of Arsenic free drinking water to the population of the state. The initiative has involved construction of Mega piped water supply projects with Surface and Sub-Surface water, from the major rivers in West Bengal (mainly river Hooghly) for the areas which are located near the river bank and for the other areas where it is difficult to transport raw water of river due to relatively greater distance from the river, through sinking of big diameter deep tubewellto deeper aquifer free from arsenic and in areas where the aquifers are infested with arsenic contamination use of Arsenic-Cum-Iron removal plant has water to the been made to ensure Arsenic free drinking water to the population. A elaborate system of water testing laboratories both of PHED and NGO driven labs were established to ensure efficient testing of water samples across the state.

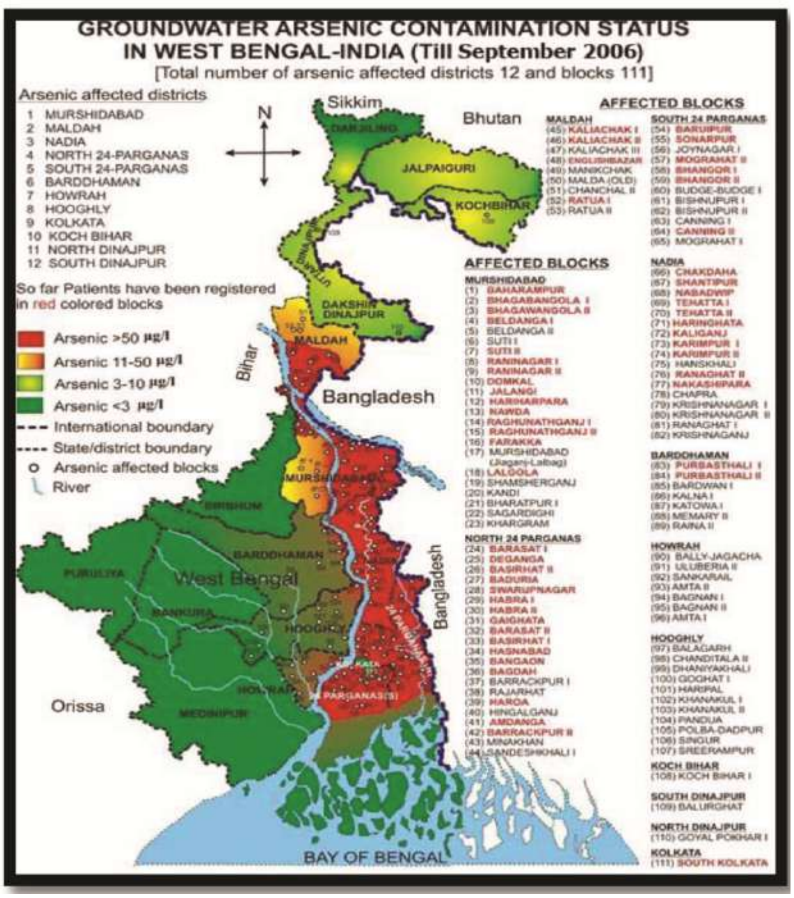

Figure 1 The map showing groundwater pollution by Arsenic, in the inter-fluvial region of the Bhagirathi-Hoogli and the Jalangi-Ichamatirivers lying mostly in the eastern part of the Bhagirathi-Hoogliriver of West Bengal. The Arsenic contamination in ground water beyond 0.05 mg/l has been found within the shallow aquifer (20-80m below ground level) (obtained from official website of PHED WB).

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Figure 2 Showing the skin lesions developed in the palms and foot of Arsenic affected patient

REMOVAL TECHNOLOGY

Arsenic is a metalloid, it is found in ground water and usually exists as inorganic arsenic in both trivalent (As (III)) and Pentavalent (As(V)) species. As(III) has relatively higher level of toxicity in comparison with As(V). Various technologies are available for removal of Arsenic from ground water. The technologies are based on following principals:-

(a) Coagulation/co-precipitation,
(b) Adsorption,
(c) Sedimentation,
(d) Ion exchange,
(e) Membrane/Reverse Osmosis,
(f) Biological treatment,
(g) Nano technology based process etc.

All the above technologies have case specific advantages and disadvantages.

The removal of arsenic from water depends on the type of arsenic species present is water. As an example coagulation/co-precipitation method using iron or aluminum salts yield better result for Arsenic (V) species rather than arsenic (III). Thus to enhance the process of removal at first oxidation of the raw water is required so that all As(III) species is oxidized to As(V) and then the removal is done by coagulation/co-precipitation. The sedimentation process is adopted following coagulation/co-precipitation for effective removal of Arsenic species from solution. The mostly widely used Arsenic cum iron removal plant (AIRP) is based on the methodology of oxidation followed by co-precipitation through coagulation, flocculation, clarification and finally filtration (either through rapid sand filter or pressure filter) and then adsorption using activated alumina. The process finally yields water with arsenic within acceptable limit as per BIS guidelines. As per the current BIS code of practice IS-10500-2012 [1]with amendment, vide table 3 sl no. X, the acceptable limit for Arsenic is 0.01 mg/l and there is “no relaxation” to this quality standard. This method is capable of removing the arsenic and iron content from ground water so that water is fit for human consumption only with disinfection by chlorination. The process of coagulation is achieved with the addition of metal based coagulant such as Ferric chloride ($FeCl_3$), the coagulant hydrolyses in water forming positively charged Ferric Hydroxide ($Fe(OH)_3$). However the process to work effectively Arsenic must be oxidized to As(V) state.

PROCESS FLOW

The process flow for Arsenic –Cum-Iron removal plant with oxidation, co-precipitation and polishing method is depicted below for clarity of understanding.

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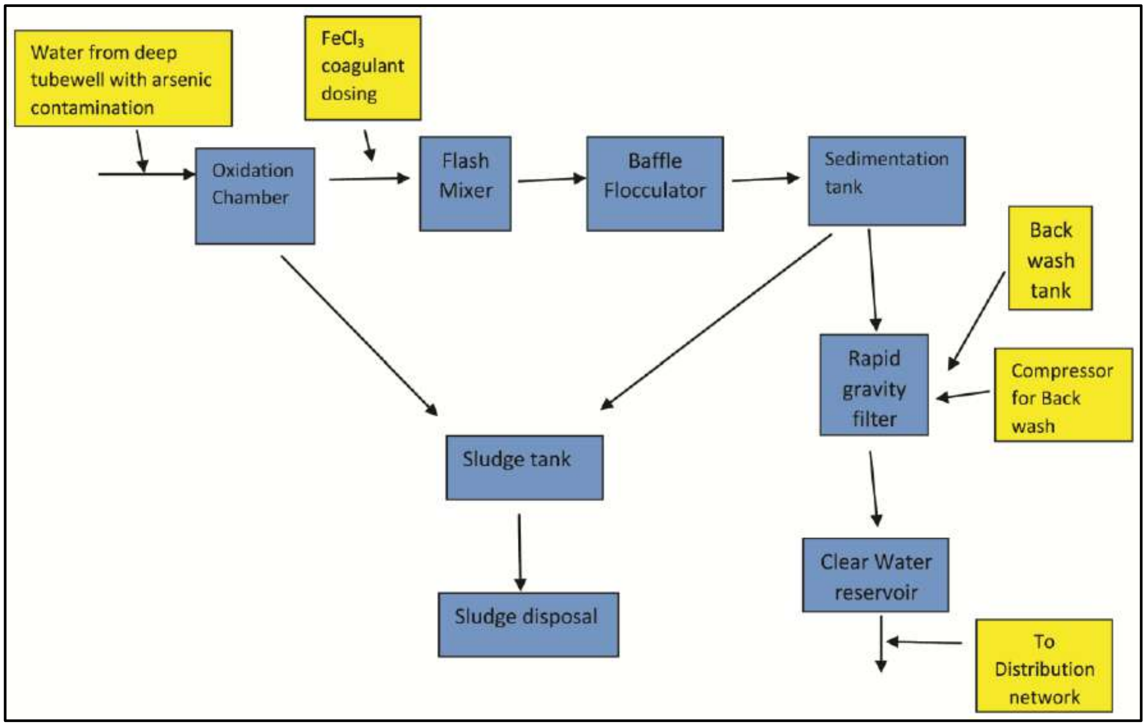

Effective performance of the above type of AIRP is much dependent on coagulation and sedimentation of the Arsenic present in the water. For ensuring removal of the arsenic species as As(V) the coagulant $FeCl_3$ is mixed at first violently in the mechanically operated flash mixer for uniform mixing. This operation is termed as rapid mixing. The water is then gently stirred and circulated in the baffles of the baffle flocculator to keep the colloidal particles in suspension and to promote collision between the colloidal particles so as to ensure effective formation of floc to assist in sedimentation. This type of AIRP may be economically constructed for ground water based piped water supply scheme with capacity varying from 30 CuM/hr to 180 CuM/hr. The AIRP can be fitted for rural piped water supply schemes with population varying from 15000 to 20000 souls. The structure is constructed with M30 grade R.C.C and Steel reinforcement providing adequate cover to the reinforcement a required vide provision of IS 456-2000 [2] and IS-3370 (part-2) 2009 [3] for water retaining structures. Flow in the different units of the plant is maintained through gravity. Proper assessment of the natural slope of the site is essential for laying out the plant. The oxidation chamber should be designed for 30 minutes detention period to ensure proper oxidation of As(III) to As(V) for proper functioning of the unit. As the process flow is based on gravity system least use of electro-mechanical instruments are done, the energy cost and the operation maintenance cost of the scheme is relatively less. Arsenic removal efficiency of the plant has been assessed between 92-95%. A significant difficulty associated with the plant is disposal of sludge generated at the sedimentation tank of the AIRP. The sludge has high concentration of Arsenic. The sludge cannot be disposed of by burying in the ground, as it will cause leaching of Arsenic in the shallow depth water table aquifer and shall further aggravate contamination in the locality. However as the concentration of arsenic in ground water is generally found in the range of 1 mg/l to 0.05 mg/l (however higher concentrations are also encountered) it takes considerable time to accumulate substantial thickness of sludge layer and hence sludge disposal is not required at frequent intervals. Researchers have established that sludge may be effectively disposed by mixing with clay for brick manufacturing or mixing with concrete in controlled ratio. Details of the process of sludge disposal is available elsewhere in literature[4].

CONCLUSION

Supply of potable drinking water to the population in proper quality and adequate quantity is the mandate for a progressive society. Nature has posed a challenge to humanity in the form of arsenic toxicity in ground water which is a major impediment for providing wholesome drinking water to the population. This hazard can be combatted with three fold approach (a) using surface or Sub-surface water as source for water supply, (b) using ground water

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from deeper aquifers which is not contaminated with arsenic & (iii) using ground water source with Arsenic –cum – Iron removal plant. Where surface and sub-surface water from major rivers are available mega water supply project can be developed by construction of Water treatment Plant (WTP) at huge capital cost and recurring operation and maintenance cost. The cost of acquiring land for WTP is also substantially large which also adds to the capital cost. As an alternative ground water based water supply scheme is a preferable alternative. Thus Ground water based water supply scheme with exploitation of ground water in deeper aquifer and fitted with AIRP is a popular alternative. In areas where ground water in deeper aquifer is free from arsenic AIRP may be installed because with overexploitation of ground water leaching of arsenic may take place form shallow aquifer to deeper aquifer, and the arsenic free layer may develop contamination in near future. Among the various technology for removal of arsenic available the one with oxidation followed by co-precipitation and then activated alumina polishing unit with gravity flow model is the most economic and practical approach for arsenic removal for public water supply schemes, hence it is discussed in this paper and is suggested for adoption for arsenic removal in water supply schemes.

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Advantages of use of Tubular/Hollow Sections over Conventional Open Sections in Hydro-Carbon Industry Structures

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Abstract: *Tubular/ Hollow sections are gaining popularity in recent times, due to its higher strength-to-weight ratio than conventional open sections as well as for the reason that, hollow sections create lightweight and visually attractive structures. Due to their cross sectional configuration, such sections have inherent advantage in torsional buckling resistance capacity and axial load carrying capacity. Thus, its usage is continuously being increased in the hydrocarbon sector as well. Tubular/ hollow sections have been successfully used in many components of the structures, in which traditionally MC boxed sections were used due to its reduced requirement of welding, as compared to MC boxed sections. Therefore, it is imperative to analyze hollow sections and open rolled sections considering design strength and steel quantity requirements, to enable the designers to select the appropriate section, fitting the functional requirements and economics of the project. This study presents the comparative benefits of using hollow sections instead of open sections by presenting a theoretical comparison as well as a case study of three categories of industrial structures in hydrocarbon industry. Further it presents a detailed account of limitations in use of hollow sections on large scale in industrial structures of hydro carbon sector.*

Keywords: *Hollow Sections; Lateral Torsional Strength; Yield Strength; IS 4923; Industrial Structures; Weight-to-strength Ratio*

INTRODUCTION

The excellent properties of the tubular shape have been recognized for a long time; there are examples of bridges etc. made of tubular sections as long back as last century. However, in the absence of readymade hollow sections, large tubular sections have been prepared by welding open sections such as channels or angles.

Hollow sections are gaining popularity in recent times, due to its higher strength-to-weight ratio than conventional sections as well as for the reason that, hollow sections create lightweight and visually attractive structures. Many examples in nature show the excellent properties of the tubular shape with regard to loading in compression, torsion and bending in all directions. For examples, tall slender plants such as bamboo tree or small weeds etc. Thus, use of hollow sections is in a way a nature inspired choice. Due to geometric configuration, such sections have inherent advantage in torsional buckling resistance capacity and axial load carrying capacity.

Even though predominant use of hollow section has been observed in infrastructure projects only, yet its usage is continuously increasing in the hydrocarbon sector as well. In the recent projects, tubular/ hollow sections have been successfully used in various structures, such as pipe supports, operating platforms and trusses in the shed or other structures, small pipe racks, or structural components such as vertical and plan bracings, longitudinal/ tie members of pipe racks and other structures etc. Many components of the structures, in which traditionally MC boxed sections were used, have been grossly taken over by hollow sections, due to its reduced requirement of welding, as compared to boxed sections fabricated from channels/angles.

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BENEFITS OF USING HOLLOW SECTION OVER CONVENTIONAL OPEN SECTIONS-

Following has been the main reasons for increasing use of hollows sections-

I. Aesthetic Reasons

Due to aesthetic reasons, hollow sections have been the first choice for buildings where structural members are exposed such as in airports, malls, exhibition centers and other amenity buildings. In structural members, as the length of member increases, their axial capacity decreases. The decrease in capacity is very less for hollow sections as compared to open sections. This makes hollow sections preferable choice for members of large span trusses. Thus, hollow sections are valuable in providing long span structures having a feel of openness and aesthetics which have always been an architect's delight.

II. Design Benefits

Hollow sections are made of similar steel as used for open steel sections, thus in principle there is no difference as long as mechanical and chemical properties are concerned. However, distribution of mass on cross sectional plane plays an important role in determining the strength-to-weight ratios of structural section. The more mass is placed away from the centroid of cross-sectional area, the more strength section has against Euler buckling and lateral-torsional buckling, which is required for a section to be loaded to its full compressive or bending strength. In this aspect, hollow sections (by having total mass placed away from centroid) have a major advantage over conventional I-sections, channels and angles, which have most of the mass placed near centroid or along axes passing though centroid (**Figure 1**).

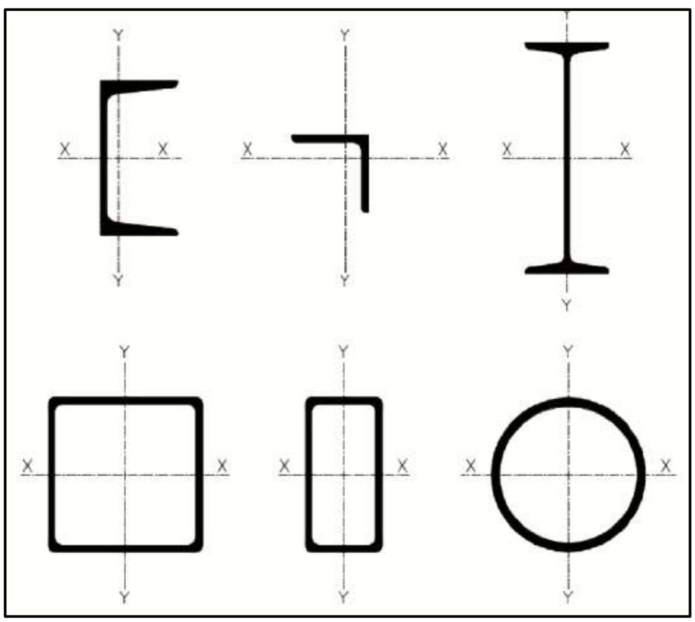

Figure 1 Centroid (intersection of x- and y-axis) and mass distribution around centroid for different types of structural steel sections

Further, **Tables 1** and **2** below show a comparison of unit weights of members required for a given Bending moment and Axial compression capacity. The percentage reduction in material is calculated and highlighted wherever there is a saving. Effective lengths of the members have been considered as 0 m (fully restraint), 4 m & 8 m for bending as well as for axial compression to incorporate the effect of slenderness on member capacity.

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Table 1 Comparison of bending capacities

Table 1a Open and hollow section required for given bending capacities (L_{EFF} = 0 M)

Bending Capacity (in kN-m)	L_{EFF} = 0 m				
	I-section	**Unit Weight (in kg/m)**	**Hollow Section**	**Unit Weight (in kg/m)**	**Difference in Weight**
50	MB200	24.2	RHS200x100x6	26.4	9.09%
100	MB300	44.2	RHS280x100x6	33.94	-23.21%
150	MB300	44.2	SHS250x250x6	45.24	2.35%
200	MB300	44.2	RHS300x150x8	53.22	20.41%
250	MB400	61.5	RHS350x250x6	54.66	-11.12%
300	MB400	61.5	RHS400x300x6	64.08	4.20%
350	MB400	61.5	RHS400x300x6	64.08	4.20%
400	NPB 450X190X67.15	67.15	RHS500x200x6	64.08	-4.57%
450	NPB 450X190X67.15	67.15	RHS400x300x8	84.62	26.02%
500	NPB 500X200X79.36	79.36	SHS400x400x8	97.18	22.45%
550	NPB 500X200X79.36	79.36	SHS400x400x8	97.18	22.45%
600	NPB 500X200X79.36	79.36	RHS500x300x8	97.18	22.45%
650	MB500	86.9	RHS500x300x8	97.18	11.83%
700	NPB 500X200X107.31	107.31	RHS500x300x10	120.43	12.23%
750	NPB 500X200X107.31	107.31	RHS500x300x10	120.43	12.23%
800	NPB 500X200X107.31	107.31	RHS500x300x10	120.43	12.23%
850	NPB 600X220X107.56	107.56	RHS500x200x14	143.74	33.64%
900	NPB 600X220X107.56	107.56	RHS500x300x14	165.72	54.07%
950	NPB 600X220X107.56	107.56	Hollow sections for these capacities are not available		-
1000	NPB 600X220X122.45	122.45			-

Table 1b Open and hollow section required for given bending capacities (L_{EFF} = 4M)

Bending Capacity (in kN-m)	L_{EFF} = 4 m				
	I-section	**Unit Weight (in kg/m)**	**Hollow Section**	**Unit Weight (in kg/m)**	**Difference in Weight**
50	MB300	44.2	RHS250x100x6	31.11	-29.62%
100	WPB 200X200X50.92	50.92	SHS220x220x6	39.59	-22.25%
150	MB400	61.5	SHS250x250x6	45.24	-26.44%
200	NPB 450X190X67.15	67.15	RHS350x250x6	54.66	-18.60%
250	NPB 450X190X67.15	67.15	RHS400x200x6	54.66	-18.60%
300	NPB 500X200X79.36	79.36	RHS400x300x6	64.08	-19.25%
350	NPB 500X200X79.36	79.36	RHS500x200x6	64.08	-19.25%
400	NPB 500X200X90.68	90.68	SHS350x350x8	84.62	-6.68%
450	NPB 500X200X107.31	107.31	RHS400x300x8	84.62	-21.14%
500	NPB 500X200X107.31	107.31	SHS400x400x8	97.18	-9.44%
550	NPB 600X220X107.56	107.56	SHS400x400x8	97.18	-9.65%
600	NPB 600X220X107.56	107.56	RHS500x300x8	97.18	-9.65%
650	NPB 600X220X107.56	107.56	RHS500x300x10	120.43	11.97%
700	NPB 600X220X122.45	122.45	RHS500x300x10	120.43	-1.65%
750	WPB 600X300X128.79	128.79	RHS500x300x10	120.43	-6.49%
800	WPB 600X300X128.79	128.79	SHS400x400x12	143.29	11.26%
850	WPB 700X300X149.89	149.89	RHS500x300x14	165.72	10.56%
900	WPB 700X300X149.89	149.89	Hollow sections for these capacities are not available		-
950	WPB 700X300X149.89	149.89			-
1000	WPB 700X300X149.89	149.89			-

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Table 1c Open and hollow section required for given bending capacities (L_{EFF}=8M)

Bending Capacity (in kN-m)	L_{EFF} = 8m I-Section	Unit Weight (in kg/m)	Hollow Section	Unit Weight (in kg/m)	Difference in Weight
50	WPB 200X200X50.92	50.92	SHS220x220x6	39.59	-22.25%
100	NPB 450X190X67.15	67.15	SHS250x250x6	45.24	-32.63%
150	WPB 250X250X73	73.14	RHS350x250x6	54.66	-25.27%
200	WPB 300X300X100.84	100.84	RHS400x300x6	64.08	-36.45%
250	WPB 300X300X100.84	100.84	RHS400x300x6	64.08	-36.45%
300	WPB 300X300X117.03	117.03	SHS350x350x8	84.62	-27.69%
350	WPB 300X300X117.03	117.03	SHS350x350x8	84.62	-27.69%
400	WPB 300X300X117.03	117.03	SHS400x400x8	97.18	-16.96%
450	WPB 360X370X136.65	136.65	SHS400x400x8	97.18	-28.88%
500	WPB 360X370X136.65	136.65	SHS400x400x8	97.18	-28.88%
550	WPB 700X300X149.89	149.89	RHS500x300x10	120.43	-19.65%
600	WPB 700X300X149.89	149.89	RHS500x300x10	120.43	-19.65%
650	WPB 600X300X177.77	177.77	RHS500x300x10	120.43	-32.26%
700	WPB 600X300X177.77	177.77	SHS400x400x12	143.29	-19.40%
750	WPB 600X300X177.77	177.77	Hollow sections for these capacities are not available		-
800	WPB 600X300X177.77	177.77			-
850	WPB 600X300X177.77	177.77			-
900	WPB 600X300X177.77	177.77			-
950	WPB 700X300X204.48	204.48			-
1000	WPB 700X300X204.48	204.48			-

From these tables, following observations are clear regarding the bending capacities of open sections vis-à-vis hollow sections-

(i) At smaller effective lengths, especially in case of fully laterally supported beams, benefits of use of hollow sections are there only for a very small number of sections. Maximum bending strength that can be achieved by using hollow sections is only 900KN-m, which is quite lesser than that of parallel flange I-sections.

(ii) As the effective length increases, bending capacity of I-sections decrease whereas capacity of hollow sections doesn't reduce much. Due to this, for larger effective lengths such as 6 m and 8 m, for any required bending capacity there is a more economical hollow section available than I-sections.

Table 2 Comparison of axial compression capacities

Table 2(a) Open and Hollow section required for given Axial Compression Capacities (L_{EFF}=0m)

Axial Capacity (in kn)	L_{EFF}=0m I-section	Unit Weight (in kg/m)	Hollow Section	Unit Weight (in kg/m)	Difference in Weight
200	MB200	24.2	RHS60x40x6	7.56	-68.76%
400	MB200	24.2	RHS70x50x8	11.77	-51.36%
600	MB200	24.2	RHS120x60x6	15.1	-37.60%
800	MB200	24.2	SHS125x125x6	21.69	-10.37%
1000	MB300	44.2	SHS150x150x6	26.4	-40.27%
1200	MB300	44.2	RHS250x100x6	31.11	-29.62%

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1400	MB300	44.2	RHS250x150x6	35.82	-18.96%
1600	MB300	44.2	SHS220x220x6	39.59	-10.43%
1800	WPB 200X200X50.92	50.92	SHS250x250x6	45.24	-11.15%
2000	WPB 200X200X50.92	50.92	SHS220x220x8	51.96	2.04%
2200	MB400	61.5	RHS350x250x6	54.66	-11.12%
2400	MB400	61.5	RHS300x200x8	59.5	-3.25%
2600	NPB 450X190X67.15	67.15	RHS300x150x10	65.48	-2.49%
2800	MB450	72.4	RHS400x200x8	72.06	-0.47%
3000	NPB 400X180X75.66	75.66	SHS220x220x12	75.46	-0.26%
3200	NPB 500X200X79.36	79.36	RHS500x200x8	84.62	6.63%
3400	MB500	86.9	RHS500x200x8	84.62	-2.62%
3600	NPB 500X200X90.68	90.68	RHS350x250x10	89.03	-1.82%
3800	WPB 300X300X100.84	100.84	SHS400x400x8	97.18	-3.63%
4000	WPB 300X300X100.84	100.84	RHS300x200x14	99.78	-1.05%
4200	NPB 500X200X107.31	107.31	RHS500x200x10	104.73	-2.40%
4400	WPB 300X300X117.03	117.03	RHS500x300x10	120.43	2.91%
4600	WPB 300X300X117.03	117.03	RHS500x300x10	120.43	2.91%
4800	NPB 600X220X122.45	122.45	RHS500x300x10	120.43	-1.65%
5000	WPB 600X300X128.79	128.79	RHS400x300x12	124.45	-3.37%
5200	WPB 600X300X128.79	128.79	RHS500x300x12	143.29	11.26%
5400	WPB 360X370X136.65	136.65	RHS500x300x12	143.29	4.86%
5600	WPB 700X300X149.89	149.89	RHS500x300x12	143.29	-4.40%
5800	WPB 700X300X149.89	149.89	RHS500x300x12	143.29	-4.40%
6000	WPB 700X300X149.89	149.89	RHS500x300x14	165.72	10.56%
6200	WPB 600X300X177.77	177.77	RHS500x300x14	165.72	-6.78%
6400	WPB 600X300X177.77	177.77	RHS500x300x14	165.72	-6.78%
6600	WPB 600X300X177.77	177.77	RHS500x300x14	165.72	-6.78%
6800	WPB 360X370X182.01	182.01	Hollow sections for these		-
7000	WPB 360X370X197.65	197.65	capacities are not available		-
7200	WPB 360X370X197.65	197.65			-
7400	WPB 360X370X197.65	197.65			-
7600	WPB 700X300X204.48	204.48			-
7800	WPB 700X300X204.48	204.48			-
8000	WPB 600X300X211.92	211.92			-

Table 2b Open and Hollow section required for given Axial Compression Capacities (L_{EFF}=4m)

Axial Capacity (in kn)	**L_{EFF} = 4m**				
	I-section	**Unit Weight (in kg/m)**	**Hollow Section**	**Unit Weight (in kg/m)**	**Difference in Weight**
200	MB300	44.2	SHS100x100x6	16.98	-61.58%
400	MB300	44.2	SHS125x125x6	21.69	-50.93%
600	WPB 200X200X50.92	50.92	SHS150x150x6	26.4	-48.15%
800	WPB 200X200X50.92	50.92	RHS240x120x6	32.05	-37.06%
1000	WPB 200X200X50.92	50.92	RHS250x150x6	35.82	-29.65%
1200	NPB 450X190X67.15	67.15	SHS220x220x6	39.59	-41.04%
1400	WPB 250X250X73	73.14	SHS250x250x6	45.24	-38.15%
1600	WPB 250X250X73	73.14	RHS300x200x6	45.24	-38.15%
1800	WPB 250X250X73	73.14	RHS350x250x6	54.66	-25.27%
2000	WPB 250X250X73	73.14	RHS350x250x6	54.66	-25.27%
2200	WPB 300X300X100.84	100.84	RHS400x300x6	64.08	-36.45%
2400	WPB 300X300X100.84	100.84	RHS400x300x6	64.08	-36.45%
2600	WPB 300X300X100.84	100.84	SHS300x300x8	72.06	-28.54%

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2800	WPB 300X300X100.84	100.84	RHS500x200x8	84.62	-16.08%
3000	WPB 300X300X100.84	100.84	RHS500x200x8	84.62	-16.08%
3200	WPB 300X300X117.03	117.03	RHS400x300x8	84.62	-27.69%
3400	WPB 300X300X117.03	117.03	SHS400x400x8	97.18	-16.96%
3600	WPB 300X300X117.03	117.03	SHS400x400x8	97.18	-16.96%
3800	WPB 600X300X128.79	128.79	SHS350x350x10	104.73	-18.68%
4000	WPB 600X300X128.79	128.79	RHS400x300x10	104.73	-18.68%
4200	WPB 360X370X136.65	136.65	RHS500x300x10	120.43	-11.87%
4400	WPB 360X370X136.65	136.65	RHS500x300x10	120.43	-11.87%
4600	WPB 360X370X136.65	136.65	RHS500x300x10	120.43	-11.87%
4800	WPB 360X370X150.87	150.87	RHS500x300x12	143.29	-5.02%
5000	WPB 600X300X177.77	177.77	RHS500x300x12	143.29	-19.40%
5200	WPB 600X300X177.77	177.77	RHS500x300x12	143.29	-19.40%
5400	WPB 600X300X177.77	177.77	RHS500x300x12	143.29	-19.40%
5600	WPB 600X300X177.77	177.77	RHS500x300x14	165.72	-6.78%
5800	WPB 360X370X182.01	182.01	RHS500x300x14	165.72	-8.95%
6000	WPB 360X370X197.65	197.65	RHS500x300x14	165.72	-16.15%
6200	WPB 360X370X197.65	197.65	RHS500x300x14	165.72	-16.15%
6400	WPB 360X370X197.65	197.65	Hollow sections for these capacities are not available		
6600	WPB 600X300X211.92	211.92			
6800	WPB 800X300X224.37	224.37			
7000	WPB 700X300X240.51	240.51			
7200	WPB 700X300X240.51	240.51			
7400	WPB 700X300X240.51	240.51			
7600	WPB 900X300X251.61	251.61			
7800	WPB 800X300X262.33	262.33			
8000	WPB 800X300X262.33	262.33			

Table 2c Open and Hollow section required for given Axial Compression Capacities (Leff=8m)

Axial Capacity (in kN)	**L_eff=8m**				
	I-section	**Unit Weight (in kg/m)**	**Hollow Section**	**Unit Weight (in kg/m)**	**Difference in Weight**
200	WPB 200X200X50.92	50.92	SHS150x150x6	26.4	-48.15%
400	WPB 250X250X73	73.14	SHS180x180x6	32.05	-56.18%
600	WPB 250X250X73	73.14	SHS220x220x6	39.59	-45.87%
800	WPB 250X250X73	73.14	SHS250x250x6	45.24	-38.15%
1000	WPB 300X300X100.84	100.84	SHS250x250x6	45.24	-55.14%
1200	WPB 300X300X100.84	100.84	RHS350x250x6	54.66	-45.80%
1400	WPB 300X300X100.84	100.84	RHS350x250x6	54.66	-45.80%
1600	WPB 300X300X117.03	117.03	RHS400x300x6	64.08	-45.24%
1800	WPB 300X300X117.03	117.03	RHS400x300x6	64.08	-45.24%
2000	WPB 360X370X136.65	136.65	SHS350x350x8	84.62	-38.08%
2200	WPB 360X370X136.65	136.65	SHS350x350x8	84.62	-38.08%
2400	WPB 360X370X136.65	136.65	SHS350x350x8	84.62	-38.08%
2600	WPB 360X370X136.65	136.65	SHS400x400x8	97.18	-28.88%
2800	WPB 360X370X150.87	150.87	SHS400x400x8	97.18	-35.59%
3000	WPB 360X370X150.87	150.87	SHS400x400x8	97.18	-35.59%
3200	WPB 360X370X182.01	182.01	RHS500x300x10	120.43	-33.83%
3400	WPB 360X370X182.01	182.01	RHS500x300x10	120.43	-33.83%
3600	WPB 360X370X182.01	182.01	RHS500x300x10	120.43	-33.83%
3800	WPB 360X370X197.65	197.65	SHS400x400x10	120.44	-39.06%
4000	WPB 360X370X197.65	197.65	RHS500x300x12	143.29	-27.50%

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4200	WPB 600X300X285.47	285.47	RHS500x300x12	143.29	-49.81%
4400	I-sections for these capacities are not available		RHS500x300x12	143.29	-
4600			SHS400x400x12	143.29	-
4800			RHS500x300x14	165.72	-
5000			RHS500x300x14	165.72	-

From the tables above, following observations can be made regarding axial compression capacities of hollow section in comparison to that of I-sections-

(i) At smaller effective lengths, benefits of use of hollow sections are there only for a very small number of sections. Maximum Axial compressive strength that can be achieved by using hollow sections is only 6600 kN, which is quite lesser than that of parallel flange I-sections.

(ii) As the effective length increases, compressive strength of I-sections decreases whereas capacity of hollow sections doesn't reduce much. Due to this, for larger effective lengths such as 6m and 8m, for any required bending capacity there is a more economical hollow section available than I-sections.

As per a study [2], comparison between the required mass of open and hollow sections for a given load and for a buckling length of 3 m, is presented in **Figure 2**. It shows that in those cases where loads are small, leading to lighter (and hence relatively slender) sections from stress point of view, hollow sections provide a great advantage (considerably lower use of material). However, if loads are heavier, resulting in requirement of heavy sections from stress considerations, the advantage (in %) will be lower. This is due to the fact that heavier open sections, similar to hollow sections, have inherently better design properties about minor axis than lighter sections. It means that for a given length, heavier open sections have lesser slenderness and thus higher allowable strength ratio than lighter open sections. Thus, if hollow sections are used in place of lighter open sections (e.g., MB200, MB250, MB300 etc.), reduction in strength due to slenderness can be avoided but same may not be the case for heavy open sections such as WPB600x300x128 or higher.

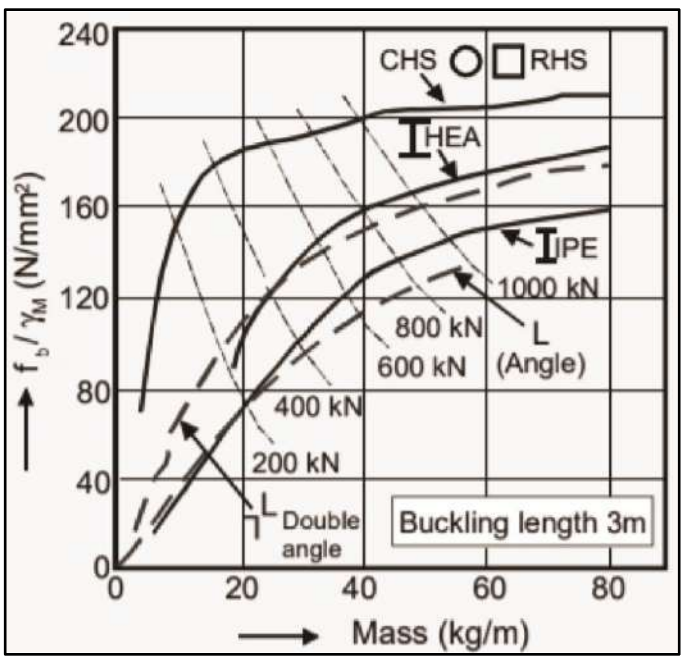

Figure 2 Mass required for Open and Hollow Sections for a given load

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III. **Lesser Requirement of Corrosion Protection**

The closed shape without sharp corners reduces the area to be protected and extends the corrosion protection life. **Figure 3** below shows surfaces requiring painting or other corrosion protect in hollow and open sections.

IV. **Material and Cost Savings**

As explained above, due to better utilization of mass hollow sections exhibit higher strength as compared to open section of same weight and same effective length and hence result in significant savings in material and cost.

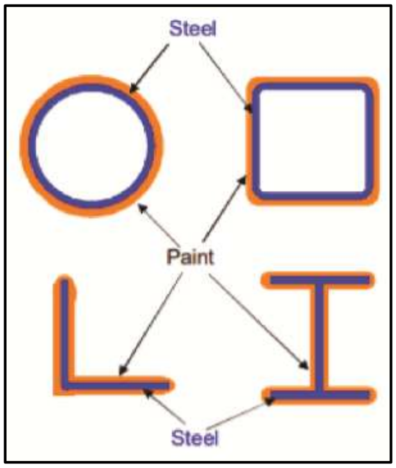

Figure 3 Surfaces requiring painting in hollow and open sections

Although the manufacturing costs of hollow sections are higher than for other sections, leading to higher unit material cost, but reduction in overall quantity of steel required have resulted in lower overall cost for structure.

In order to establish the actual savings in different types of structure sample design have been performed for T-supports, Pipe rack and Technological structures; first using conventional open sections or built-up box sections and then using standard hollow sections. The results of this comparative study are presented below-

T-supports

Comparison presented in **Table 3** shows that there is approximately 2.78-11.23% savings in material if hollow sections are used in place of built-up channel box sections for design of T-supports of various width and height (**Figure 3a**)

Pipe Rack

A comparison of Structural steel MTO for a sample Pipe rack (**Figure 3b**) designed with two above mentioned section categories is presented in **Table 4**. It shows that there is approximately 6.27% savings in material if hollow sections are used in place of conventional open sections.

Technological Structure

A comparison of Structural steel MTO for a sample Technological Structure (**Figure 3c**) designed with two above mentioned section categories is presented in **Table 5**. It shows that there is approximately 14.67% savings in material if hollow sections are used in place of conventional open sections.

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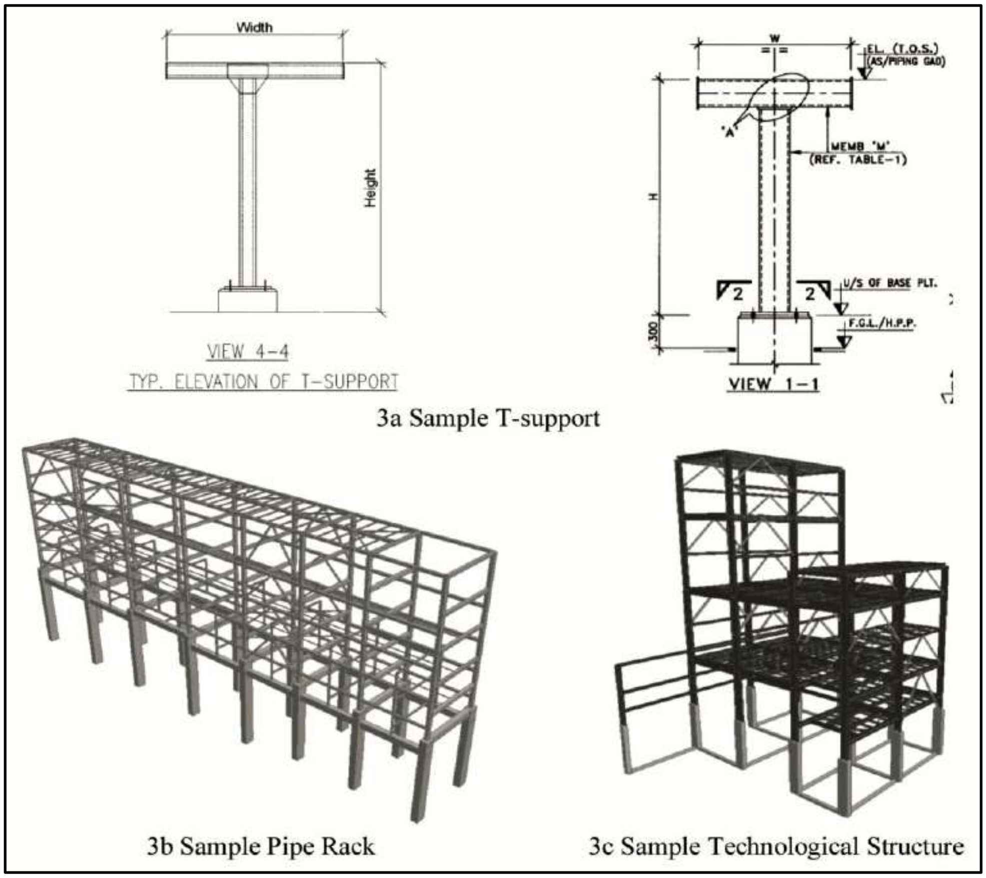

3a Sample T-support

3b Sample Pipe Rack

3c Sample Technological Structure

Figure 3 Sample industrial structures selected for study

Table 3 Reduction in MTO for t-supports

T-support details			**Standard T-support using MC [ ] section**		**Standard T-support using SHS/RHS section**			**%age reduction in weight**
Type	Width (mm)	Height (mm)	Member	Total weight (kg)	Member type	Member	Total weight (kg)	
A	750	2000	ISMC150[]	92.40	RHS	RHS220X140X6	88.28	4.46%
					SHS	SHS180X180X6	88.22	4.52%
B	750	3000	ISMC200[]	167.25	RHS	RHS260X180X6	148.50	11.21%
					SHS	SHS220X220X6	148.46	11.23%
C	750	4000	ISMC250[]	290.70	RHS	RHS300x200x8	280.73	3.43%
					SHS	SHS250X250X8	282.63	2.78%
D	1500	1500	ISMC150[]	100.80	RHS	RHS220X140X6	96.30	4.46%
					SHS	SHS180X180X6	96.24	4.52%
E	1500	2300	ISMC200[]	169.48	RHS	RHS260X180X6	150.48	11.21%
					SHS	SHS220X220X6	150.44	11.23%
F	1500	3000	ISMC250[]	275.40	RHS	RHS300x200x8	265.95	3.43%
					SHS	SHS250X250X8	267.75	2.78%

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Table 4 Reduction in MTO for sample pipe rack

Section Type used in sample pipe rack	Steel MTO (in MT)	Reduction due to use of hollow sections
Conventional Open sections	104.25	6.27%
Hollow sections	98.16	

Table 5 Reduction in MTO for sample technological structure

Section Type used in sample Technological structure	Steel MTO (in MT)	Reduction due to use of hollow sections
Conventional Open sections	210.81	14.67%
Hollow sections	179.90	

PROBLEMS IN USE OF HOLLOW SECTIONS

In spite of the benefits listed above, use of hollow sections in industrial structures has been limited by various factors which are being overtaken by manufacturers and designers both with advancement of technology and domain knowledge.

Limitations on Availability

Hollow sections are manufactured (and used) in accordance with IS: 4923 (Hollow Steel Sections for Structural Use), by either Seamless or Hot finished welded or Electric resistance or induction welded process. So far hollow sections in India have been available for very small sections sizes. Reason being that use of hollow section for structural purposes is governed by IS 4923 which included structural properties of members up to 108 mm x 180 mm and 172 mm x 92 mm only. With new IS 4923-2017, hollow section up to 400 mm x 400 mm and 500 mm x 300 mm size have been incorporated and large hollow section sizes are now being manufactured. Still, there is need for even larger sections as heavy industrial structures in hydrocarbon sector require the rolled sections even up to WPB 900 x 300 x 291, in order to support large equipments and to satisfy stringent design criteria applicable to them.

Other aspect of availability limitation is that even though hollow sections are being manufactured in a larger spectrum of sizes but the same are not available in market very easily especially if the quantity required for a particular section size is small. However, this is being taken care of by manufactures by establishing manufacturing units all across the country, strengthening distribution network and upgrading rolling process to ensure easy changes in process for producing any section size as per order. Further designers are also ensuring to limit the number of sections used in design to the minimum to avoid generating demand for large number of sections with small quantities.

Limitation on Bending Capacity

Though axial capacities of SHS or RHS are substantial, flexural capacities of these sections are not so impressive, resulting in hindrance of its global usage in all structures, which is required for heavily loaded elements for strength & serviceability requirements.

Limitation on Use for Certain Type of Members Only

Hollow sections (especially SHS sections) have similar properties about both the axis. This property is useful for members carrying axial and bending stresses. However in case of purely bending members, such as beams of operating floors etc, minor axis strength is not that much of importance due to presence plane bracing. In such cases, SHS sections usually are in fact a wrong choice of section type. RHS section can be a better choice for such members depending on the unsupported length of compression flange.

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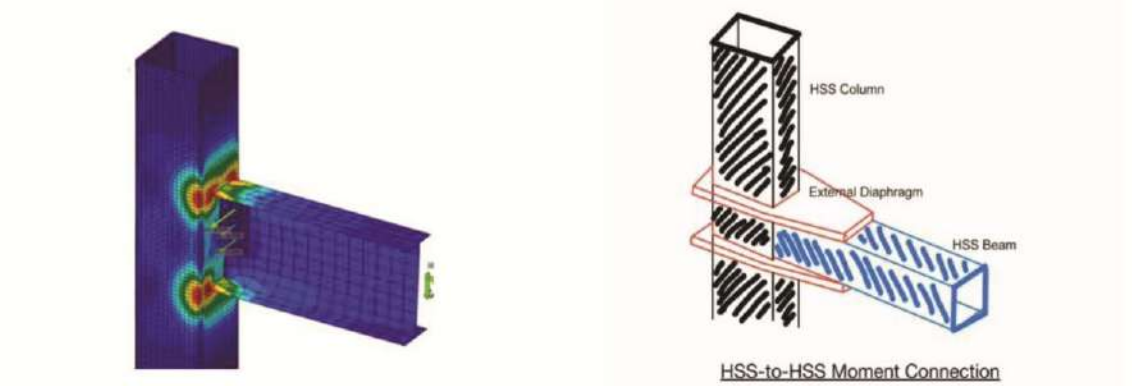
Limitation due to Connection Detailing

These sections being closed from all sides, application of stiffener plates, at the point of stress concentration, such as beam-column junctions (**Figure 4a**), equipment supporting members etc. are not possible. There are studies being done to use external stiffeners at stress concentration points (**Figure 4b**) however this makes connection very cumbersome and unaesthetic. This discourages the usage of these sections for such applications.



4a Stress concentration at joints in hollow sections 4b External diaphragm at stress concentration points

Figure 4 Connection in hollow sections

CONCLUSION

So far, use of hollow sections in large industrial structures has been limited to bracing and tie members only and thus percentage of hollow sections in total weight of steel used in structures is approximately 7-10% only. Major limitation in using hollow sections as main members is the scarcity of connection detailing for hollow sections when used as beams and columns especially in a moment frames. Based on feedback from industry, prominent hollow section manufacturers have started joint efforts with educational and research institutes for development of standard details for various type of connections used in hydrocarbon industry. Once such details are finalized and successfully adopted, use of hollow sections is expected to rise rapidly.

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Effective Utilization of Rolled Sections in Hydrocarbon Plant Structures

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Abstract: *"Make in Steel" strategy is one of the core contributor to take India towards $5-trillion economy goal. Hydrocarbon industry is one of the major sectors, where structural steel consumption is substantial. Along with the growth of the nation, capacities of refineries and petrochemicals are also growing noticeably and thereby demanding variety of structural steel rolled sections in huge quantity. Age-old vicious cycle of demand-supply is continuing to be unbeatable for rolled sections as well. In past few years, manufacturers have geared up to produce more variety of sections. Though it is fascinating for the structural engineers to have more options, tradeoff between various sections becomes difficult; moreover ordering process and inventory management get more stringent for both of the contractors and manufacturers. Various structural components have a particular pattern of axial force and bending moment carrying mechanism; by deep understanding of the same and mapping certain types of rolled sections along with a specific types of structural components, sections can be effectively utilized and variety of sections can be reduced thereof. This paper aims at reducing variety of structural steel rolled sections, by effective utilization of axial and bending capacities of the sections, particularly for structures associated with hydrocarbon industry.*

Keywords: *Structural Steel; Rolled Section; Axial Capacity; Bending Capacity; Hydrocarbon Industry*

INTRODUCTION

Steel has a crucial role in India's growth and the journey towards $5-trillion economy goal. Structural steel being a subset of total steel consumption of the nation, increase of its usage is equally important. Major component of Refinery and petrochemical plants are built in structural steel, thereby hydrocarbon industries are significant contributors towards economic growth of India.

Structural steel rolled sections are primarily used in the structures of hydrocarbon plants. Leading steel manufacturers are evolving continuously in terms of introducing variety of rolled sections and also structural steel grades to expand its base and facilitate its usage. Though enlistment of numerous sections and their huge variety in the manufacturer's catalogue fascinates structural engineers, tradeoff between various sections sizes becomes precarious decision. Moreover, too many varieties of sections cause bottlenecking of the ordering process and inventory management down the line.Certain rolled sections perform well under axial load than under bending moment; whereas the other set of sections show better performance against bending moment than axial load. Also, various components of a structure have a particular pattern in terms of their load transferring mechanism. Rolled sections can be effectively utilized when these two aspects namely section's predominant capacity and structural component's load transferring pattern are mapped properly. Thus, reducing the variety of sections for usage in structures associated with hydrocarbon industry. Though there isa paper available onselection of parameter for I-beam [1], abovementioned aspects is not covered in the study.

The aim of this paper is to reduce the variety of rolled steel sections by shortlisting them on the basis of their predominant axial and bending capacity and by effective utilization in various structural components.

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STUDY DESIGN

Process units of refinery and petrochemical plantsprimarily have three types of major structures.Depending on the capacity of the process units, size of the below mentioned structures may vary; however, configuration remains the same.

Type-I: Pipe racks are the structures that carry all process and utility pipes throughout the process units. Various components (**Figure 1**) of a pipe rack are (a) column, (b) portal beam, (c) longitudinal beam and (d) horizontal/vertical bracing.

Portal beams and columns are connected through moment connections whereaslongitudinal beams and the vertical bracings are connected to the columns through shear connections. All the pipes are supported over the portal beams.

Type-II: Technological structures are the structures that support various equipments, pipes, valves and occasionally air-fin coolers.Various components (**Figure 1**) of technological structures are (a) column, (b) portal beam, (c)longitudinal beam, (d) equipment supporting beam, (e) horizontal/vertical bracing. Grating supporting beams being nominal in quantities shall not form part of this study.

Type-III: Compressor sheds, as the name suggest are for housing compressors along with EOT cranes for removal of part of the motors. Various components (**Figure 1**) of compressor sheds are (a) laced twin column, (b) portal column, (c) portal beam, (d) longitudinal beam-1 (with moment connection at the level of twin column) (e) longitudinal beam-2 (with shear connection at the level of portal column, (f) horizontal/vertical bracing. (g) Crane girder.

Percentage utilization in axial and bending for the abovementioned components of various structures are tabulated (**Table 1**) and the percentages are mentioned against utilization factor. Range of rolled structural steel sections namely NPB and WPB are selected for detailed study of their axial and bending capacities. Bending capacities,maximum and corresponding to lateral torsional buckling(LTB) length of 1.5 m, 3 m and 4m for the selected NPB and WPB sections aretabulated (**Table 2**); maximum and minimum (LTB length=4m) bending capacities are plotted for NPB400 to NPB600 and WBP200 to WPB360 against weight (**Figure 2**); bending capacities for WPB600 to WPB900 are plotted (**Figure 3**) separately. Similarly, axial capacities for the selected NPB and WPB sections are tabulated (**Table 3**) andplotted for NPB400 to NPB600 and WBP200 to WPB360 against weight (**Figure 4**); axial capacities for WPB600 to WPB900 are plotted (**Figure 5**) separately.

RESULT AND DISCUSSION

A: Structural Component Wise Axial & Bending Capacity Utilization Factor

From the utilization factors mentioned in **Table 1**, it is evident that some of the components predominantly behave as bending members; e.g. portal beams of pipe racks; portal beams and equipment supporting beams of technological structures; portal columns, portal beams, longitudinal beams-1 of compressor sheds etc. Similarly some of the components predominantly behave as axial members; e.g. longitudinal beams, horizontal/vertical bracing of pipe racks; longitudinal beams, horizontal/vertical bracing of technological structures; individual section of laced twin columns, longitudinal beams-2, horizontal/vertical bracing of compressor sheds etc. Few of the components such as columns behave as combined bending and axial members.

Refer **Table 2**, maximum bending capacities to weight ratio for NPB sections (67.2-154.5kg/m) varies from 0.5-0.7 (T-m)/(kg/m), whereas for WPB sections with similar weight (50.9-197.7kg/m) varies from 0.2-0.4. Refer Fig. 2, maximum bending capacities of NPB sections (67.2–154.5kg/m)vs. weight is represented in Curve-IA and WPB sections (50.9– 197.7kg/m) is represented in Curve-IB. Slope of the best fit line of Curve-IA is steeper than that of curve-IB. From the slope of the best fit lines of these two curves, it is evident that, for same weight, NPB sections give more bending capacities than WPB sections, or NPB sections are more effective in bending than WPB sections

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of the mentioned weight range. With increase of LTB length, ratio of bending capacity against weight reduces for NPB sections and remains the same for WPB sections. Bending capacities corresponding to LTB length equals to 4m vs. weight for NPB sections (67.2–154.5kg/m) is represented in Curve-IIA and WPB sections (50.9–197.7kg/m) is represented in Curve-IIB. Difference in slope of the best fit lines for Curve-IIA & Curve-IIB is less than that of Curve-IA & Curve-IB. Thus, it can be opined that with increase in LTB length, bending capacities of NPB sections reduces more as compared to WPB sections.

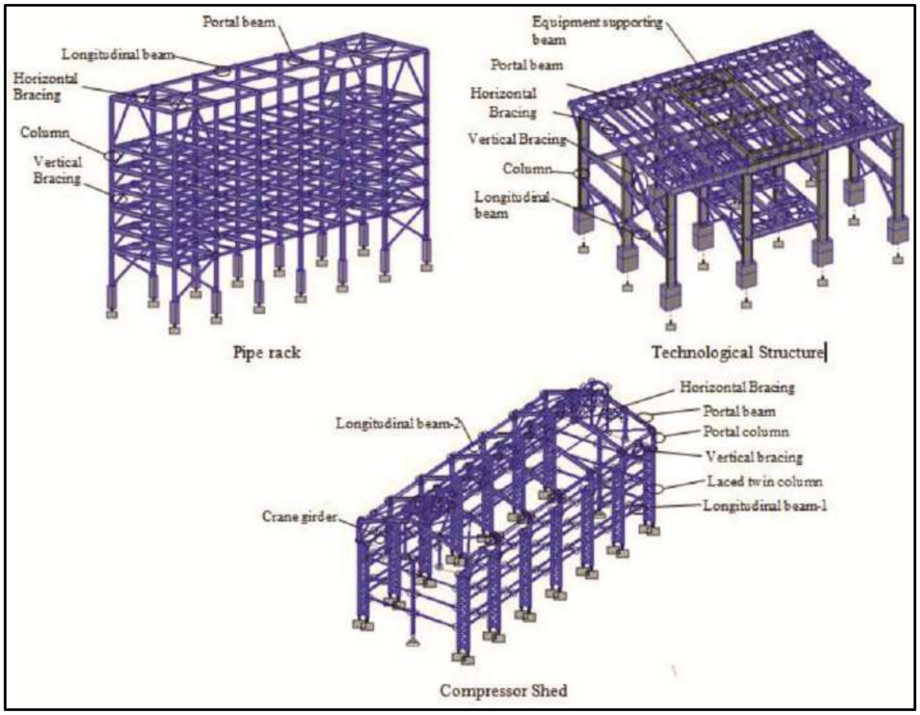

Figure 1 3D View

Table 1 Utilization factor against axial and bending capacities for various structural components

Structure Type	Member	Utilization Factor		Predominent Behaviour
		Axial	Bending	
Piperack	Column	30- 60%	40-70%	Combined Axial & Bending
	Portal Beam	1-5%	95-99%	Bending
	Longitudinal Beam	90-95%	5-10%	Axial
	Horizontal/ Vertical Bracing	100%	Negligible	Axial
Technological Structure	Column	30- 60%	40-70%	Combined Axial & Bending
	Portal Beam	Negligible	100%	Bending
	Longitudinal Beam	100%	Negligible	Axial
	Equipment Supporting Beam	Negligible	100%	Bending
	Horizontal/ Vertical Bracing	100%	Negligible	Axial
Compressor Shed	Laced Twin Column (Individual Sections)	100%	Negligible	Axial
	Portal Column	15-20%	80-85%	Bending
	Portal beam	15-20%	80-85%	Bending
	Longitudinal Beam-1	1-8%	92-99%	Bending
	Longitudinal Beam-2	70-95%	5-30%	Axial
	Horizontal/ Vertical Bracing	100%	Negligible	Axial
	Crane Girder	0.4-1%	99-99.6%	Bending

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Table 2 Bending capacities vs. weight for NPB & WPB sections

Section Names	WT. kg/m	M_{d_max} T-m	M_d/ Wt.	$M_{d\_1.5m}$ T-m	$M_{d\_1.5m}$/ Wt.	M_{d_3m} T-m	M_{d_3m}/ Wt.	M_{d_4m} kN-m	M_{d_4m}/ Wt.
NPB450X190X67.2 (a)	67.2	34.0	0.5	32.5	0.5	28.3	0.4	24.0	0.4
NPB400X180X75.7 (b)	75.7	34.1	0.5	32.6	0.4	28.5	0.4	24.6	0.3
NPB500X200X79.4 (c)	79.4	44.2	0.6	42.6	0.5	37.5	0.5	32.3	0.4
NPB500X200X90.7 (d)	90.7	49.9	0.5	47.9	0.5	42.2	0.5	36.5	0.4
NPB450X190X92.4 (e)	92.4	46.5	0.5	44.6	0.5	39.4	0.4	34.5	0.4
NPB500X200X107.3 (f)	107.3	59.4	0.6	57.2	0.5	50.9	0.5	44.9	0.4
NPB600X220X107.6 (g)	107.6	71.4	0.7	69.2	0.6	62.2	0.6	55.1	0.5
NPB600X220X122.5 (h)	122.5	79.8	0.7	77.3	0.6	69.2	0.6	61.3	0.5
NPB600X220X154.5 (i)	154.5	101.6	0.7	98.6	0.6	89.4	0.6	80.9	0.5
WPB200X200X50.9 (j)	50.9	11.9	0.2	11.6	0.2	10.8	0.2	10.1	0.2
WPB250X250X73 (k)	73.1	22.2	0.3	21.9	0.3	20.7	0.3	19.7	0.3
WPB250X250X103.9 (l)	103.9	32.6	0.3	32.3	0.3	30.7	0.3	29.7	0.3
WPB300X300X100.8 (m)	100.8	36.0	0.4	35.9	0.4	34.3	0.3	33.1	0.3
WPB300X300X117.0 (n)	117.0	42.5	0.4	42.4	0.4	40.5	0.3	39.2	0.3
WPB360X370X136.7 (o)	136.7	59.2	0.4	59.2	0.4	57.4	0.4	55.8	0.4
WPB360X370X150.9 (p)	150.9	66.0	0.4	66.0	0.4	64.0	0.4	62.4	0.4
WPB300X300X182.0 (q)	182.0	80.4	0.4	80.4	0.4	78.1	0.4	76.2	0.4
WPB360X370X197.7 (r)	197.7	87.7	0.4	87.7	0.4	85.3	0.4	83.3	0.4
WPB600X300X128.8 (a’)	128.8	82.3	0.6	81.5	0.6	76.5	0.6	72.1	0.6
WPB700X300X149.9 (b’)	149.9	110.0	0.7	108.7	0.7	101.7	0.7	95.4	0.6
WPB600X300X177.8 (c’)	177.8	121.6	0.7	120.9	0.7	114.6	0.6	109.6	0.6
WPB700X300X204.5 (d’)	204.5	159.8	0.8	158.7	0.8	149.9	0.7	142.9	0.7
WPB600X300X211.9 (e’)	211.9	146.0	0.7	145.3	0.7	138.0	0.7	132.4	0.6
WPB800X300X224.4 (f’)	224.4	197.7	0.9	196.0	0.9	184.6	0.8	175.1	0.8
WPB700X300X240.5 (g’)	240.5	189.3	0.8	188.6	0.8	178.0	0.7	170.2	0.7
WPB900X300X251.6 (h’)	251.6	245.7	1.0	243.2	1.0	228.6	0.9	216.1	0.9
WPB800X300X262.3 (i’)	262.3	232.5	0.9	230.5	0.9	217.5	0.8	207.1	0.8
WPB600X300X285.5 (j’)	285.5	199.4	0.7	198.6	0.7	189.5	0.7	183.1	0.6
WPB900X300X291.5 (k’)	291.5	286.0	1.0	283.2	1.0	266.6	0.9	252.9	0.9
WPB700X300X300.7 (l’)	300.7	239.5	0.8	238.2	0.8	226.4	0.8	217.7	0.7
WPB800X300X317.4 (m’)	317.4	283.8	0.9	281.7	0.9	266.8	0.8	255.2	0.8

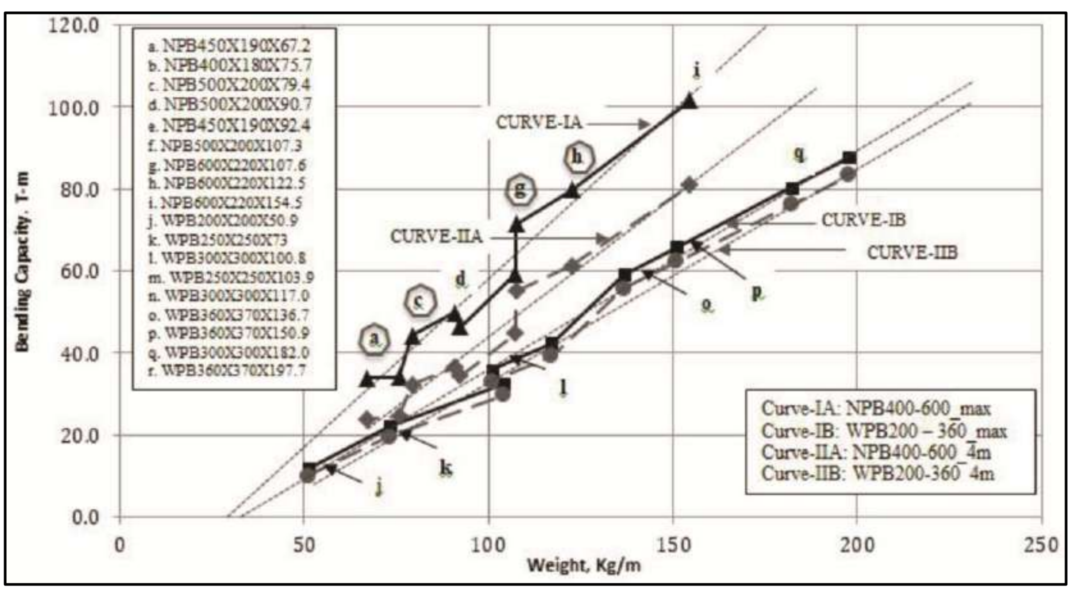

Figure 2 Weight vs. Bending Capacity for NPB400-600 & WPB200-360

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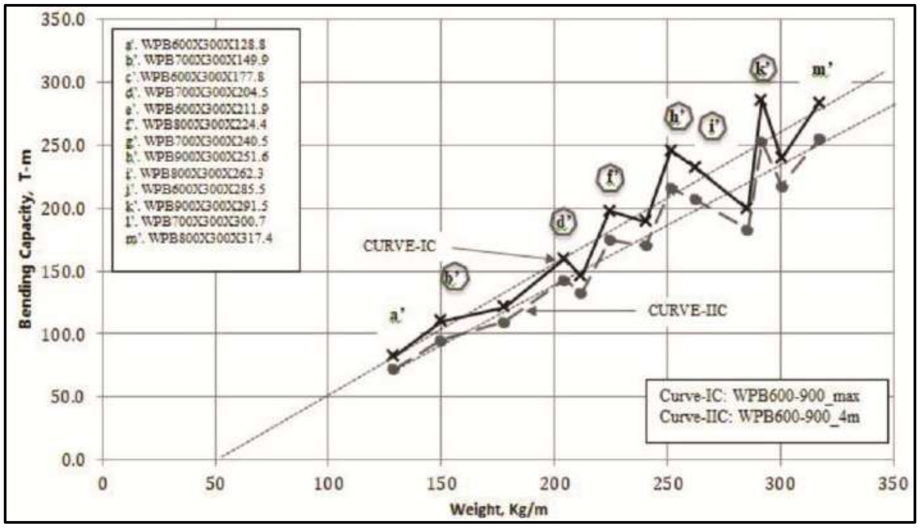

Figure 3 Weight vs. Bending Capacity for WPB 600 - 900

Table 3 Axial capacities vs. weight for NPB & WPB sections

SECTION NAMES	WT. kg/m	$Axial_{max}$ T	$Axial_{max}$/ Wt.	$Axial_{1.5m}$ T	$Axial_{1.5m}$ / Wt.	$Axial_{3m}$ T	$Axial_{3m}$ /Wt.	$Axial_{4m}$ T	$Axial_{4m}$ /Wt.
NPB450X190X67.2	67.2	194.3	2.9	185.0	2.8	154.0	2.3	119.2	1.8
NPB400X180X75.7	75.7	219.1	2.9	207.6	2.7	169.5	2.2	128.0	1.7
NPB500X200X79.4	79.4	229.8	2.9	219.8	2.8	186.6	2.4	148.5	1.9
NPB500X200X90.7	90.7	262.5	2.9	250.7	2.8	211.3	2.3	166.6	1.8
NPB450X190X92.4	92.4	267.5	2.9	254.8	2.8	212.6	2.3	165.1	1.8
NPB500X200X107.3	107.3	310.7	2.9	297.2	2.8	252.3	2.4	200.8	1.9
NPB600X220X107.6	107.6	311.4	2.9	300.3	2.8	262.8	2.4	219.4	2.0
NPB600X220X122.5	122.5	354.5	2.9	341.2	2.8	296.4	2.4	244.4	2.0
NPB600X220X154.5	154.5	447.3	2.9	431.6	2.8	378.1	2.4	316.3	2.0
WPB200X200X50.9	50.9	147.5	2.9	140.3	2.8	118.2	2.3	98.3	1.9
WPB250X250X73	73.1	211.8	2.9	206.3	2.8	182.7	2.5	162.4	2.2
WPB250X250X103.9	103.9	300.9	2.9	294.4	2.8	263.2	2.5	236.7	2.3
WPB300X300X100.8	100.8	292.0	2.9	289.4	2.9	264.4	2.6	244.3	2.4
WPB300X300X117.0	117.0	338.9	2.9	336.1	2.9	307.6	2.6	284.7	2.4
WPB360X370X136.7	136.7	394.3	2.9	394.3	2.9	370.7	2.7	351.2	2.6
WPB360X370X150.9	150.9	436.8	2.9	436.8	2.9	411.0	2.7	389.6	2.6
WPB300X300X182.0	182.0	527.0	2.9	527.0	2.9	496.7	2.7	471.2	2.6
WPB360X370X197.7	197.7	572.3	2.9	572.3	2.9	539.6	2.7	512.0	2.6
WPB600X300X128.8	128.8	373.0	2.9	368.1	2.9	342.7	2.7	318.0	2.5
WPB700X300X149.9	149.9	433.9	2.9	427.5	2.9	396.5	2.6	365.7	2.4
WPB600X300X177.8	177.8	514.8	2.9	510.3	2.9	479.1	2.7	450.3	2.5
WPB700X300X204.5	204.5	592.0	2.9	585.9	2.9	548.4	2.7	513.0	2.5
WPB600X300X211.9	211.9	613.6	2.9	608.4	2.9	571.5	2.7	537.5	2.5
WPB800X300X224.4	224.4	649.5	2.9	641.8	2.9	598.8	2.7	557.5	2.5
WPB700X300X240.5	240.5	696.4	2.9	689.3	2.9	645.5	2.7	604.3	2.5
WPB900X300X251.6	251.6	728.4	2.9	718.8	2.9	668.8	2.7	620.0	2.5
WPB800X300X262.3	262.3	759.5	2.9	750.7	2.9	700.7	2.7	653.0	2.5
WPB600X300X285.5	285.5	826.6	2.9	820.4	2.9	772.1	2.7	728.1	2.6
WPB900X300X291.5	291.5	843.9	2.9	832.9	2.9	775.4	2.7	719.5	2.5
WPB700X300X300.7	300.7	870.5	2.9	862.6	2.9	809.4	2.7	760.1	2.5
WPB800X300X317.4	317.4	918.9	2.9	909.0	2.9	850.1	2.7	794.3	2.5

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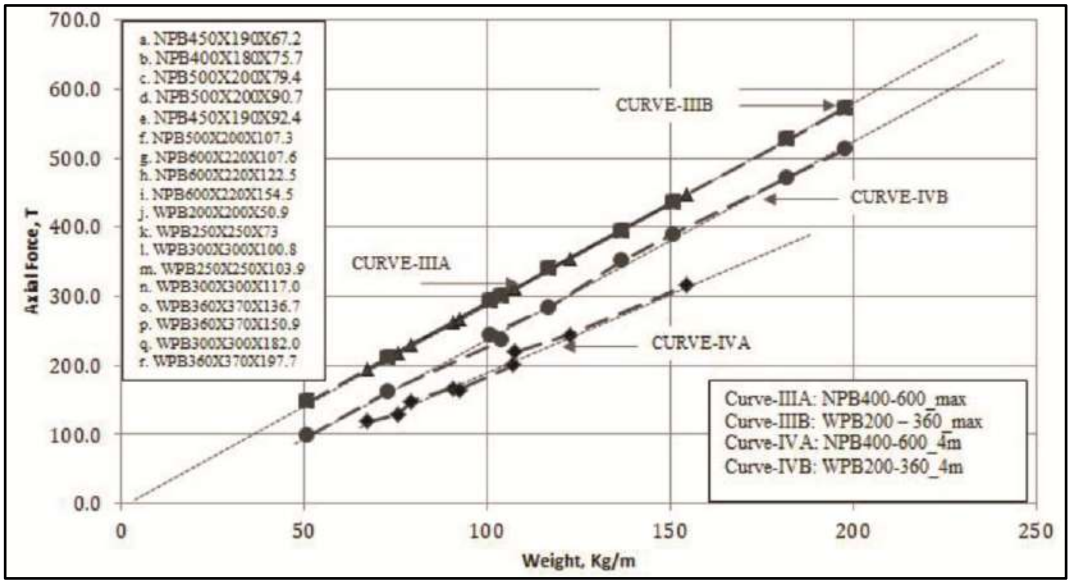

Figure 4 Weight vs. Axial Capacity for NPB 400 – 600 & WPB 200 - 360

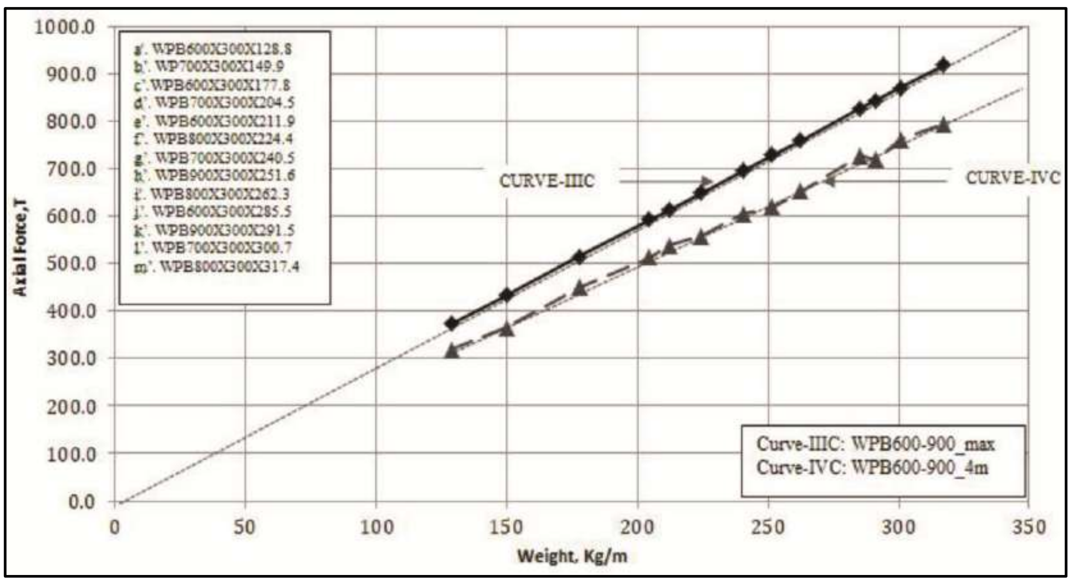

Figure 5 Weight vs. Axial Capacity for WPB 600 - 900

B: Bending Capacities of NPB & WPB Sections - Maximum and against Various LTB Lengths

Refer Curve-IA of **Figure 2**, sections above best fit line, as represented by point “a”, “c”, “g” and “h” have better bending capacity to weight ratio than rest of the sections. Sections represented by points “d” and “i” are lying over the best fit line, ratio of maximum bending capacity to weight ratio of NPB500x200x90.7, represented by point “d” is 0.5 (T-m)/(kg/m), whereas the same ratio of NPB500x200x79.4, represented by point “c” is 0.6 (T-m)/(kg/m); so for the same depth 500 mm and same flange width 200mm, utilization of NPB500x200x79.4 in bending capacity is better than that of NPB500x200x90.7.However, from Curve-IB, WPB sections represented by points are near to the best fit line, so in this range most of the WPB sections are more or less similar in terms of utilization.

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In reference to Curve-IC of **Figure 3**, WPB sections represented by points b', d', f', h', i', k' are lying above the best fit line, and therefore, they are utilized better than the rest of the sections in terms of bending capacity w.r.t.weight. WPB 900x300x291.5, represented by point k' is having more bending capacity as compared to WPB 800x300x317.4, though the weight of earlier section is less than that of the later. Thus, WPB 800x300x317.4 is not effective in terms of its utilization in bending capacity. Also, slopes of the best fit lines of the Curves-IC & IIC are almost similar; therefore, it is clear that bending capacities of this range of WPB sections do not reduce much as compared to their maximum capacities up to LTB length of 4m and thus the sections are well utilized for this length. For higher LTB lengths further study can be done to understand the utilization.

C: Axial capacities of NPB & WPB Sections - Maximum and against Various Unsupported Lengths

Refer **Table 3**, though maximum axial capacities for NPB400 to 600 sections and WPB200 to 360 sections with similar weight rangevaries, axial capacities of NPB sections for higher unsupported length, say 4m are quite less than that of WPB sections. Thus, it is evident that, WPB sections are better for axial members than NPB sections. Refer **Figure 4**, difference in slope of Curve-IIIA and IVA is much more than that of Curve-IIIB and IVB. Therefore, it is evident that utilization of WPB sections against axial capacity is much better than NPB sections. **Figure 5** also depicts similar pattern for WPB600 to 900 sections.

However, in case of axial capacity, all the sections of NPB and WPB for the mentioned range of weights have uniform efficiency in terms of axial capacity w.r.t. weight.

CONCLUSION

On the concluding note, findings from the present study can be summarized as below –

1. NPB400 to 600 sections (67.2-154.5kg/m) are more efficient as bending member than as axial member, especially for LTB length up to 3 to 4m. Thus, they may be better utilized as portal beams of lightweight pipe racks,portal beams and equipment supporting beams of lightweight technological structures; portal beams, columns, and longitudinal beams at twin column level.

2. WPB200 to 360 sections (50.9-197.7kg/m) are more efficient as axial member than as bending member.Thus, they may be better utilized as longitudinal beams in braced frame directions for pipe racks, technological structures and compressor sheds. These sections are also effective as bending members for LTB length more than 4m; thus they may also be effectively used for beams where the same cannot be laterally restraint up to 4m.

3. For column of lightly loaded piperack or technological structures, any of the abovementioned sections may be used based on actual predominant behavior either axial or bending. Laced twin column of the compressor sheds being almost restraint against LTB, any of the NPB or WPB section based on actual requirement of axial capacity may be used.

4. WPB600 to 900sections (128.8-317.4kg/m)are efficient as bending as well as axial member; thus may be effectively used as portal beams, columns, equipment supporting beams etc.

5. For horizontal/vertical bracings, some small sizes of WPB sections may be used, though angle sections and square hollow sections (SHS) are more effective for the same. However, angle and SHS sections are not in the purview of this paper, separate study may be carried out in similar line for these sections.

6. Few sections are more efficient in terms of their utilization in bending or axial capacities w.r.t.weight than other sections, those sections may be shortlisted at the onset of any projects based on nature and size of process units, so as facilitate ordering and inventory management by means of reduction in variety.

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This study, thus suggests a concept, which may be adopted for other industries as well. However, values mentioned here are relevant for this case study only and the same should not be used for otherareas withoutanalytical backup.

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Tomographic Image based Pavement Condition Assessment using Machine Learning Approach

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Abstract: *Tomography is a new nondestructive concrete pavement diagnostic tool that may be utilized for better quality assurance and control during construction as well as to aid in rehabilitation decision-making. Pavement condition evaluation gives data that may be used to economical judgments about its maintenance. Surveys are carried out with the help of high-end vehicles or on-the-ground processes to calculate distress on pavement. As this system is man-dependent, it tends to be dangerous, less efficient and costly. Photos of road to be used for determining distress is yet a challenge to be solved. Researchers have been able to construct strong techniques for evaluating pavement tomographic pictures with remarkable accuracies because to recent advances in machine learning. Machine learning algorithms, on the other hand, require a large ground truth dataset, which is typically unavailable in the pavement field. Pictures from the Mumbai-Pune highway and Dehu road were manually removed and tagged for categorization, resulting in a large number of Google street-view images. The model was then trained using the labelled dataset of Indian roads using the YOLO (you only look once) machine learning framework. The model is used in this study to categorize the distresses and estimate their intensity at the same time. Indicators for determining pavement conditions are created for distress categorization segmentation and distress densification utilizing the YOLO machine learning framework using machine learning techniques. These outcomes are used to create a complete tool for pavement monitoring that assigns a score to each pavement Tomographic picture based on the kind and intensity of the distressed part. Thus, human intervention is restricted. This study might be useful in evaluating pavement conditions over time and assisting in making informed judgments for road restoration or rebuilding at the appropriate time.*

Keywords: *Tomographic Images; Pavement Condition; Machine Learning; YOLO; Accuracy Index*1.

INTRODUCTION

In the construction sector, quality may endeavor to meet different consumer expectations despite shifting dynamics [1]. As the consumers become conscious regarding the quality, the construction firms are aggressively seeking to adopt high quality to ensure long-term viability [2]. Quality assurance (QA) is usedalong with total quality management (TQM) in construction business for quality management systems (QMS) according to Lau and Tang [3]. TQM is a culture that prioritizes customer satisfaction above constant improvement and innovation across the whole company process [4]. TQM make it possible to improve the satisfaction levels of the customer, enhances productivity and qualityand healthy environment for competition according to Jaeger and Adair [5].

The building sector has long struggled to achieve acceptable quality standards. Each year, lot of resources are wasted due to lack of good quality management methods. TQM ideas, originally employed in Japan and more recently in the USA, have improved productivity, reduced the cost, and improved dependability in the manufacturing business. These ideas may be used to the building business as well. During the 1970s, for example, Japanese construction businesses began applying TQM, based on the experiences of Japanese manufacturers. Despite the fact that building is a creative, once-in-a-lifetime activity, the Japanese construction sector adopted TQM ideals that some believed were only applicable to mass manufacturing.

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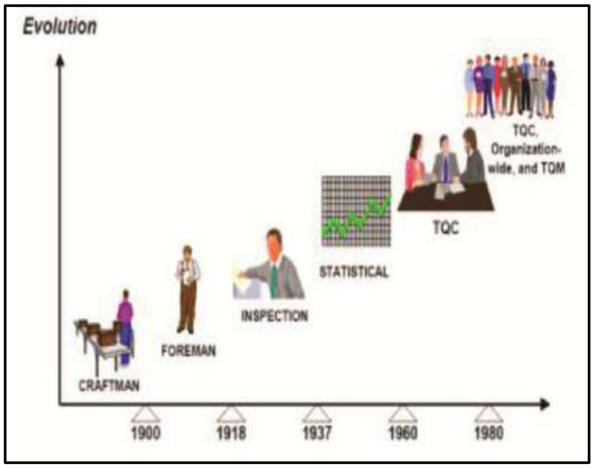

Figure 1 Quality Control Evolution

Definition of Quality

The quality of a project is described as meetings its functions and legal standards along with its aesthetics. The project requirements are expressed based on expectations from it. Quality is said to be good if the work carried out meets these expectations.

An efficient pavement management system (PMS) can be developed by identifying the distress on the pavement which gives in-depth analysis of its condition. Thus, economical and constructive decisions may be taken for its management. As the system for distress identification is man-dependent, it tends to be dangerous, less efficient and costly.

Benefits of TQM using Pavements model in the construction industry:Benefits of TQM in construction business are:

- Achievement of consistency throughout project.
- Enhanced control over all processes.
- Reduced cycle time for construction.
- Less losses.
- The time it takes to get to the location has been cut in half.
- Chemical spillage is reduced.
- Increased performance measurement and improved consumer views of the business.
- Gives the predication of unnecessary incident.

LITERARURE REVIEW

Following section discuss the overall review of related work related to TQM,

Arash Hosseini, et al, 2019, This paper deals with different Quality control indicators for long-term performance of pavements. Geo-relational data base of in-service pavement is created and then linked with quality indicators and long-term performance. Methodology adopted is 1. Data collection, 2. Production quality data, 3. A dataset of 30 projects for about two hundred miles is used for performance analysis. The segments used are: alligator, transverse

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and rutting types of cracks along with longitudinal cracking. And to quantify this DI (Deterioration index) is calculated (DI=416.1X^0.02875-383.7).

The goal of this study is to link pavement performance at a specific area to individual data points collected during the mix manufacture and building stages. A total of 30 pavements were used to create 101 test sections. The resistance of HMA mixtures containing 12.5mm NMAS to rutting and alligator cracking is investigated.

Abhay Tawalare, et al 2016, This paper deals with PPI for rural roads which is useful for further development of rural areas. Because funding resources for rural road maintenance are limited, there is always a decision-making tool. Many parameters are considered in this paper which will be useful for PMGSY field engineers.In totality, twenty-two PD parameters were identified and out of which only necessary parameters were selected through expert opinions and these experts were having more than 25years of experience in rural road construction. A questionnaire was created to determine the severity of each characteristic contributing to rural road deterioration on a scale of 10 to 100 percent, and it was delivered to all district officials. 117 responses were received. And this data was analyzed and weightage of each was used to find PPI i.e Pavement Performance Index and validation was done.

The model is built on a priority ranking model, and it is the result of multiplying each degrading parameter's rating and weightage. A distress survey may be used to establish a rating for each. Validation revealed a PPI of 3.746, indicating that pavement performance in April 2015 was satisfactory. PMGSY field engineers will benefit greatly from this concept. PPI may also be used to generate a priority list of rural roads in need of repair and upkeep.

Aman A et al,2016, A Hidden Markov Model (HMM) based framework for dealing with expectations of customers is formed in this paper. It utilizes house of quality for generating future requirements. The QFD make the decisions for pavement maintenance based on HMM. Data was collected and was in the form of pie charts and this data was marked in three categories namely High with 5, Medium with 3, and Low with 1 weightage. Socio-economic, safety, maintenance efficiency and environment are considered the main parameters.Further non-stationary hidden Markov model can be used for improvement, along with this uncertainties model can also be prepared. Also, advanced modelling techniques will be required for vast amount of computer programming and simulation.

Umesh Sahoo et al; 2014, This report is on rural roads, specifically 19 rural roadtest-sections are considered for performance study.Roughness and rutting are considered as main factors in varying traffic conditions. Here conditions used were tenth was kept shorter for better results considering minimum length limit upto 200m suggested by Cundil(1996) for roughness measurement. Herea NDT method of FWD(falling head deflectometer) is commonly used. The defection data is used to back calculate the layer moduli. Other parameters considered are as suggested in the previous study like rutting, raveling and cracking which form potholes and depressions. Pavement layer composition were also studied.

Research Problem

- The conventional method of evaluating project bids, which places the most focus on price and gives less weight to prior expertise, present workload, and reputation for quality.
- Determining the state of a pavement is critical in determining the type and scope of repairs that should be made to the road in order to provide the necessary level of service to vehicle traffic.
- Efficient design and preservation of drains is necessary for main road especially in the mountains and heavy rain areas.
- TQM implementation for long term, particularly in the construction sector, causes a big issue.
- A lack of understanding and information on TQM.
- Heavy traffic, axle load, and a water-logged location are the main causes of distress.
- The occurrence of the pavement condition under evaluation in the Critical PCI Range does not require its immediate restoration.

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- There is no way to measure the quality of building procedures.

Objective I: To Analyze existing method control statements used in pavement construction processes

Method Statement for Chandani Chowk Flyover Project:

Granular sub base (GSB)

The scope of this job is to lay and compress well-graded GSB material on a prepared and authorized subgrade in line with MORT&H standard Article 401.

Quality Control

• At the job site, the gradation of the material must be managed by making required modifications.

• At a rate of one test per 1000 sq.m., the compacted surface will be examined for field density. When evaluated according to IS: 2720, the degree of compaction should not be less than 98 percent (Part-28).

• The surface must be examined for levels at MORTH intervals longitudinally and transversely, and the difference must be less than 10mm.

Subgrade:

Scope:

Construction of sub grade with approved borrow material as per MoRTH.

Construction of sub grade with approved suitable material available from the roadway excavation or any other excavation

Quality Control:

Compaction control: The compaction control shall be done by comparing the field dry density with the laboratory Maximum Dry Density for achieving 97% of compaction at the OMC +1% to -2%. Control shall be exercised on each layer to meet the required degree of compaction before going to the subsequent layer.

Dense Bitumen Macadam:

Scope:

- The work will consist of a double course of 135mm in two stages of construction. On a previously prepared non-bituminous / existing bituminous surface, the thickness of pavement the required as per specification. The purpose of this methodology is to outline the guideline for laying of Dense Bituminous Macadam At site
- Asphalt Batch mix plant (120 TPH) : 1 No
- Sensor Paver: 1 No
- Smooth Wheel tandem vibratory roller : 1 No
- Truck Mounted Bitumen Sprayer: 1 No
- Tippers : As per site requirement
- Thermometer for Measuring Temperature : 1 N of Mix.

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Wet Mix Macadam Construction:

Material Specifications :

Los Angeles Abrasion Value	Max 40%
Aggregate Impact Value	Max 30%
Combined Flakiness and Elongation Index	Max 35%
Plasticity index	Max 6
Gradation	Confirming to 400-13
Compaction	1 set for 1000Sq.m

Questionnaire :

- From IRC 57 2000, Table (E-2)-1 for Quality Grading for Concrete construction the following Questions were considered to know the acceptable quality of concrete.

- This Questions were asked to the Expert from NCC (Nagarjuna Construction Company) by physical visiting on site (Chandni Chowk Flyover Project).

Sr. No.	Item/Factor
1.	QA/QC System/Service available*
2.	Storage of Cement*
3.	Type and Storage of aggregates
4.	Water used Quality*
5.	Use of admixtures
6.	Type and use of machinery
7.	Training of personnel and *level of awareness
8.	Client Supervision QTY+Qlty
9.	Workability of Concrete*
10.	Control and checks on W/C ratio*
11.	Sequence of loading in mixer (for tilting mixers)
12.	Transport and placing time lag, tools, equipment, ski
13.	Formwork design Accuracy*
14.	Formwork-Water tightness*
15.	Formwork- Release agent
16.	Formwork-Sequence of release
17.	Reinforcement: Type and testing
18.	Reinforcement: Storage & Fabrication
19.	Reinforcement placing and cover blocks*
20.	Reinforcement congestion-detailing
21.	Construction joints type- execution*
22.	Finishing of concrete-tools
23.	Finishing of concrete materials*
24.	Curing method*
25.	Curing Time
26.	Surface blemishes*
27.	Dimesion and profile of finished concrete
28.	Testing of concrete frequency
29.	Hot weather concreting precaution*
30.	Provision for maintenance of concrete surface

Outcome of Questionnaire Survey for

Chandani Chowk Project :

- W.c ratio, Workability, Testing, Target Strength are used as per the MORTH Specifications and IS 456.
- Various Factors/ Items from the table are properly followed and maintained as per the given information so we can conclude that acceptable Quality work is done.

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MCS by Ajwani Infrastructure Pvt. Ltd for Development of road (concrete road) at sector No. 16 Rajeshivajinagar in prabhag No. 2”

METHOD STATEMENT FOR EXCAVATION OF ROAD IN SOIL / ROCK.

- Compaction at OMC to achieve min. of 95% / 97% of MDD for the given case
- The cut formation, which serves as sub grade if found suitable, then the same shall be checked for its relative compaction as per table 300.2, and if fails then the same shall be loosened and compacted in layers in the specified manner.

Stemming:

- Stemming may be used if required, of free dry running material, which passes through a 2.8mm sieve and retained on 1.2mm sieve by 90%.

METHOD STATEMENT FOR EARTHWORK IN EMBANKMENT (FILLING)

The following types of materials are not appropriate for embankment.

a. Plants found in swamps, marshes, and bogs.

b. Peat, log stumps, and perishable materials any soil classified as OL, OI, OH, or Pt. by IS: 1498.

c. Materials that can spontaneously combust.

d. Materials that have been frozen.

e. Clay with a liquid limit more than 50 and a plasticity index greater than 25.

f. Materials containing salts cause leaching in the embankment.

Acceptance Criteria :

- Field Dry Density Shall be greater than 95% of MDD.
- Optimum moisture content shall be +1% to -2% during the time of compaction

METHOD STATEMENT FOR EARTHWORK IN SUBGRADE (FILLING)

- The material that have LL less than 50%,PI less than 25%,Free swell Index Less than 50% shall be used for Sub grade construction. The material which is having Lab MDD of min.
- For sub grade, clods and hard lumps of soil will be broken down to a maximum size of 50mm.

Acceptance Criteria:

- Field Dry Density Shall be equal to or greater than 97% of MDD.
- Layer thickness tolerance shall be+ 20 mm.
- Optimum moisture content shall be +1%to -2% during the time of compaction.

METHODOLOGY FOR GRANULAR SUB BASE

- Rolling shall be continued for giving sufficient number of pass to achieve field density in excess of 98 % of M.D.D. as per Lab.

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METHODOLOGY OF CONSTRUCTION PAVEMENT QUALITY CONCRETE

- MORT&H specification clause No. 602 IRC 15 – 2011 and technical specification of contract.

MCS By Ajwani Infrastructure Pvt. Ltd. For "Widening and construction of road and Nalla on the land Transferred by Agriculture Department from Wadhmukhwadi Fata To Chavisawadi Fata on Pune

METHODOLOGY FOR BITUMINOUS MACADAM / DENSE BITUMINOUS MACADAM / BITUMINOUS CONCRETE

- Bituminous concrete of 5.4% (Vg30) provides hot-laid and mixed bitumen of bituminous concrete by the total mixed weight per MORTH Clause 509.
- Bituminous' Macadam concrete of 4.5% (Vg30) provides hot-laid and mixed bitumen of bituminous concrete by the total mixed weight per MORTH Clause 507.
- Bituminous' Macadam concrete of 4.5% (Vg30) provides hot-laid and mixed bitumen of bituminous concrete by the total mixed weight per MORTH Clause 507.

Quality Control

- All materials and workmanship must meet the requirements of section 900 of the MORTH, IRC, I.S., or the Tender QAP.

Objective II:To perform Tomographic image analysis on constructed and operated pavements, determine pavement condition index(PCI)

Proposed Methodology:

In this project, we are attempting to use a python code written to extract photos from Google street-view utilizing the Google Application Programming Interface (API). Pavement specialists analyzed the images by hand, considering nine various levels of discomfort. After then, the data set's performance was evaluated using You Look Only Once, a well-known deep learning framework (YOLO v2). YOLO's proposed model, on the other hand, did not quantify the fracture density. Hence, we studied the U-net type of model and developed it to evaluate the signals of distress density. Decisively, the conditional indices of the proposed developed models of YOLO and U-Net based ML predictive models were used to propose the distress conditional detection of the pavements of concrete or asphalt using the deep learning based predictive models. The key to verify the variety, quantity and quality of the utilization of the data is promptly noted.Because of the labeled datasets developed for the conditional rigid pavement author Majidifard et. al. represented the tomo-graphical image of pavement datasets. The extracted images consists of 7237 types of images which are considered as the datasets amongst 22 different sectionized pavements including the ones with interstate-wise routes and highways. Illustrated **Figure 2** summaries the major contributory part of the study.

Automated Detection, Segmentation and Classification Methods gor Cracks

First, we presented a one-of-a-kind dataset annotated for PD categorization and densification at the same time. The data comes from Google Street View, as well as manually collected photographs of the Mumbai Pune highway and Dehu Road, which provide us a diversity of camera perspectives to help the recognize severity of distinct types of fracturs and cracks.

Secondly, implementation of the delineating boundries of various abnormal conditions like critical shadow and non-cracked objects like trees, cars, etc. is segmented model to model as per the distress signals. Overcoming intelligent models with high-end architectural designing are envisaged by accepting the challenge.

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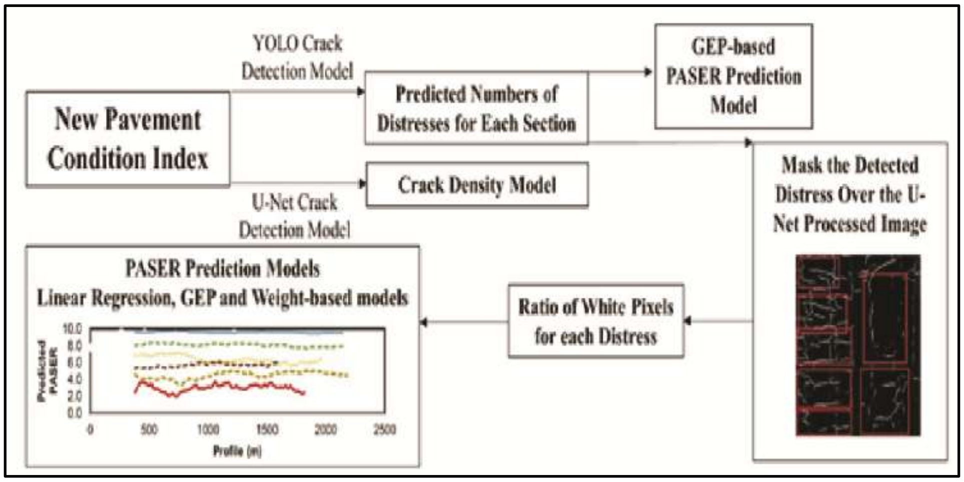

Figure 2 Proposed Work flowchart

Contemporary conditional pavements based on cracked YOLO classifier, hybrid-ML and U-Net density model is used to detect the distress signals.

The tomographic process of segmenting one picture into many parts is known as image segmentation. Classification of lines and curves in the images under conceptual image segmentation is performed. Considering the background areas of the objects in the image, its segmentation is nothing but the extraction of edge-detection.Semantic objects like humans, cars or buildings in the tomographic and videos associates computer vision and image-processing copes for detecting object-based classification. In the ML and AI based development, the object-based classification and segmentation under both the image processing techniques carryout precisely. The segmentation of the classifier related to the objects in a single image is possibly used for grouping and categorizing into a single class. During segmentation, each object in an image belonging to a single class is highlighted with distinct hues in order for computer vision to recognise them. The degree of the distresses can be detected in crack segmentation, but there is no way to divide them into different categories. On the other hand, the distresses can be grouped into distinct categories in the classification techniques, but the severity cannot be quantified.

Thresholding and edge detection are the two most used segmentation methods. In automatic PD systems, threshold-based segmentation is often used. Edge detection is another common image processing approach. The quick reduction of picture data to useful information is a key advantage of edge detection. Various edge detectors like Roberts, LOG, Prewitt and Sobel detectors are used to carry-out the process.Nevertheless, problems under edge-detection corresponds to characterization under spatial scale is tiresome to be detected. Because of the many features at various scales, it is recognized that working with Pavement Tomographic pictures in the process of PD is difficult. Wavelet-based edge identification at many scales has been prominent in pavement image processing during the last decade. Various hindrances of sudden lighting and shadows in the pavement images are introduced automatically with new technical challenges in the distressed signaling schemes.Here, we're attempting to create a new PCI using data from a crack categorization model and machine learning models.

Research carried by Majidifard et. al. on comprehensive development of the deep learning algorithms from the pavement-based data-set's distress signals have inspired this work.This section focuses on their work and how it relates to the present research. After evaluating several studies, the researchers classified and documented nine categories of the most essential distresses that impact pavement condition. Huge, distress database of pavement from 22 various US based areas are distributed section ally using python code in which communication between the API is carried-out with the google view street.In addition to this, the images acquired from the google view street is predefined as per the distress classifier signals, which is illustrated in the Figure-3. It offers an instant annotation of the 9 distinct types of categorical paving types. Therefore, from the figure illustrated, the blocking of cracks, selective reflection, sealed and lane based longitudinal cracks are amongst the highest boundaries in the boxes that are founded in the paving datasets.

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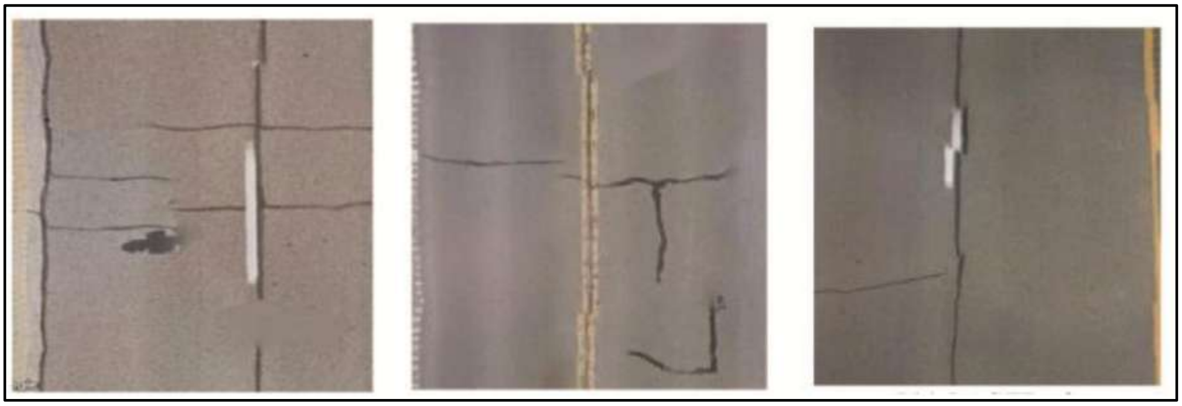

Figure 3 Sample Tomographic images for proposed model

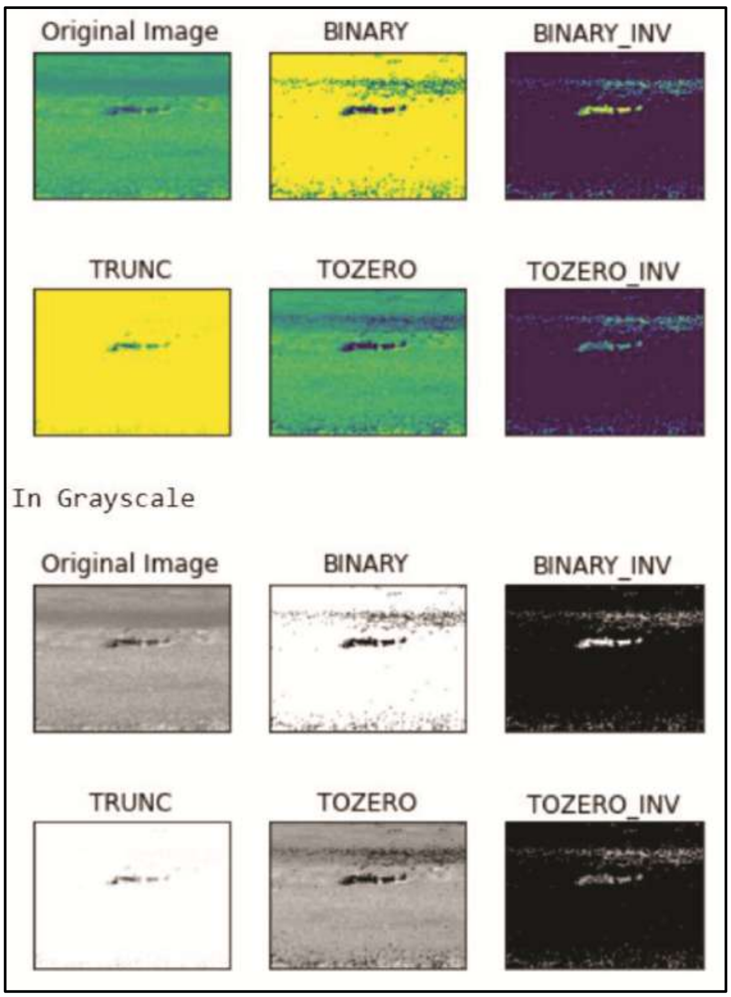

Figure 4 Conversation of tomographic images

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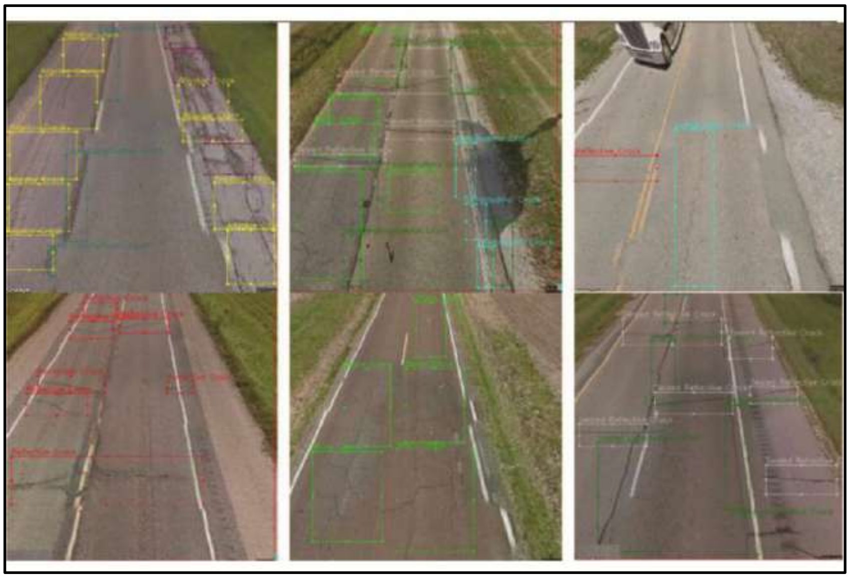

Figure 5 Obtain Result using proposed model

CONCLUSION

A deep machine learning technique was used in this work to forecast road-way pavement quality.The models were trained using a large dataset of road conditions derived from Google Street View. Bounding boxes with nine distinct PD were added to the photographs. A cutting-edge deep learning system was used to automatically identify andcategorize the PD. Moreover, 9 segments were formed for PDI. The density of the distresses was calculated using a pre-trained model approach.A U-Net based algorithm was used for this purpose. Road photos obtained manually in a range of atmospheric circumstances were used to fine-tune the pre-trained model. The proposed algorithm can distinguish characteristics such as automobiles, shadowsand PD with accuracy.

The suggested algorithm has certain benefits over other deep-learning based algorithms. First, this technology reduced PASER's reliance on human judgement and improved its accuracy. Furthermore, this research is a trailblazer in terms of producing a PCI prediction after PDI. Second, the algorithms were trained with freely available Google street-view pictures of roads. In future we will try to work on comparative analysis of different models with number of input images for more accurate analysis

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Optimum Size of Radius of Curvature for a Trapezoidal Channel to Minimise Hydraulic Loss

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Abstract: *Optimum value of the radius of curvature to be provided to join the bed of a trapezoidal channel with side slopes has been worked out, to minimize the head loss in the channel. It has been found to be equal to 0.4 R, where R is the mean hydraulic radius of the channel, for all values of side slopes. Provision of curves with a radius equal to the depth of the channel has been found to increase the head loss instead of decreasing it, thus defeating the very purpose for which it is provided.*

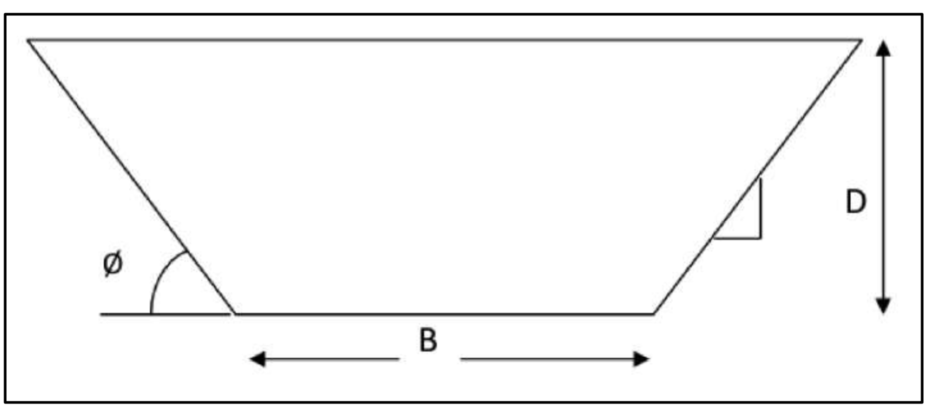
Keywords: *Hydraulic Loss; Trapezoidal Channel; Radius of Curvature*

INTRODUCTION

In lined canals and hydel channels with trapezoidal cross-section, usually circular curves are provided to join the bed with the side slopes. The objective of these curves is to smooth the flow of water and hence reduce the hydraulic head loss in the channel. The radius of the curves is fixed on ad-hoc basis. In India, for more than a century, the practice is to provide a radius equal to the water depth in the channel. In this paper, the optimum value of the radius of curvature has been worked out, to minimize the hydraulic head loss in the channel. This optimization becomes of paramount importance in the case of hydel channels and tail race channels of hydro power plants, as each millimeter of head saved, can result in thousands of more units of power generation. It has been found that the century old practice of providing curves equal to the water depth of the channel, actually increases the head loss, instead of decreasing it, thus defeating the very purpose for which it is provided.

DERIVATION OF MATHEMATICAL RELATION

Consider a trapezoidal channel of width B and depth D with inclination angle of the sides to the base of the channel as {Zl and having a curve of radius r at the bottom 2 corners



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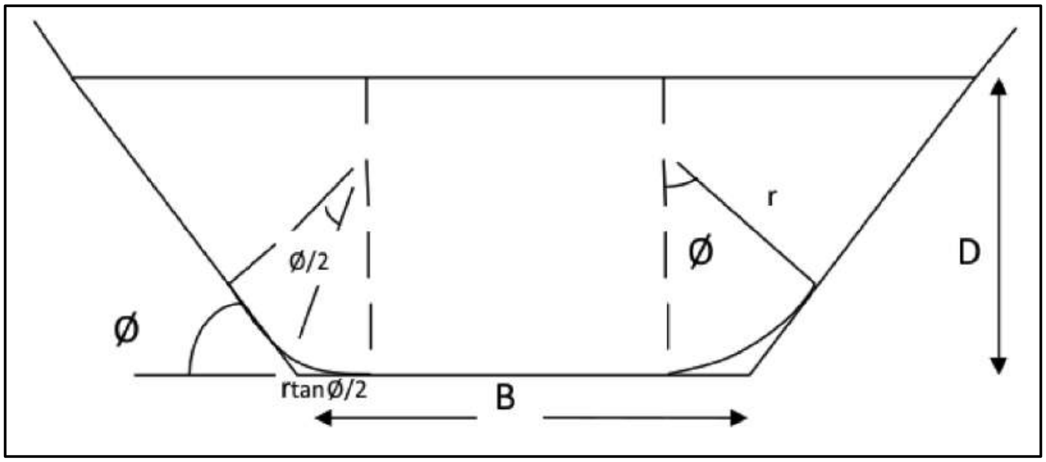
Area (A) of trapezoidal channel A = $BD+D^2\cot Ø$

Wetted perimeter (P) of trapezoidal channel P =$B+ 2D(1+\cot^2 Ø)^{1/2}$

=$B+2D\operatorname{cosec}Ø$



Wetted perimeter of trapezoidal channel with curve(P_1)

$P_1= B + 2D \operatorname{cosec}Ø - 2x [2 \times r\tan Ø/2 - 2\Pi r \times Ø /2\Pi]$

$= B + 2D \operatorname{cosec}Ø - 4 \times r\tan Ø/2 + 4r \times Ø /2$

$\delta A= A-A_1 = 2 r^2 \tan Ø/2 - 2r^2 \times Ø /2$

$= 2r^2[\tan Ø/2 - Ø /2]$

$\delta P= P-P_1 = 4 r \tan Ø/2 - 4r \times Ø /2$

$= 4 r [\tan Ø/2 -Ø /2]$

Velocity (V) of fluid flowing through the trapezoidal channel

$V =\frac{Q}{A}$(Q is discharge of fluid)

By Manning's equation

$V =\frac{1}{n} R^{2/3} s^{1/2}${where n= rugosity coefficient

R= Hydraulic Radius = A/P

s= longitudinal slope}

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$s^{1/2} = \frac{nQ}{A} R^{-2/3}$

s $= \frac{n^2Q^2}{A^2} R^{-4/3}$

$= \frac{kR^{-4/3}}{A^2}$

(where $k=n^2Q^2$)

$= \frac{k}{A^{\frac{10}{3}}} * P^{4/3}$

$= k * P^{4/3} * A^{-10/3}$

$s_1 = \frac{k(P-\delta P)^{4/3}}{(A-\delta A)^{10/3}}$

As δP and δA are small compared to P and A,

$\therefore s_1 = \frac{k\left(P^{4/3} - \frac{4}{3}P^{1/3}\delta P\right)}{\left(A^{10/3} - \frac{10}{3}A^{7/3}\delta A\right)}$

$= k\left(P^{4/3} - \frac{4}{3}P^{1/3}\delta P\right)\left(A^{-10/3} + \frac{10}{3}A^{-13/3}\delta A\right)$

$= kP^{4/3}A^{-10/3}\left(1 - \frac{4}{3}\frac{\delta P}{P} + \frac{10}{3}\frac{\delta A}{A}\right)$

$= s\left(1 - \frac{4}{3}\frac{\delta P}{P} + \frac{10}{3}\frac{\delta A}{A}\right)$

$\delta s = s - s_1 = s\left(\frac{4}{3}\frac{\delta P}{P} - \frac{10}{3}\frac{\delta A}{A}\right)$

$\frac{\delta s}{s} = \frac{4}{3}\frac{\delta P}{P} - \frac{10}{3}\frac{\delta A}{A}$

For $\frac{\delta s}{s}$ to be maximum, $\frac{dy}{dr} = 0$ where $y = \frac{\delta s}{s}$

$\delta A = 2\, r^2\, [\tan \emptyset/2 - \emptyset/2]$

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$\delta P = 4\ r\ [\tan \text{Ø}/2 - \text{Ø}/2]$

$$\therefore \frac{\delta s}{s} = y = \frac{4}{3}\left(\frac{4r\ [\tan \text{Ø}/2 - \text{Ø}/2]}{P}\right) - \frac{10}{3A}\left(2\ r^2\ [\tan \text{Ø}/2 - \text{Ø}/2]\right)$$

$$\frac{dy}{dr} = \frac{16}{3P}\ [\tan \text{Ø}/2 - \text{Ø}/2]\ - \frac{40r}{3A}\ [\tan \text{Ø}/2 - \text{Ø}/2] = 0$$

$$\therefore \frac{16}{3P} = \frac{40r}{3A}$$

$$r = \frac{2A}{5P} = 0.4 * \frac{A}{P}$$

$$= 0.4 * R$$

Illustration

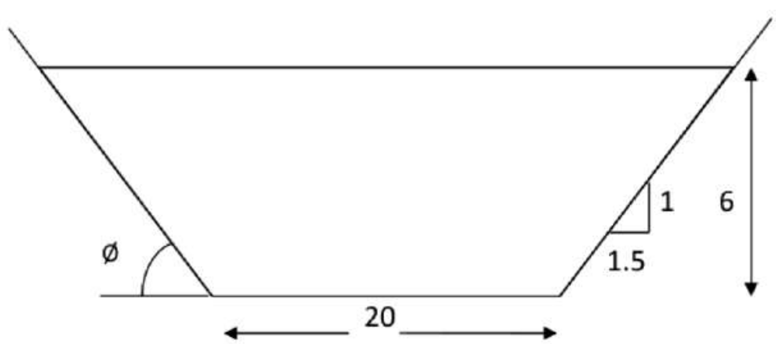
Assume a trapezoidal channel with Discharge (Q) =400 cumecs, B=20m, Depth of channel= 6m, Side Slope = 1.5:1

Using rugosity coefficient (n) = 0.018

Bed Width of the channel (B) = 20m

Depth of the channel (D) = 6m

Case I: Without Curve



Area (A) of trapezoidal channel

$$A = \frac{1}{2}(20 + 38)6 = 174$$

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Wetted perimeter(P) of trapezoidal channel

P = B + 2D cosecØ

= 20+ 2x6x1.8028

P = 41.6336

R = A/P = 4.1793

V = $\frac{1}{n} R^{2/3} s^{1/2}$

Q = $A \frac{1}{n} R^{2/3} s^{1/2}$

400 = 174 x $\frac{1}{0.018} 4.1793^{2/3} s^{1/2}$

s = 2.5435 x 10^{-4}

Case II: With radius of Curve, r=D

i.e. r=6m

cotØ = 1.5 ; Ø=33.6901°

A =BD + D^2 cotØ - 2 r^2 tanØ/2 + 2r^2 xØ /2

A = 20x6 + 6^2x 1.5 – 2x 6^2 x tan (33.6901/2) + 2 x 6^2x 0.588/2

A = 173.3664

P=B + 2D cosecØ - 4 x rtanØ/2 + 4r xØ /2

P = 20 + 2x6x1.8028 – 4x6x0.3028 + 4x6x0.588/2

P = 41.4224

R = A/P = 4.1853

Q = $A \frac{1}{n} R^{2/3} s^{1/2}$

400 = 173.3664 x $\frac{1}{0.018} 4.1853^{2/3} s^{1/2}$

s = 2.5572 x 10^{-4}

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Case III: With radius of Curve, r=0.4R where R = Hydraulic Mean Radius

cotØ = 1.5 ; Ø=33.6901°

A =BD + D^2 cotØ - 2 r^2 tanØ/2 + $2r^2$ xØ /2

A = 20x6 + 6^2x 1.5 – 2x r^2 x tan (33.6901/2) + 2 x r^2x 0.588/2

A = 174 – $2r^2$(0.3028 - 0.294)

A = 174 – 2 $(0.4R)^2$(8.8 x 10^{-3}) = 174 – 2.816 x 10^{-3} R^2

P=B + 2D cosecØ - 4 x rtanØ/2 + 4r x Ø /2

P = 20 + 2x6x1.8028 – 4 x r [0.3028 - 0.294]

P = 41.6336 – 4 (0.4R) (8.8 x 10^{-3})

P = 41.6336 – 14.08 x 10^{-3} R

R = A/P

R =174 – 2.816 x 10^{-3} R^2/ 41.6336 – 14.08 x 10^{-3} R

R = 4.18405

A = 174 – 2.816 x 10^{-3} R^2 = 173.9507

$$Q = A \frac{1}{n} R^{2/3} s^{1/2}$$

$$400 = 173.9507 \times \frac{1}{0.018} \quad 4.18405^{2/3} s^{1/2}$$

s = 2.5411 x 10^{-4}

	Longitudinal Slope (S)
Without Curve	2.5435 x 10^{-4}
Radius of Curve, r =D	2.5572 x 10^{-4}
Radius of Curve, r =0.4R	2.5411 x 10^{-4}

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Assuming length of hydel channel=10kms

For Radius of Curve, r =D and r=0.4R

Head saved = 10000 x (2.5572×10^{-4} - 2.5411×10^{-4}) = 0.0161 = 16.1mm

Extra power generated = 400 x 9.8 x $\frac{16.1}{1000}$ x 1000

= 63.112 kW

Considering load factor = 60%

Extra units of power generated per annum = 63.112 x 0.6 x 24 x 365 = 331716.67kWh = 3,31,716 units, say 3.3 Lakh units

Therefore, provision of Radius of Curve, r =0.4R in place of r=D saved 3.3 Lakh units of power per annum.

CONCLUSION

It has been found that the optimum radius of curvature to minimize the hydraulic head loss, is equal to 0.4 R where R is the hydraulic mean radius of the channel, for all values of side slopes. It has also been found that provision of a radius equal to the water depth in the channel, actually increases the head loss, instead of decreasing it, and thus defeats the very purpose for which it is provided. The practice of providing a radius equal to the depth of the channel must be discontinued forthwith, and instead, a radius equal to 0.4 R should be provided. Provision of a curve with radius equal to 0.4R becomes of paramount importance in the case of Hydel channels and tail race channel of power plants, as each millimeter of head saved can result in thousands of more units of power production.

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Computer Engineering

Engineering Collaborations for Accessing Hidden Web Resources

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Abstract: *The world wide web has always been a research platform for information and data scientists. The value of information is generally seen as a proportional to the depth of the world wide web. While the surface web is being taken good care of by the search engines at a great length, It is the deep web that posed challenges to the information and data scientists. A lot of research has been expended in the direction of extracting information from the deep web resources. Many researchers have studied the problem statement in their perspective and devise solutions to address their formulated problem statements. Individually these efforts showed promising results. However, there has been a gap of the joint effort to bring these individual efforts together to reap the collective fruits to address the much larger and more sensible problem statement. This paper highlights the different problem statements of different researchersand suggests the collaborative approach to bring out one common problem statement to envisage one big problem and its probable solution.*

Keywords: *Collaborative Approach; Hidden Web; Deep Web; Information Retrieval*

INTRODUCTION

World Wide Web (WWW) scores high when it comes to the ranking of information resources to satisfy the information need. There is a plethora of information (organized, unorganized, validated and invalidated) available in the WWW that needs to get tapped and validated before it gets consumed. Various validating organizations certify the correctness and validity of the information prevalent on the WWW. However, such validated information resides in the databases of the validating organizations which can only be accessed by presenting queries to these databases. For automating queries, organizations design search interfaces which need to be filled up to form queries and fetch information from the databases [1]. The information residing in databases is categorized as hidden web resource since it is hidden behind search interfaces into the databases. Traditional search engines can extract the information present in the documents but they are not able to extract data from the databases of validating organizations. However, many researchers have extended their resources and efforts to tap this area of information extraction and have been successful as well. But there is a research gap of collaborative efforts to completely address the problem in a way it should have been addressed. This paper firstly presents the related work in the direction of hidden web data extraction followed by the examination of the efforts which are potential candidates for collaboration. The anticipated results that will be probably achieved in the light of collaboration are discussed at the end of the paper.

RELATED WORK

There are two parts to the World Wide Web (WWW). One part is exposed to the search engines so is easy to navigate, while the other is hidden in the databases, unlinked, non-textual form and hence out of reach of the traditional search engines thereby is hard to tap. The irony of the matter is that the later part of the WWW is 99% of the WWW implying the fact that what traditional search engines are capable to tap is just 1% of the entire WWW [2-5].

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A lot of work has been done to study the techniques to extract the hidden data. Khurana and Chandak [6] surveyed methodologies to select deep web source to extract the data hidden underneath. The problem statement of their research is to highlight the fact that "among multitudes of information available in the deep web, the quality of data should derive its selection measure to keep less relevant and redundant information from getting unnecessarily processed". Singh and Anuradha [7] proposed a methodology of sponger and squeezer to extract (Sponge) data from the hidden web page and after analyzing and processing it, pouring it (Squeeze) to the local repository for the future analysis by knowledge experts. Their problem statement is to "detect the type of data in the hidden web pages to guide the correct extraction of tabular information presented in HTML page onto the local repository".

Singh and Prasad in [8], suggested an ontology-based approach to extract the hidden web data for automatically filling up the query interface form after fetching the domain specific values from the built ontology of the specific domain. In their research, they also mentioned the need of ontology builder, in case there is no ontology for the subject being investigated. Their problem statement is to "design a unique system to uncover hidden web using existing ontologies". In the related research [9], Singh and Prasad proposed the replacement of ontology with that of database indexed by search engines, to gain the advantage of the existing WWW repositories containing virtually any domain information, thereby eliminating the need of Ontology Builder asked for in the earlier research [9]. Their problem statement is "overcoming the need to design ontology builder by replacing ontologies with the indexed databases of traditional search engines as they are there for virtually any domain". In [10] Y. Wang and J.Hu proposed a machine learning approach to sense the presence of tables on the hidden web pages. Their problem statement is to investigate the web pages for the presence of relational data so as to categorize the pages as relevant/irrelevant." B. Liu et. al in [11] proposed the effective strategy to mine the contiguous and non-contiguous data records to extract important information out of them. Their problem statement is to "address the issues present in exiting data mining approaches to bring out more accurate data mining approach". On the lines of extracting and processing data at the large scale in a collaborative manner Felix, Biswanath and Mirek introduced Web Lab Collaboration Server [12]. The underlying problem statement is to "recognize the fact that despite latest advances in data extraction and processing technologies, the users from non-technical background find it difficult to deal with the tools to fetch the relevant data for various applications and build an abstract model that presents easy to use interface for inputs to extract and process data to the non-technical users".

The approaches mentioned can be categorized as the improvements of the existing methods to make the life of application users easy. The author has envisaged the need to engineer the collective efforts of some of the above-mentioned techniques to achieve a larger objective. The following section throws light on the potential candidates of collaboration.

PROPOSED WORK

In this paper, the different individual approaches to extract hidden web data are selected and viewed from a larger perspective for collaboration to extract hidden web data using the goodness of the collaborating approaches.

Figure 1 represents the collaborated technologies proposed in the current research. D and SD in **Figure 1** represent the domain and statement of domain as two inputs to the UDDWE [9]. UDDWE initially fetches the documents from WWW for the corresponding D (Domain) and SD (Statement of Domain). At the later stage of UDDWE processing the hidden web pages from the fetched documents are fetched. Two categories of hidden web pages (Structured and Unstructured) are identified by UDDWE [9]. White colored documents are the pages which represent unstructured information, whereas the red colored blocks the hidden documents with the structured information. This mixed set of documents is passed to the data mining approach suggested by [11] and Machine learning approach proposed by [10] at the same time. Both [10] and [11] are designed to identify the documents with and without table tag. The output of Machine learning approach [10] is the set of documents with the tabular structures whereas Data mining approach [11] provides the mined data out of non-tabular unstructured documents. This mined data is stored in the local repository LR1 The tabular structured documents are parsed by HWPDE [7] as a result of which the data types of the columns of the tables are detected, the data present in the data cells of the table is sponged (extracted) and filled (squeezed) in the local repository LR2. The data from LR1 and LR2 is fed to the agent-based system for Data Integration suggested by [14]. The agent-based system introduced at the end collects the data from LR1 and LR2 and stores in its local repository LR3. LR3 is the considered as the data rich repository containing structured relational and unstructured mined data. This source of knowledge paves the way of strategic planning for the organizations dealing with the data.

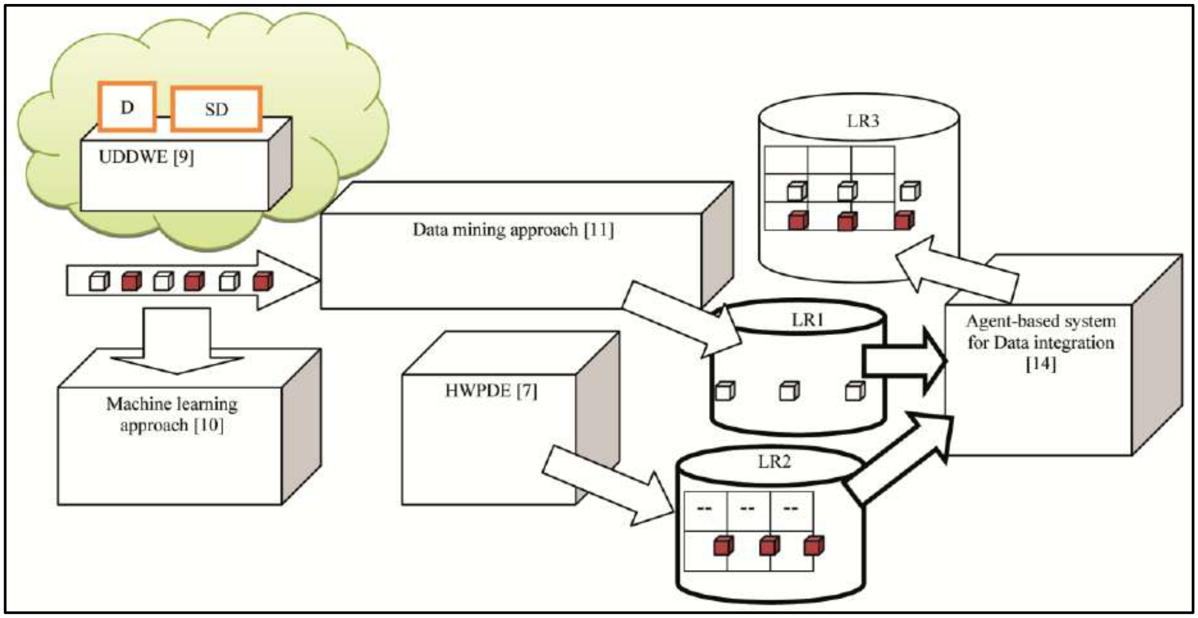

Figure 1 Collaborative approach for effective data extraction from hidden web

ALGORITHMIC ANALYSIS AND RESULTS

The process of such collaboration needs a planning and planning leads to the algorithm. Following algorithm CollabH (coined for the collaboration for achieving Hidden web resources) is suggested to accomplish the stated objective.

Algorithm CollabH (D, SD)

HybridC = UDDWE (D, SD);
UnstructC = DMA (HybridC);
StructC = MLA (HybridC);
LR1=PrUSC(UnstructC);
LR2 = PrSC(HWPDE(StructC));
IntegratedC = DIA(LR1,LR2);
LR3=PrIR(IR)
return L3;

D (Domain) and SD (Statement of domain) are the only two arguments required for the proposed algorithm. In the beginning UDDWE is called to fetch the structured and unstructured collection (collectively refered here as hybrid collection and mentioned as HybridC in the algorithm) of hidden web pages. The hybrid collection is processed by DMA (Data Mining Approach) and MLA (Machine Learning Approach) to filter the unstructured and structured collections (refered in the algorithm as UnstructC and StructC). The unstructured collection (UnstructC) is processed and translated (by Processing function PrUSC) in to the format suitable for getting stored into the local repository (LR1 in the algorithm). The structured collection is processed by HWPDE (Hidden Web Page data Extractor) to automatically transfer the structured data on the webpage into the relational database (LR2) after suitable processing

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by the processing function PrSC (identification of data types, checking if the repository is being built for the first time etc). Finally, the DIA (Data Integrator Agent) picks up the contents of the local repositories LR1 and LR2 and integrates the repositories in the collection IntegratedC. This Integrated Collection is stored in Local repository LR3 which is returned as the output. The difference in HybricdC and IntegratedC is in their format. HybridC is the collection of Webpages both structured and unstructured, whereas IntegratedC is the collection of the relevant and the focused data extracted from the webpages.

The experiments were carried out on sample domains (D) and statement of domains (SD) depicted in **Table 1**.

Table 1 Domains and Statement of domains for collaborative analysis.

Sr. No	**Domain**	**Statement of Domain (Query)**
1	Cricket	Orange Cap award in IPL 2019
		ICC World Cup history
2	Food	Order from Swiggy: One Masala Dosa, Two Cokes and one small French Fries
		I want to buy pedigree animal food for my Labrador dog.
3	Civilization	The Egyptian civilization
		The culture and civilization of Sindh

UDDWE brings out the hidden web entry points and consequently enable fetching of hidden web data (both unstructured and structured) corresponding to each statement of domain for the corresponding domain mention in Table I. The result of UDDWE on the information present in **Table 1** is represented in **Table 2**. The fetched pages by UDDWE are from the WWW, which are processed further in UDDWE for the presence of hidden web entry point signature (Search query interface form). After the firing of queries by UDDWE and human intervention two categories of documents (Structured and Unstructured) are fetched. Data mining approach identifies unstructured data and pour in in the local repository, whereas machine learning approach identifies structured data and passes it to HWPDE for sponging and squeezing processes. HWPDE automatically detects the data types of the columns of structured data stored in HTML table, and creates the local repository with the detected type information before storing the information in it. Finally, both structured and unstructured information repositories are merged together using agent-based approach for data integration.

Table 2 UDDWE Results

Sr. No	**Domain**	**Statement of Domain**	**Fetched Pages (K)**	**Relevant Pages(R)**	**Identified Hidden Web Entry Points(H)**
1	DM1: Cricket	Orange Cap award in IPL 2019	12	8	1 (Relevant)
		ICC World Cup history	27	23	17 (Relevant)
2	DM2: Food	Order from Swiggy: One Masala Dosa, Two Cokes and one small French Fries	15	11	0
		I want to buy pedigree animal food for my Labrador dog.	22	18	4 (Relevant)
3	DM3: Civilization	The Egyptian civilization	26	22	13 (Relevant)
		The culture and civilization of Sindh	17	13	9 (Relevant)

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CONCLUSION AND FUTURE SCOPE

The collaborative approach depicted in the research promises the combined goodness of the individual research efforts. The final repository shown in the proposed work serves as the backbone of the data analysis and proves helpful in effective decision making for the stakeholders involved. Though the approaches discussed in the collaboration effort are separated apart in the time domain, however such efforts will always be welcome in future as by using collaborative approach, system designers don't need to re-invent the wheel for designing a subsystem if the similar subsystem is already in place by other researchers. The paradigm shift to collaborative efforts will ensure the greater emphasis on solving bigger problems with the solutions of the smaller sub problems which are already solved for specific applications.

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A Machine Learning Approach for Predicting Heart Disease using Efficient Algorithm

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Abstract*: In our country, there is a high increase in death due to heart disease cases. It's very important to predict such cases beforehand. It is a primary concern as its necessity to safeguard the people to live their lives in secured way so as to take precautions. In modern medical research they have concluded that the over rate of heart disease is because of extreme levels of exercise, i.e peoples mind set is that doing jogging, bodybuilding, running, and exercises leads to good fitness but medical researchers have proved that they may lead to the sudden death of a person at the very early age. It's difficult to predict manually whether a person is undergoing heart disease or not. So to overcome this difficulty we proposed a heart disease prediction system based on the medical history of patients. In this paper, we mainly focus on proving how best the machine learning models can be built to predict even at the worst case to overcome the early death of a patient. In this paper, a novel method that identifies the disease in heart the proposed algorithm by name, Gradient Boosting Classifier algorithm. Our proposed Gradient Boosting Classifier is used to corporate with machine learning models so has to improve the performance of Prediction system by reducing the complexity. The simulated results of the proposed algorithm are compared with that of KNN algorithm. It is observed that the proposed Gradient Boosting Algorithm shows better performance as compared to KNN in terms of Learning rate and decision tree model.*

Keywords*: Heart Disease; Confusion Matrix; Machine Learning; KNN; Gradient Boosting Classifier*

INTRODUCTION

Data science is a study that combines domain knowledge, programming skills, mathematical and statistical skills to extract meaningful information from data, data can be either in the table format, text, image, audio or video. Machine learning algorithms can be applied to all these types of data to produce artificial intelligence systems to perform a given task. In turn, these systems analyse the task into tangible business values. A heart attack occurs when one or more of your arteries become blocked. India has the highest rate of heart disease worldwide.

LITERATURE SURVEY

There are few researchers who have worked on prediction of disease in heart. In [1], the authors have studied that yearly the number of deaths in India has been a rise from 3 million in 1990 to 5 million in 2020. In the rural population it has ranged from 1.6% to 7.4% of Indian population is discussed in [2]. Abdominal obesity, hypertension, tobacco, lack of physical activity, and higher diabetes, are the risk factors of causing CVD, at very young age, than among other ethnic groups [3]. The rates of CVD risk factors have been rapidly rising in Indian urban communities over 25 years is studied in [4].In [5], authors have analyzed heart disease prediction using more input attributes. Till now the researchers have used 13 input attributes for predicting heart diseases, in this paper, the authors have two added attributes i.esmoking and obesity. Using this dataset they have applied a Decision tree algorithm and KNN achieved the highest accuracy of 87.5%. In [6], they built an intelligent classifier that predicts the heart disease problem this diagnosis component is integrated with the mobile applications with the real-time monitoring component and raises an alarm whenever an emergency occurs. Results of their proposed methods have achieved the highest accuracy of 85% for SVC and Naive Bayes. In [7], researchers used 13 input attributes and 1

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output attribute and applied Naive Bayes machine learning algorithms, achieving 86% accuracy. In [8], the authors have reduced 2 input attributes from 13 attributes. The authors used three classifiers like Naive Bayes, J48 Decision Tree, and Bagging algorithm, which has achieved 85% for the bagging classifier algorithm. In [9] they used Naive Bayes classifier for pre-existing data and achieved 74% accuracy. In [10], in this paper experiments have been performed using UIC machine learning dataset and evaluated for all the methodologies, they have used Naive Bayes accuracy of 81% and SVM accuracy of 90 %. It is observed that the authors in [11], achieved 80% using KNN, SVM as 82% and ANN as 84%KNN. It is studied in [12], the authors have achieved 90% using KNN and 88.1% using Navie Bayes.

Table 1 Prediction of disease in heart with different Algorithms in terms of Accuracy

Authors	Accuracy	Techniques
Danger Chaitrali S [5]	87.5 %	KNN
OtoomAF[6]	84.5 %	SVM
	84.5 %	Naive Bayes
VembandasamyK[7]	86.4 %	Naive Bayes
ChaurasiaV[8]	84 %	J48
	85.03 %	Bagging
Parthiban G[9]	74 %	Naive Bayes
Deepika K[10]	81 %	Naive Bayes
	90%	SVM
Dwivedi AK [11]	80%	KNN
	82%	SVM
	84%	ANN
Devansh Shah1[12]	90%	KNN
	88.1 %	Naive Bayes
Proposed models	91%	KNN
	92.9%	GradientBoostingClassifier

The analysis is carried out using publicly available data for heart disease in kegel. The dataset holds 303 instants with 14 attributes from [13], such as thalach, slope, age, thal, thena, gender, cp, trestbps, chol, fbs, restecg, exang, oldpeak, ca, target, dataset is analyzed with visualization tools, preprocessing, and Machine Learning Algorithms.

It is observed from **Table 2**, represents the attribute name and its description for each attribute taken from [13]. The data classification is shown from **Figure 1** we can classify the data into 'Qualitative' is again classified as Nominal and Ordinal data where as the'Quantitative' data classified as Discrete and Continuous data.

PROPOSED METHODOLOGY

The proposed methodology employs Gradient Boosting Classifier Algorithm for prediction of heart disease in terms of Learning Rate and Decision Trees. In this paper we will discuss two supervised machine learning algorithms, namely, 'K Nearest Neighbor Classifier' (K-NN) and Gradient Boosting Classifier.

'K' Nearest Neighbour Classifier

This algorithm is quite a simple and very powerful Machine Learning model, representation of the field is done using the training dataset. The predictions of the output values are calculated by checking the complete dataset for K data nodes with the same values, and using the Euclidean number to determine the resulting values. Such a dataset can require lots of space to store and process the data, when there are multiple attributes and have to be constantly curated . However, they very accurately, and efficiently at finding the needed values in a large dataset. The K value indicates the count of the nearest neighbours.

Table 2 List of Various Attributes Used [13]

Sl No	Observations of Attributes	Description	Values
1.	Age	Age in years	Continuous
2.	Sex	Sex of Subject	Male/Female
3.	CP	Chest Pain	Four Types
4.	Trestbps	Resting Blood Pressure	Continuous
5.	Chol	Serum Cholesterol	Continuous
6.	FBS	Fasting Blood Sugar	<, or >120 mg/dl
7.	Restecg	Resting Electrocardiograph	Five values
8.	Thalach	Maximum Heart Rate Achieved	Continuous
9.	Exang	Exercise Induced Angina	Yes/No
10	Oldpeak	ST Depression when Workout compared to the Amount of Rest Taken	Continuous
11.	Slope	Slope of Peak Exercise ST Segment	Up/Flat/Down
12.	Ca	Gives the number of Major vessels Coloured by Fluroscopy	0-3
13.	Thal	Defect Type	Reversible/Fixed/Normal
14.	Num(Disorder)	Heart Disease	Not present/ present in the four major types

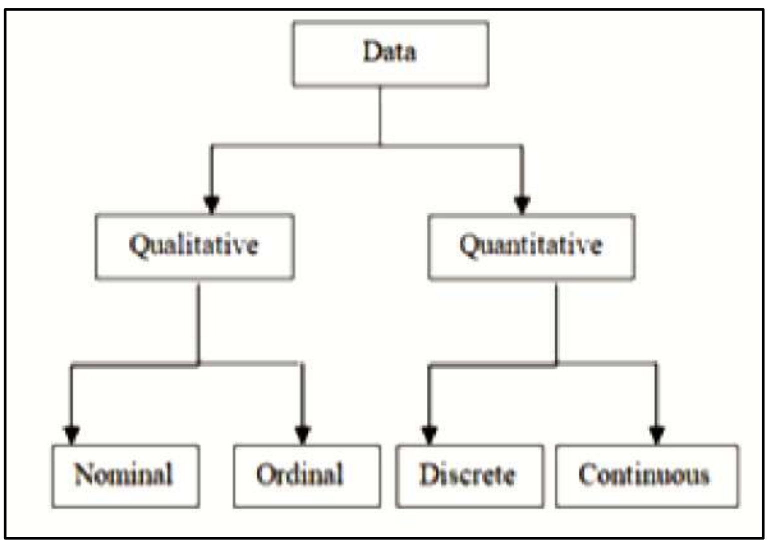

Figure 1 Data Classification

We need to compute the distance between the trained and tested labels. There is no mathematically or statically pre-defined way to find the K value. Initialize a random K value and start computing. Choose the K value which has the minimum error rate. Before applying any machine learning algorithm, split the data into training and testing. Split the dataset into X and Y, where X will be all the attributes present in the dataset leaving the answer key attribute, Y will only answer key attribute. 10% of data is used for testing and the remaining 90% of data is used for training,

KNN Algorithm for different K values:

Step 1: Load the training and testing data set.

Step 2: Now, we need to fix a K value for calculating the distance for the whole dataset, K value must be integer.

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Step 3: Perform the following steps for each point in the test data:

3.1- using the euclidean approach, calculate the distance between the value of the testing data and each row of the training data.

3.2- Sort the calculated values in ascending order based on the distance between them.

3.3- choose the top K rows from the sorted array

3.4- Assign a class to the test points based on the most commonly categorised rows.

Step 4: Evaluate the KNN module using a confusion matrix.

Step 4: Evaluate the KNN module using Matrix of Perplexity

Step 5: END

Gradient Boosting Classifier

As the name implies, this method is one of the machine learning algorithms used for categorization. The goal of this approach, Gradient Boosting, is to boost the algorithm's strength by tweaking a poor learning algorithm. PAC is the foundation for this type of learning (Probability Approximately Correct Learning). Gradient Boosting Classifiers apply a similar notion in this learning method, which tells the machine learning problem how complicated it is.The logarithmic loss is frequently used in the gradient boosting process.

Gradient Boosting algorithms frequently use logarithmic loss; however, there is no need to develop a new loss function every time the method is implemented; instead, any differentiable loss function can be applied to the model. There are two parts to the boosting systems: an additive component and a weak learner. In gradient boosting, decision trees are used to deal with weak learning. The additive components of this technique are gradually introduced to the model, and as a result, previous trees cannot be changed and their values remain fixed. By taking the computed loss and applying gradient descent, the error of the provided parameters can be minimised; tree parameters are updated to reduce the loss.The new tree's output is added to the output of the preceding trees in the model. This process is repeated until the loss falls below a particular level. Gradient Boosting Classifier is a useful technique for determining whether or not a patient is sick. There are 303 instances and 14 attributes in the collection. When the k value is 5, the first iteration of the KNN algorithm achieves 83 percent accuracy. When the number of instances is increased from 303 to 918 in the second iteration, we achieve 91 percent accuracy for the same K value. And after 918 instances of experimenting with the Gradient Boosting Classifier method, we were able to reach a 93 percent accuracy.

Gradient Boosting Classifier Algorithm

Step1:Compute the average of the target attribute.

Step2:Compute the residuals.

Step3:Construct a decision tree.

Step 4: Using all of the trees existing in the ensemble, predict the goal value.

Step 5: Subtract the old residuals from the new residuals.

Step 6: Repeat steps 3–5 until the total number of estimators equals the total number of estimators.

Step 7: Once the trees have been trained, make a final forecast using all of the trees in the ensemble.

EXPERIMENTAL RESULTS AND CONVERSATIONS

The suggested algorithm's simulation experiments are carried out with the Jupyter notebook python 3 simulators and the simulation parameters specified in the proposed technique. When compared to the K nearest neighbours classifier, the proposed Gradient Boosting Classifier produced better results. Before proceeding to the experimental

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results of machine learning algorithms, one of the most essential concepts in machine learning, the confusion matrix, should be discussed.

Matrix of Perplexity

The confusion matrix is also known as the 'error matrix' in machine learning and statistical classifications, and it is specifically in the form of a table arrangement that permits visualisation of an algorithm's performance as illustrated inbelow **Figure 6**.

		ACTUAL	
		Positive	Negative
PREDICTED	Positive	TRUE POSITIVE	FALSE POSITIVE
	Negative	FALSE NEGATIVE	TRUE NEGATIVE

Figure 6 Matrix of Perplexity

If we plot the predicted values against actual values we get the matrix as shown in the above table.

The matrix depicted in the above table is obtained by plotting anticipated values against actual values.

Let's define 'True positive,' 'False positive,' 'True negative,' and 'False negative,' respectively.

True Positive (TP) data points are those in which the projected values were positive and the actual values were positive as well.

True Negative (TN): These are data points with negative actual values and similarly negative forecasted values.

False Positive (FP): These are data points whose actual values were negative but which were wrongly identified by the algorithm.

False Negative (FN): These are data points whose true values were positive but were misidentified as negative by the algorithm.

Now let's look at the findings of the algorithm and see which one is the best.

K Nearest Neighbour Classifier

Applying the KNN algorithm as mentioned in proposed method it has achieved an accuracy of 83% when the k value is 5 for 303 instances and 14 attributes. As it is less accurate, and tried to improve the better accuracy by increasing the number of instances from 303 to 918 and 14 attributes have drastically increased the accuracy to 91% for the same k value.

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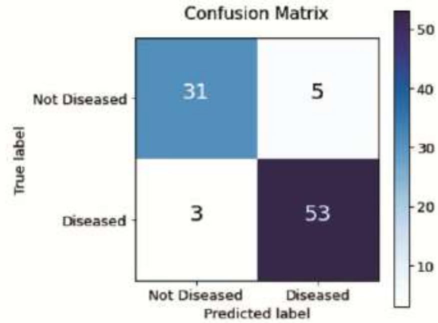


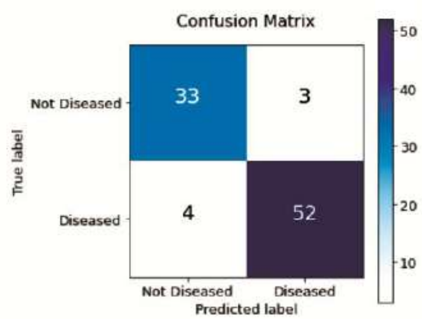
7.a. Matrix of Perplexity for KNN

	precision	recall	f1-score	support
0	0.91	0.86	0.89	36
1	0.91	0.95	0.93	56
accuracy			0.91	92
macro avg	0.91	0.90	0.91	92
weighted avg	0.91	0.91	0.91	92

7.b.Classification report

Figure 7 a is a KNN confusion matrix for 918 instances and **b** is a classification report that explains precision, recall, and f1-score.

Applying Gradient Boosting Classifier as studied in previous sections, achieved the highest accuracy of 92.9% when compared with other algorithms for 918 instances and 14 attributes. The parameters of this algorithm estimators were set to 100, learning_rate=0.1, and max_depth=4.



8.a. Matrix of Perplexity (Confusion matrix) of Gradient Boosting Classifier

	precision	recall	f1-score	support
0	0.91	0.89	0.90	36
1	0.93	0.95	0.94	56
accuracy			0.92	92
macro avg	0.92	0.92	0.92	92
weighted avg	0.92	0.92	0.92	92

8.b.Classification report for GradientBoosting

Figure 8 a represents a confusion matrix of Gradient Boosting Classifier and **b** represents classification report which explains precision, recall, and f1-score.

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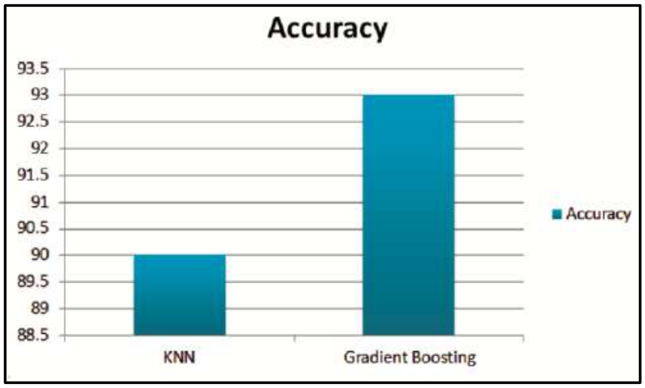

Figure 9 Comparison between KNN and Gradient Boosting classifier

It is observed from **Figure 9** we can conclude that Gradient Boosting Classifier has achieved the highest accuracy compared to KNN algorithm. So we prefer the Gradient Boosting Classifier model in terms of Learning rate and Decision tree for prediction of heart disease that gives 93% of accuracy compared to KNN.

CONCLUSION

In this paper, we used Machine Learning algorithmsto predict whether a person is suffering from heart disease. After importing the data, we analyzed it using histogram plot, barplot for target and age, barplot for grouped data i.e gender versus age concerning the target. We then generated dummy variables for nominal data and ordinal data features and scaled other features. We then split the data for training 90% and 10 % for testing. Then applied Machine Learning algorithms, K Neighbour Classifier for different K values, Gradient Boosting Classifier(parameters with estimators, learning rate, and depth), then varied dataset across each model to improve their scores. In the end, GradientBoosting Classifier achieved the highest score of 92.9% when the estimator value is 100 in terms of learning rate and decision trees.

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A Smart Phone Application to Evaluate Candle Flame Characteristics

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Abstract: *Today, smartphones are used for a variety of applications it is not limited to calling and receiving, and sending text messages, they have a variety of features such as a camera, torch, games, social media, news, and so on. This paper aims to utilize the device for yet another application that is capturing the flame height, wick width, and flame width using a smartphone camera. The experimental setup is quite trivial; the camera should be as close as possible to the flame, the reference length has to be measured to have an idea about the total length captured which aids to calculate the pixel length of the image. Further, the change in height and width with respect to time is also recorded.*

Keywords: *Image Processing; Candle Flame; Smart Phone; Python*

INTRODUCTION

A smartphone is used for various applications in today's world. A smartphone is a very common device that is used by almost everyone these days. It is already used for various applications such as maintaining the caloric balance in the human body [1]. Furthermore, there are applications such as ithlete™ which determine ultra-short-term heart rate variability [2]. Covid-19 pandemic has made a huge impact on each one of us in some way or the other, mental health of the youth being one of the major issues, but a smartphone application on assessment and management of youth mental health could help in reducing the anxiety and depression cases among youths [3,4]. GeoTools is another android application that aids to do tasks in the area of geology, such as being a pocket compass [5].

According to the literature, there are about 76% of undergraduate students use smartphones for educational purposes [6]. Some studies aim to incorporate learning via smartphones Supadi et al. recorded a positive impact when smartphone application was used for mathematics learning [7]. A feedback survey on undergraduate students for academic library applications was taken and it suggested that students were willing to utilize the applications [8].

The candle flame dimensions can help us to understand diffusion flame characteristics, help to facilitate industrial design, and help in understanding ignition potential. The flame height characteristics also help in the characterization of the soot formation [9]. Sunderland et al. developed a model to predict flame width and heights by capturing the length and width of the wick with a high-resolution camera and utilizing the Rayleigh number and Nusselt number for their model [10]. This paper aims to provide a simple methodology and a basic setup to capture the wick width, flame height, and flame width. The model suggested in this paper facilitates that a common person without any laboratory equipment can capture the flame dimensions and process it with an open-source language python. Subsequently, the variation in these parameters are noted which could give us an insight into how much wax is burned in a candle flame in every frame.

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METHODOLOGY

Experimental Setup

The candle has to be placed as near as possible to the reference length. Reference length is the pre-measured length, the length should include the whole flame height, for example, if the flame height is about 40mm the references length should be at least 50 mm. The camera should be as near as possible to the flame, if we increase the distance of the camera the measurement error would increase.

Model

The model was made utilizing OpenCV library from an open-source language python. The image as captured on the phone is now ready for further processing. The noise is reduced using medianblur (appropriate Kernel size has to be selected) as this blurring preserves edges that are in our interest for the calculation of flame height and flame width. After that use canny (using appropriate threshold values) to get the edges. After that number of pixels between the edges is counted and the pixel length is multiplied to get the appropriate results. This is repeated for the various frames and the variation in height and width can be observed.

RESULTS AND DISCUSSION

The candle was kept close to the white paper which was 63mm in length (reference length, that is the height of **Figure 1**). The camera was placed in such a way that the whole length just fit in the frame and the lens was as close as possible. The video was captured with a Nokia 7 plus phone, with 30fps. Then the frames were extracted using the OpenCV library in python, as shown in **Figure 1**. After getting the frames noise reduction is done using medianblur, we can use the same or different kernel size for detecting appropriate height and width which depends majorly on the lighting and the background of the taken image. In this case for the height calculation, the kernel size is 23, the wick width the kernel size is 81, and for the width calculation, the kernel size is 121. The built-in function of OpenCV, cv2.canny is used to get the edges with appropriate thresholds of the in as shown in **Figure 2**.

Figure 1 A sample Frame from the video of the candle burning

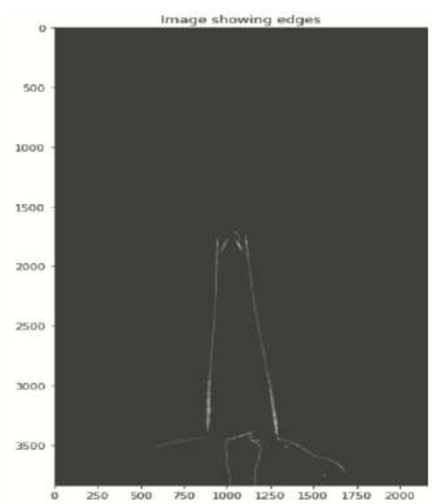

Figure 2 Image showing edges for the height calculation

Now the pixel length has to be calculated as 63mm = 3840 pixels, which results in 1 pixel= 0.0164mm. Further, the using various kernel sizes and appropriate thresholds, the result which is shown in **Figure 3** is obtained.

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Using the same methodology the variation of flame height and flame width is shown in **Figure 4** and **Figure 5** respectively.

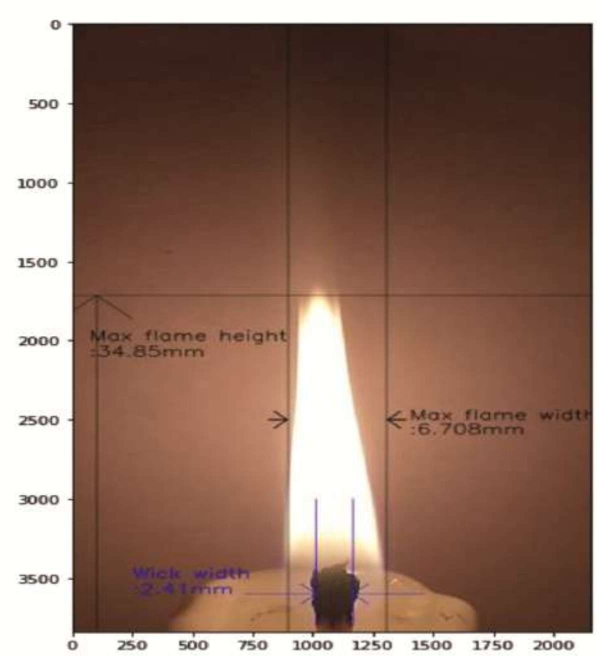

Figure 3 Image capturing critical dimensions of a flame

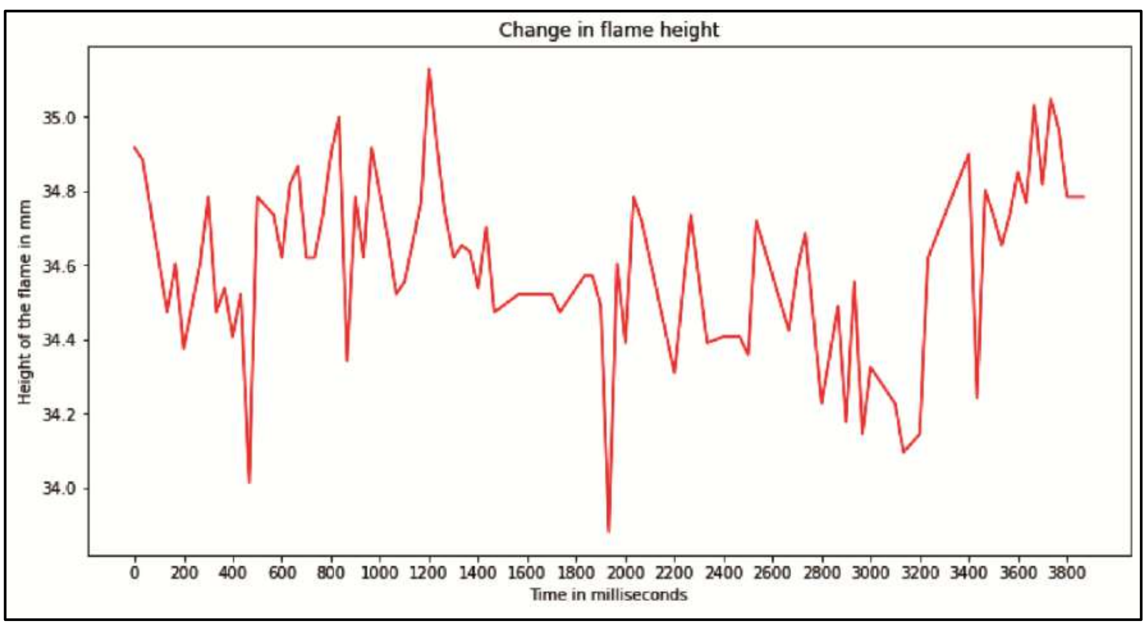

Figure 4 Change in flame height with respect to time (millisecond)

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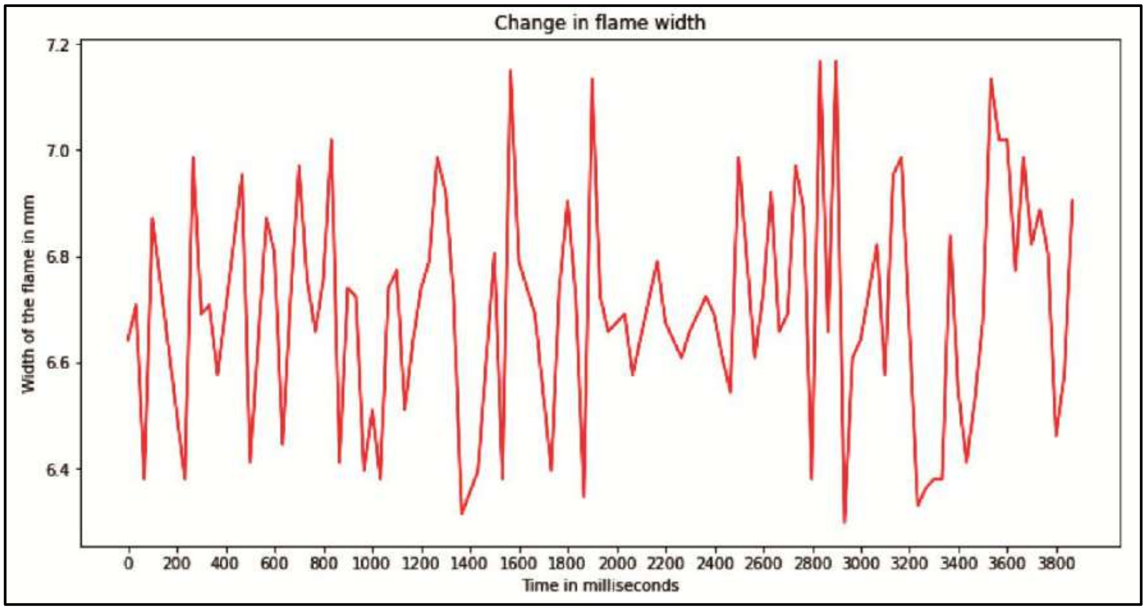

Figure 5 Change in flame width with respect to time (milliseconds)

Image processing helps to easily identify the changes of critical dimensions with respect to time. The variation of the flame height and flame width can be will help in calculating various other parameters such as how much wax is burnt every frame, and other parameters similar to it. The average height recorded was 34.6 mm and the width average was 6.7 mm.

CONCLUSION

A model was put forward which is simple to perform using open source language like python and doesn't require any laboratory equipment, just a smartphone. The wick width, flame height, and its variation, and flame width and its variation are measured by this model. Which further can give us ways to calculate different factors affecting it. Further the average flame height of 34.6 mm and width of 6.7 mm was also recorded.

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Electrical Engineering

Supraharmonics in the Electric Power Grid: Detection and Measurement in Textile Industry

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***Abstract**: Solar and wind energy technologies, as well as smart grids, have gotten a lot of attention lately in the electric power distribution system. With the help of power electronics equipment, it is possible to convert energy from natural power sources into electrical power. The electronics technologies have resulted in the discovery of new emissions that occur between frequency 2 and 150 kHz, which is outside of the conventional power quality frequency range. Supraharmonics is the term used to describe these emissions, which are found all over the planet (SH). As a result, these emissions have a significant negative influence on the power quality and lifespan of the electrical distribution system.In the textile business, inverters are used to modernise the machines in accordance with the process requirements. In the home, inverters are being used in air conditioners, refrigerators, and ceiling fans to reduce power usage. In addition, solar panels are becoming increasingly popular as a means of transitioning to a more environmentally friendly energy source, with inverters being used to convert the DC voltage to the alternating current. Due to these factors, conductive emission occurs in the frequency range of 2 kHz to 150 kHz, which is referred to as Supraharmonics. Interference sources, victims, and consequences are addressed in detail.*

***Keywords**: Harmonics; EMI; Supra Harmonics; 2.5 to 150 kH*

INTRODUCTION

Grids are changing due to (1) increased incorporation of sustainable power sources including solar photovoltaic and wind power, (2) the electrification of automobiles demanding battery recharging techniques, (3) the approaching decentralized energy management trend and (4) the use of electrical machines. Power electronics offers the technological solutions to CO_2 challenges listed above. All of these new technologies contribute to grid concerns by generating emissions in the conventional power quality frequency band of 0–2 kHz.

Supraharmonics are a distinct sort of emission that happens between 2 and 150 kHz and can be distinguished from other types of emission. Several power converters, including rectifiers diode, dc to dc converters, Inverters, are used extensively in these technologies. Their integration into power networks results in serious power quality issues, notably with regard to sulphur dioxide emissions. Changing Harmonic Emission levels are a relatively new occurrence in the electrical grid that is associated with the use of renewable energy sources such as solar and wind. Furthermore, the SH emission range is significantly depend on the quantity of power electronics equipment connected to a power grid [1]. As more renewable energy sources are integrated into the electricity system, SH emissions are injected. So, in recent years, several studies have been carried out to identify, measure, and minimise this new high-frequency phenomenon [2]. Recently, many problems like as household equipment failures, capacitor overheating, and electromagnetic incompatibility have been reported due to strong SH emission. As a result of increased thermal stress induced by SH emissions, the life of electrical appliances is reduced.

A growing number of fully automated processes necessitates power electronic devices like variable frequency drives and servo drives. However, by emitting in the 0–2 kHz range, these new technologies cause grid issues. Supraharmonic emissions (between 2–150 kHz) have also emerged as power electronics converter switching

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frequencies increase to produce more compact and efficient equipment. All these technologies rely on power converters such as inverters and rectifiers. Integration into electrical grids causes significant power quality issues, particularly supraharmonic emission.

Pollution and noise have caused a labour shortage in the textile industry. Because the textile industry is nonstop, technicians must maintain their power electrical devices. If any of the gadgets fail, substantial profits are lost. Thus, the technician must take all precautions to avoid component failure. Technicians currently know about 0-2kHz harmonics and their mitigation, but not supraharmonics. Supraharmonics research and study is now popular in research institutes.The textile mill's main goal is to turn cotton into yarn, a six-stage process. These are discussed briefly for benefit of understanding. Textile mills are classified as card, combed, and ring spun. The card sliver system cleans raw cotton and card it into thick yarn (sliver). It has draw frame and comber machines to ensure consistent sliver thickness and remove short fibres. This method of turning sliver into yarn utilises speed frames and ring frames (thin thread).

The definition of Supraharmonics is highlighted in this study. The findings of a practical experiment done in textile mills are discussed in this paper.

SUPRAHARMONICS

The harmonics were in the range of 0–2 kHz in frequency. Many modern gadgets, particularly those powered by renewable energy (RE), raise worries about high levels of noise exceeding 2 kHz, which is a concern for many people. All kind of current and voltage waveforms disruption occurring between the spectrum range of 2 to 150 kHz is referred to as SH [12], and it is used to depict this distortion. When electronic switching technologies slice the voltage sinusoidal waveform between the cutoff and conducting states, they generate extremely large harmonics such as SH.Circuits such as inverter circuits, for example, are known to produce harmonics. Electrical device breakdown, especially touchscreen technologies, mechanical resonant frequency noise, and thermal expansion stress are all possible consequences of these massive harmonics, which might shorten the equipment's lifespan. PLCs and power-electronic converters [14] are the most significant producers of SH on the grid.To understand SH creation, it is necessary to first understand harmonics. When dealing with constant loads, the voltage quality has an impact on the demand current, which in turn has an impact on the utility grid. The voltage waveform deviation results in a current waveform deviation, which in turn induces the voltage waveform to be affected [15]. Even though the input voltage is virtually sinusoidal, the load consumes a disordered amount of current. As a result, a sine input voltage results in a quasi-load voltage if applied.

Fortunately, modern power-electronic technology, such as controlled power supplies and energy transformation devices, has brought the problem back to life. Switched mode power supply (SMPS) have progressed from using transformers operating at 50 or 60 Hz to adopting high frequency transformers. Apart from the magnetic flux current, which is negligible when compared to the practically sinusoidal load current, transformers were essentially linear devices. SCRs with non-sinusoidal characteristics are extensively used in modern power supplies.As a result, Fourier analysis detects its waveform as a frequency range of fundamental frequencies and harmonic components. Every time the current distortion is measured, it is discovered that the voltage deformation at some of these frequencies is the maximum [12] and [18]. A significant amount of influence is exerted on power systems by the harmonic content of such non - sinusoidal current waveform. As a result of the high frequency operation of power electronics interface converters, they produce increased harmonic distortions [19–21]. Because there is less iron core, there is less weight, mass, and expenditure. The disruption of frequencies that are higher than the low-frequency harmonic spectrum receives very little attention in the scientific community. This was most likely due to low levels of disruption in previous years.

SUPRAHARMONIC IMPLICATIONS AND CHARACTERISTICS

SH has recently gained increased attention [21] because of the potential impact on other networked devices. Increased capacitive current may damage the power supply, will result in increased safety hazards because of the use of the SH.In addition, it may consequence in (a) obvious faults through sense of touch technician modules and lightbulb duller, (b) decrease the operating period of Lighting systems, (c) contact errors (PLC communication

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systems), (d) getting too hot of transformers and static var compensators, (f) failure of safety protection equipment, (g) failure of communication among smart meters, and (h) malfunction of household components, medical equipment, and surveillance systems, as well as road transport controls..Additionally, the SH distortions generated by non - linear loads would result in significant energy wastage, which would have a severe influence on electricity transmission systems and their components. Furthermore, it has been demonstrated that SH has an impact on network instability in poorly built networks with hybrid renewable energy inverters, resulting in bogus inverter activation [4] and [21] in badly designed networks with renewable energy system inverters. Unless the dangers of SH are identified and addressed, it is reasonable to believe that they are potentially harmful.

The desire to improve power-factor and reduce harmonic interference in inverter at low-frequency output current used in grid connected equipment has resulted in an increase in SH emissions [21]. In this case, the Supraharmonics is created by the power electronic switches of IGBT switching frequency of the inverter and can be exported to the grid. If the inverter does not function or does not provide output, the unit is classified as a SH basin [22]. The main grid's RE sources, which use inverters as output interfaces, have the potential to generate significant Supraharmonics.A current is driven by two driving forces that are generated by a connection between an inverter and the grid, as depicted in **Figure 1**. Primary emission is a quantity of the current generated by power electronics or any other electrical equipment that is either ordinary or supraharmonic in nature. Secondary emission, on the other hand, is a regular or supraharmonic portion of current caused by sources external to the device (e.g., from a power source).

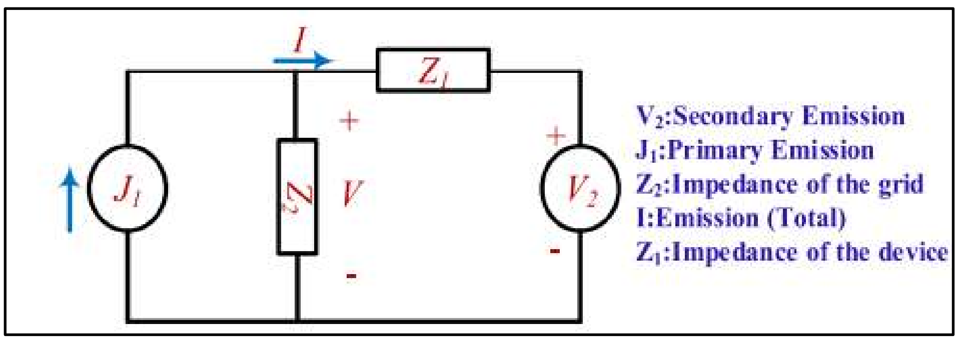

Figure 1 Equivalent circuit for emission of primary & secondary

THE ANALYSIS OF SUPRAHARMONICS BASED ON REAL-TIME MEASUREMENTS

SH is conducted in a textile mill in Tamilnadu, India, where the Supraharmonics measurements are taken. Even though there are numerous PQ measuring devices available on the market today, the manufacturer Powerside https://powerside.com is developing the P Qube 3 metre, which measures the Supraharmonics in the power quality frequency band between 2.5 and 150 kHz to quantify the power quality frequency band. This instrument has been approved for Class A PQ permitting in accordance with IEC 61000-4-30 [2]. Dranetz also manufactures the PQ metre, which is used to measure harmonics (https://www.dranetz.com). However, it is possible that another manufacturer has that feature, which will be investigated further. The Pqube 3 metre has been installed in the Textile mill for the purpose of collecting data for the study. At the textile mill, the instrument is fixed on a weekly basis, for a total of one week. Every one second, the data is gathered, and it captures every power quality event that occurs. **Figure 2** depicts a single line diagram of load sharing and the capability of the shared load system.

The industry's sanctioned demand for electricity at this location is 1250 KVA, according to the utility. There are nonlinear loads on the machines, which are fed by a frequency converter that provides power to the motors. The total installed power of a single machine ranges between 45kW and 55 kW, depending on the model. The Pqube 3 meter is linked to the load side, and data is collected for a period of one week in continuous operation. The data is collected on a day-to-day basis. The Supraharmonics level is observed in different frequency spectrums, and the voltage peak at 2kHz is measured to be 30Vpk.

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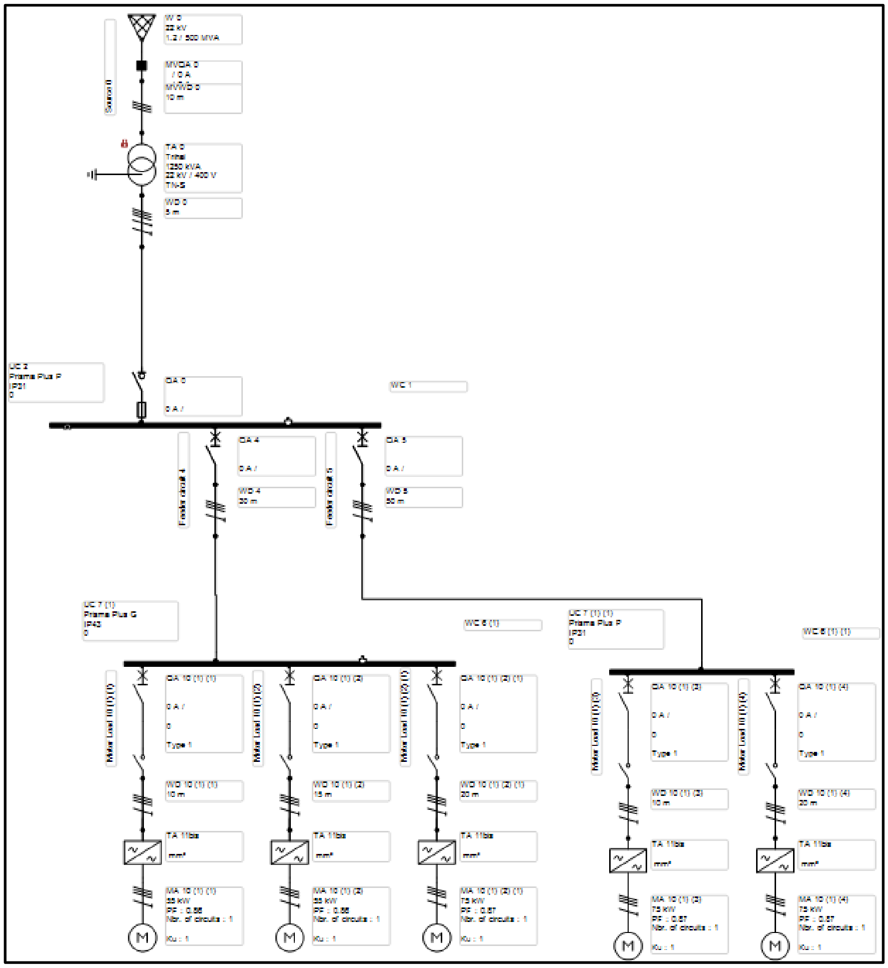

Figure 2 Power line diagram of Textile mill

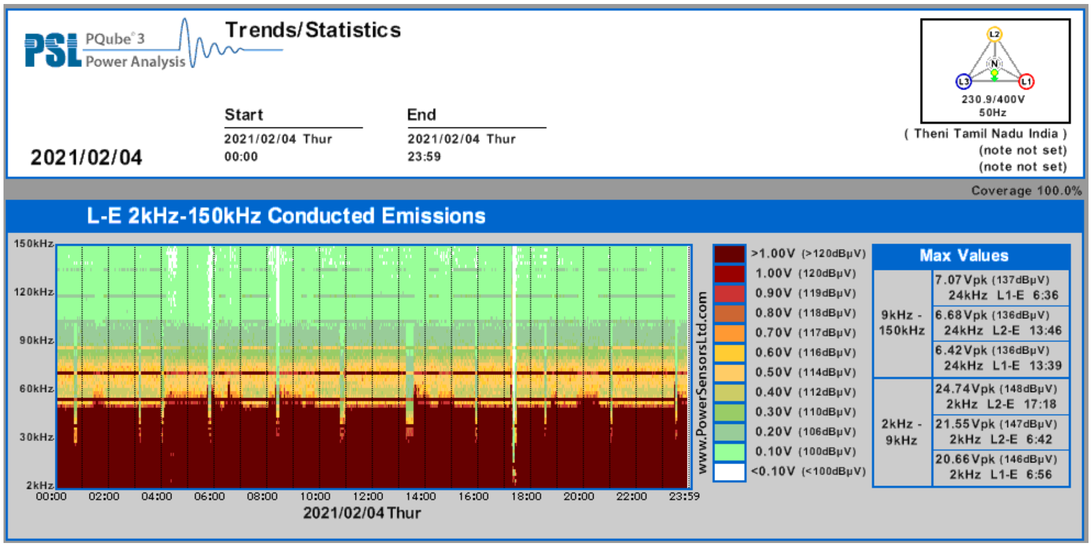

Figure 3 Real time graph on Supraharmonics taken through Pqube meter for one day.

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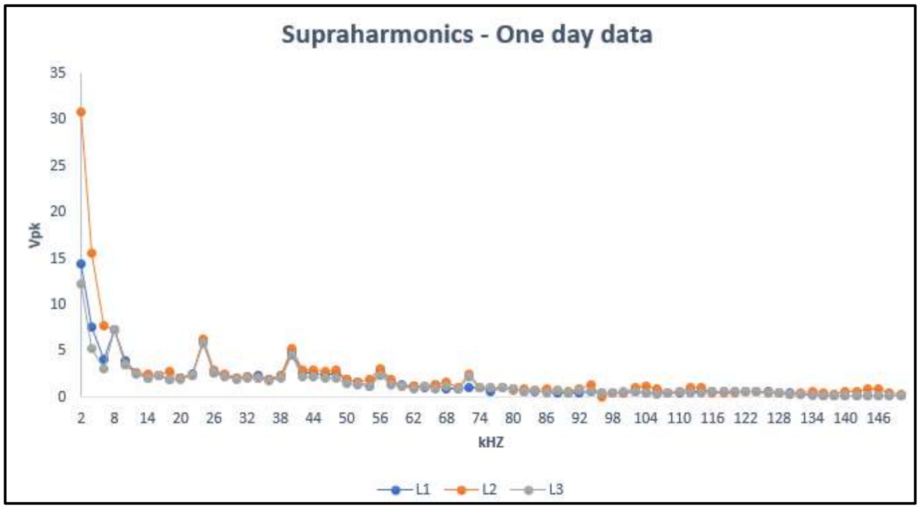

Figure 4 One day data on Volage peak vs kHZ

CONCLUSION

In power-electronic converters, harmonic distortions occur. Whenever these technologies are incorporated into the electrical grid, these distortions present major issues. Disadvantageous harmonic emission about 2 kHz occurs in typical grid-commutated power-electronic converters This is achieved by using pulse-width modulation (PWM) waveforms having fast switching frequencies to reduce discrete low-order harmonics. But these signals may induce heightened harmonics emission in the 2–150 kHz range, which acts differently than harmonic emission at lower frequencies. Numerous studies at textile mills revealed the predominance of supraharmonic emissions today.

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Electric Vehicle Charging Landscape Aiming for Self Reliant India

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Abstract: *One of the revolutionizing global strategies for the de-carbonization of the transport sector is the transition to electric mobility. India is amongst the few countries that propagate the globalEV30@30 campaign, targeting to have at least 30% new electric vehicles by the year 2030. An essential pre-requisite to achieve this ambitious transition comprises of accessible and robust network of electric vehicle (EV) charging infrastructure for which the Government of India has enabled various policies to promote the development of the charging network. However, in view of the present scenario of this new infrastructure type, there is a need for customizing to the Indian transport system along with building capacity among stakeholders to support the on-ground expansion. This paper aims at giving the efficient and timely implementation of electric vehicle charging structure ensuring proper integration of transportation and supply networks.*

Keywords*: Electric Vehicle; Battery Swapping; Rating*

INTRODUCTION

With the rising demand for electric vehicle it can eventually lead to replacement of conventionalvehicles. Thepaper aims for understanding the Electric vehicle charging structure along with the introduction to concepts (technical) of EV equipment's, AC/DC charging, power ratings & charging standards. It also focuses on supply of electricity for charging structure along with the financial viability for the same.

EV CHARGING STRUCTURE

The basic unit of EV charging structurecomprises of the Electric vehicle supply equipment (EVSE). This accesses power from theelectricity supply and makes usage of a control system & wired connection to safely charge Electric Vehicles. An Electric vehicle supply equipment control system enables many different functions such as authentication of user, charging prior to authorization, recording of information & exchange of network management along with ensuring data privacy &security. It is advised to use Electric vehicle supply equipment with least basic control & and management functions for all purposes related to charging. Conductive charging or plug-in charging, is the main charging technology in practice.

EV charging depends on the specification of Electric Vehicle batteries, as power needs to be supplied to the battery at the exact right voltage & levels of current to give permission for charging. In India, in view of the EVs, transport electrification is expected to be driven by light electric vehicle which primarily comprises of two-wheelers and three-wheelers. Moreover, Cars and light commercial vehiclesare the other vehicle segments being electrified.

Electric Vehicle charging requirements primarily depend on specifications of batteries of EV. The voltage & capacity of Electric Vehiclebatteries differ amongst the various EV segments, as shown in **Table 1**.

It is evident that low-voltage batteries are able to power the E-2Ws and e-3Ws. The lowvoltage batteries were the ones to power the first generation of e-cars. The 2ndgeneration of e-cars can be seen in the future e-car models which

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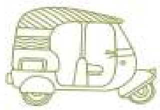
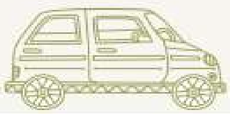
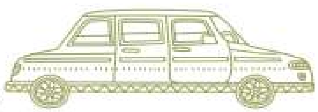
are powered from high-voltage batteries. Electric Light Commercial Vehicles will comprise of both low-voltage and high-voltage vehicles, depending on their load-carrying capacity.

Table 1 Voltage & Capacity of EV vehicles

VEHICLE SEGMENT	BATTERY CAPACITY	BATTERY VOLTAGE
E-2W 	1.2-3.3 kWh	48-72V
E-3W (passenger/ goods) 	3.6-8 kWh	48-60V
E-cars (1st generation) 	21 kWh	72V
E-cars (2nd generation) 	30-80 kWh	350-500V

CHARGING METHODS & POWER RATINGS

The charging method comprises of supply of direct current to the battery pack. Aconverter is required to provide (DC) power to the battery, as the electrical distribution system supplies (AC) alternate current. Conductive charging can be both Alternating Current and Direct Current. In the case of an AC electric vehicle supply equipment, the Alternating Current power is delivered to the on-board charger of the Electric Vehicle whichresults in conversion into Direct Current. A Direct Current electric vehicle supply equipmentresults in external conversion of the power and supplying the Direct Current power directly to the battery and thus bypassing the on-board charger.

As per depiction in **Figure 1**, AC &DC charging are classified into charging modes of four types with AC charging depicted by Modes 1-3 & DC charging shown by Mode 4.

As per **Figure 1**, modes 1 &2 are applicable for connecting an Electric vehicle to a socket outlet of standard type which utilizes a cable and plug. The typical Mode 1 which is also known as dumb charging, allows nil communication between the EV & EVSE and thus is not recommended. The portable cable that is used in Mode 2 has an inbuilt protection &control capability. It is typically used for home charging. Modes 3 & 4 provide a separate charger device to give power to the Electric vehicle. They have improvised control systems &are primarily used for commercial & public charging[1].

POWER RATINGS

Electric vehicle supply equipment have various ratings of power or levels based on charging requirements, which determine the power requirements for charging structure. The **Table 2** depicts the categorization of electric vehicle charging by power level along with the normal power charging. The normal power charging goes up to 22kW, whereas the highpower charging goes upto 200kW.

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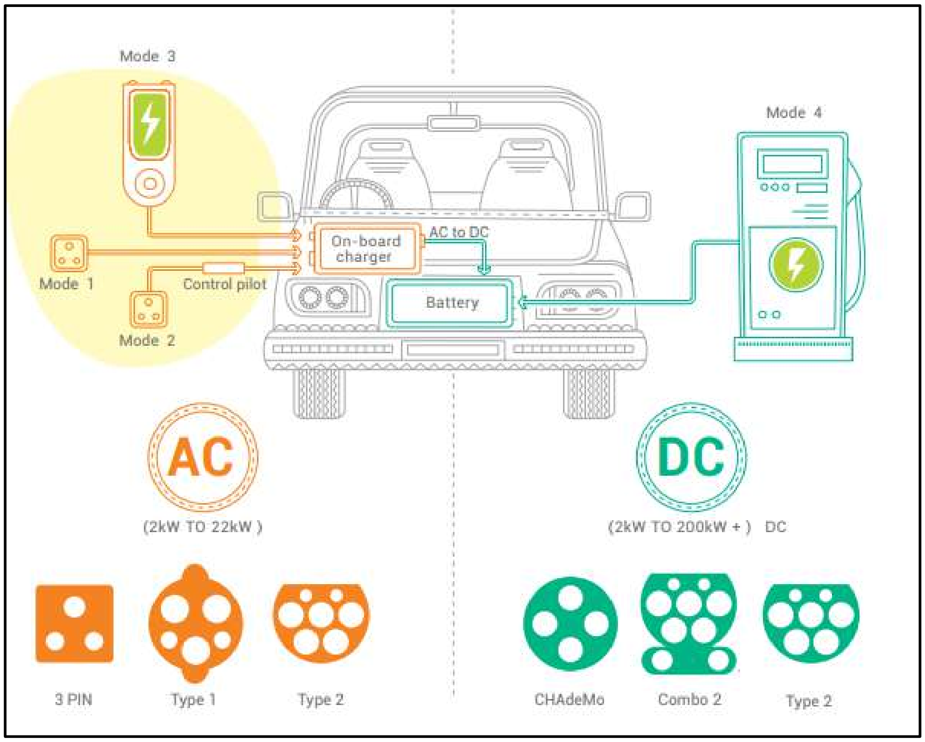

Figure 1 Classification of AC & DC Charging

Table 2 Normal & high power charging

	Power level	Current type	Compatible EV segments
Normal power charging	P ≤ 7kW	AC & DC	E-2Ws, e-3Ws, e-cars, other LCVs (up to 1 ton)
	7kW < P ≤ 22kW	AC & DC	
High power charging	22kW < P ≤ 50kW	DC	E-cars, LCVs and MCVs (1-6 tons)
	50kW < P < 200kW	DC	

Supply equipment's with ratings up to 500kW are available globally, however they are mainly applicable for heavy vehicles like trucks or buses. Primarily normal power Alternating current charging is sufficient for e-3Ws, e-2Ws, & e-cars. Normal power DC charging is specific to India, due to the commonness of Light EVs & the usage of low-voltage batteries in e-cars.

Single-phase AC chargers which have a capacity of maximum power rating of 7kW, are adequate for Light Electric Vehicles & cars with single phase chargers which are available on-board Moreover, 3-phase Alternating Current (AC) chargers having a power rating up to 22 kW, are required for cars havinglarger on-board chargers. Most importantly, input power supply for the normal power charging can be provided from the standard electricity distribution network. For e-cars having battery capacities between 30-80kWh (high-voltage), high-power DC charging of capacity 50kW is used. The power level of DC chargers in the market ranges between 25kW and 60kW. High-power DC charging takes less time for e-cars. However, it requires electricity supply higher along with with

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additional structure. Thus, normal power charging points are sufficient for charging requirements primarily, including overnight or slow charging of cars.

BATTERY SWAPPING

An alternative recharging method for the battery that is receiving attention globally is battery swapping. The process includes removal of the depleted EV battery and corresponding replacement with a fully charged one. The technology is under trial phase for various Electric vehicle segments which includes the e-2Ws, e-3Ws, e-cars & even e-buses.

The types of battery swapping includes:

a) Manual: The battery swapping station consists of a standalone device, in which batteries are placed &removed manually from the individual slots. Manual swapping stations are modular & take a minimum amount of space. These are used for 2W & 3W battery, as the battery pack size are much smaller & the weight can be handled by one person.

b) Autonomous: A robotic arm is to be used in autonomous type of swapping stations with the swapping process being semi/fully automated. Robotic swapping is primarily used for 4W & e-bus applications. The battery packs are larger and heavier, and require much mechanical assistance. In addition to the above, these swapping stations are more expensive and have a higher land requirement.

EV CHARGING STANDARDS

Standards ensure compatibility of any Electric vehicle supply equipment's with all Electric Vehicles [2]. The (BIS) Bureau of Indian Standard is primarily responsible for formulating Electric vehicle standards for the charging in India. It is to be noted that Indian standards for ElectricVehicle charging are compliant with global standards, however climate & the variations in available vehicle types necessitate modifications which are specifically applicable to India.

INDIAN STANDARDS FOR AC CHARGING

IS 17017 (key EV charging standard) comprises of three parts & six sections. IS-17017- Part-1 details of the basic features of all electric vehicles charging systems. An AC Electric vehicle supply equipment must adhere to this standard & specific to Alternating Current connector standards in the IS-17017-Part-2[3]. Both Alternating Current and Direct Current Electric vehicle supply equipment need to confirm to the standards IS-17017-Parts 21 & 22. Additional Indian standards for Alternating Current Electric vehicle supply equipment s have been approved for light EVs and e-cars.

INDIAN STANDARDS FOR DC CHARGING

IS-17017-Part-23 gives the requirements for Direct Current charging stations, with power output ranging from 50kW to 200kW. Above this, high power charging standards are required which cater to buses and other heavy vehicles [3].

FROM CHARGING STATIONS TO CHARGING POINTS

Charging stations refer to high-power Electric vehicle supply equipmentoften referring to the multiple charging guns. Charging points also refer to normal power electric vehicle supply equipment that can be accessed by a portable charging cable. While the initial deployment of public charging structure in India focused on charging stations, it is increasingly evident that most public charging needs can be served by a densely distributed network of charging points.

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An Electric vehicle charging network comprises of many normalpowered charging points. This is preferable to one with high-power charging stations in limited number. For Electric vehicles, anywhere parking location where the vehicle is stationary& having access to an EV charging point can have access to recharge the battery of the vehicle battery. This is popularly known as destination charging, as against the “onthe-go charging”. In the latter, vehicles rapidly top up their battery charge so as to drive to their destinations. Thus, EV charging structure should be provided where vehicles are parked on a regular basis, rather than finding out new locations as hubs for EV charging. This approach eventually leads to a charging structure implementation which promotes a distributed network of Electric vehicle. It enables charging points to the users at various locations - at apartments, office, malls, railway stations, bus depot etc. Such network approaches which are distributed have multiple advantages for users & operator and range from ease of access to financial viability.

ARRANGING FOR ELECTRICITY SUPPLY FOR CHARGING

The 1ststep in arranging for the electricity supply for Electric Vehicle charging is to estimate the demand for required power in kilowatts. Precisely, this is equivalent to the summation of the rated input requirement of all the points for charging. In case of a system comprising of battery charging, this would be equal to the power for simultaneous charging of the total number of. As soon as the total power demand is known, an Electric Vehicle owner may choose of the 3 options for provision of electricity for the Electric vehicle chargingstructure which comprise of (i) Drawing electricity from the existing power connection (ii) Arranging a new electricity connection (iii) Using a renewable energy generation system.

CONCLUSION

Electric Vehicles represent a revolution for both the power and transportation sectors, with having the potential to move ahead in the reduction of carbonization in both sectors by coupling them. Though the transportation sector has a very low share of renewable energy, it is presently undergoing a revolutionizing change, specifically in the vehicle segment on plying on the roads where the EVs are ready to rule the roads.In view of the new infrastructure type, there is aneed for customizing to the Indian transport system along with building capacity among stakeholders to support the on-ground expansion. This paper describes upon giving the efficientimplementation of electric vehicle charging structure along with ensuring proper integration of transportation & supply networks.

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Solar based Bi-Directional Electric Vehicle Charger

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Abstract: *Electric vehicle is an emerging as a solution for the problems caused by the vehicles which are powered by fossil fuels. The adaptability of Electric Vehicle (EV) depends on the charging infrastructure. This paper proposes a solar based bidirectional electric vehicle charger is designed which integrates the solar array directly on the DC bus of the charger. It is a two stage charger which consists of a bidirectional AC-DC converter followed by a bidirectional DC-DC converter. The EV battery gets charged using the solar power or grid power. The solar or the battery power is also feed to the grid. The charger works in both G2V and V2G mode. In this charger both the converters shares a common DC link capacitor. The bidirectional AC-DC converter acts as a rectifier in G2V mode and as an inverter in V2G mode. The DC-DC converter acts as a buck converter in G2V mode. During the V2G mode the DC-DC converter acts as a boost converter to raise the voltage of the battery to the sufficient DC link voltage. DQ control is implemented for bidirectional AC-DC converter and PI controller is used to control the bidirectional DC-DC converter. The charger is designed for a single phase 230 V, 50 Hz supply and for a load of 300 V, 66 Ah. The charger is designed and simulated using MATLAB simulink software. The results of the simulation are used to validate the design and control of the proposed charger.*

Keywords: *Electric Vehicle; Bi-directional Charger; Solar Array; G2V; V2G*

INTRODUCTION

The increase in population, shrinkage of resources like fossil fuels and the growing concern for reduce the environment pollution has made the automobile industries to think of an alternative approach of propulsion. Due to this electric vehicle is an emerging as a solution for the problems caused by the vehicles which are powered by fossil fuels. The adaptability of Electric Vehicle (EV) depends on the charging infrastructure. However, charging of electric vehicle require a large amount of electrical energy. Most of the electrical energy comes from thermal power plants which use coal and gas. Thus electric vehicle can be a clean and green alternative way of transportation when the energy required for charging the vehicle comes from renewable energy sources. Renewable energies such as solar and wind based grid connected system can be used for charging the EVs. This requires revamping of transmission lines for carrying more power. A solar based energy generating station produces electric supply that can be used on-site. The advantage of this charging station is that the power is generated locally and used locally. Thus, the transmission line does not have to be upgraded for high power and power does not have to been drawn from the grid to charge the vehicle when the cost of energy is high. The used of solar based charging station minimizes the cost of charging and avoids overloading of grid.The solar PV power output is intermittent in nature and discontinuous. Energy storage devices like battery can be combined with solar panels to provide continuous power. The operation of Electric Vehicle and solar array reduces the impacts of solar generation. Electric Vehicles are parked for 90% of the time due to which their batteries store a large amount of energy. This energy can be used in V2G (Vehicle to Grid) mode. Vehicle to grid mode provides voltage support and reactive power compensation to the grid.

The synchronous reference frame conversion is used to implement a current control for the bidirectional AC-DC converter. With proportional integral (PI) controllers, active power and the reactive power outputs of the inverter is controlled in the dq reference frame. Using a Phase-Locked Loop, the grid current and grid voltage are used to produce an orthogonal signal pair. PLL is used to push the injected grid current to be in phase with the grid voltage.

"Mohamed O. Badawy, Y. Sozer" presents an optimal power flow technique of a solarbattery powered Electric Vehicle (EV) charging station to minimize the operational cost. The objective of the technique is to help penetration of power from the solar and battery system to the grid. This also supports the growing need for the fast electric vehicle charging rates. This can be achieved by continuously reducing the running cost of the system while considering both the battery degradation cost and the grid traffics. An optimization algorithm is formulated along with the constraints which is required. The cost of operation is chosen as a combination of both the battery degradation cost and the grid prices. The battery degradation cost model accounts for the cycle DOD, average SOC and the operating temperature. Particle Swarm Optimization (PSO) is used as a predictive optimization tool for setting the SOC limits of the battery according to the solar PV power, grid prices and the load forecast [1].

"H.N. de Melo, J. P. F. Trovao, P. G. Pereirinha, H. M. Jorge" proposes a functional and a simple bidirectional plug-in electric vehicle charger topology which is capable of making interaction with an autonomous EMS (Energy Management System) in a residential setting. The EMS achieves potential benefits like energy exchange between the consumer and grid with the help of bidirectional electric vehicle charger. A suitable controller charger design is presented which includes the size of all passive elements and controllers. The charger can be adjusted for booth charging and discharging mode using the power level which is provided by the energy management system. The power of the charger is bidirectional and flexible, thus it allows charging and discharging operation at various power levels which is beneficial with integrating the power allocated and for scheduling the power among all the residential loads [2].

"Anjeet Verma, B. Singh" proposes an electric vehicle (EV) charger which operates in all the four quadrants of the reactive and active power (P-Q) plane. The charger consists of a full bridge AC-DC converter and a bi-directional DC-DC converter. The charger operates in both Grid to Vehicle (G2V) and Vehicle to Grid (V2G) modes. The bidirectional charger is capable of exchanging both reactive and active power. The batteries state of charge is also been preserved during the reactive power flow. The charger is designed to operate in a single phase 230V, 50Hz supply [3].

"L. Albiol Tendillo, E. Vidal Idiarte, J.Maixé Altés, J.M. Bosque Moncusí, H. Valderrama Blaví" presents the design and the control of bidirectional DC-DC converter for electric vehicles charging application. The DC-DC converter topology uses sliding mode control which uses only one surface. The bidirectional operation of the converter allows the permanent magnet synchronous motor (PMSM) to work either as a generator or motor. During motoring mode, the current flow is from the battery to the motor and the converter acts as a boost converter. During braking mode, the current flows from the PMSM to the battery and the converter acts as a buck converter. The sliding mode surface successfully controls the DC-DC converter in both the motoring and regenerative braking mode of the machine [5].

"Liwen Pan, Chengning Zhang" presents a high power density SIC based bidirectional AC-DC and DC-DC converter for electric vehicle charging application. The on board vehicle charger is multifunctional it transfers energy between the battery and the electric traction system and as an AC-DC battery charger. The converter control is developed for the motor drive system and for the battery charging system. It consists of a power pulsation reducing circuit. The improved control is designed to achieve better performance than the DCM control used in AC-DC converter in the battery charging mode [6].

Problem Statement

The electric vehicle can be a clean and green alternative way of transportation if the energy required for charging comes from renewable energy sources. The renewable energy based charger must be able to transfer power in both V2G and G2V mode based on a power management strategy and must also aim in minimizing the utility grid dependency.

The rest of this paper is organized as follows. In Section II, system configuration is provided. In Section IIIexplainsthe control algorithm of the proposed charger. Section IVexplains the bidirectional AC-DC converter control for both grid to vehicle and vehicle to grid mode.Section V briefly explains the design of the proposed

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system. In Section VI the MATLAB modelling of the proposed charger is given. In Section VII the results of the simulation work is discussed. Finally, Section VIII concludes this paper.

SYSTEM CONFIGURATION

Figure 1 shows the block diagram of proposed charger. The charger consists of a bidirectional AC-DC converter followed by a bidirectional DC-DC converter. The EV battery gets charged using the solar power or grid power. The solar or the battery power is also feed to the grid. The charger works in both G2V and V2G mode.

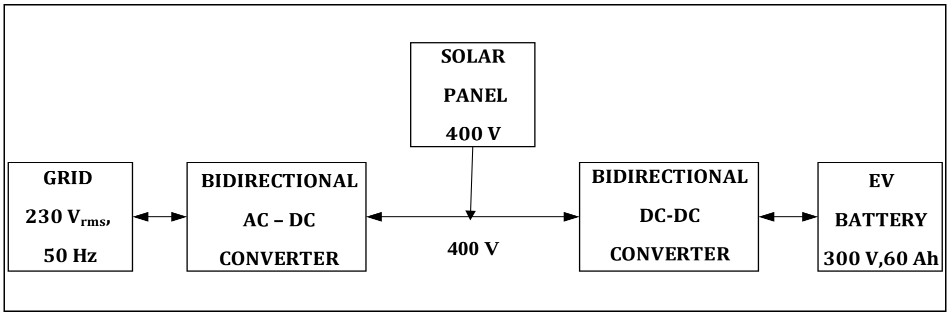

Figure 1 Block diagram of the solar based EV charger

Figure 2 shows the circuit diagram of the proposed charger. Two converters share a common DC capacitor in this proposed charger. One converter connects to the grid, while the other connects to the battery. During G2V mode the bidirectional AC-DC converter acts as a rectifier. It converts AC voltage into DC voltage for charging the battery. The power is transferred to the battery through the DC link capacitor. A bi-directional DC-DC converter is necessary to interface the battery. It acts as a buck converter for the control of charging voltage and current during grid-to-vehicle mode.During the V2G mode the DC-DC converter acts as a boost converter to raise the voltage of the battery to the sufficient DC link voltage. The AC-DC converter acts as an inverter. It converts the DC voltage to AC voltage for feeding the solar power and battery power to the grid. The coupling inductor (L_c) is used to connect the charger to the grid. The coupling inductor eliminates the harmonics and smoothen the grid current.

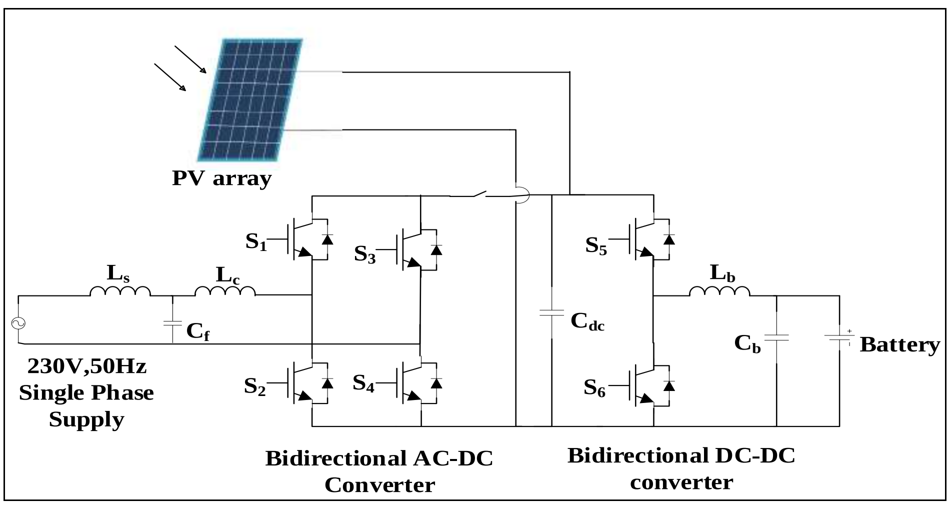

Figure 2 Circuit Topology of Solar Based Bi-Directional battery charger

CONTROL ALGORITHM

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The control Algorithm of the proposed charger is shown in **Figure 3**. The solar based electric vehicle charger operates in two modes. The two modes of operation are grid to vehicle and vehicle to grid mode. Each mode of operation depends on the solar power generated and the state of charge (SOC) of the battery. When the SOC of the battery is less than 20% the battery gets charged. The battery gets charged from the solar power when the PV power generated is greater than the battery power. When the PV power generated is less the battery gets charged from the grid power until the SOC of the battery reaches 80%.

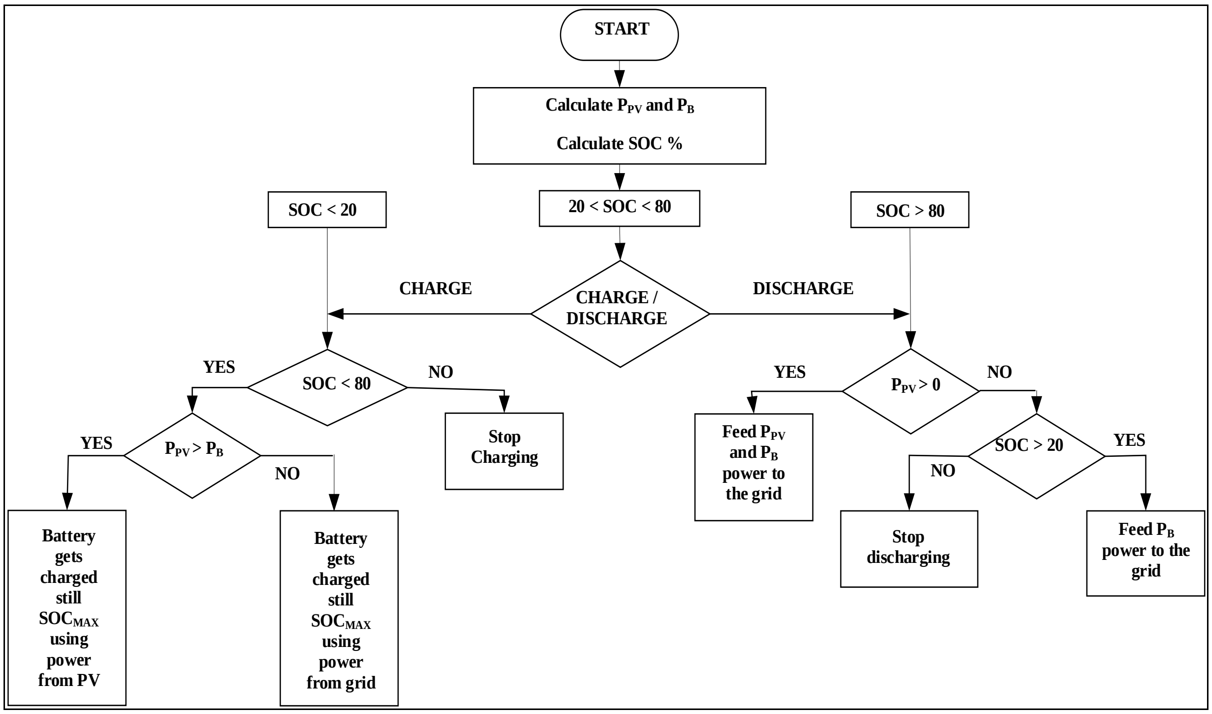

Figure 3 Control Algorithm

The charger operates in vehicle to grid mode when the SOC of the battery is greater than 80%. When the PV power generated is more than zero both the solar power and the battery power is fed to the grid. When no power is generated from the PV array only the battery power is fed to the grid. When the SOC of the battery reaches 20% the battery stops discharging.

BIDIRECTIONAL AC-DC CONVERTER CONTROL

Grid to Vehicle Mode

The Grid to vehicle control block diagram is shown in **Figure 4**. In the G2V mode the bidirectional AC-DC converter acts as a rectifier. For this control, the grid voltage, grid current and the output DC voltage are sensed at the inverter side. The error between the actual DC voltage and the reference voltage is found which is then fed to a PI controller. The output of the PI controller is then multiplied with cos(wt) to get the value of reference current. Cos(wt) is the unit vector generated by PLL and this is aligned in phase with the grid voltage. The block diagram of PLL is shown in **Figure 5**. The reference current is then compared with the inverter current to find the error. The error is then fed to a PIController. The output of the PI controller is then added with the grid voltage to get the reference voltage value. The obtained reference voltage is fed to the PWM generation block. In the PWM generation block, the reference voltage is compared with triangular carrier waves to generate PWM pulses. The output of each comparator is inverted using NOT gate. The generated PWM is connected to the respective switches of the bidirectional converter. The PWM generation block diagram is given in **Figure 6**.

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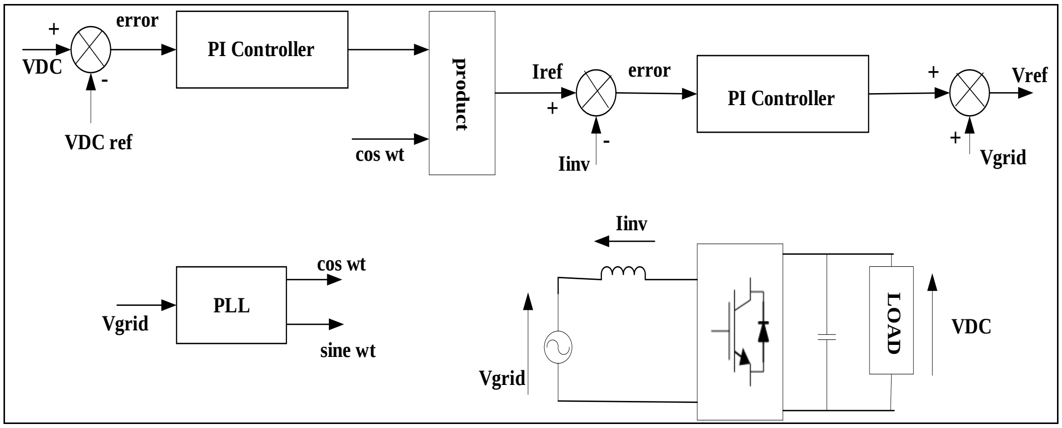

Figure 4 G2V Controller Block Diagram

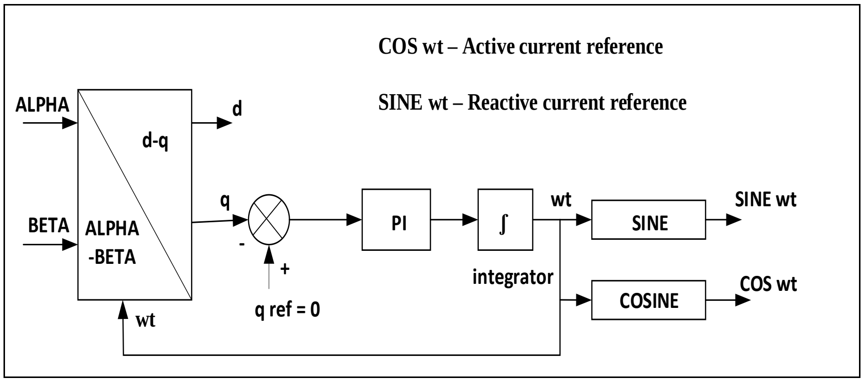

Figure 5 Phase Locked Loop (PLL) Block Diagram

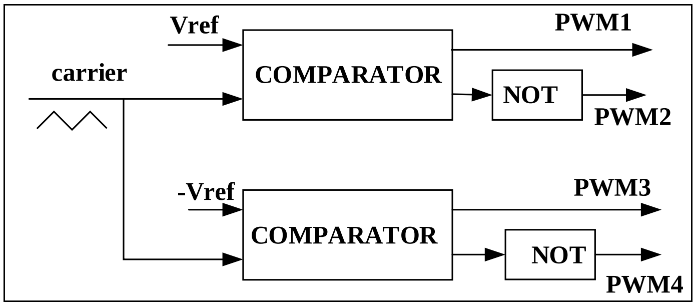

Figure 6 PWM Generation Block Diagram

Vehicle to Grid Mode

The vehicle to grid control block diagram is given in **Figure 7**. In V2G mode the bidirectional converter acts as an inverter. The switching pulse of the inverter is controlled using dq control. The grid voltage is sensed and it is transformed into αβ frame. The alpha (α) and beat (β) voltages is given to the PLL to get wt. The αβ voltages are converted into dq voltages. Similar to the grid voltage, the inverter current is also sensed and transformed into dq frame. Id and Iq are compared with its reference values and the output is given to the PI controller. The output of the PI controller is added with Vq+LwId and Vd-LwIq respectively. The added values are then transformed back to the αβ frame. The beta voltage is multiplied with $1/V_{DC}$ and given to the PWM generation block[7].

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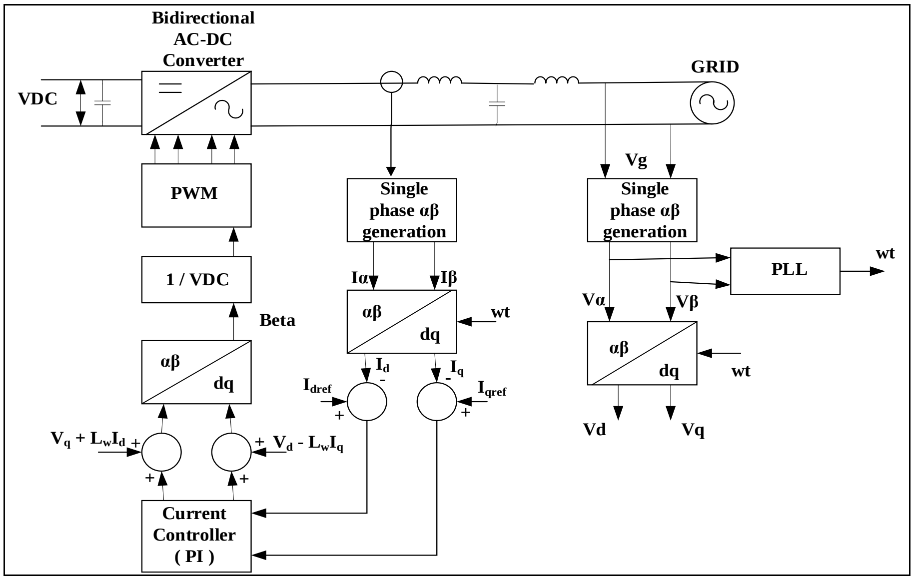

Figure 7 V2G Controller Block Diagram

DESIGN OF PROPOSED SYSTEM

The bidirectional AC-DC converter is designed for a power of 3kW. The DC link voltage which is required for power transfer to the battery is 325V. Therefore, for design of DC link capacitor a voltage of 400V is considered.

$$C_{dc} = \frac{I_{dc}}{2 * \omega * \Delta V_{dc}} = \frac{P_{dc}/V_{dc}}{2 * \omega * \Delta V_{dc}}$$

$$= \frac{3000/400}{2 * 314 * 0.015 * 400} = 1990.4\ \mu F$$

The value of the DC link capacitor is rounded off and considered as 2000 μF.

The switching frequency considered for the design of the coupling inductor is 20 kHz. The fundamental supply current peak value is 20A. 3% of the fundamental supply current is taken as the current ripple.

$$L_c = \frac{mV_{dc}}{6 * f_s * h * \Delta i_c}$$

$$= \frac{400}{6 * 20 * 10^3 * 1.2 * 20 * 0.03} = 4.62\ mH$$

The inductor value is rounded off to 5 mH for simulation.

There will be harmonics injected from the grid. To prevent this inductive and capacitive filter is designed.

$$C_f = \frac{I_{peak}}{\omega_L V_{peak}} \tan(\theta)$$

$$= \frac{20\sqrt{2}/230}{314 * 230\sqrt{2}} \tan(1) = 318\ nF$$

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A filter capacitor value of 330 nF is considered.

The filter inductor is designed as

$$L_s = \frac{1}{2\pi f_s * \left(\frac{I_g}{V_g}\right) * \left(1 - \frac{(2\pi f_s)^2}{(2\pi f_{res})^2}\right)} = 7.35 \text{ mH}$$

The filter inductor in the dc side is designed for a switching frequency of 10 kHz. The duty ratio is considered as 0.75.

$$L_b = \frac{V_{dc} k(1-k)}{f \Delta I_b}$$

$$= \frac{400 * 0.75 * 0.25}{32 * 1000 * 10 * 0.05} = 4.68 \text{ mH}$$

Thus, by rounding off the obtained value 5 mH is selected as the inductor value.

Table 1 AC-DC Converter Specification

S.No	Name	Rating
1	Supply Voltage	230 V
2	Supply Current	20 A
3	Switching Frequency	20 kHz
4	Output Voltage	400 V
5	Output Current	13 A
6	Filter Circuit Inductor	7.35 mH
7	Filter Circuit Capacitor	330 nF
8	Coupling Inductor	5 mH

Table 2 DC-DC Converter Specification

S.No	Name	Rating
1	Input Voltage	400 V
2	Switching Frequency	10 kHz
3	Output Voltage	325 V
4	Output Current	10 A
5	Modulation Index	0.8
6	DC Link Capacitor	2000 µF
7	Filter Inductor	5 mH
8	Filter Capacitor	700 µF

Table 3 Battery Specification

S.No	Name	Rating
1	Battery Voltage	300 V
2	Rated Capacity	60Ah
3	Type	li-ion

Table 4 PV Module Specification

S.No	Name	Rating
1	No. Of Modules	60
2	Cell per Module	60
3	Open Circuit Voltage	36.3 V
4	Short Circuit Current	7.84 A
5	Output Current	13 A
6	Maximum Power	213 W
7	Output Voltage	400 V

MATLAB MODELING

MATLAB Block – Grid to Vehicle Mode

In **Figure 8** the electric vehicle charger is simulated in grid to vehicle mode. An AC supply of 325 V is given at the supply. The bidirectional AC - DC converter is controlled using dq control. The AC supply is converted to DC source and a DC voltage of 400V is obtained across the DC link capacitor. A solar panel is connected after the bidirectional AC – DC converter. A voltage of 400V is obtained from the solar panel. The DC – DC converter acts

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as a buck converter in grid to vehicle mode. The 400V DC supply is reduced to 300V. A battery of 300V, 66Ah is connected at the load. The battery gets charged during this mode.

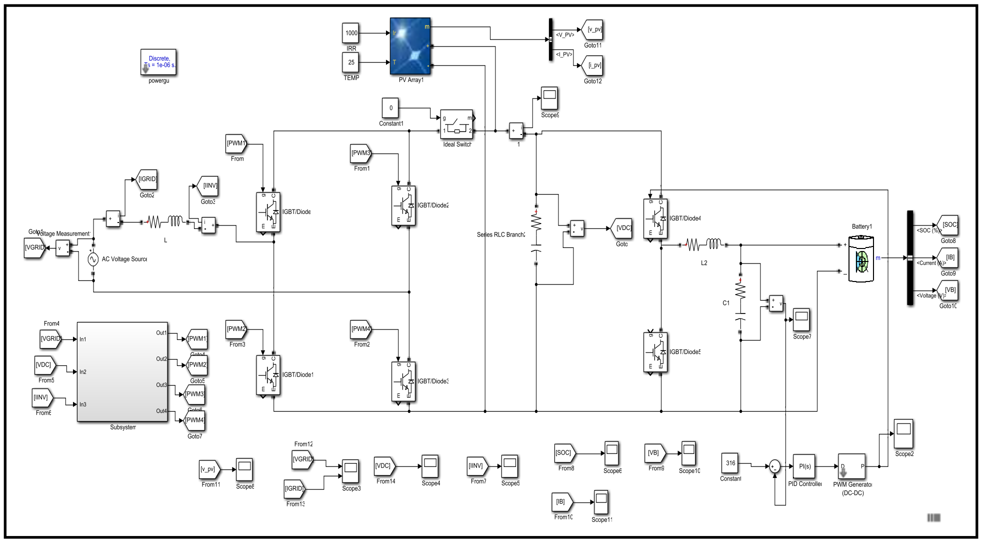

Figure 8 Grid to Vehicle Mode

MATLAB Block –Grid to Vehicle Control

The grid to vehicle control simulation block is shown in figure 9. The grid voltage is sensed and is converted from alpha beta to dq frame. The error between the actual DC voltage and the reference voltage is found which is then fed to a PI controller. The output of the PI controller is then multiplied with cos(wt) to get the value of reference current. The error between the actual and the reference current is fed to the PI controller. The controller output is then given to the pulse generation block.

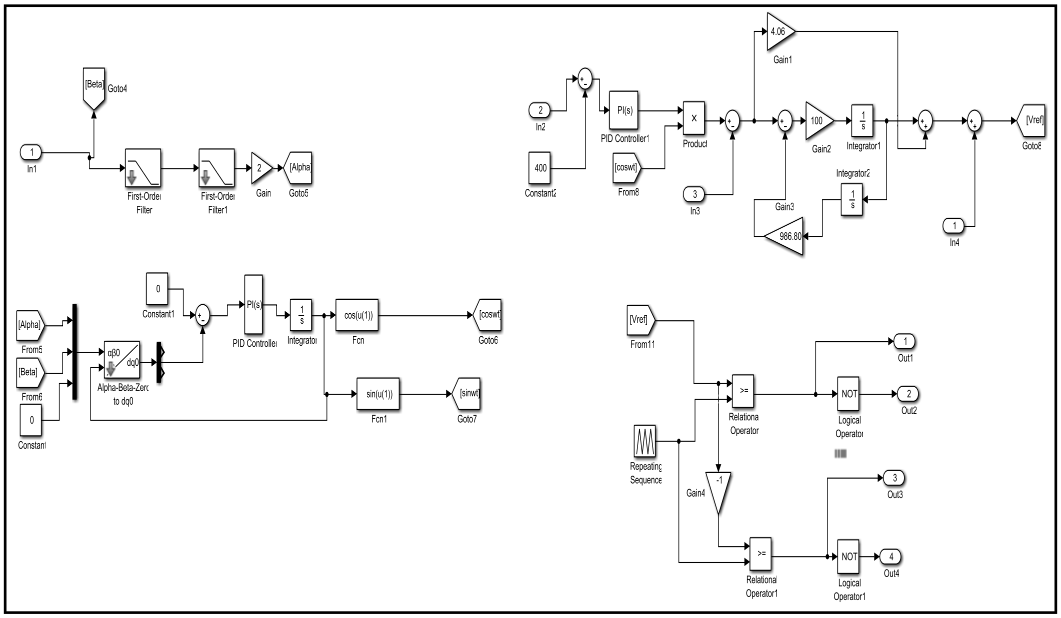

Figure 9 Grid to Vehicle Control

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MATLAB Block – Vehicle to Grid Mode

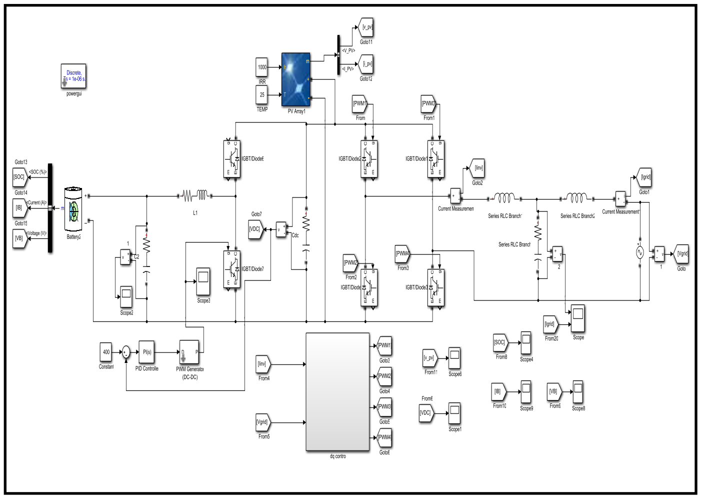

Figure 10 Vehicle to Grid Mode

In **Figure 10** the electric vehicle charger is simulated in vehicle to grid mode. A battery of 300V, 66Ah is connected at the supply. The bidirectional DC – DC converter act as a boost converter in this mode. The 316V battery voltage is converted to 400V. A solar panel is connected after the bidirectional AC – DC converter. A voltage of 400V is obtained from the solar panel. The bidirectional AC - DC converter is controlled using dq control. The DC supply is converted to AC source and an AC voltage of 240 V and 10 A current is obtained at the output of the converter.

MATLAB Block – Vehicle to Grid Control

The vehicle to grid control simulation block is shown in **Figure 11**. The grid voltage and current is sensed and transformed form alpha beta to dq frame. The Id and Iq are compared with its reference values and the given to the PI controller. The output of the PI controller is transformed to alpha beta frame. The beta voltage is given to the PWM generation block.

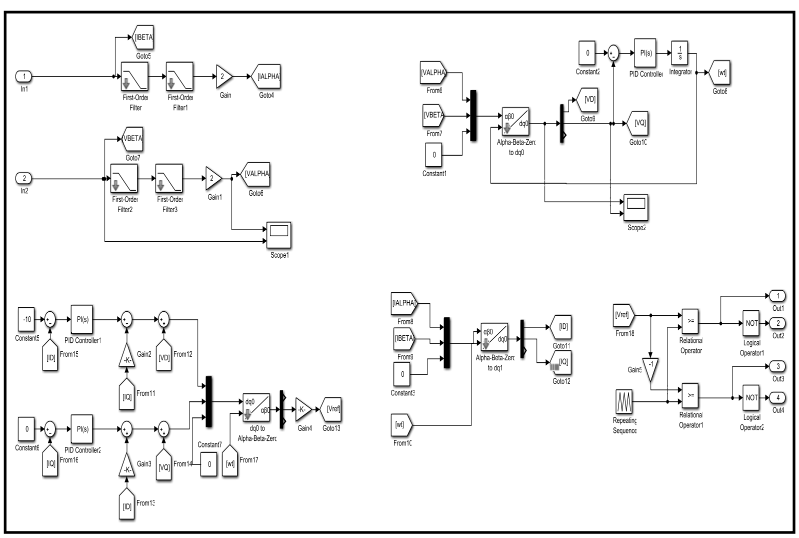

Figure 11 Vehicle to Grid Control

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RESULTS AND DISCUSSION

Grid to Vehicle Mode

The grid voltage and current is shown in **Figure 12**. A grid voltage of 325V and 50Hz is given to the converter. The grid current is 10A.

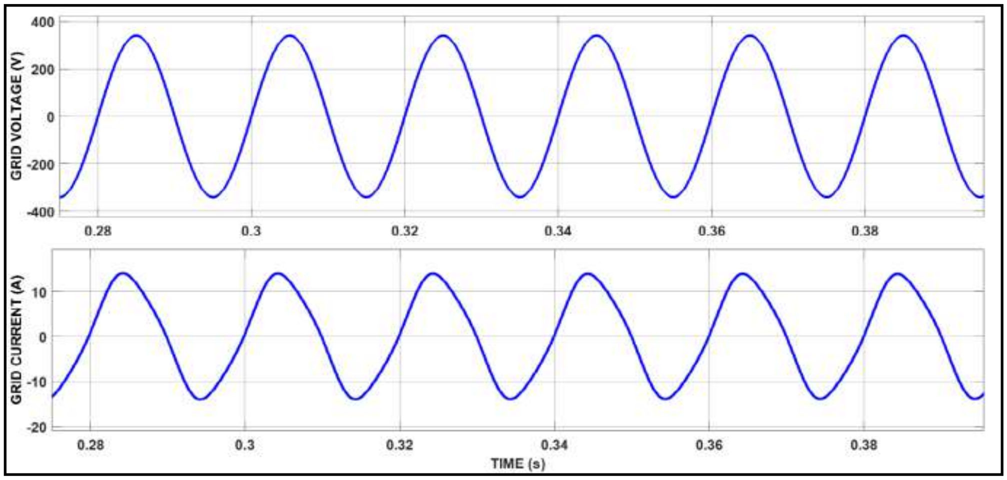

Figure 12 Input Grid Voltage and Current

The output DC voltage of the bidirectional AC-DC converter is shown in **Figure 13**. DC link capacitor is boosting the voltage 1.5 times of the input supply voltage. The DC voltage obtained is 400V.

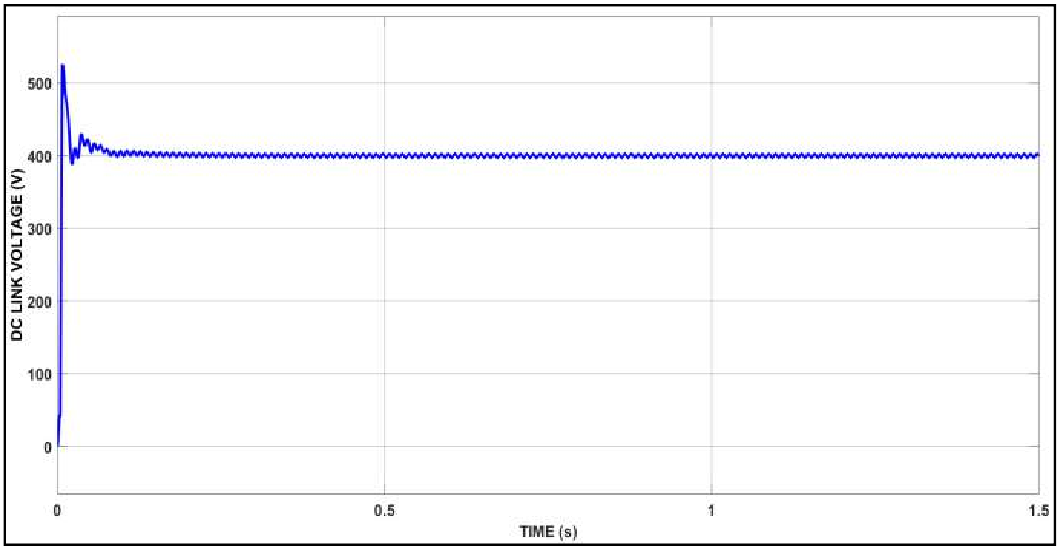

Figure 13 DC link voltage

The output DC voltage of the solar panel is shown in **Figure 14**. The DC voltage of 425V is obtained from the PV array.

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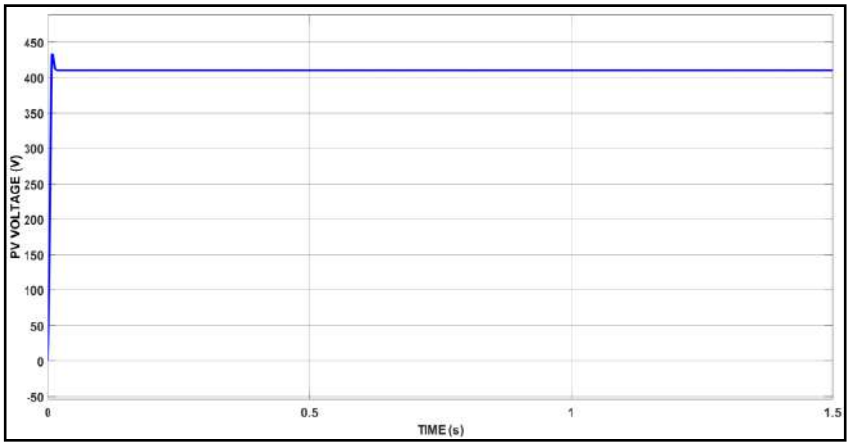

Figure 14 Solar PV Output Voltage

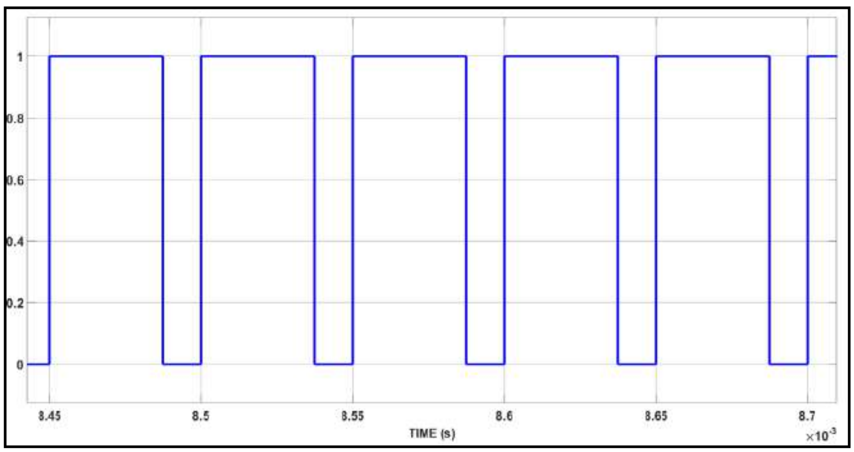

Figure 15 PWM Pulse to the Bidirectional DC – DC Converter

The battery state of charge is shown in **Figure 16**. The SOC % increases as the battery is getting charged.

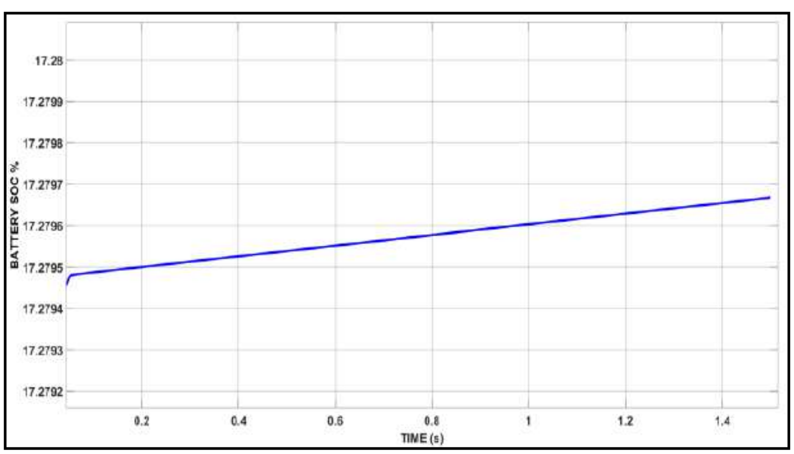

Figure 16 Battery SOC

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The waveform in **Figure 17** shows the battery voltage when it is getting charged. The battery voltage obtained is 316 V.

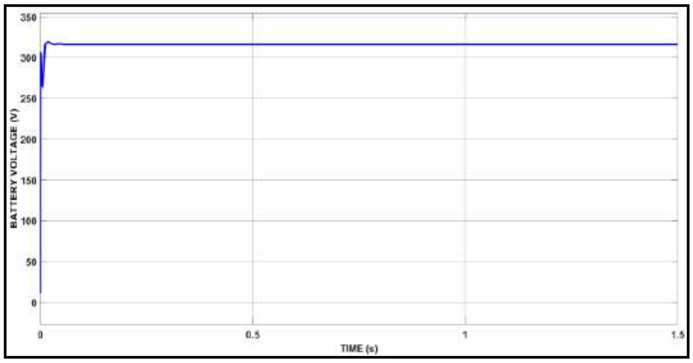

Figure 17 Battery Voltage

The waveform in **Figure 18** shows the battery current. The battery current obtained is -10 A. The obtained current is in negative polarity as the battery is getting charged.

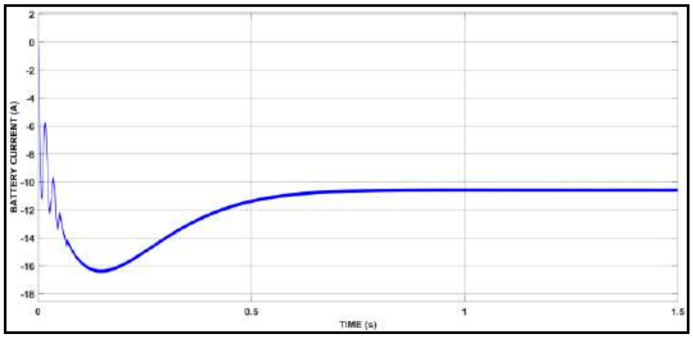

Figure 18 Battery Current

Vehicle to Grid Mode

This waveform shown in **Figure 19** is the battery voltage when it is getting discharged. The battery voltage obtained is 316 V.

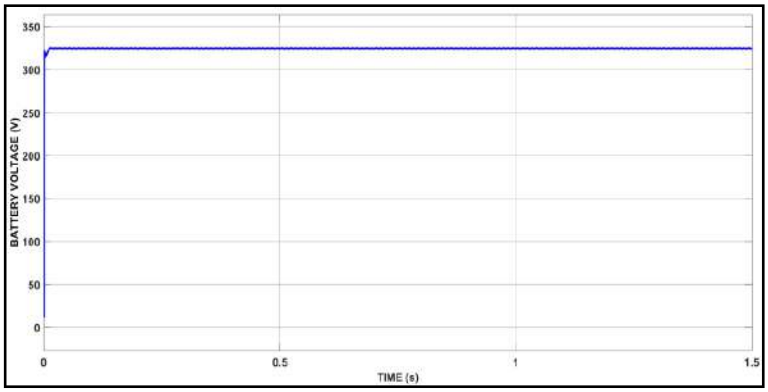

Figure 19 Battery Voltage

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The battery state of charge is shown in **Figure 20**. The SOC % decreases as the battery is getting discharged.

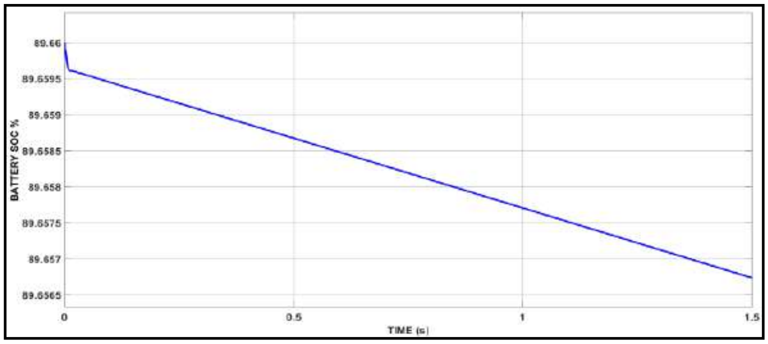

Figure 20 Battery SOC %

The battery current waveform is shown in **Figure 21**. The battery current obtained when the battery is getting discharged is 10 A.

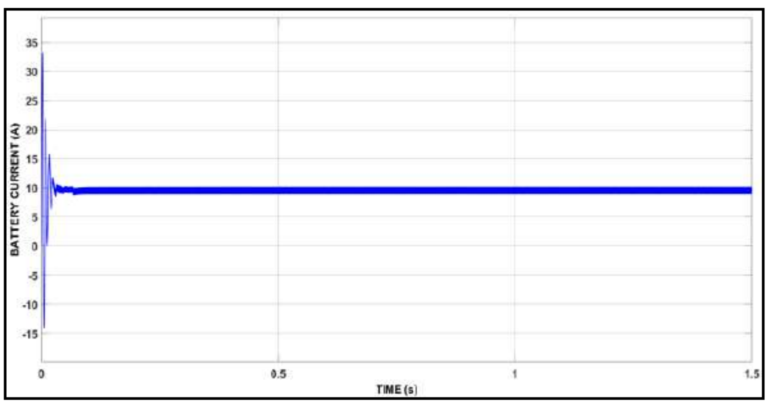

Figure 21 Battery Current

PWM pulses given to the switch 2 of the DC – DC converter is shown in **Figure 22**. The switching frequency is 10 kHz.

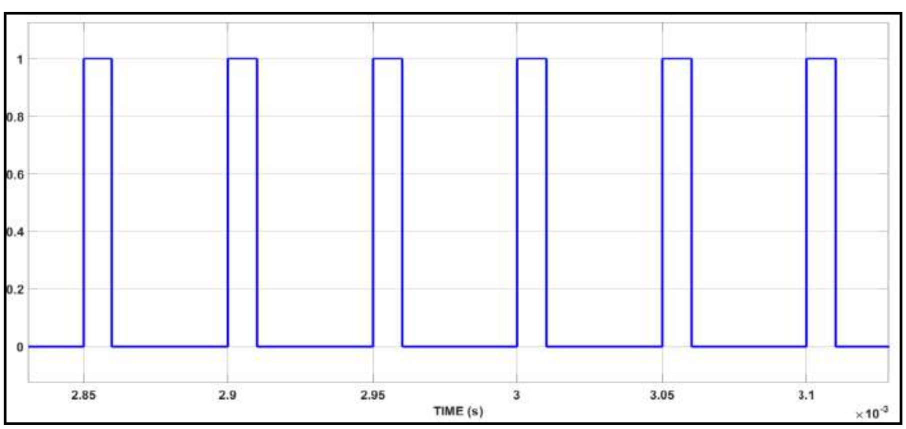

Figure 22 Gate Pulse

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The output DC voltage of the bidirectional DC-DC converter is shown in **Figure 23**. The DC-DC converter act as a boost converter and a voltage of 425V is obtained.

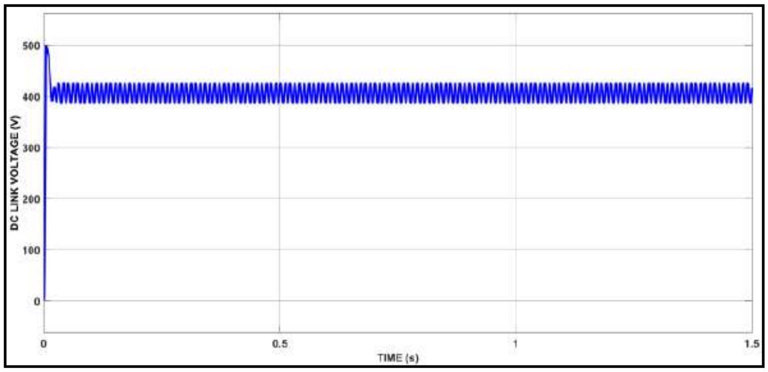

Figure 23 Output Voltage of DC-DC Converter

The output DC voltage of the solar panel is shown in **Figure 24**. The DC voltage of 425V is obtained from the PV array.

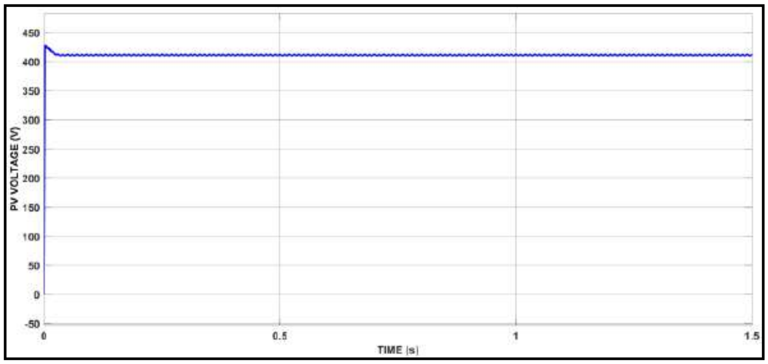

Figure 24 Solar Panel Voltage

PWM pulses given to the switches of the bidirectional AC – DC converter is shown in **Figure 25**. The switching frequency is 20 kHz.

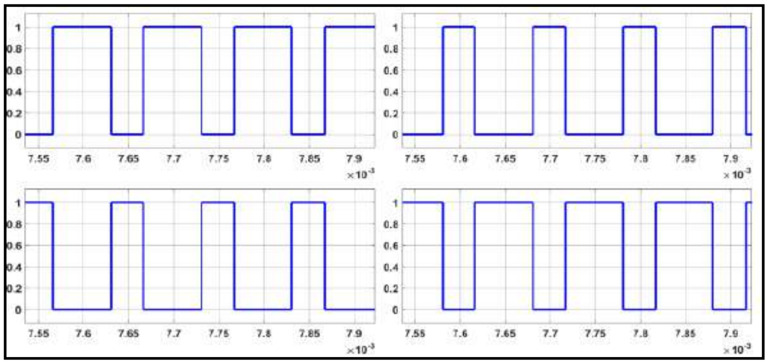

Figure 25 PWM Pulse to the AC – DC Converter

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The obtained AC voltage and current is shown in **Figure 26**. AC voltage of 240 V and 10 A current is obtained at the output of the converter.

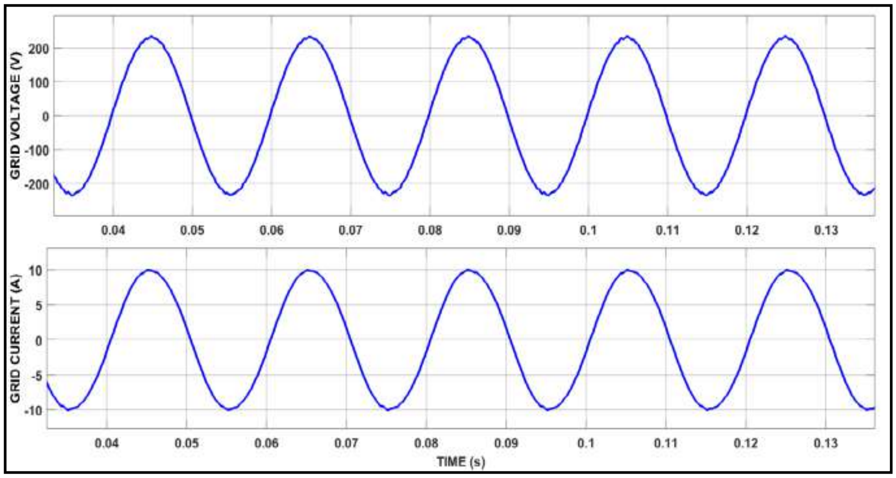

Figure 26 Output AC Voltage and Current

CONCLUSION

In this papera solar based electric vehicle charger which has a bidirectional AC – DC converter and a bidirectional DC – DC converter along with the solar panel has been designed and simulated. The electric vehicle charger has the capability of working in both the grid to vehicle and vehicle to grid mode. The charger is controlled based on the control algorithm. The proposed system is modelled and simulated using MATLAB software.Thesimulation resultsobtainedindicates that the operation of the charger is achieved as per the control algorithm in both the modes. The proposed system also minimizes the utility grid dependency.

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Analysis of the Pivotal Role of Entrepreneurship in the Solar Energy Sector of India — A Focus on the Indian Renewable Market

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Abstract: *Renewable Energy, is considered to be the need of the hour, as the world is grappling with issues of climatic change, energy poverty and un-employability. In a developing country like India, solar energy holds the key to aforementioned challenges as it is abundantly available and free of cost. The solar energy market of India, in the last decade has been growing at an unprecedented pace, with rapid developments being made in both on-grid and offgrid sector. This study highlights the pivotal role of entrepreneurship in the solar energy sector of India. The topic of research being inter-disciplinary takes into consideration the aspects of entrepreneurial theory and the current trends in renewable energy. The quintessential role of entrepreneurship in promoting the cause of solar energy, has been analyzed using three different parameters i.e. Number of starts-up or entrepreneurial ventures conceived, the investments made in the solar energy sector and the policy incentives by the Government of India. This study also characterizes the current status of the solar start-ups into ideation, validation, traction and scale-up stages. It is expected that growth of the solar energy sector, catalyzed by the innovative actions of entrepreneurs will help in achieving the sustainable development along with the future energy needs.*

Keywords: *Renewable Energy; Solar Energy; Entrepreneurship; Start-ups; Policy Incentives*

INTRODUCTION

The CoVID-19 pandemic has shown how fragile the world is. A microscopic virus has brought the entire humanity on the knees. Millions of lives and livelihood have been threatened and lost. In-fact today, also happens to be the time, when we need to introspect the future we want to build and the planet we want to leave for the upcoming generations. The last 18 months of the pandemic has shown that the humans can adapt to evolving circumstances and indeed have enormous capacity to change the way they live, work and organize themselves. On 25 September, 2015, the members the United Nations, signed up for the 17 sustainable development goals, a set of solution to the biggest problems the world faces. Many of these problems are interlinked and interconnected. Climate change happens to be one of them and quintessentially a critical one [1]. According to the latest reports by NASA on climate change 2010-2019 was the warmest decade, indicating the fact that climate change is real and happening [2]. Today as the globe confronts the verity of climate change, these warmer temperatures further aid in the fueling of a host of natural calamities resulting in further degradation of the natural habitat and environment. Carbon dioxide (CO_2) and other greenhouse gas emissions are considered to be the major sources of continued global warming. As a matter of fact, the CO_2 concentration in the atmosphere has increased by up to 48% since 1850, when compared to the pre-industrialized era and the continuous usage of fossil fuels has played the major part in it. [3]

Affordable and Clean Energy is one of the seventeen goals adopted by the UN. One of the many objectives that is meant to be achieved through this goal is to considerably enhance the percentage share of renewable energy in the overall global energy scenario. According to IRENA (International Renewable Energy Agency) by the beginning of the year 2021, the international energy generation by renewable means reached 2799 GW, superseding the previous year by 10.3%. The maximum increase occurred in Solar Energy, which increased by 22% (+127GW) closely

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followed by wind energy at 18% (+111GW) [4]. **Figure 1** depicts the distribution of the global renewable energy generation by energy source in the beginning of 2021. In terms of the continental distribution, Asia (in particularly China) played a pivotal role in enhancing the renewable energy generation by a staggering 64%, followed by the North American & European markets, where an increase of 8.2% and 6% was witnessed respectively. India too has made its make on the international scene, with the rapid generation and deployment of the renewables, specifically the solar power. It's in fact among the top 5 nations of the world in photovoltaic power programs. Today, the aggregate capacity of installed solar PV in the country is nearly 40 GW as compared to 161 MW in 2010. This includes both the roof-top solar and ground-mounted solar along with the off-grid solar power.

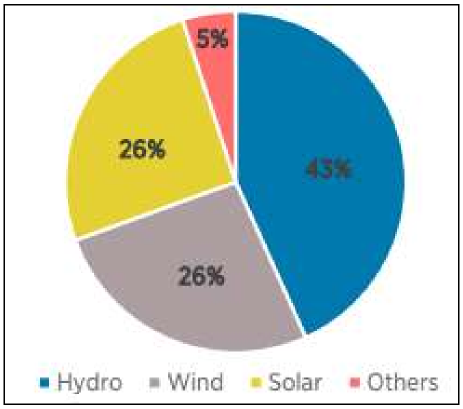

Figure 1 Distribution of Energy sources in Renewable Energy generation

The surge of the usage of renewables serves dual purpose:

1) It is considered to be an imperative action for reducing the impact of the climatic change in agreement to the Paris Accord, besides

2) the goal of providing universal clean, affordable and reliable energy to everyone becomes more enabled.

According to 2019 Energy Progress Report by IEA (International Energy Agency), IRENA, UN Statistics Division, World Bank & WHO (World Health Organization) even today, 12-14 percent of the world's population haven't got any access to modern electricity and more than 2.9 billion inhabitants have no ingress to clean cooking and heating [5]. Renewable energy is not only close to local communities but also possess the potential to create a difference in the lives of millions.

Today, there's no denying the fact that innovation and entrepreneurship are critical for the further development and deeper penetration of the renewable energy. Multiple opportunities exist for entrepreneurs to identify the gap in the existing renewable energy market, deploy creative and innovative solutions with scalable business models, procure liberal benefits and create an impact. Many entrepreneurs are focusing their ventures along the different aspects of renewable energy entrepreneurship like consultation, installation, financing and maintenance. Globally green energy investments are expected to be at least half of the total investments in the entire energy sector in 2020. Start-Ups across the globe, are being conceived in the energy industry with solar energy, wind energy, hydro energy and biomass being the prominent fronts in the area of renewable energy. Furthermore, besides the conventional mainstream energy market, ample possibilities do exist in the off-grid energy sector as well with social enterprises like SELCO Solar, Urja Unlimited, Pollinate Energy etc having made a mark for themselves by working at the BOP (Base of Pyramid) in developing countries like India. [6]-[7]

In this paper, the importance of entrepreneurship in promoting the growth of solar energy in a developing country like India is highlighted. The paper is structured as follows: After the introduction in section I, a review of renewable energy entrepreneurship, both on and off grid is presented in section II. Section III explores and studies the role of entrepreneurship in the solar energy sector of India in terms of number of start-ups conceived and

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investments made by government, private and public-private networks. The start-ups conceived has also been characterized on the basis of their stages in this work. The paper also highlights the new governmental policies and regulatory frameworks of the recent past introduced to promote/support the same. Section IV concludes the paper.

ENTREPRENEURSHIP IN THE RENEWABLE ENERGY SECTOR

With the ever increasing demand for energy in our daily lives, from the household needs to commercial obligations, the role of renewable energy is gaining more prominence. According to IRENA Global Energy Transformation: A Roadmap to 2050 report, the intended target for the next three decades is to create a renewable energy dominated market for creating a sustainable energy future. In order to achieve the same and to ensure that the targets are met, both the market incumbents and new ventures, created by Renewable energy entrepreneurs have a significant role to play [8]. Traditionally, the incumbents had an upper hand when it came to government energy policies, regulations, market share and dynamics; however, with the changing times, the role of start-ups in the renewable energy sector is gaining prominence. The new entrepreneurial ventures or start-ups in the renewable energy sector are usually associated with disruptive innovation, (when compared to the incremental innovation followed by the incumbents); as well as being more sustainable [9]. As a matter of fact, the literature suggests that pressures of sustainable development have resulted in ample opportunities being created for new entrants, who tend to follow a value based approach in creating products, processes or services with the aim to create a more social and environmental impact. [10]

Another aspect that's important from the economics point of view and is fundamental to entrepreneurship, in general, is the creation of jobs. The Renewable sector has generated about 11.5 million jobs in year 2019, with the solar photovoltaic (PV) leading among the renewable energy technologies (RETs). It accounted for every 1 out of 3 jobs created in this sector. However, the lack of skilled labor that could deal with the specific necessities of the job-at-hand like installation, maintenance, consultation, repair work etc does at times impede, the brisk pace of the renewables especially in developing countries of South Asia and South East Asia. Questions have also been raised in the past, regarding the need to introduce new specialized programs in Higher Educational Institutes (HEIs) that deals with imparting technical skills required in the 21st century renewable energy sector. The authors on researching found out that in India, out of 54 central universities, about 26 universities offer a specialized course in renewables at the Master's level, whereas the number is comparatively very less at the Bachelor's level. Furthermore, out of 31 National Institute of Technology (NITs) ,23 institutes offer renewable related courses at postgraduate level, but similar to central universities here also, the figure for the under-graduate courses remains comparatively low. Does this hinder, up to an extent the prospects of interested future taskforce of renewables? Could the launch of vocational training course specific to the needs and requirements be introduced? These questions do intrigue a thinking process that could help by creating a future task force in the renewable sector.

Renewable Energy Entrepreneurship is an inclusive domain, with the research being carried out, broadly segmented into two different areas i.e. entrepreneurship and renewable energy. Renewable Energy Entrepreneurship (REE) can be defined as the "starting-up, running and potentially growth of a new business venture that focuses on the development, design, production and distribution of renewable energy as well as renewable energy systems and technologies including all aspects of the renewable energy value chain, comprising of planning, consulting, financing, installation, maintenance and end of life management or disposal" [11]-[12]. The development and execution of technological feasibility along with sustainable business model are critically important from the renewable energy entrepreneur's perspective for the success of any venture. Furthermore, their significance from the investors perspective is no less and it also aids the governments in formulating policies and regulations that helps in supporting new innovations. As a matter of fact, new ventures and start-ups with creative business models are on the rise, with numerous new entrants trying to create an impact. The major funding of the renewable energy sector comes from the private investments, which according to an estimate accounts for more than 80% in the last decade.

Off-grid renewable energy also represents an equally important domain, that presents magnitude of opportunities in terms of new entrepreneurial ventures, that could create interventions which could benefit millions of people who have no access to the grid connected modern energy. Tailored approaches in terms of technology innovative solutions, creative financial and business models, cross sector linkages and capacity building programs have proved to be game changers in numerous circumstances, across the continents of Asia, Africa & South America. Besides,

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the conventional venture and start-ups, social entrepreneurs have also played an important role in reaching out to the underprivileged masses and improving their daily lives by helping to increase the work hours, providing light for children's study and other household chores (especially during evening, after the natural light is no longer present). [13]-[14] The concept of iterative learning and empathizing with the end user are central to many of these initiatives. Moreover, they tend to engage the local rural population by providing them with training and easier payment mechanisms. .Selco Solar in India, Grameen Shakti in Bangladesh, Solar Sister in Tanzania, Sistemas de Technologia Adequada Agroeletro (STA) in Brazil are few examples of social enterprises that has helped millions of rural people who suffer from energy crisis, across the globe.

ANALYSIS OF ENTREPRENEURSHIP IN THE GROWTH OF SOLAR SECTOR IN INDIA

The Indian economy has grown in the last many years and is considered one of the key drivers for the pursuit of renewable energy along with the needs of energy security and reduced carbon footprints. As of 2021, India stands tall among the top five countries of the world having the largest installed capacity of 95.66 G-Watts renewable energy, with Solar and Wind constituting the major stake, as shown in **Figure 2**. The country further intends to reach a target of 40% generation through renewables by the year 2030 to meet it's growing domestic, commercial and industrial demands and has taken a lot of policy measures and regulatory frameworks, both at the Central and State levels to achieve the same. Among the renewable technologies, the solar power has witnessed tremendous growth in the last decade. The Govt. of India launched National Solar Mission, a three phased project in 2010 with the intention to streamline the diffusion of solar energy across India. Various subsidies and incentives were given as a part of the scheme to enhance the adoption of solar based products like solar lanterns solar pumps etc. Among the various objectives outlined to be achieved, focus was also given on promotion and conceptualization of start-ups and entrepreneurship in the solar energy sector by leveraging financial assistance, mentoring and networking to the upcoming entrepreneurs interested in the domain. The state of Telangana, for example established an Incubation center in association with Texas University, United States of America to nurture and support new ventures in the area of solar energy for promoting the cause

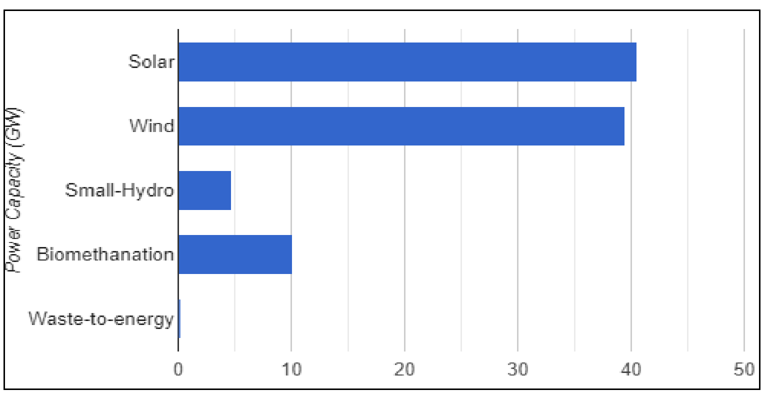

Figure 2 The Installed All India power capacity of renewables

This section of the paper, investigates the pivotal role of entrepreneurship in the growth of the solar energy sector of India. The number of start-ups conceived in the last 10 years, the investments made by private players along with governmental offerings & policy incentives and regulatory frameworks have been chosen as the parameters of assessment. Content based analysis has been used for carrying out this research by studying data in a methodological and organized manner. Important keywords related to the solar energy sector and entrepreneurship were targeted for carrying out this search

Start-Ups & Entrepreneurial Ventures in the Solar Sector of Indian Market

Under the Jawaharlal Nehru National Solar Mission, numerous incentives were taken to promote the spirit of entrepreneurship in the solar energy sector by providing subsidies, rebates and tax benefits to the energy entrepreneurs venturing in the solar sector. Furthermore, the Start-Up India initiative introduced by Govt. of India in

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2015 aimed at promoting innovation and entrepreneurship by handholding, providing funding and simplifying the overall mechanisms, facilitated to the growth of start-ups across industries in multiple sectors including solar renewable energy. The research indicates that in the last five years the number of startups have grown in an exponential manner, with 3678 registered start-ups in the Renewable Energy sector of India till Jan 2021. The distribution of registered start-ups and entrepreneurial ventures, according to the technologies is shown in **Figure 3**. The results indicate that the entrepreneurial ventures in the solar energy sector, far exceed its counterparts. Many of these ventures are in the areas of design, consultancy, distribution, installation and maintenance. **Figure 4**, further illustrates the stages of the solar start-ups /entrepreneurial ventures. The results are encouraging as majority of the start-ups are in validation, early traction and scaling mode, thereby signifying a positive trend in the growth of the renewable solar sector of India. Moreover, Incubators and Accelerators, both governmental and private too play an important role in creating an ecosystem for nurturing of the new companies. As of Jan 2021, there are more 179 incubators and 43 accelerators at Pan-India level that supports the new entrants in Solar energy and creates an ecosystem for nurturing the start-ups in the solar sector.

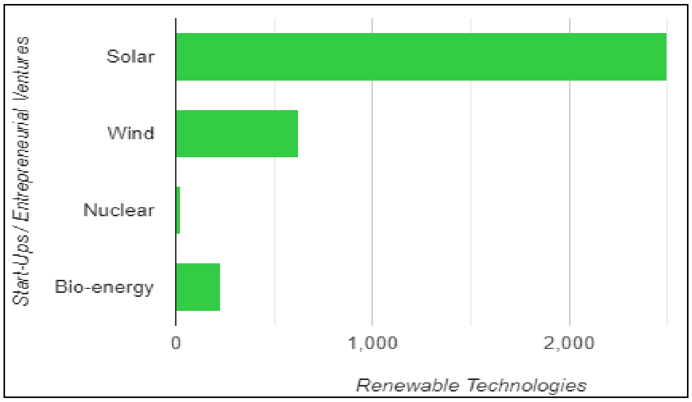

Figure 3 The registered Start-Ups/ Entrepreneurial ventures in the last 10 years in Renewable Energy sector of India

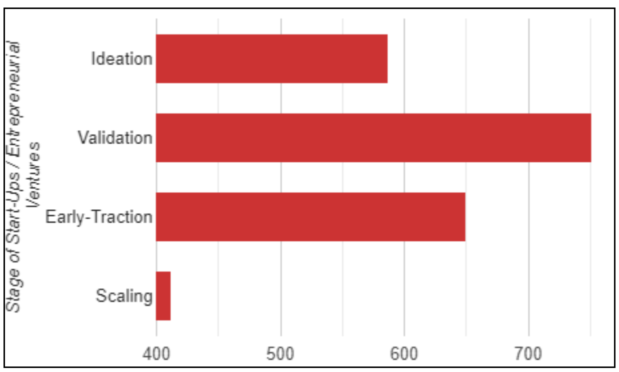

Figure 4 Stages of the start-ups/ Entrepreneurial ventures in the Solar energy sector of India

Investments in the Indian Solar Sector

The investments made by private players (angel investors, venture capitalists, equity firms across Series A, B and C round of funding), government agencies or public-private networks has also been chosen as another parameter of assessment, signifying the important role, investors play in nurturing and growth of any sector of the market. Funding is an essential aspect of the growing business, and is required atdifferent stages for product or process development, R&D, procuring the essentials, obtaining governmental licenses and certifications besides marketing & sales operations. It also helps in improving the operational capacity of the existing systems.

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Furthermore, India has a 100 per cent FDI policy for the renewable energy sector under automatic route, thereby making the Indian market an attractive proposition for both national and international investors. The key findings illustrate that in the last seven years since 2014, 69 Billion $ have been invested in the Indian renewable market, with more than 55 percent of these investments being made in the solar energy sector. In-fact the net investment in the last one-year financial time frame i.e. 2020-21 exceeds 10 Billion $. The key research however suggest that the country further requires an investment of 500 Billion $ by year 2030, to reach its capacity target. Recently in June 2021, Reliance Industries, an incumbent and a major player of the fossil fuel industry, pledged 10 Billion $ over the next three years for manufacturing and generation of green energy, with solar energy being one of the prime areas of focus as it intends to achieve a production of 100 G-Watt in the next 10 years.

Policy Incentives & Regulatory Frameworks

Inadequate policy support by the government or policymakers has been cited as one of the major constraints that hinders the diffusion of renewable energy at a decent pace in developing countries. It's of immense importance to create a positive outlook among incumbents and new entrants by creating, designing and implementing policy incentives and regulatory frameworks that brings an optimistic attitude as a general sentiment. The policymakers and the Govt. of India have taken a lot of initiatives under various schemes of different ministries and departments to promote the cause of clean and green energy, to limit the bureaucratic disruptions and to promote the spirit of entrepreneurship and start-ups in the solar energy sector. Some of the latest initiatives, by the government and highlighted as a part of this study are as follows:

1. Though the "Make in India" initiative, the Central Govt. intends to promote the manufacturing and production process in the renewable solar sector like for example Solar PV's, solar charging infrastructures, batteries etc. The scheme, besides reducing the dependability on other countries for procuring the raw materials and equipment's is also expected to provide a boost to the solar industry of the country by promoting innovation and entrepreneurship at both the local and national level. It could further help the economy of the country, with the increased exports as there's always a possibility of becoming a major production hub.

2. Production linked incentives (PLI) scheme "National program on High Efficiency on Solar PV Modules" endorsed by Ministry of New and Renewable Energy (MNRE) has recently been approved in November 2020. An estimated 4500 Crores has been allocated for the next 5 years, specifically to upgrade the production capability of High efficiency solar PV modules. The scheme also promotes entrepreneurship at both manufacturing and integration capacity, as both new entrants and incumbents are eligible for the bidding process.

3. Approved List of Models and Manufacturers i.e. ALMM of Solar photovoltaic modules is yet another initiative by the Ministry of New and Renewable Energy (MNRE) to safeguard long term energy interests of the country, by assuring that the quality and reliability of the solar PV modules and cells used is in accordance to the BIS compliances. The scheme was launched in January 2019 and gives boost to local and national entrepreneurial efforts in regards to the manufacturing of the components at the domestic level.

4. Indian Renewable Dashboard, launched in April 2021 is a joint initiative by Central Electricity Authority (CEA) and CEEW's Centre for Energy Finance, to provide a single platform for providing information regarding the upcoming and ongoing renewable energy projects in the country.

However, in-spite of the aforementioned there are still issues to be tackled and challenges to be faced, in order to achieve the goals of energy security and sustainability. Infrastructure related issues in the remote parts of the country, the shortage of the skilled technical manpower and hindrances in obtaining the finance in a systematic and synchronized manner are those matters which needs to be looked into for further strengthening the roots of entrepreneurship in the solar sector.

CONCLUSION

In this working paper, the pivotal role of entrepreneurship in the growing solar energy sector of India is presented. The number of start-ups or entrepreneurial ventures conceived, investments made by private-public institutions and

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favorable policy incentives by the government have been chosen as the parameters of assessment. The renewable energy sector, in general offers ample opportunities of employment as well. The sector in the last five years has created 0.8 million full time jobs at different designation, based on the possessed skillset. The basic aim of providing clean and green energy to everyone, along with the motivations to reduce the carbon footprints does gain momentum with the enhanced coverage of renewable technology, for which the new entrants, start-ups and entrepreneurial ventures do play a critical and quintessential role.

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Electronics and Telecommunication Engineering

On Some Findings on Micro-strip Patch Antenna for Biomedical Applications

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Abstract: *The author aims to find the possibilities of using Micro-strip Patch antenna in the fields of Bio-Medical applications. Due to the advancements in the medical technologies the requirements of miniaturized and compact devices has been increasing which leads to the technological developments in this area. The work is dedicated for finding the gateway of antenna technology in this field. The simulations are carried over by the HFSS software.*

Keywords: *Micro-strip; Bio-medical; Radiation Pattern*

INTRODUCTION

The microwave/ millimeter wave [5,6] signal generation, detection and radiation by the antenna has become an interesting application area. The applications include the spectroscopy, secure communication, bio-medical engineering, wireless communication etc. As it is known that the silicon technology offers its applications in the high-density signal processing with its scaling capacity consisting of the diverse size variations. The recent developments are finding way to the silicon-on chip products worldwide. Due to the increase in high level of integration the size reduction become noticeable.

A. Micro-strip Patch Antenna

The micro-strip patch antenna is having a lot of applications in the field of transmission, detection/sensing and radiation with its wide variety of usage as per the selection of frequency [7]. The author here tries to find the application in the field of bi-medical engineering. The simulated results also confirm the capability of the proposed antenna in the mentioned field [8].

B. Proximity Coupled Feeding

The Micro-strip patch antenna may contain different type of feeding by which the excitation is applied to the antenna. The author has taken the Proximity coupling method for the feeding to the antenna. The **Figure 1** here represents a proximity coupling technique.

RESULTS

The simulation has been carried out in HFSS software and the following results have been noted. The **Figure 2** shows the simulated antenna in the software.

The S11 plot is shown in the **Figure 3** where the results show a considerable response of the antenna for the Bio-medical applications. The radiation pattern is shown in the **Figure 4** where the results also show the response to be taken for the Bio-medical applications.

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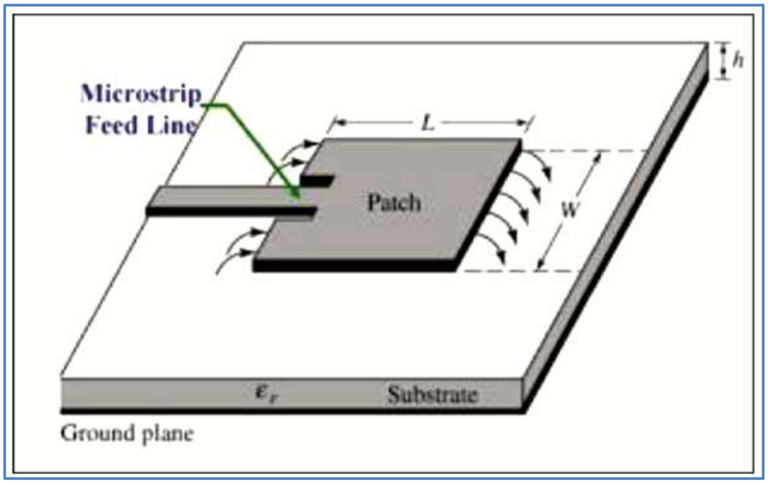

Figure 1 Proximity coupling technique in Micro-strip patch antenna

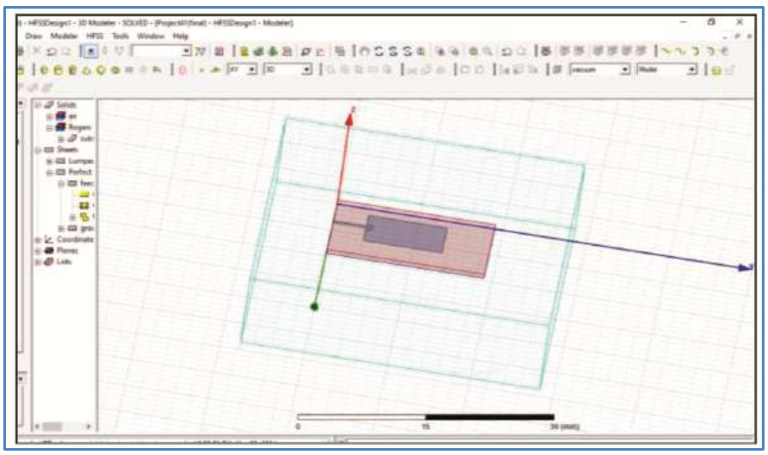

Figure 2 Simulated antenna in HFSS software

Figure 3 S11 plot

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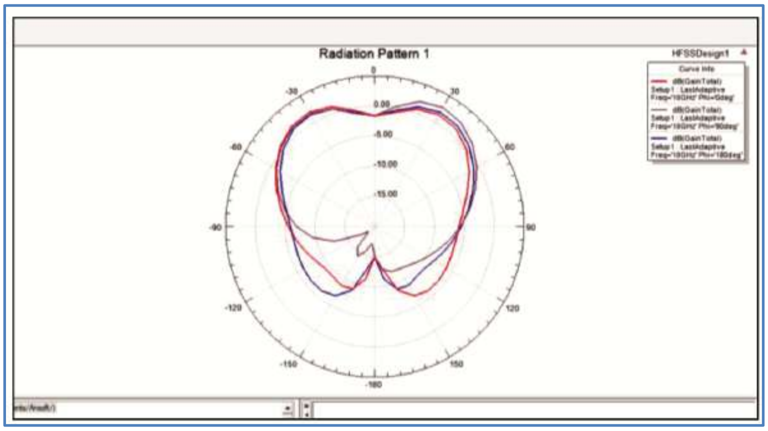

Figure 4 Radiation Pattern of the simulated antenna

CONCLUSION

The simulated results show that the proposed antenna can be considered for Bio-medical applications. The frequency response, radiation pattern is compatible with the Bio-medical environments.

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Integrated Maritime Domain Information Awareness

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Abstract*: The centralized maritime domain awareness information system is the most important and effective factor to the country covered by the sea. This paper presents detailed information on the implemented Automatic Identification System (AIS) network is used to collect the data using the central point as well as the selected 13 points in the whole over the country. Further, using this system collecting the ships and crafts plying the waters around the island can be viewed through a single interface. There are 14 outputs of the AIS system and can grab all details from 13 points to the central point. The implemented system is low cost and reduces the complexity of collecting information at a central point. The implemented system is more beneficial to the naval parties and the port authority.*

Keywords*: Automatic Identification System; Integrated Maritime Domain System (IMDS); Serial to Ethernet Converter*

INTRODUCTION

Sri Lanka is called the pearl of the Indian ocean and it is covered by Indian seawater. Due to the geographical situation of the country, the centralized maritime information system is more important to the day to day life. Further, the maritime information system is useful to harbour needs, fisheries as well as security departments in Sri Lanka. The AIS provides the navigational data of the ships and seaboard. Also, location details, identification details were received from AIS [1].

Using a Wide Area Aerial Surveillance (WAAS) system facilitate awareness of the large area of the sea with high-resolution images [2]. The system of e-navigation contributes to the planning and implementation of integrated information to distribute the static and dynamic information to the vessels [3]. The traffic system was implemented to the aware traffic information for the sea travellers. Moreover, it gives the information of the whole journey of the travellers [4]. The human resource for maritime activities creates many difficulties in the day to day life. Therefore, introduced An integrated maritime reasoning and monitoring system for maritime shipping and port activities [5].

The Integrated Maritime System (IMS) is a chart plotting software, was designed by the new design cell for visualizing the vessels sailing around the island which was gathered by the 13 automatic identification system stations. All Ships and crafts must transmit their ship details through the AIS system and the receiving station can receive the ship details using their receiver. The 13 numbers receiving stations are established for the IMDS around Sri Lanka. The proposed system consists of 4 stages such as IMS, serial to Internet Protocol (IP) converter, network and integrated software interface.

The remainder of the paper is organized as follows: In section A, include the system model with AIS, serial to parallel converter, integrated software interface and the configurations. In section B, includes results and discussion. Finally, Section C concludes the whole paperwork.

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System Model

The AIS system has been used the track the vessels and it is an automated system. Further, it is operating in the Very High Frequency (VHF) mobile maritime band. Moreover, it is connecting with the ships and able to identify using navigational marks.

Figure 1 shows the proposed overall system model of the integrated maritime awareness system.

Figure 1 Proposed system model

AIS

The AIS system has two types of classes as class A and class B. Class A contains passenger ships and all vessels 300 GT on international voyages. There are limited functional in class B and non-SOLAS vessel are class B. The 161.975 MHz 161.975 MHz VHF frequency is used for simplex ship to ship communication and the 162.025 MHz frequency is used for duplex ship to shore communication. Also, it is used Self-organizing Time Division Multiple Access (STDMA) technology and it has 40 miles line of sight limitation. AIS is transmitting static information, dynamic information and voyage related information. Static details are MMSI number, IMO number, name and call sign, length and beam, type of ship, location of position fixing antenna. Dynamic details are ship's position with accuracy indication, position timestamp (in UTC), Course Over Ground (COG). Voyage related details are ship's draught, type of cargo, destination and ETA, route plan (waypoints).

Figure 2 shows the proposed locations of the AIS network in Sri Lanka.

AIS Data Format

Transmitter transmit the information in RS232 format in NMEA standard. The sample data format is as follows.

!AIVDM,2,1,3,B,55P5TL01VIaAL@7WKO@mBplU@<PDhh000000001S;AJ::4A80?4i@E53,0*3E

!AIVDM,2,2,3,B,1@0000000000000,2*55

Figure 3 shows the AIS data in the software interface and it is in NMEA standard.

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Figure 2 Proposed AIS network locations.

Figure 3 AIS data in the software interface.

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Serial to IP Converter

The remote access, control and manage serial devices using serial to IP converter through IP network and internet. The asynchronous data transfer over an RS232, RS422, or RS485 port to TCP/IP or UDP packets. Further, it is connected with a direct cable connection or over Ethernet.

There are 3 types of Serial to IP converters that have been used for this system.

1. PortServer® TS by DIGI
2. USR-TCP232-302
3. Hi-Link USR-TCP232-30

Configuration of Serial to IP Converter

There is the same configuration procedure that will be followed for the above three types of converters.

1. First, the device must be powered with the help of a designated power supply.
2. The data output of the AIS unit has to be connected to the serial data input of the converter unit.
3. Ethernet cable has to be connected to the ethernet port of the converter and the PC.
4. Each device has its default IP address and it can be found by referring user manual of each device.
5. IP address, subnet mask and the gateway address of the PC must be changed according to the default IP range of the converter unit.
6. After configuration, log in to the web interface of the converter using a web browser by entering the user name and the password of the converter unit.
7. In the web interface, several sub-pages can be adjusted according to our device.
8. Most AIS transponder’s output their data at a 38400 bps baud rate. Therefore, the serial configuration has to be changed (baud rate, number of bits, start bits, stop bits, parity bits) according to the AIS unit.
9. The port settings have to be changed according to the cloud network. IP addresses of the converter have to be assigned according to the Network.
10. After finished configuration, the network cable can be plugged into the network switch

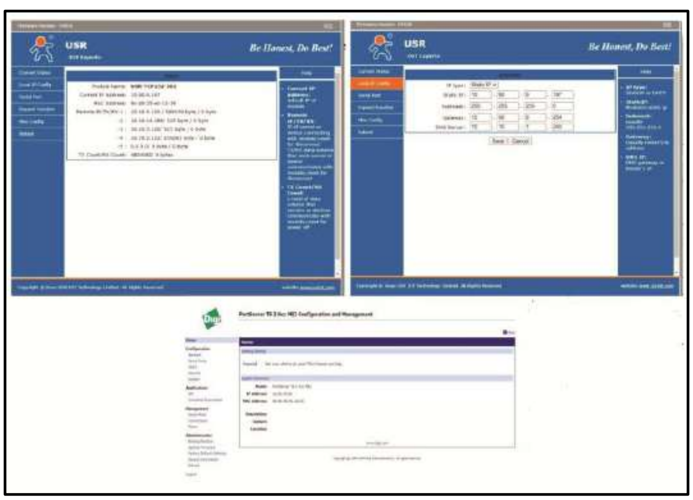

Figure 3 Details of computer interfaces.

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Table 1 shows the 13 AIS locations of the network with the IP address and port details.

Table 1 Network details of the AIS locations

S.No.	Station	IP Address	Port
01	Station A	192.168.1.1	2001
02	Station B	192.168.1.2	2001
03	Station C	192.168.1.3	2001
04	Station D	192.168.1.4	2002
05	Station E	192.168.1.5	2002
06	Station F	192.168.1.6	2002
07	Station G	192.168.1.7	10001
08	Station H	192.168.1.8	10001
09	Station I	192.168.1.9	10003
10	Station J	192.168.1.10	8080
11	Station K	192.168.1.11	8080
12	Station L	192.168.1.12	2001
13	Station M	192.168.1.13	2002

Integrated Software Interface

A concise chart plotter software called “Integrated Maritime Surveillance System” is used to decode the AIS data and visualize it on a single interface. This software was designed using free open-source software called “OPEN CPN”.

This software was written by C/C++ programming languages.

Software Configuration

The software has to be configured before use,

1. A suitable chart has to be added to the software interface using add chart menu.
2. Network settings (IP address and Port) has to be entered using add connection menu.
3. Display settings have to be changed according to the user requirements.
4. After configuration vessels begin to appear on the display.
5. Clicking on the vessel icon will allow viewing the vessel data.

Figure 4 Adding the interface.

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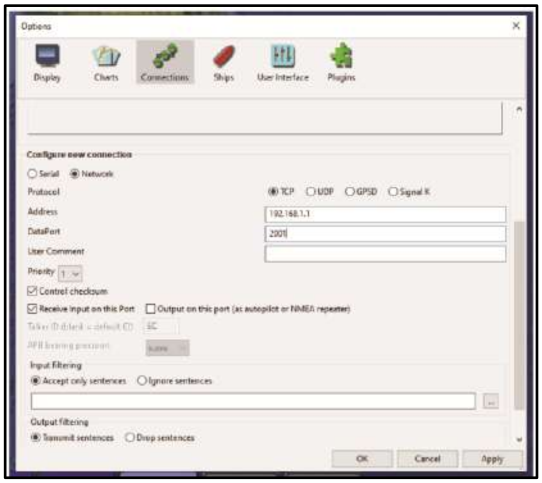

Figure 5 Adding new connection.

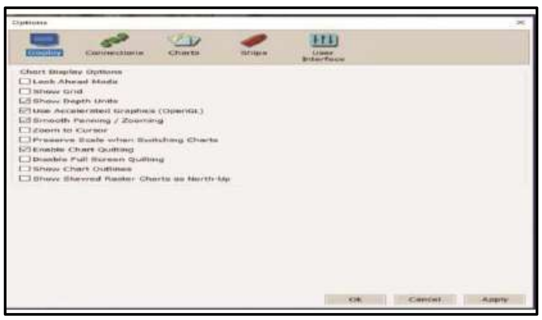

Figure 6 Display options.

RESULTS AND DISCUSSION

There are 3 inputs for the software interfaces such as chart, IP addresses of the converters and ports of the converters. Also, there are 14 outputs such as MMSI number, Call Sign, IMO number, class, navigational status, type of the vessel, size, destination, estimate time to arrive, course, speed, heading, rate of turn, range and bearing to receiving station and position data.

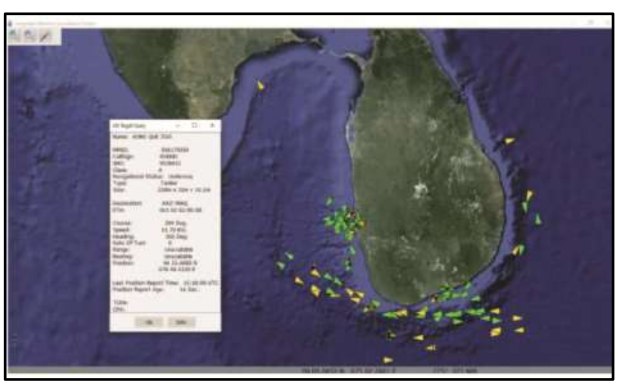

Figure 7 Vessel details

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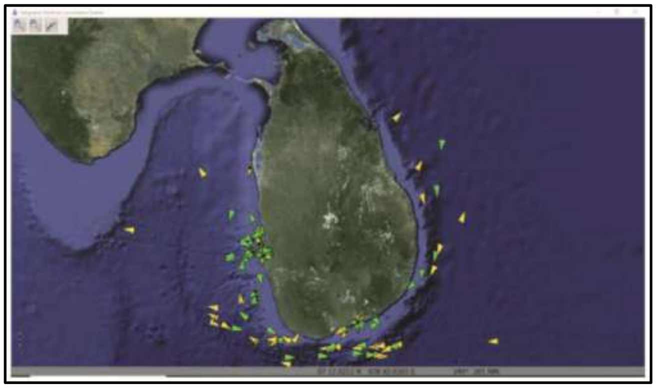

Figure 8 Software interface after adding all AIS stations

CONCLUSION

The integrated maritime domain information awareness system is more advantages in many ways. All the AIS stations around the island are networked so that the details of all ships and crafts plying the waters around the island can be viewed through a single interface. Ability to view a wide range of data as all systems are networked. Ability to easily trace the location of the vessel as it maps the current location. Ability to easily analyze the data of the vessel by viewing the data of the vessel on a screen at the same time. Vessels that are capable of being captured by the AIS system are divided into different categories, with the ability to easily observe vessels belonging to these categories by representing those vessels in different colours and icons. One system failure is covered by another nearby system so that the failure of one AIS doesn't affect the entire system.

Serial to IP Converters can now be purchased at a relatively low price in the market, making it possible to make new connections at a very low cost. Increase the ability to expand the network as the number of systems that can be included is unlimited. There are a few limitations of the system such as Since the system performance depends on the performance and the speed of the network, a system failure can occur during a network crash. Problems with data storage due to unavailability of centralized sever system. Inability to analyze past data due to inability to record. Due to the shortage of serial to IP converters in the local market, it takes a long time to repair a breakdown. Some Serial to IP converters has limited access to the number of users that can be accessed, reducing the ability to monitor from a large number of monitoring stations.

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Point-of-care Diagnostic Device in Healthcare: A Literature Review

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Abstract: *Point-of-care (POC) device is an in-vitro diagnostic device utilized by medical professionals near patients, bedside or extra laboratory testing to obtain results quickly and simply and improve the patient care. POC device alert only the crucial data to clinicians or medical professionals. In addition to patient health monitoring, POC devices can be used for cancer, diabetes, and cardiovascular diseases diagnosis (rule-in or rule-out) and management especially in emergency departments, physician office, paramedicine, and mobile units. This review aims to illustrates the use of POC devices for diabetes and cardiovascular management.*

Keywords: *Point-of-care; In-vitro Diagnostic; Cancer; Diabetes; Cardiovascular Disease; Emergency*.

INTRODUCTION

Health care is the organized provision of diagnose, treatment, prevention and management of diseases or illness and improve the quality of patient. Fast evolving healthcare industry has led to numerous innovations in diagnostic devices to treat patients quickly and accurately to assess and treat more patients in emergency, primary care. Health care is becoming transformative in identifying the onset of disease at an early stage and in some cases health care prevents even before the onset of diseases. One of the best ways to achieve is patient centered and near patient testing for faster triaging and treatment. The Point-of-care (POC) devices also known as near- patient testing typically placed near the patient or bedside and obtain quicker results. As the need for faster test results growing, diagnostic devices like easy to use, portable, miniaturized devices have evolved.

A. Applications of POC

1) Diabetes Management

Diabetes is a highly prevalent diseases in development of several other diseases are cardiovascular or renal disease. Based on International Diabetes Federation (IDF) Diabetes Atlas, in 2030 diabetes incidence is projected to increase to 552 million [35]. In emergency clinics, hypoglycemia and hyperglycemia are related with higher death and length of stay. Hence, bed-side glucose monitoring with rapid, accurate and high turnaround time (TAT) was in demand. However, central laboratory testing (CLT) is the reference testing of plasma glucose. Various lab tests are prescribed in the detection of patients with diabetes. The initial stated use of POC is observed in early documents from 1550 B.C, in which physicians used ants to measure sugar in the blood [39]. After enormous research, the breakthrough came in 1965 by an Ernie Adams tram develop primary stick, a Dextrostix, stick that used oxidoreductase enzymes. Further followed by advancement in quantitative blood glucose result by Ames team and developed Ames Reflectance meter in 1970 [38].

Immediate results obtained from POC device are crucial in reducing the diagnosis time and initiate the treatment for patients. Some of the POC devices available in the market are tabulated below (Table I).

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Table 1 POC devices in Diabetes Management

POC Device	Company	Purpose
Accu-Chek Aviva Plus	Roche	Glucose meter
Accu-Chek Nano	Roche	Glucose Meter
ReliOn Prime	ReliOn	Glucose meter
OneTouch VerioIQ	LifeScan	Glucose Meter
Nova Max	Nova	Glucose meter
FreeStyle Lite	Abbott	Glucose meter
Afinion HbA1C Dx Assay	Abbott	HbA1C testing
HemoCue HbA1c 501 system	HemoCue	HbA1C testing

2) Cardiovascular Diseases

Cardiovascular diseases are one of the life-threatening and early diagnosing is first and foremost. Cardiac Markers can be effectively used not only for the treatment of cardiovascular diseases but also early diagnosis.

a) History of Cardiac Markers

Ladue et al (1954) proposed the first cardiac biomarker aspartate aminotransferase (AST) released from cardiac muscle cells experiencing cell death would be beneficial in identifying severe myocardial infarction (MI) using paper-based chromatography [4]. At present, AST has been ruled-out due to lack of specificity for diagnosing AMI. AST levels elevate in hepatic disease, pulmonary embolism. Wroblewski and Ladue found a change in lactate dehydrogenase (LDH) activity in AMI patients. But Ulmer et al. corroborated this finding. Schmiechen et al (1997) proposed another crucial biomarker lactate dehydrogenase (LDH) for detecting myocardial ischemia. LDH peaksin 6 to 12 hours after an AMI [6]. It is also specific for non-cardiac diseases like erythrocyte haemolysis and testicular germ cell tumour markers.

Dreyfus et al (1960) proved creatine kinase (CK) activity in the detection of myocardial infarction. Although various studies and experiments observed higher sensitivity of CK during diagnosis of AMI, it highly lacks its specificity as a biomarker [7]. Wroblewski proposed that the measurement of specific isoenzymes (CK-MB) provide a reliable result and increase the specificity of cardiac enzyme biomarkers [8]. Gilkeson et al (1978) developed the earlier method to detect serum myoglobin using radioimmunoassay (RIA) but late discontinued for STAT analysis due to time consuming process [10].

In 1985, mass assays to estimate the protein concentration for CK-MB were developed by Chan et al. [11]. Later in 1986, Vaidya et al, created the first monoclonal antibody to CK-MBand at present all automated immunoassay instrumentation are used [13]. In 1963, after several studies Professor Setsuro Ebashi proved that a new troponin compound is responsible for the muscle regulation [14].Various studies showed the two mutated human cardiac troponin (cTn) components, cTnI and cTnT are the main cause of cardiomyopathies. In 1987, Cummins established the effective primary RIA for the measurements of cTnI in serum [15]. Over the past 30 years, several research groups continuously optimizing cTnI immunoassay and have analytical sensitivity is almost 100-folder higher than experimental assays that were initially described.

In 1989, Katus et al developed the first-generation immunoassay based on enzyme linked immunosorbent assay (ELISA) with two antibodies [16]. Cross reactivity was the major problem and resulted in the introduction of second-generation assay in 1997. In 1999, the linearity is improvised in third-generation troponin T assay. In 2007, the fourth-generation assay using fragment antigen-binding (FAB) of two cTnT antibodies is developed. The new high-sensitivity cTn assay is the improvised fourth-generation assay with the sample amountupto 50 µL and buffer optimization through background noise cancellation.

Heart-type fatty acid binding protein (H-FABP), a responsive cardiac biosignature was discovered in 1988 byProfessor Jan Glatz for the detection of myocardial within one to three hours of pain. Vupputuri et al (2015) and other research groups studied and evaluated in accordance with which heart type protein could remain used whilst early diagnostic quantitative marker in heart attack patients [17]. The simultaneous measurement of cTnI and C-reactive protein (CRP) was achieved by developing an electrochemical immunoassay by Zhou et al (2010) based on microfluidic chips [18] and the carbon fibre electrode was surface modified to increase the assay performance.

Lee et al (2012) developed a polyaniline (PANI) nanowire biosensor with greater biosensing ability, good biocompatibility to monoclonal antibodies by integrating with microfluidic microchannels for the detection of myoglobin (Myo),CK-MB, cTnI, and b-type natriuretic peptide (BNP) [20]. Philips Minicare I-20 point-of-care (POC) system could care by testingin the patient vicinity for people enduring chest pain when they turn up at the hospital or health care. Minicare work through blending ofnovel materials in the blood sample, and the sensor can perceive and compute the amount of a given cTnI biomarker [21]. The biggest challenge in POC is doctor's confidence level and reliability.

Jasper et al, studied the clinical execution of high-sensitive cardiac troponin I assay in POC device in people with myocardial infarction and compared with central laboratory assays and resulted high diagnostic accuracy in early detection. Though the higher efficiency of the POC-hs-cTnI resulted direct triage toward rule-out or rule-in without the need of serial sampling, there has been lack inoverall performance of central laboratory testing i.e.., higher number of analytically false-positive results. Table II list the currently available POC devices.

DISCUSSION

Throughout the course of this review, it has been very evident that research and vast advancement of diagnostic technology and delivery of health care services has resulted in an increase in the demand of POC devices especially in primary care, emergency care and urban health centers. With recent advancement, POC can lead to increased and improved patient outcomes. But it can replace the conventional laboratory testing if the result is accurate and authenticate. But that not true. The POC devices can act as better substitution in diagnosing. The major advantages or purpose of using POC are reduced time to obtain results of diagnostic testing, decline in pre and post analytical mistakes such as mishandling/ mislabeling of patient specimen, delayed reporting of critical results, clinicians' convenience, lessen the patient visiting time and finally the best patient outcome. The major drawback of POC devices is diagnostic accuracy in terms sensitivity and specificity due to low concentration sample. Human errors are also included due to sampling inaccuracy, lack of knowledge. A device with quick, accurate, authenticate, user friendly, small, easy-to-use, pre-analytical error proof should be designed for wide implementation in all the health centers and reduce the overall cost of the diagnostic devices.

Table 2 POC devices for detecting cardiac markers

Manufacturer & Device	Device Type	Cardiac Biomarkers
Alere, Triage Cardiac Panel	Portable type	CK-MB, Myoglobin, Troponin I
Abbott, i-STAT	Handheld device	cTnI, CK-MB, BNP
Trinity, Meritas	Portable	hs-cTnI
Response Biomedical, RAMP	Benchtop analyser	D-Dimer, NT-proBNP, Troponin I, Myo, CK-MB
Siemens Stratus, CS	Benchtop analyzer	Troponin I, D-Dimer, NT-proBNP, hsCRP, beta-HCG, CK-MB, Myo
bioMerieux, Vidas Ultra	Benchtop analyzer	hs-cTnI, CK-MB, Myo
Roche, Cardiac T Quantitative	Handheld device	cTnT
Cobas h 232 POC system	Handheld device	Troponin T, NT-proBNP, D-Dimer, CK-MB
Minicare I-20	Handheld device	cTnI

CONCLUSION

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Diabetes Mellitus and cardiovascular diseases were one of the major contributing sectors for the research and growth of POC diagnostic devices. Over population and under-staff in the emergency department is a serious barrier to provide the best health service. The POC devices reduce the pressure or crowd on emergency departments, faster triaging and better rule-in/ rule-out decision making and fulfill the healthcare development goals of 'no one left behind' in terms of effective health services, efficient health systems, better patient outcome and faster discharging rates. Testing near the patient bed-side, has grown drastically. POC have been more efficient and effective for early detection and treatment, and faster field triage. Successful innovation and development of new devices which makes POC as near-future.

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Radar Cross Section Estimation for a Complex Shaped Objects using SPSG and PO Methods

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Abstract: *Radar plays a crucial role in the present war scenario and defence applications. RCS is an important parameter that defines the target cross sectional area. The higher the RCS value, the greater the target detection capability of the Radar. RCS estimation mainly depends on the size, shape, orientation of the object towards the Radar, and also the material of which the object is made. Among these, the size, shape, and orientation of the object are considered to be the most significant features in RCS estimation process. RCS determination is an important task for identifying or classifying the objects as either friend or foe. Accurate estimation of Radar Cross Section (RCS) at high frequencies and reduction of radar perceivability at different frequencies is a challenging task. An efficient algorithm is required that can run on a standard PC which provides RCS predictions within a short time. In this paper, Spherical Polar Scattering Geometry (SPSG) and Physical Optics (PO) based algorithms are proposed to estimate RCS of complex structured objects.*

Keywords: *Radar Cross Section (RCS); Spherical Polar Scattering Geometry (SPSG); Physical Optics (PO); Frequency; Dimension; Wavelength*

INTRODUCTION

The Radar Cross Section of an object accepts a fundamental part in disclosure by radar. Redesign or decreasing of RCS of object which is being recognized by radar needs control dependent upon the applications. A thorough perception of the electromagnetic scattering characteristics of an object is essential for productive execution of needed control of its RCS. In military applications, decrease the RCS of air targets like rockets, flying machines, and spy satellites. Correspondingly, ground vehicles and rocket launchers ought to be arranged with the objective that they have least RCS. For testing of radars and searchers, counterfeit targets are required. These fake targets are to be expected for required RCS and sometimes, redesign the RCS to meet the range and testing conditions. [1-5].

A. RCS CONTROL

RCS Increase: A few applications require improvement of the RCS. Getting ready planes require persevering after and along these lines for dependable following their RCS is extended. Fabricated airborne objects are used for rocket execution evaluation and these targets are followed by radars. The RCS of these airborne targets is improved. Customary practice is to use Luneburg focal points, corner reflectors and moreover transponders with enhancers. It depends on the application.

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RCS Decrease: Diminishing the RCS of a ship proposes its late recognizable proof, which is basic to surprise and movement. The RCS of an oceanic boat is moreover essential since most present day weapons have presented radar for use in the midst of the last commitment stage. This is by virtue of a ship with a lower RCS would be recognized later, just as would endure better in a hostile area. As such, the RCS of an oceanic boat has changed into a basic arrangement factor for secrecy to achieve awe, movement, and survivability. Accordingly, accurate RCS affirmation and RCS decreasing are matters of phenomenal importance for oceanic boats [6-9].

RCS reduction strategies incorporate passive cancellation or impedance loading, active cancellation or active loading, radar absorbing materials (RAMs), and shaping. Shaping and radar absorbing materials are the two essentially utilized RCS diminishment strategies on maritime ships

B. RCS EVALUATION

The performance of the objects is evaluated using RCS prediction methodologies and RCS full scale measurements. Standard spheres that undergo calibration test with the dimensions 3”, 7” and 11” radius the RCS obtained are -17.44 dBsm, -10 dBsm and 6.10 dBsm considered for comparison. From **Figure 1** it is observed that RCS can be evaluated using techniques like full scale measurements, scaled model measurements, RCS theoretical prediction software tools [10-15].

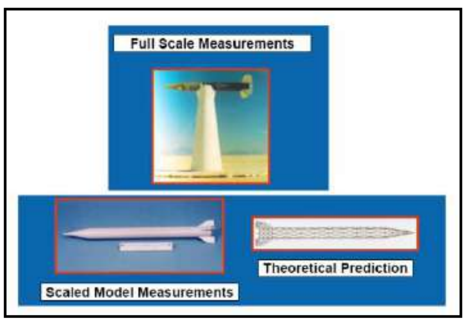

Figure 1 Techniques to RCS analysis and evaluation

RCS Simulation of Sphere:

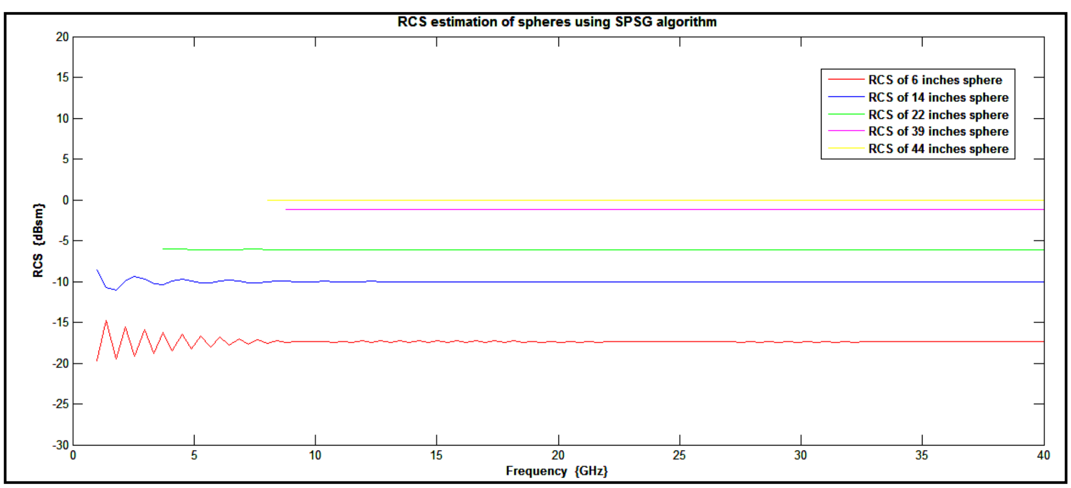

Figure 2 RCS (dBsm) vs. frequency (GHz) for diameters of sphere

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From **Figure 2** it is observed that the spheres with standard diameters are considered for RCS estimation with respect to frequency varying in the range of 1 to 40 GHz using SPSG algorithm. Standard spheres with diameters of 6", 14", 22", 39" and 44" are considered for estimation using SPSG.

RCS Simulation of Cylinder, Frustum and Cone:

RCS of Cylinder model with variation in dimensions of radius and height are considered for frequencies from 1 GHz to 40 GHz using PO method is shown in **Figure 3.**

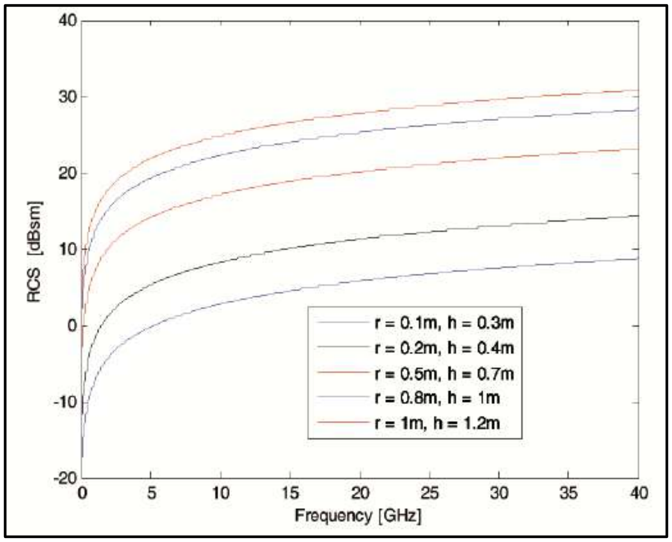

Figure 3 RCS variation with frequency at different dimensions of cylinder

RCS of Frustum model with variation in dimensions of radius and height are considered for frequencies from 1 GHz to 40 GHz using PO method is shown in **Figure 4**.

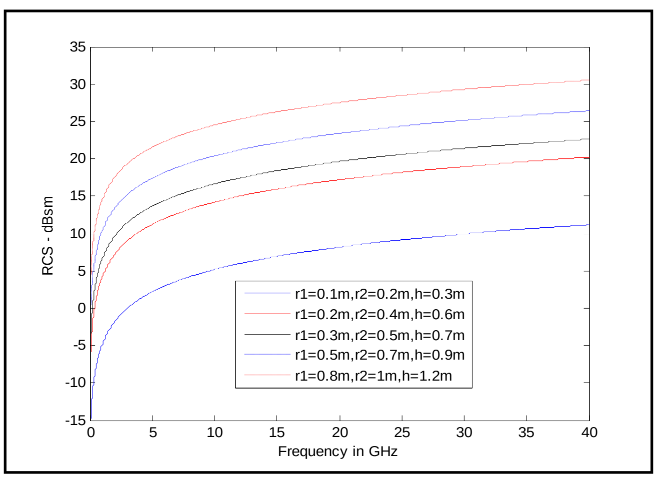

Figure 4 RCS variation with frequency at different dimensions of frustum

RCS of Cone model with variation in dimensions of radius and height are considered for frequencies from 1 GHz to 40 GHz using PO method is shown in **Figure 5.**

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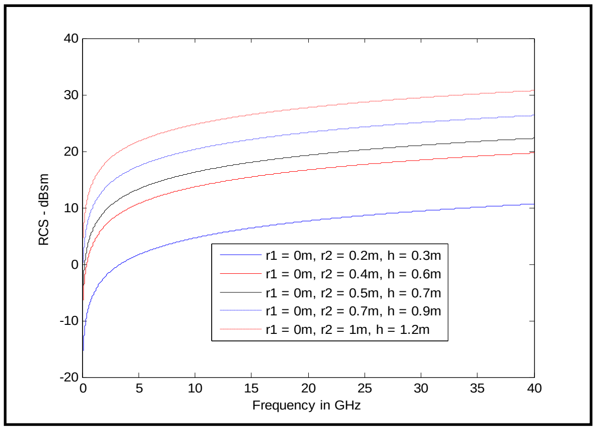

Figure 5 RCS variation with frequency at different dimensions of cone

RCS of Cylinder model with radius and height dimensions are considered for aspect variation 0 to 180 degrees using PO method is shown in **Figure 6**. Peak RCS occurs at 90 degrees.

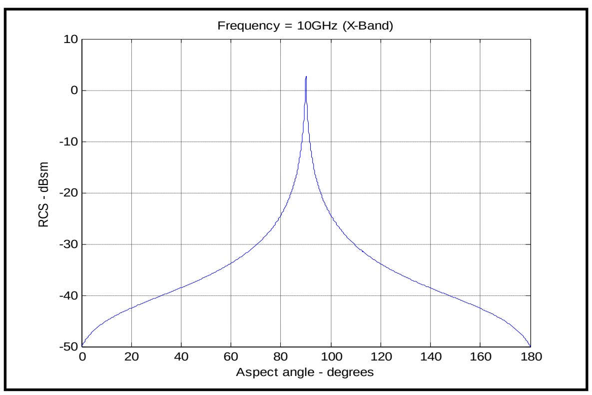

Figure 6 RCS variation with aspect angle at r = 0.1m, h = 0.3m

RCS of Frustum model with radius and height dimensions are considered for aspect variation 0 to 180 degrees using PO method is shown in **Figure 7**. Peak RCS occurs at 90 + α degrees.

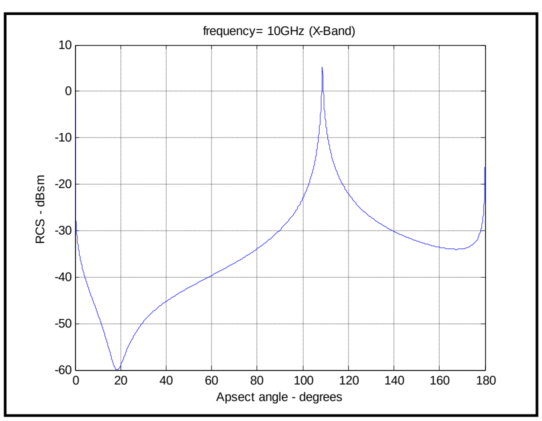

Figure 7 RCS with aspect angle at r1 = 0.1m, r2 = 0.2m, h = 0.3m

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RCS of Sphere model with different dimensions of radius are considered for frequencies ranging from 1 GHz to 40 GHz covering all frequency bands (L, S, C, X, Ku, K, Ka) are shown in **Figure 8**.

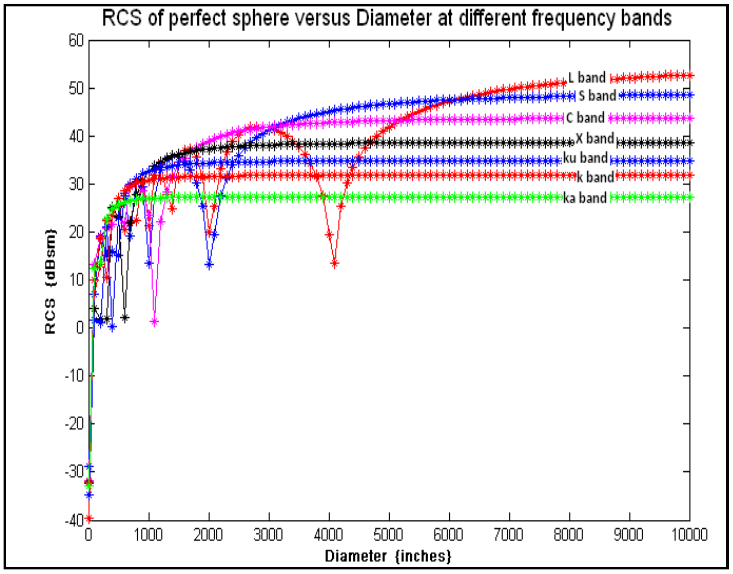

Figure 8 RCS of Sphere with different dimensions

RCS Simulation of Sphere without Dent (Simple Object):

Perfect sphere when manufactured and when it's RCS is measured it may slightly differ due to manufacture fault. Here, RCS analysis has been carried out for sphere without dent [2] using SPSG based algorithm. A solid perfectly conducting sphere with radius 'r' is shown in the **Figure 9** has been considered for RCS analysis sphere radius 7 inches. **Figure 10** shows polar plot for RCS of sphere without dent. It is observed that RCS of sphere remains constant around -10 dBsm over entire aspect range of 0º to 360º. Equation (1) is radar cross section 'σ' of sphere with sphere radius 'a' using Kerrs relation as [1-7],

$$\frac{\sigma}{\pi a^2} = \frac{1}{\rho^2}\left|\sum_{n=1}^{\infty}(-1)^n(2n+1)(a_n^s - b_n^s)\right|^2 \tag{1}$$

Where $\rho = 2\pi a/\lambda$, λ is the wavelength, and a_n^s and b_n^s are terms of a "multi-pole expansion". These terms are proportional to the amplitudes of magnetic and electric multi-poles induced in the sphere by the incident wave.

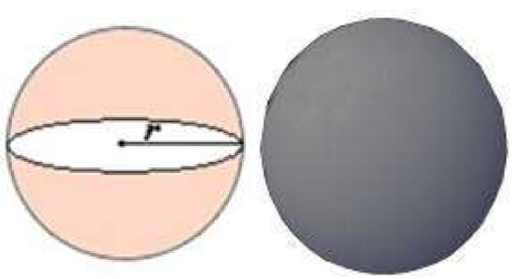

Figure 9 Sphere without dent

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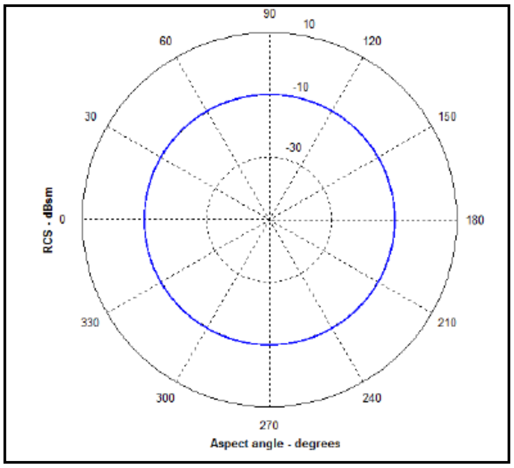

Figure 10 Polar plot for RCS of Sphere without dent

RCS Simulation of Sphere with Dent (Complex Object)

No sphere is perfect sphere when manufactured and when it's RCS is measured it may slightly differ due to manufacture fault. Here, error analysis has been carried out for RCS of sphere with dent [2]. RCS analysis is carried out for a sphere with hemispherical dent using modified SPSG. A solid perfectly conducting sphere with radius 'r' with a hemispherical dent radius 'p' is shown in **Figure 11** has been considered for RCS analysis with sphere radius 7 inches and dent radius 1 inch. Taking dent location on sphere at 60º in azimuthal considering elevation fixed [16].

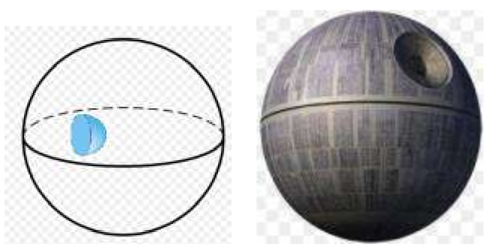

Figure 11 Sphere with dent

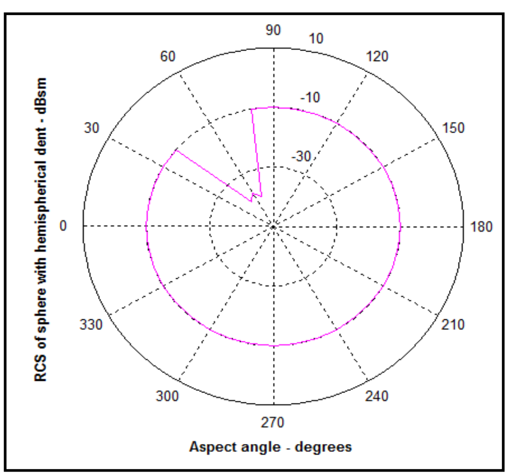

Figure 12 Polar plot for RCS of Sphere with dent

It is observed from **Figure 12** that dent RCS is around -38 decibels in squaremeter or dBsm at 60º whereas RCS of sphere is around -10 dBsm in remaining aspects of 0º to 360º.

Table 1 Error analysis for RCS of sphere with and without Dent

Sphere RCS	Dent RCS
-10 dBsm	-38 dBsm

RCS values of sphere values with and without dent are given in **Table 1**.

RCS of Plasma Sphere (Complex Object)

Plasma stealth is known as active stealth technology and the plasma is the fourth state of substance. It is a mixture of electrons, ions, and neutral particles and is electrically neutral. Because the charged particles can interact with the electric and the magnetic field of the em wave, the em wave will be scattered, refracted and/or absorbed when it strikes the plasma [10,12].

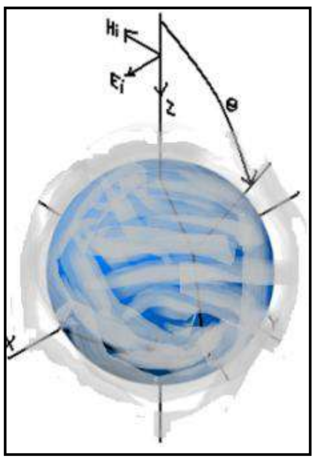

Figure 13 Plasma sphere

The Plasma sphere is shown in **Figure 13**. Standard spheres that undergo calibration tests with the dimension 7" Radius with RCS value of 0.1 m^2 or -10.0 dBsm is considered for comparison with the results simulated for RCS of plasma sphere and RCS of metal sphere. Plasma based SPSG is developed to simulate plasma RCS. Equation (2) is radar cross section of plasma sphere, letting $n=n_1+jn_2$, according to Mie's theory, RCS of the plasma sphere is given by 'σ' as [1]-[10],

$$\sigma = \frac{\pi}{k^2}\left\{\left[\sum_{l=i}^{\infty}(-1)^l(2l+1)(a_{lr}-b_{lr})\right]^2+\left[\sum_{l=1}^{\infty}(-1)^l(2l-1)(a_{li}-b_{li})\right]^2\right\} \quad (2)$$

Where the subscripts 'r' and 'i' represent the real and imaginary part of a complex respectively, a_l and b_l are factors from Mie's theory. Equation (3) is a propagation constant 'k' given by [4] and [5-10],

$$k = \omega\sqrt{\mu_0\varepsilon_0\left(1-\frac{\omega_p^2}{\omega^2}\right)} \quad (3)$$

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When $\omega < \omega_p$, 'k' is imaginary, wave will be reflected in this case, because EM wave can't penetrate into the plasma as incident waves will be scattered and RCS is more as it acts like a metal sphere.

When $\omega > \omega_p$, 'k' is real, wave will propagate in the plasma, because EM signal will penetrate through the plasma shell, reflects off objects surface will drop in intensity while travelling through the plasma.

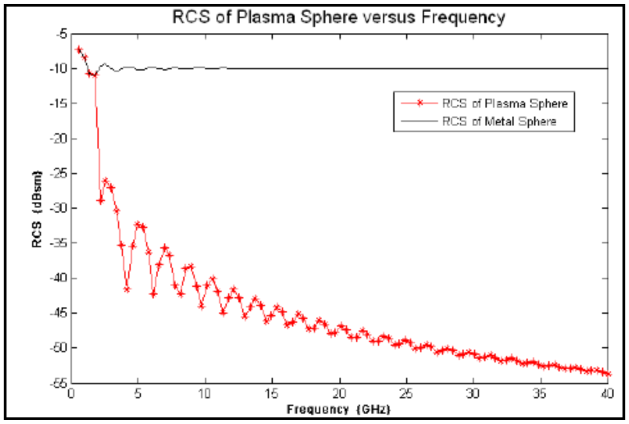

Figure 14 RCS of plasma sphere

From **Figure 14** it is observed that RCS of plasma generated around sphere when wave frequency is less than plasma frequency $f<f_p$ considering plasma frequency of 2.5 GHz. 'k' is imaginary that is electromagnetic (EM) wave can't penetrate into plasma, incident waves will be scattered , wave may be reflected and it is like a metal sphere implying RCS is more. When EM wave frequency is greater than plasma frequency $f>f_p$ and 'k' is real , EM signal penetrates into plasma and reflects off objects surface and will drop in intensity while travelling through plasma implying RCS is less. Hence, Plasma covers on targets helps in getting less RCS.

Table 2 Error analysis for RCS of Sphere

S.No	Sphere Diameter in inches	Radar Observation(P)	SPSG (Q)	Error (P)-(Q)
1	6"	-17.44	-17.45	0.01
2	14"	-10	-9.99	0.01
3	22"	-6.10	-6.12	0.02
4	39"	-1.05	-1.06	0.01
5	44"	-0.1	-0.09	0.01

RCS values of sphere using SPSG and Radar observation are shown in **Table 2**. It is observed that the error between radar observation and proposed algorithm is random in nature. It is also observed that the proposed SPSG algorithm is found to be nearer with the practical observed values of the radar. Measurement values for sphere without dent is available whereas, sphere with dent is not available in open literature.

RESULTS AND DISCUSSION

There is a change in RCS with respect to dimension and frequency for different target models sphere, cylinder, frustum and cone shown in **Figure 2** to **Figure 5**. RCS change s also seen with some fixed aspect angle for cylinder and frustum models shown in **Figure 6** and **Figure 7**. As size of a target increases, obviously RCS increases and as frequency increases, RCS also increases. RCS variation is observed for different dimensions of Sphere for different frequency bands shown in **Figure 8**. RCS of sphere with and without dents are shown in **Figure 10** and **Figure 11**. RCS of plasma sphere is shown in **Figure 14**.

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CONCLUSION

It is concluded that radar cross section was computed for curved shaped objects like sphere, cylinder, frustum and cone. The backscattered RCS for these objects were estimated using RCS prediction methodology called Physical Optics. The far field monostatic RCS for these objects has been computed at various dimensions and at some specified Radar frequencies ranging from 1 GHz to 40 GHz. In this plots are obtained for RCS verses frequency for various dimensions for the given objects and the plots are also obtained for various frequencies for RCS verses aspect angle for the given objects. RCS enhancement is seen with respect to size and frequency. Using SPSG, RCS versus frequency plots are obtained for different diameters of sphere which are highly impractical with radar measurements and also with RCS prediction software tools. The proposed algorithms are easy to use with mathematical modeling for RCS estimation of objects in the absence of radar measurements due to system complexity and cost effective with hardware and software.

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Two Applications of FBG Temperature Sensor for Environmental Safety

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Abstract: *Detection and monitoring of temperature in fire sensitive areas, high temperature zones such as underground coal mines and smelting plant applications is a crucial requirement in order to ensure safety of working personnel and to avoid unnecessary damage to life and infrastructure. Smoldering combustion is most often responsible for underground coal mine fire. A commonly used method for detection of underground fire can be done through temperature gradient. Similarly smelting plants as mandated in various stages of aluminium production starting from the mixing stage typically having 160°C-180°C to the alumina electrolysis process that is characterized by about 1000°C. Therefore, detection and subsequent monitoring of temperature change in underground coal mines as well as smelting plants is an important concern. A four channel FBG temperature sensor based system is proposed in this paper that demonstrates multiple FBG sensors. These four sensors sense different temperatures and a single channel making use of wavelength division multiplexing (WDM) is used thereafter to send the sensed data. The originally transmitted signal is retrieved at the receiver by a WDM demultiplexer. Three different channels such as Optical fiber cable (OFC), Free Space Optics (FSO) and Optical Wireless communication (OWC) channels have been simulated here to assess and compare the performance of the proposed WDM-FBG sensor system.*

Keywords: *FBG; Optical Sensor; Temperature; OFC; FSO; OWC*

INTRODUCTION

Temperature sensing is an important concern for the environmental safety. Detection of increase in temperature before any exposure is required. Accurate timely temperature detection prevents any life loss and industrial damage in areas where in temperatures can go beyond some safety limits due to a slew of reasons. Conventional temperature sensors like Thermocouple, resistance temperature detector (RTD)s, pyrometers and thermistors do exist to sense temperature in different applications. Although theseare in practice, however different temperature ranges mandate the use of different temperature sensors and may not lead to multiplexing easily. An optical Fiber Bragg Grating (FBG) sensor is better than these electrical sensors from the point of view of electromagnetic interferences, electric sparks. Also an FBG can be used in a multiplexed configuration to sense temperature at several locations and sensing mechanism is optical in nature avoiding the need for expensive electrical isolation. Such sensors are immune to environmental changes and passive in nature. It is with these constraints that we make use of an optical Fiber Bragg Grating (FBG) sensor to detect different changes in temperature [1-2] as point sensors. The same type of sensor can be used to detect different temperature ranges with different thermo-optic coefficients and the system designer need not worry about different sensors for a host of temperature ranges. Besides offering immunity to electromagnetic interference that is widespread in industrial applications and ease of deployment in inflammable, hazardous areas such aluminium smelting plant and underground coal mines, these sensors are also easily amenable to multiplexing. Typically the Hall-Héroult process [3] is used for aluminium smelting in the process of extracting aluminium from its oxide, alumina. This is done in many stages with particular temperature scaling. During aluminium production, temperature sensing is required in various stages [4]. A temperature in the range of 160-180°C [4-5] is required in the mixingstage. After the mixing stage, the green paste comes out of the mixer which has to be cooled to about 110-120°C temperature before it is fed into the block press in the Block Forming stage. This is

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done in order for the finished blocks to retain their shape [5]. For baking of green blocks, the furnace is slowly heated up to the range of 1100 – 1120°C and then slowly cools down again [5-6]. Baking of the green blocks is carried out above 1000ºC [5-6]. An exothermic reaction resulting due to the natural oxidization of coal over time leads to underground coal mine fire [7]. This is one of the terrible hazards that must be taken care of without or as less as possible human intervention. Exothermic internal reactions arising out of self-heating due to an increase in temperature paves way for smouldering combustion that leads to explosion subsequently. A gradual rise in temperature results inthe forthcoming mine fire.Due to the change in temperature, heat is produced which defines the energy transmission between the coal and its surrounding[8-9]. The heat produced leads to coal mine fire which is a risky hazard in underground coal mines.

In both the applications, it is criticalto sense and maintainanaccurate temperature change to avoid the losses of precious lives as well as infrastructure damage. Multiple FBG sensors are proposed to be distributed in the area of concern to detect the temperature change and to multiplexthe sensed data to be sent over a common channel to some remote monitoring unit. Wavelength Division Multiplexing (WDM) is used to multiplex temperature as coming from several sources distributed over a given area [10-11]. The number of components and installation cost within a sensor network is reduced through multiplexing several channels. The sensed information is transmitted and subsequently received over an analog communication link. The communication links in this work makes use of Optical Fiber Cable (OFC), Free Space Optic (FSO) and Optical Wireless Communication (OWC) as the channel. An FSO channel is used to transmit the sensed measurand to the receiver. However, in all these, FBG sensor was used as a point sensor over OFC or FSO in a multiplexed configuration. The capability of a multiplexed sensor over an OWC is yet to be explored and the resulting performance needs to be compared with those obtained over OFC and FSO. This particular issue is addressed in the present work. The primary difference between an FSO and an OFC lies in the fact that free space is used as the transmission medium in case of FSO while it is an optical cable in OFC [12-13]. The OWC is not much different from the FSO except the difference is in the propagation medium. OWC is considered for outer surface where it is assumed to be free from atmospheric attenuation factor [14]. In the receiver a WDM Demultiplexer is used to separate the sensed data that has been transmitted from each FBG sensor. Section II describes the proposed FBG sensor over the three different transmission media. The experimental layouts for proposed WDM-FBG system are shown in Section III. Section IV compares the results and analysis of experimental arrangements. Section V provides a conclusion of the experimental results.

SYSTEM MODEL

A shift in thewavelength of an optical source from its centre wavelength due to a change in temperature forms the basic principle of FBG sensors in the measurement of temperature. An FBG sensor reflects only one particular wavelength while transmitting the remaining wavelengths for white light from an optical white light source (WLS) being shoneonto it. The particular wavelength which is reflected off satisfies the Bragg condition and the corresponding wavelength is called the Bragg wavelength given as [15-16],

$$\lambda_B = 2n_{eff}\Lambda \tag{1}$$

where n_{eff} is the effective refractive index of FBG sensor, Λ is the grating period, and λ_B is the Bragg wavelength. The wavelength shift with respect to any change in the reference temperature is given as [17]:

$$\Delta\lambda_B = \lambda_B(1+\xi)\Delta T \tag{2}$$

where, $\Delta\lambda_B$ is the change inwavelength λ_B is the centre Bragg wavelength, ξ is the thermo-optic coefficient and ΔT is the change in temperature. The FBG sensor responds by shifting the centre wavelength for any change in temperature other than the set reference temperature.

PROPOSED SENSOR LAYOUT

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Distributed sensors can used to detect the temperature change at different locations in the smelting plants and coal mines as per the requirements. Many FBG sensors are placed to detect the change in temperature and the sensed data is in the form of a wavelength shift from a preset central wavelength. These sensors are said to be working upon wavelength modulation. The WLS sends the optical spectrum having all the wavelengths between 1.5430 µm to 1.5600 µm, in which 1.5499 µm is the centre wavelength. With any change in temperature other than reference temperature, the wavelengths that satisfy the Bragg condition in Eq. (1) will be reflected at each grating period and these small wavelengths that are reflected is omitted from the incident optical spectrum and form a notch having Bragg wavelength [18]. The Any increase or decrease of the temperature from a reference value results in shifting the grating centre wavelength accordingly. At the transmitter side, the WDM combines multiple sensed data simultaneously with high data rate at a time from different sensors over a common communication channel and send it to the receiver side [19-20]. This paper illustrates transmission of the sensed data over both wired and wireless channels. The sensed datais transmitted to the receiver via OFC for wired channels and for the wireless, FSO and OWC channels have been simulated. **Figure 1**, **Figure 2** and **Figure 3** show theblock schematic of a 4-channel WDM-FBG system over OFC, FSO and OWC as a communication channels, respectively. Each FBG is used to sense a different temperature as it is located at a different location and send all the sensor data through a single channel. At the receiver, WDM demultiplexer is used toretrieve the measure and arriving from each of the FBG sensors.

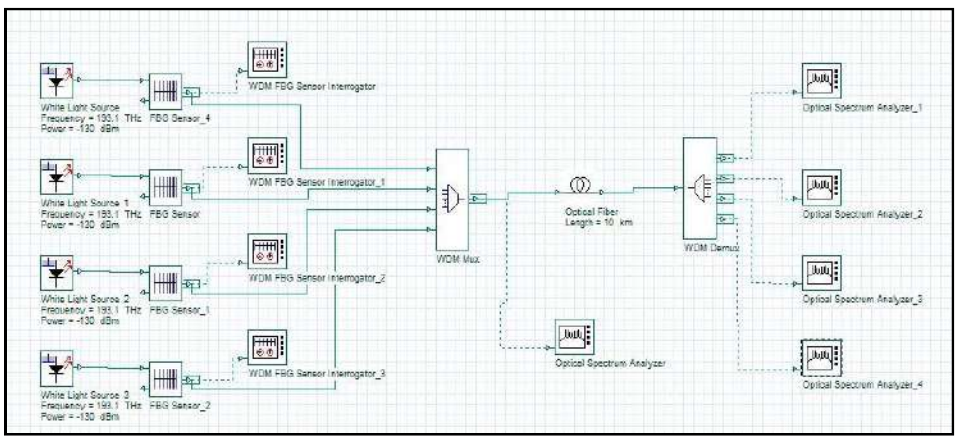

Figure 1 Block schematic of 4-channel WDM-FBG System over OFC channel

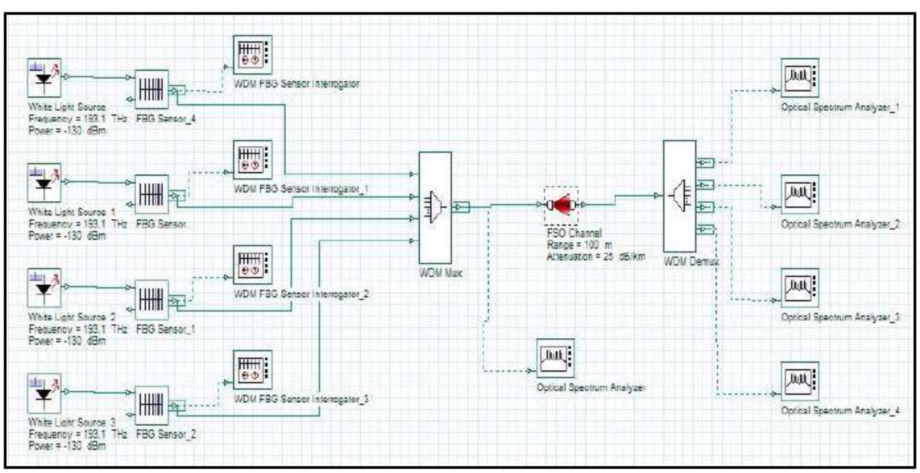

Figure 2 Block schematic of 4-channel WDM-FBG system over FSO channel

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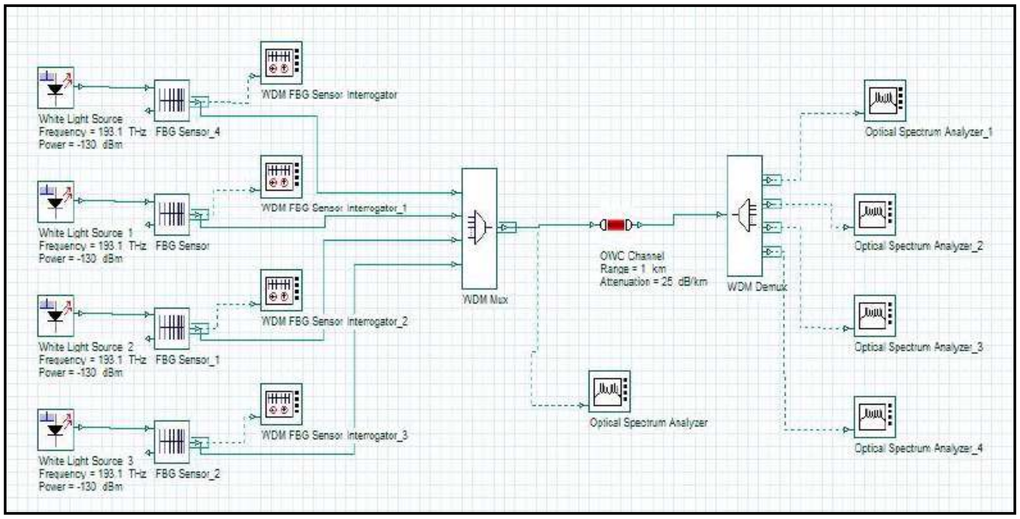

Figure 3 Block schematic of 4-channel WDM-FBG System over OWC channel

RESULTS AND ANALYSIS

Opti System 16.0 software has been used here to perform all the simulations. The graphs are obtained using MATLAB R2016b. In 4-Channel WDM-FBG system, four number of FBG sensors are used to sense 4 different temperature ranges, i.e. between 200^{o}C, 350^{o}C, 600^{o}C and 1000^{o}C with respect to a reference temperature of 0^{o}C that has a centre Bragg wavelength 1.54999 nm. The thermo-optic coefficient ξ used for temperature sensing of 200^{o}C and 350^{o}C is10^{-4}/^{o}C and for 600^{o}C and 1000^{o}C the ξ value is 10^{-5}/ ^{o}C. The change in temperature will shift the centre 1.5499 µm wavelength into four different wavelengths for four different temperatures; these wavelengths are multiplexed using WDM which is shown in **Figure 4** and passed through a 1 km OFC that has a 0.2 dB/km of typical channel attenuation.

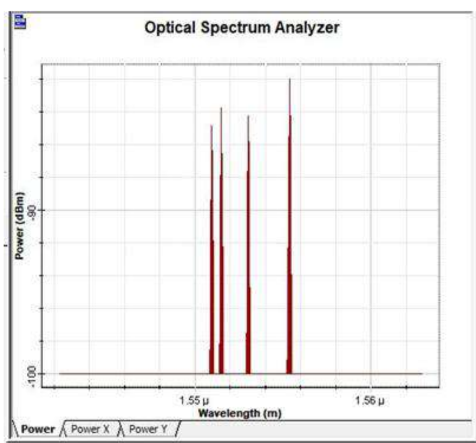

Figure 4 4 x1 WDM Mux output OFC channel

AWDM demultiplexer is used to retrieve the data from each transmitter at the receiver side. We have assessed the capability of FSO and OWC channel to send out and receive the multiplexed data in as to be used in these two applications also. An FSO channel is 100 m range with 25 dB/km attenuation and OWC with arange of is 1Km with 25dB/Km has been used in the schematic. The Bragg wavelength shift according to the change in temperature as transmitted through OFC, FSO, and OWC channels is compared in **Table 1**.

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Table 1 Bragg wavelengths shift vs.Temperaturechange over OFC, FSO and OWC

Temperature (°C)	Bragg Wavelength over OFC (µm)	Bragg Wavelength over FSO (µm)	Bragg Wavelength over OWC (µm)
200	1.55304	1.55309	1.55301
350	1.55539	1.5556	1.55536
600	1.55096	1.55097	1.55094
1000	1.55151	1.55149	1.55147

We have considered the centre Bragg wavelength as 1.54999 µm in obtaining **Table 1**. **Table 2** shows the difference in Bragg wavelength shift for OFC, FSO, and OWC communication channels as a function of temperature as obtained by using Eq. (2). Here, we have taken the reference temperature as 0^{o}C and n_{eff} is considered to be 1.45.

Table 2 Difference between Bragg wavelengths shift and centre Bragg wavelength

Temperature (°C)	Theoretical ($\Delta\lambda_B$) (nm)	Simulated ($\Delta\lambda_B$) (nm) in OFC	Simulated ($\Delta\lambda_B$) (nm) in FSO	Simulated ($\Delta\lambda_B$) (nm) in OWC
200	30.1	31.06	31.061	31.0602
350	54.24	54.43	54.44	54.43
600	92.1	93.05	93.058	93.056
1000	154.1	155.15	155.14	155.147

A look at **Table 2** clearly shows that thesimulated temperature shifts over the three different channels follow the theoretical shifts closely. The comparative plot of temperature vs. both theoretical and simulated Bragg wavelength shifts as a function of the ambient temperature asobserved over OFC, FSO and OWC channels are compared in **Figure 5**. All the results show the detection and sensing capability of the proposed scheme over three different channels as the same result is observed to be obtained in each case.

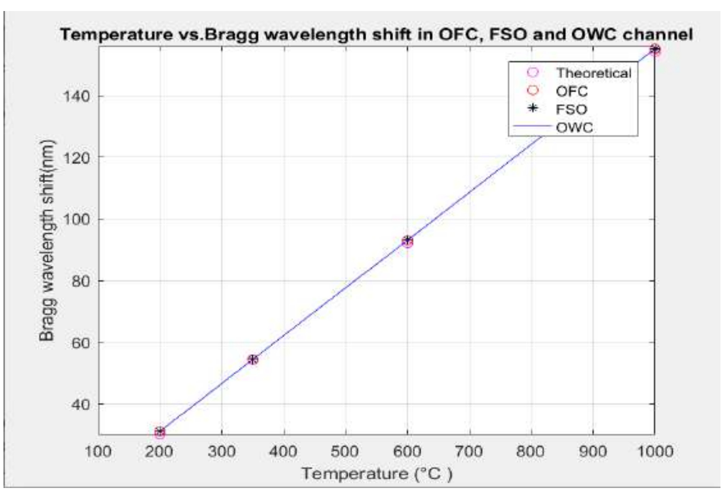

Figure 5 Graph depicting Temperature as a function of Bragg wavelength shift observed over OFC, FSO and OWC communication channels

The FBG sensor can reliably transmit the sensed temperature up to a certain range through the OFC, FSO and OWC communication channels. **Table 3** shows the reliable distance to detect the sensed temperature at the receiver. All the three channels are assumed to have an attenuation of 0.2 dB/Km.

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Table 3 Communication range overOFC, FSO and OWC channel for the 4 channel WDM FBG Sensor

Communication Channel	Range
OFC	75 km
FSO	520 m
OWC	30m

CONCLUSIONS

Two applications of FBG sensor in fire related hazardous areas like underground coal mines and smelting plant applications are presented through computer simulations that demonstrate the multiplexing capability offered by fibre based temperature sensing and subsequent monitoring. The maximum range is observed to be obtained for OFC which is 75 km while OWC is pretty restricted in its range to 520 m for a temperature range of 200°C to 1000°C. Results obtained show promise for the use of such sensors in avoiding mishapsdue to unmonitored sharp temperature changesas well as providing environmental safety in both of the areas.

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Environmental Engineering

Sustainable Ash Management in Thermal Power Plants in Parity with COP26's Mission of Phasing Down of Coal for Empowerment of India's Economy — Case of the Country's First Multipurpose Project

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Abstract: *Almost 70% of electricity produced in India come from coal for economic reasons. However this is a great challenge for the country in view of coal phase down policy adopted in COP26 as the ash percentage of domestic coal supply has exceeded 40% and it is still increasing. The Government of India and Thermal Power Plants demonstrated a number of cases of turning waste into wealth by productive use of ash from thermal power plants in brick manufacturing, land filling for highway, cement manufacturing and so on, showing an upward trend of some utilization of ash from mere 10% in 1996-97 to 79% in the first-half of 2021-21. A great opportunity exists to optimize, replicate and coordinate the productive utilization of ash in 281 thermal power plants in the country operational in both public and private sectors. As per the data received from 199 thermal power plants, 313 million tons of coal was consumed producing 106 million tons of ash in the first half-year of 2020-21 only. Out of this, more than 22 million tons of ash not utilized while the rest may be better utilized. A case of large thermal power station of India's first multipurpose project viz. Damodar Valley Corporation (DVC) has been studied and multiple alternatives for economic as well as environmental benefits has been presented with details of factual information in four scenarios in the present paper. We have used Analytical Hierarchy Process (AHP) for ranking all the identified hindrances in the ash transportation and dumping process. After identifying all the hindrances, we have proposed different feasible and suitable scenarios for overcoming these hindrances. AHP application also revealed that prioritization amongst these alternative scenarios including solar photovoltaic power generation would be subjective issues for the large number of thermal power plants in India and effective for optimization towards attaining SDGs, according to local conditions and sustainability in the long run during the phase down process. Besides emission reduction from power sector, which is also the largest CO_2 emitter among all economic sectors of India, some of the scenarios presented here have been found to have simple payback period of less than three months.*

Keywords: *Sustainability; Sustainable Ash Management; Waste to Wealth; Phasing Down on Coal; India's Economic Empowerment Tools*

1. INTRODUCTION

Since India has more reserves of coal than any other fossil fuels, thermal power plants are producing more than 70% of total electricity produced in India (Central Electric Authority, 2021). Since India has huge reserves of coal, thermal power plants are the major source of electricity production. As energy demands are increasing by many folds, new thermal power plants were being installed in the country as the most economical solution until recently when due to commitments at COPs and environmental issues, India decided to stop building new thermal power plants by 2022 (Mathiesen, 2021). The large numbers of existing power plants use poor coal quality coal which generate lots of ash as a by-product which are dumped in ash pond/dyke/mines. The dumping of ash is a serious concern which adversely affects our environment. However, a good number of success stories in India and abroad

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are there to turn this waste into wealth (Council of Scientific and Industrial Research, 2020). Ash is also used sometimes to fill the mines/quarries which are now devoid of minerals/stones. Such initiatives for productive utilization of ash is going to also help fulfil the mission of the Government of India to turn into a five trillion economy by 2025 (Press Information Bureau, 2018). In most of DVC owned thermal power plants, ash is being dumped in vacant quarries/mines of West Bengal (WB) and Jharkhand (JH). Damodar Valley Corporation (DVC), India's first multi-purpose project (Damodar valley Corporation, n.d.) owned Koderma Thermal Power Station (KTPS) at Koderma, JH which is one such thermal power plant out of total 8 presently operating in DVC. The ash generated at KTPS, Koderma is being dumped in stone quarries of Dhab and Domchanch areas of Koderma district of Jharkhand. HYVAs are being used to transport ash on daily basis from thermal power plant to the stone quarries. These HYVAs are generally covered by Tarpaulin sheets to minimize air pollution. The transportation through HYVAs isn't nuisance free. DVC contracts generally demand of nuisance free transportation. There are lots of daily hindrances in transportation of ash from power plants to quarries. These hindrances are sometimes natural and sometimes man-made. These hindrances seriously affect the work and hence earnings and also attract penalty due to less quantity of ash transported in such cases The fuel is used in transportation of ash from HYVAs which suck a lot of fuel in the process which sometimes become a serious concern. The cost of fuel becomes a burden when the targeted quantity of ash to be handled annually or monthly isn't met and penalty is imposed by DVC or other government organizations. The fuel becomes a very critical commodity as rate of Diesel at which ash transportation work has been contracted isn't the same when work is actually started. There are several parameters which can affect fuel consumption in ash transportation. This analysis is a sincere effort towards analyzing, understanding and validating the fuel consumption trends and ash transportation work which helps us to understand in depth the excess fuel consumption at each step and potential for saving fuel cost at those steps. Various tools like sensitivity analysis, Analytical Hierarchy process, cost-benefit analysis etc have been used for proper in-depth analysis of hindrances in ash transportation. The cost incurred due to fuel consumed is a serious concern for the company as the fuel costs were to the tune of 2501300/- INR for the year April 2020 to April 2021. There are several areas where fuel is being consumed but transportation plays one of the biggest roles in increasing fuel bills. This study analyses the transportation work and corresponding costs incurred etc due to ash transportation from ash pond to abandoned stone quarries.

LITERATURE REVIEW

Ash Generation

In our country, more than 60% of the electricity is still being produced by thermal power plants (Hannan, 2015). Since we have abundant coal reserves in our country, they are the major source of power generation (Tropical Forest Research Institute, 2017). In a coal-fired boiler, bottom ash constitutes of total ash and rest constitutes fly ash (Indian Audit and Accounts Department, 2015). The quality of coal found in India produces 35-45% of ash on average basis (Indian Audit and Accounts Department, 2015). One of the biggest concerns with Indian coal quality is that the burning of such coal produces ample amount of ash (bottom ash and fly ash) (Chouhan, et al., 2016). (Chouhan, et al., 2016) further states that such produced ash has low utilization potential and cause huge environmental problems. Chimneys of the thermal power plants capture fly ash (Ahmad, et al., 2014). Earlier practices of disposing off fly ash directly into the atmosphere has been curbed by pollution control board (Ahmad, et al., 2014). Now, fly ash must be captured before releasing into the atmosphere (Ahmad, et al., 2014).

Ash Transportation

One of the most important concern regarding on fly ash is certainly is its disposal (Tropical Forest Research Institute, 2017). According to the current practices, ash in its slurry form is released in the ash pond (Central Pollution Control Board, 2013). The overflow from the ash pond from natural or man-made reasons used to discharged in the nearby water bodies which used to create huge problem of environmental problems (Central Pollution Control Board, 2013). Sometimes, fly ash is transported and dumped in abandoned mines or sone quarries (Tropical Forest Research Institute, 2017).

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Ash Disposal

(Lopes, 2021) quotes from an April 22nd notification of the central government that Coal and lignite-based thermal power plants should ensure 100% utilisation of ash generated by it in an eco-friendly manner. “Since last two decades, government is issuing notifications regarding proper disposal and utilization of fly ash (Lopes, 2021). Also, according to other notifications, fly ash should be used in building materials and backfilling of abandoned mines and quarries (Lopes, 2021). In our country main utilization of fly ash is in cement industries, backfilling mines and quarries, low lying areas, construction of roads, embankments, ash-based bricks etc (Indian Audit and Accounts Department, 2015). This slurry disposal generally requires huge area of land (“usually 350 acres or 0.35 acre / MW for 2 X 500 MW TPP”) for creating ash pond and also ample amount of water, both of which are sparse now a days in current scenario (Indian Audit and Accounts Department, 2015). One major drawback of the wet disposal process is that it reduces the "lime reactivity" in ash which is an important property of fly ash to be used in cement manufacturing process (Indian Audit and Accounts Department, 2015).

Ash Recycling

Innovative methods of using fly ash is in vogue since many years as many companies around the world are engaged in finding new methods for using this material (Carpenter, 1997). Also, these days, companies are marketing fly ash for finding better prospects (Carpenter, 1997). A technique has been devised and patented for converting fly ash into Flashag™ which is made by heating fly ash until it crystallizes (National Institute of Environmental Health Sciences, 2007) Flashag™ is an aggregate that can be mixed with sand, water, and Portland cement to make concrete.(National Institute of Environmental Health Sciences, 2007). In a presentation at the April 2005 World of Coal Ash Conference, the process of manufacturing Flashag™ was shown to deliver strength in concrete with 25% more compressive strength than concrete made with fly ash pellets (National Institute of Environmental Health Sciences, 2007). Burnt clay brick is still the most basic building material for construction of houses in our country in most of the states (Gadling & Varma, 2017).

OBJECTIVES & METHODOLOGY

Materials

Study Area

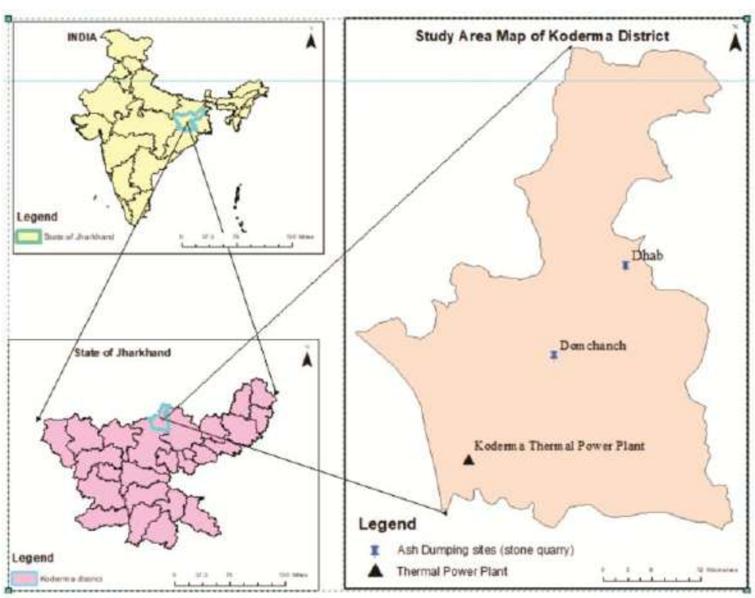

Figure 1 Study Area Map

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Methods

Data Collection

Primary Data - Data regarding hindrances in ash transporting work, ratings for those hindrances, data regarding different aspects of fixed and portable cantilever shed like price, size, strength, dimension etc, data needed for knowing different usages of ashetc have been collected after survey

Secondary Data - Data regarding daily ash trips and quantity, dataregarding monthly rainfall in Koderma, regarding rake details, freight charges of BTAP and BOXN rakes, distance slab applicable etc, solar panels efficiency, electricity production from panels, size of panels and cost of the panels have been collected from various sources

Methodology used for objectives:

- Aim I: To identify the issues and factors that affect variation in Diesel consumption in ash transportation

  Methodology: To fulfil this aim, the data regarding ash transportation work will be plotted against each month. The fuel consumption per MT-km trend of ash transportation for each datewill be plotted and minimum monthly value in the trend will be verified with the help of 'Hindrance register' available at the site. The data will again be verified with the help of monthly rainfall data.

- Aim II: To assess the savings potential in Diesel consumption in ash transportation work

  Methodology: The monthly minimum value of fuel consumption per MT-km will be compared with the minimum fuel consumptionper MT-km value for each month to assess the potential of cost savings for each month.

- Aim III: To analyze theoretically all the hindrances involved in ash handling and transporting work for assessing their weights for finding an ideal investment weightage factor

  Methodology: All the hindrancesin ash transportation workwill be been ranked using Analytical Hierarchy Process. The weighted hindrances will be used for finding best possible alternatives for the hindrances. The weighted hindrances will also be used to find out the investments required in minimizing the hindrances.

- Aim IV: To maximize the benefits of fuel saving assessed for improving the ash transportation work

  Methodology: The alternatives for reducing the negative impact of the hindrances will be maximized using sensitivity analysis and return on investment method.Product Matrix will be used for assessing quotations of possible scenarios and finding best possible scenarios for the hindrances

- Aim V: To calculate quantitively the impact of fuel savings potential in terms of reduced carbon footprint

  Methodology: The fuel savings potential will be used to calculate reduced Diesel consumption. This extra actual Diesel consumed can be used to find the extra cost incurred and extra CO_2 generated.

Instrument and Software Used

- Analytical Hierarchy Process (AHP) will be used for finding weights of the hindrances. Sensitivity analysis will be used on weighted hindrances after applying AHP. SPSS v 26.0 and Excel 2019 have been used for analysis.

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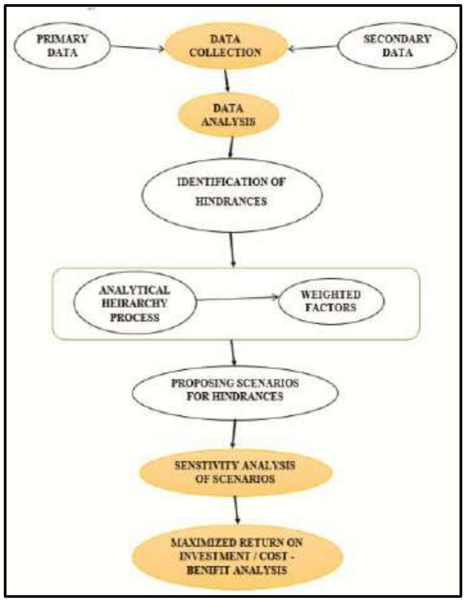

Figure 2 Methodology Chart

DATA ANALYSIS

The data regarding fuel consumption in hauling 1 MT-km of ash for each month from April 2020 to April 2021 was plotted using the data of MT-km of ash haulage per month and HSD consumed in Litres per month.

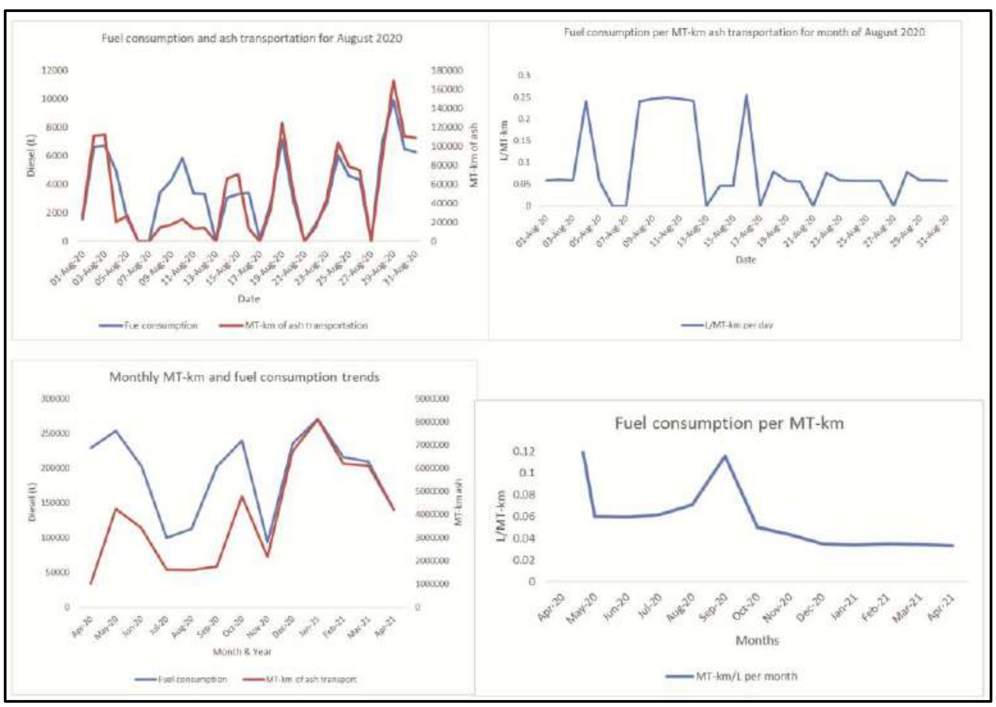

Figure 3 Plots showing MT-km of ash transported, corresponding fuel consumption and fuel consumption per MT-km of ash haulage

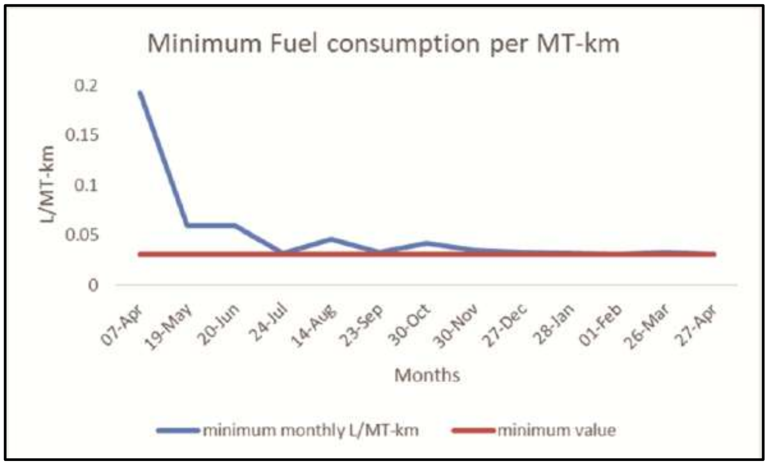

Figure 4 Plot showing monthly minimum fuel consumptions per MT-km and minimum of monthly minimums

An interesting observation from Monthly fuel consumption and MT-km trends graph in **Figure 3** may be observed that the L/MT-km ratio is decreasing so MT-km and fuel consumption lines are almost merging as we move towards April 2021. It may also be observed from **Figure 4**, monthly Diesel consumption per MT-km of ash transportation has been decreasing as we move towards 2021 and has become minimum at 0.031 L/MT-km in April 2021. The values are mentioned in the **Table 1**.

Table 1 Table showing Ideal vs actual Diesel consumption and corresponding savings potential

Months	**Diesel Consumption (L)**	**Diesel Consumption as per min L/MT-km (L)**	**Difference in Actual and Ideal Diesel Consumption (L)**	**Savings Potential in INR (Rs)**
April 2020	228340	36676	191663	17698219
May 2020	253085	132976	120108	11090785
June 2020	202405	106348	96056	8869867
July 2020	100100	96971	3128	288851
August 2020	112700	75950	36750	3393495
Sep 2020	202265	190006	12258	1131948
October 2020	239225	176570	62654	5785485
Nov 2020	93205	82553	10652	983606
Dec 2020	234955	220715	14239	1314894
January 2021	270865	262400	8464	781615
February 2021	215915	215915	0	0
March 2021	208915	208915	12661	1169164
April 2021	139335	139335	0	0
Total	2501310	1932673	568636.	52507931

Now, monthly variation in trips and fuel characteristics were also validated with average rainfall data over the same period.

So, we found that:

Correlation between Rainfall and MT-km of ash transported = -0.59

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Correlation between Rainfall and MT-km of Diesel consumed = -0.48

There is not good correlation in both the cases as there are other hindrances also apart from rainfall in transporting of ash from ash pond to ash dumping sites. Those other hindrances have been determined using Analytical Hierarchy Process. After using AHP, we had our results as:

Table 2 Criteria weights of different hindrances

	Heavy rains	Weighbridge Issues	Local Issues	Road Conditions	Ramp Issues	Shifting of Ash Pond	New Contract
Criteria Weight	38.91%	17.86%	17.4%	16.34%	3.7%	3.03%	2.76%

Now, we propose different scenarios to overcome these hindrances for bringing Fuel consumption in 1 MT-km of ash haulage to the minimum value of 0.031 L/MT-km

Figure 5 Satellite Image showing ash pond of KTPS, Koderma, JH

SCENARIO I: Ash Bricks Manufacturing Plant

A normal brick manufacturing plant using ash can cost around Rs 3,00,000 INR/- and covers around ½ acre to 1 acre (4046.86 m^2) of land. Also, it can produce around 12000 bricks per day. It also requires water which is also readily available. About 1/3rd area, i.e., 192700 m^2 of the ash pond area can be used in brick manufacturing. If all produced ash is consumed here then no transportation would be required which is a serious burden for any thermal power plant.

The selected area in the figure above is around 19500 m^2 area which doesn't fetch too much of the ash pond area and suitable for one brick manufacturing plant.

If we install 4 such manufacturing units in the available land, then we will require Rs 12,00,000 which will produce 48,000 fly ash bricks per day.

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Figure 6 Satellite image showing selected area in yellow border which might be an apt location for setting up fly ash brick manufacturing unit

SCENARIO II: Portable Cantilever Shed

A cantilever prefabricated portable shed can be constructed at the edges of the ash pond. A mild cantilever fixed shed 10-20 feet high, 50 m in length and10 m in width spanning both sides of the support and having thickness of 10-15 mm and made of mild steel costs around Rs 220 per square feet. The rooftop is color coated. The rooftop can also be covered with solar panels. The portable pre-fabricated roof shed costs around Rs 1200 per square feet.

Figure 7 Satellite image showing highlighted edge in yellow which might be an apt location for installation of portable shed

The portable prefabricated shed of 100 m can be placed on the edge of the ash pond as shown in the figure above. As can be seen, the ash isn't being currently excavated from the left edge of the pond, so ash can be stored here under the roof shed.

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Size of portable shed = 5381.96 $feet^2$

So, the portable shed can cost around Rs 64,58,352

Cost of installation of 1 kW solar panel = Rs 98,000[i]

Area required by 1 kW solar panel = 9.29 m^2 [ii]

So, almost 50 solar panels can be installed on our shed.

Cost of installation of 50 solar panels of 1 kW = Rs 4,90,00,00

1kW solar panel is sufficient to produce around 3.75 units (average of 3 units and 4.5 units) of electricity per day on a normal sunny day and 112.5 units of electricity in a month and hence 1350 units of electricity in a year. [iii]

So, 50 such solar panels can produce around 187.5 kWh units of electricity every day.

So, total cost of installation of shed with solar panels = Rs 1,13,58,352

i. [1]*https://www.loomsolar.com/blogs/pricelist/1kw-solar-system-price-in-india*
ii. [1]*https://letsavelectricity.com/how-many-solar-panels-i-can-install-in-100-sq-ft-area/*
iii. [1]*https://letsavelectricity.com/how-much-electricity-does-one-solar-panel-produce-in-a-day/*

Payback Period

We have average/normal fuel consumption per MT-km of ash transportation for April 2020 to April 2021 = 0.05 L/MT-km

Also, we have average L/MT-km for the month of August 2020 when rain was maximum at 352.7 mm = 0.09 L/MT-km

So, difference of average/normal L/MT-km and L/MT-km value of August 2020 = 0.04 L/MT-km which comes out to be 63851.45 L of Diesel.

So, Ideal Diesel consumption = Actual Consumption – Difference = 48848.55 L

For the rate of 1 L of Diesel = Rs 92.34, we get Rs 4510675.1

Also, 187.5 units of electricity can be generated per day which can be converted to Rs 796.87

For a month of 31 days = Rs 24703

So, Total Benefit = Rs 24703 + 4510675 = Rs 4535378

If we spend Rs 1,13,58,352 on the installation of shed with solar panel as well, then we can save Rs 4519436.

So, Payback period = Rs 1,13,58,352 / Rs 4535378= 2.5 months

SCENARIO III: Ash Transportation by Rail

Koderma Thermal Power plant is having proper facility for unloading of coal using BOXN rakes through rail transport. The same BOXN wagons can be used to transport ash to 100 kms to any cement plant or any other industry which might consume ash in proper quantity as per norms laid down by Central Pollution Control Board. So, while transporting ash using BOXN wagons, proper tarpaulin sheets should be used for covering the wagons. In case of BTAP wagons, no sheets are required to cover the wagons. There might be 2 cases in transporting of ash using railways: AKA Logistics is already purchasing Diesel from various petrol pumps situated on Ranchi – Patna NH 20 near Koderma town. So, purchasing our own Diesel might be a better idea. Also, when Diesel purchased is to the tune of 1 Lakh Litres, then petrol pump owners provide concession also on per Litre of Diesel purchased.

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Figure 8 Satellite Image showing railway infrastructure facility inside KTPS, Koderma, JH

Also, train load is always beneficial and considering the size of the ash pond, it would be apt to use whole rake of BTAP wagons.

BTAP wagons cost less to the transporter, so these might be a better option for transportation considering the fact that it should be made readily available by railways

So, considering all the scenarios, we have:

Table 31 Different scenarios of BOXN/BTAP wagons based on load and diesel purchased for successfully transporting 1 rake

	BOXN wagons (train load)	**BTAP wagons (wagon load)**	**BOXN wagons (wagon load)**	**BTAP wagons (train load)**
Diesel purchased	Rs7,39,721	Rs7,69,446	Rs7,91,781	Rs7,19,427
Diesel not purchased	Rs7,57,560	Rs7,87,285	Rs8,09,620	Rs7,37,266

So, benefits in BOXN wagons are intangible benefits which might be quite evident in long run considering the fact that BOXN wagons frequent the power plant already while BTAP wagons might be difficult or expensive to get in intangible terms as its rake placement due to nature of rakes which are more common in Dhanbad – Gaya stretch of Delhi – Howrah route might not be easy. Also, conventional loading and unloading methods won't work in case of BTAP wagons which need special arrangement in both the cases and unloading occurs only via closed pipe system connected directly to fly ash silos for which minimum pressure should be 2 bars[iv].So, after proper scrutiny, we can choose train load of BOXN/BTAP wagons with Diesel purchased which are most suitable among all scenarios.

[1] *https://www.youtube.com/watch?v=K43_lnYL01k*

Payback Period

We have average rate per ton as per workorder for placing 1 rake = Rs 100 per tonne (since the rate is based on transportation, so per tonne rate will be same for coal/ash)

Also, Quantity in BOXN wagons = 3800 MT

So, we will earnRs 3,80,000 in placing 1 rake

Now, we have Rs 3,597,21 in loss for placing and transporting 1 BOXN rake of ash from KTPS, JH and loss of Rs 2,54,327 in case of placing 1 BTAP wagon

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This loss doesn't include social benefits which will be having due to reduced traffic, reduction in no of accidents, reduced pollution, reduction in local issues and many more which isn't in the scope of current study to quantify in monetary terms to achieve at the true loss or gain.

Scenario IV: Setting up SPV Power Plant

SPV power plant consists of PV systems arranged in an array of SPV modules and associated components.In this power plant, DC form of electricity is produced. SPV power plant can be installed to produce electricity as well as supply storage area for dry ash. The SPV can be set up around the edges of the ash pond or in the vicinity of the pond.

Figure 9 Satellite image showingarea around the vicinity of the ash pond

For setting 1 kW solar PV power plant, area required is 10 m^2.

Almost, 600 m^2 area is required for setting up a 100 kW solar PV plant.

Electricity generated = 12000 units/month = 400 units/day

Costs required = Rs 3,00,000 to Rs 5,00,000

This area covered by solar PV plant can be quite useful in storing dry ash which has to be transported in 3-4 days approx.

FINDINGS & DISCUSSION

- Minimum fuel consumption per MT-km of ash transportation for the period of April 2020 to April 2021 at Koderma Thermal power plant site came out to be 0.031 L/MT-km.
- Total Diesel consumption for the period April 2020 to April 2021 was 2501310 L of Diesel
- Total Diesel costs due to ash transportation was Rs 23,09,70,965 for the year April 2020 to April 2021.
- If our fuel consumption per MT-km of ash transported was ideal which in our case is 0.031 L/MT-km, then Diesel consumption would have been 1932673 L of Diesel for the period April 2020 to April 2021
- The savings potential in terms of Diesel quantity came out to be more than 5,60,000 L of Diesel for the period April 2020 to April 2021

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- We found that there are 7 most important hindrances in ash transportation work from ash pond to ash dumping sites.
- The ash transportation through HYVAs cause lot of pollution to the environment, increase in accidents on the road, traffic jam situations, decline in road conditions, breakdown etc
- Heavy rains came out to be the biggest hindrance factor in our study.
- We found 4 most appropriate and apt ways of reducing the hindrances in the transportation by trying to use the fly ash generated in situ, by making arrangements for keeping ash to be transported dry and transporting ash to nearby cement plants or any other suitable industry in the range of 100 kms
- 1/3rd area of the ash pond is still not in use and can be used for brick manufacturing plant or shed construction
- Sheds can be constructed at the edges of the ash pond to that side where ash excavation isn't being executed currently.
- The movable shed will felicitate that we can change the location of the shed as per the need and the area available for ash storage around ash pond.
- Solar panels can be installed on the roof of the sheds though proper arrangements need to be done for keeping the panels clean from the ash dust as in a study it was found that ash dust can reduce its efficiency by around 30 percent
- Solar panels can't be installed on the ash surface, only feasible placement is above the roof of the sheds.
- 100 kW Solar PV plants if installed at the edge or in the suitable vicinity of the ash pond will require around 600 m^2 area of land and will cost Rs 3 lacs to Rs 5 lacs.
- 100 kW Solar PV plants if installed at the edge or in the suitable vicinity of the ash pond can be used to provide storage of ash which have to be used in 3-4 days and will also produce 14,4000 units of electricity per year approx.
- 15,23,946 kg of CO_2 emission can be avoided per year if we can reduce our fuel consumption per MT-km of ash transportation to 0.031 L/MT-km
- 67,03,510 kg of CO_2 emission can be avoided per year if we can completely stop our ash transportation and can consume in situ by making brick manufacturing units
- The calculations show that we may have to suffer Rs 3,597,21 in loss for placing and transporting 1 BOXN rake of ash from KTPS, JH while loss of Rs 2,54,327 in case of placing 1 BTAP wagon. But this loss doesn't include social benefits which will be having due to reduced traffic, reduction in no of accidents, reduced pollution, reduction in local issues and many more which isn't in the scope of current study to quantify in monetary terms to achieve at the true loss or gain.
- The payback period of using shed with solar panels on-board at the ash pond came to be 2.5 months which is quite encouraging.

CONCLUSION

- Diesel consumption is one of the biggest contributors of expenses to the company in ash transportation at KTPS, Koderma, JH
- 7 major hindrances are involved in the ash transportation at KTPS site from ash pond to the ash dumping sites
- These hindrances have been tried to overcome with the help of 3 scenarios presented in our report.
- Total Diesel costs due to ash transportation was Rs 23,09,70,965 for the year April 2020 to April 2021 which can be overcome by our 3 scenarios proposed.

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- Setting of fly ash manufacturing units in the available land in the ash pond or in the vicinity of the ash pond will cost around Rs 12,00,000 while our ash transportation costs per month comes around Rs 1,92,47,580 on an average basis.
- Establishing portable shed at one of the edges of the ash pond with solar panels installed on the roof costs around Rs 4,90,00,00 and it also has the potential of producing 187.5 units of electricity every day, 5625 units of electricity every month and 67500 units of electricity every year which can be beneficial in long term.
- A 100 kW Solar PV plants if installed at the edge or in the suitable vicinity of the ash pond will require around 600 m^2 area of land which will cost Rs 3 lacs to Rs 5 lacs and can be used as storage of dry ash and can produce 1,44,000 units of electricity per year.
- Transporting ash by rail to any cement plant or any other suitable industry can cost around Rs 7,00,000 to Rs 8,00,000 per rake using BOXN wagons and BTAP wagons
- A single full BTAP rake can carry 3561 MT of ash and a full BOXN wagon can carry 3800 MT of ash.
- Currently, 6000 MT to 7000 MT of ash transporting is being done in whole day by HYVAs from ash pond to dumping site. Only 2 such rakes (BOXN and BTAP) can load more than 7000 MT of ash per day.
- Also, KTPS, Koderma is connected to Dhanbad – Gaya section of Delhi – Howrah route and also all the railway routes in 100 km range are electrified, so there won't be any use of diesel locos for transportation of ash.
- The reduced hindrances with minimum damage to the environment, human lives, road traffic, roads etc can't always be compared in monetary terms and the results are far-fetched.
- 15,23,946 kg of CO_2 can be generated less if we can reduce our fuel consumption per MT-km of ash transportation to 0.031 L/MT-km and 67,03,510 kg of CO_2 can be generated less if we can completely stop our ash transportation and can consume in situ by making brick manufacturing units
- The calculations show that we may have to suffer Rs 3,597,21 in loss for placing and transporting 1 BOXN rake of ash from KTPS, JH while loss of Rs 2,54,327 in case of placing 1 BTAP wagon. But this loss doesn't include social benefits which will be having due to reduced traffic, reduction in no of accidents, reduced pollution, reduction in local issues and many more which isn't in the scope of current study to quantify in monetary terms to achieve at the true loss or gain.
- The payback period of using shed with solar panels on-board at the ash pond came to be 2.5 months which is quite encouraging.

LIMITATIONS AND WAY FORWARD

- There were limited number of people available for data collection. If we can extend the study to several thermal power plants having almost the same issues, then we can extend our study and get more data leading to greater accuracy.
- Average Diesel consumed in each trip has been taken same for each trip but in certain situations fuel consumed is more than the average due to some unavoidable circumstances. If we can coordinate with the concerned site regarding exact data for each and every trip, then we can achieve greater accuracy.
- Underload and Punitive Overload charges have not been taken into account while calculating freight in case of ash transportation by rail. We can consider taking into account RR copy of ash transported by NTPC or any other thermal power plant entity to include approx. underload and punitive overload charges also.
- Prices of portable sheds considered is as per quoted from vendors in different cities in Jharkhand. We can survey through a greater number of vendors to achieve on an average price of the required shed.
- The shed construction site at the edge of ash pond has been considered as per the suitability and current excavation area from ash pond. Due to constraints which were not in our control, we couldn't visit ash pond. If more time is provided, then we can arrange to visit ash pond at different sites to understand the site for installation of portable shed better.

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- The wind direction, soil and other factors hasn't been considered in deciding the area at the edge for shed construction. We need more time and authority to receive all the data regarding different parameters of environment at the ash pond.
- Solar panels have been found to have efficiency reduced due to dust particles. Hence, they would need to have proper cleaning system on periodic basis. More studies are needed to develop such system or panels which can counter the effects of ash dust on solar panels.
- The price of brick manufacturing unit has been taken as per the quoted prices received from different vendors from different cities in Jharkhand. We can survey through a greater number of vendors to achieve on an average price of the required brick manufacturing unit
- The dimension of the shed has been taken as per the feedback received from different vendors from different cities in Jharkhand. We can survey through a greater number of vendors to achieve on an average price of the required brick manufacturing unit
- Exact area of the ash pond isn't available. Due to constraints which were not in our control, we couldn't visit ash pond. If more time is provided, then we can arrange to visit ash pond at different sites to understand the site for installation of portable shed better.
- The area of the ash pond and its different sections have been taken through the satellite image. Due to constraints which were not in our control, we couldn't visit ash pond. If more time is provided, then we can arrange to visit ash pond at different sites to understand the site for installation of portable shed better.
- The payback period achieved for transporting ash via rail using BOXN rakes instead of road is based on some of the available variables quantifiable. As per the scope of the study, it wasn't possible to take into account all the variables and quantify them for arriving at true loss or gain data.

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Mechanical Engineering

Preliminary Prototype and Analysis of a Customized Handle for Winding Machine using Fused Filament Fabrication

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Abstract: *Additive manufacturing transformed the prospect of product development. Customized and individualized product development never be so effortless. In this context, aim here is to develop a preliminary prototype of customized handle for winding machine using in handloom industry. Design of the handle is completed according to the hand anthropometric data of workers. CATIA V5R20 is used for 3D modeling and Analysis. Polylactic Acid (PLA) used as material and Flash Forge Dreamer Additive Manufacturing (AM) machine, which works based Fused Filament Fabrication (FFF) is employed for prototyping. Analysis confirms that the design using PLA material is safe as maximum von Moses stress obtained (6.57 × 104 N/m^2) is less than the yield strength of PLA material (4.9×107 N/m^2).*

Keywords: *Prototype; Customization; Fused Filament Fabrication; Handle; Hand Anthropometry; Additive Manufacturing*

INTRODUCTION

By eliminating tool and reducing wastage of material, Additive Manufacturing (AM) or 3D Printing (3DP) can be considered as one of the most noteworthy development in manufacturing in recent years, which directly prints from Computer Aided Design (CAD) data layer – by – layer [1]. It helps the technology to be a potential player in Industry 4.0 [2]. Fused Filament Fabrication (FFF) or Fused Deposition Modeling (FDM) is an AM technology which usually fabricate the objects layer-by-layer by extruding material through a nozzle [3, 4]. FFF parts can be used in wide variety of applications from unarmed aerial vehicles to 3D Printers [5].

Parry et al. developed a customized crutch grip using 3D scanner, Autodesk Fusion 360, and Stereolithography (SLA) additive manufacturing and recommended that AM is a worthwhile method for fabricating customized Daily Living Aids (DLA) [6]. Additionally, using reverse engineering and FDM additive manufacturing technology, a customized helmet is developed with enhanced comfort. The researchers concluded from the study that the method is suitable for rapid product development and to address the needs of the customer individually [7].

A customized hand orthosis is developed using 3D Scanner and FDM AM machine with a printing time of about 11 hours and lead time of about 1 day, which will be useful for patients [8].In addition to this, individually customized wrist orthosis was designed using the 3D scanned data of a patient and fabricated by employing FDM technology withupper layer of the orthosis was made of ABS and inner layer was made using TPU (Thermoplastic Polyurethane) [9]. TPU has considerable elasticity and research proved that the flexible inner layer increases the comfort of user [9].

Furthermore, customized orthosis is fabricated using Autodesk Inventor 3D modeling software, 3D scanner, MeshLab software for creating an automated algorithm of 3D scan data, and Raise 3D Pro FDM AM machine [10]. The study concluded that Polylactic Acid (PLA) is strong when compared to other materials used such as Acrylonitrile Butadiene Styrene (ABS), High impact Polystyrene (HIPS), and Polyamide 12 (PA12 – nylon)

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[10].Fabrication of customized prosthetic sockets for upper limbs using 3D scanner and FDM process proved the feasibility of fully functional products [11].

Textile industries facing a challenge to deliver more customized products and amalgamation of product, process, and supply chain designs is the feasible to achieve customization in textile industry [12, 13]. At the same time, Chatterjee and Ghosh believed that textile industry can utilize 3DP by exploring its unique capability of manufacturing customized products [14].

From above it can be understood that the research explored the possibility of customized products in various areas including textile industry, especially for fabrics. However, the research is not concentrated on developing customized products for textile machines including for the machines used in handloom industry, which will increase the comfort and productivity of workers. This research proposes a preliminary step towards this. Here, objective is to develop preliminary prototype of a customized handle according to the hand anthropometric data of workers using additive manufacturing technology.

METHODOLOGY

Handle of the winding machine is causing more discomfort based onthe consultation with the workers in a handloom industry situated at Kannur. The reasons for discomfort can be concluded from the discussion as follows:

(i) The machine is operated by female workers. In general, tools and equipments are made with the logic that "one size fits all".

(ii) The handle is made by wood which comparatively has more wight.

(iii) The awkward wrist posture of the workers during the operation.

A. **Materials, Software and Machine used**

Polylactic Acid (PLA) is the material and Flash Forge Dreamer AM machine which works based on FFF technology is used for fabricating the preliminary prototype of the handle. CATIA V5 R20, a Computer Aided Design (CAD) softwareused for modeling the handle according to the hand anthropometric data and CATIA V5R20 Analysis and Simulation, a Computer Aided Engineering (CAE) environment in CATIA is used for stress analysis of the handle.

B. **Hand Anthropometric Data**

Based on the above information, the required hand anthropometric dimensions are identified as palm width (PW) and grip diameter (GD). **Figure 1** shows the winding machine (A) and hand anthropometric data (B and C) collected from workers of selected handloom industry.

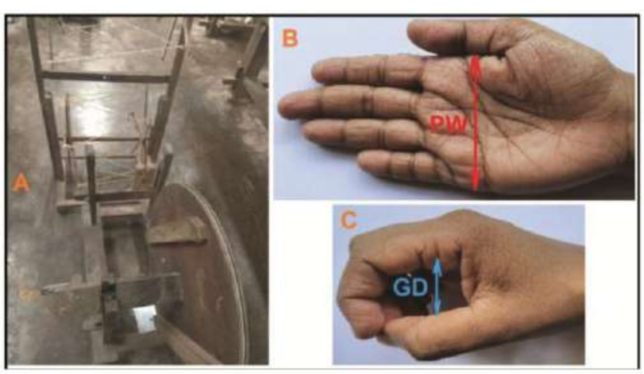

Figure 1 Winding machine using in handloom industry (A), Palm Width (B), and Grip Diameter (C)

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Hand anthropometric data is collected from 65 female workers of handloom industry along with height and are tabulated in the **Table 1**. **Table 1** displayed mean, maximum, and minimum values of the data collected and three designs are proposed to include all the workers within the design and after creating the database, individual design can be printed by exploring the capability of AM technology.

Table 1 Descriptive Statistics of hand anthropometric data

	Height (mm)	Palm Width (mm)	Grip Diameter (mm)
MEAN	1615	76	39
MAXIMUM	1870	86	54
MINIMUM	1400	70	30

C. **CAD Model and Prototyping**

3D CAD model of the customized handle is prepared based on the collected hand anthropometric data. **Figure 2** shows the 2D proposed design and the details of utilization of collected hand anthropometric data in the customized handle. The elbow shaped handle is for making the wrist in a neutral position and thereby increasing the comfort for users.

The CAD models of customized handles with dimensions displayed in **Table 1** is completed using part design in the mechanical design environment of CATIA V5R20 3D modeling software. These are shown in **Figure 3** (A, B, and C). The small diameter part in the handle, shown at the extreme left end in the **Figure 3**, will be inserted into the handwheel. Handwheel is attached to the winding machine and it will be rotated to fulfill the intended function.

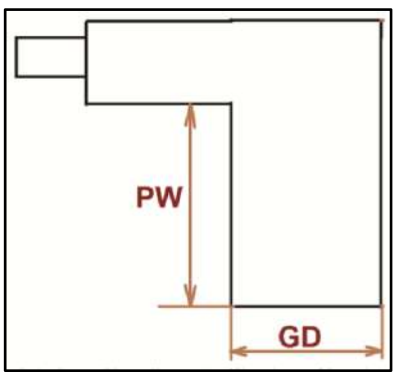

Figure 2 Proposed design of handle and utilization of hand anthropometric data

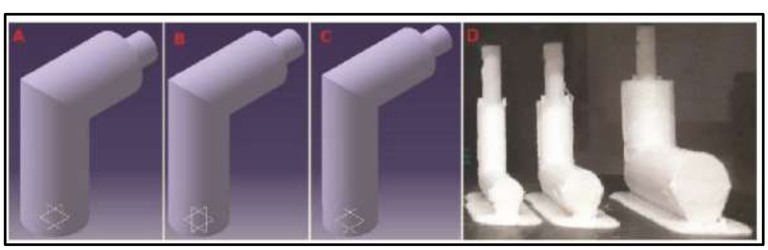

Figure 3 CAD models of customized handles with maximum (A), mean (B), and minimum (C) dimensions and Prototypes of customized handles (D)

The prototyping of the models is completed using FlashForge Dreamer AM machine and material is selected as PLA with a diameter of 1.75 mm and white in colour. The total Build Time taken was 6 hour and 22 minutes. **Figure 3**

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(D) displayed the prototypes with minimum, mean, and maximum hand dimensions in the build chamber of the machine surrounded by support material.

ANALYSIS AND DISCUSSION

The stress analysis of handle is accomplished by generative structural analysis in the analysis and simulation environment of CATIA V5R20.The handle designed according to the minimum hand anthropometric dimensions (palm width = 70 mm and grip diameter = 30 mm) was used for analysis. It was based on the assumption that the handles with median and maximum dimensions will withstand the same load.

The grip force, 336 N, was identified from research by Koley and Melton [15]. The research reported the grip strength of Indian males and females. Highest value of grip strength was selected for the analysis in this project. This force was converted to pressure force as this was acting throughout the handle surface. By dividing by surface area, 6597.34 mm^2, found that 0.051 N/mm^2 will be acting on the entire surface of the handle. When converted to N/m^2, 0.051 N/mm^2will be 51000 N/m^2. This is the value used for analysis and is applied on the handle surface. The properties of PLA are tabulated in the **Table 2**.

Table 2 Properties of PLA

Parameter	Value
Elastic or Young's Modulus	3.6×10^9 N/m^2
Poisson's Ratio	0.3
Yield Strength	4.9×10^7 N/m^2

Figure 4 (A) shows the constraints and pressure force on the surface of the handle and **Figure 4** (B) illustrates the von Mises stress developed on the handle by applying the above-mentioned pressure force on the handle surface. The maximum von Mises stress attained is 6.57×10^4 N/m^2. The design of the handle is validated based on the von Mises stress criterion of failure. This states that the von Mises stress obtained from analysis should be less than the yield strength of the material [16]. Here the maximum von Mises stress obtainedis 6.57×10^4 N/m^2 and yield strength of PLA material is 4.9×10^7 N/m^2 obtained from Matweb 2021 [17]. Obtained maximum von Mises stress is less than the yield strength of PLA. This proved that the design by using PLA material is safe for handles using in winding machine in the handloom industry.

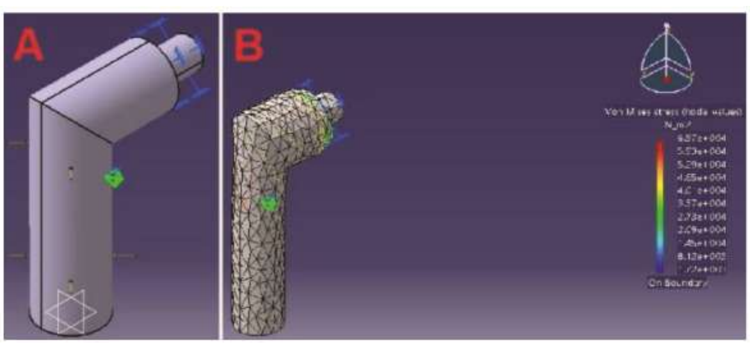

Figure 4 Constraints and pressure applied on the handle (A) and von Mises Stress (B)

When using hand tools, it is necessary to have a neutral arm and wrist posture for improving the comfort of users [18]. The customized design of handles presented in this research considered this aspect. Refer the figure shown in **Figure 5** which illustrated the wrist posture of existing wooden and customized handles (used representative images, not in the real environment). This confirms that customized handles are bringing the wrist in a neutral position and in turn enhance the comfort of workers who uses the winding machine. Another contributing factor to the comfort is the reduced weight of customized handle (PLA) when compared to the wooden handle.

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RECOMMENDATIONS

Design and fabrication of handles based on minimum, mean, and maximum hand anthropometric data are completed. However, individual customization can be done through necessary alterations with respect to individual's palm width and grip diameter in the existing CAD models. By exploring the possibility of AM technology, product can be delivered within a short span of time.

Figure 5 Wrist postures of existing and modified handles

CONCLUSIONS AND LIMITATIONS

A customized handle using for winding machine according to the hand anthropometric data of workers from handloom industry is developed. Palm width and grip diameter of 65 female workers are collected. By adopting AM technology, customized products can be developed within a reasonable time.Similar strategy can be applied to similar hand tools for enhancing comfort of users. Preliminary prototype is developed in this research and the hand anthropometric data can be collected from more workers and the accuracy of data can be enhanced.

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Integration of AI & ML with High-speed Compression Ignition Engine being used on Diesel Locos of Indian Railways

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***Abstract**: India has proved itself to be the major economy having the fastest growth the world over. By 2025, India's target is to the tune of $5 trillion economy. The target is still more challenging due to the Pandemic COVID19 period. Currently, India's GDP is about $2.78 trillion. India's nominal GDP, estimated at about $2.74 trillion in FY20 has presently shrunk to $2.66 trillion in FY21.*

In particular, the focus on “Make in India” are directly influenced by the strength of India's infrastructure. The way India has handled the COVID19 vaccination project indigenously for its 1.3 billion people is commendable and this is in line with the initiative of the Government for “Atmanirbhar Bharat”. The services sector has adversely suffered during Covid-19 pandemic. But the software services sector, an unexpected beneficiary, gained from the pandemic situation is the surging global demand for digital services, reviving client additions, top line growth and most important, hiring. India has certain SDGs mapped by NITI (National Institution for Transforming India) Aayog based on various defined indicators responding to national needs. The Government is committed to ensuring “Sabka Saath, Sabka Vikas, Sabka Vishwas” in the spirit of the Sustainable Development Goals' motto of “Leaving No One Behind”.

Indian Railways is one of the largest networks for train operation and it is the fourth largest in the world. Since Railways are mainly concerned with train operation carrying passengers as well as freight services. As on 1st April 2021, the national rail network consists of 123,542 track km over a defined route of 64689 km with 7,325 stations.

For efficient train operation, Railways have to maintain a large fleet of rolling stocks hence importance of locomotive cannot be ignored.

These mainline diesel electric locomotives have definitely an impact on overall performance of the train operation.

In view of above, the efforts are made to integrate the functioning of high-speed compression ignition engines installed on high horse power locomotives working over Indian railways. This integration has been made possible with the help of Artificial Intelligence (AI) & Machine learning (ML) the latest technological approach. By using this technology, the railways are also capable to maintain punctuality of trains & reduce failures of locomotive to the extent possible.

Internal combustion engines have powered our civilization since the second industrial revolution. Today, Internal combustion engines stand at a critical intersection, seeking immediate breakthrough technologies to produce highpowerand achieving near-zero carbon emissions targets.

Artificial intelligence (AI), particularly with the advances in machine learning (ML) and deep learning, outperforms humans in solving many highly complex real-world problems. In recent years, AI has revolutionized a huge number of disciplines. Internal combustion engine is a complicated system that involves combustion, heat transfer, fluid dynamics, system control, and design, among other mechanisms, and thus provides a perfect yet challenging platform for AI applications. Testing and simulations of engine operations generate a huge amount of data that can

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be utilized to train AI models. Meanwhile, applications of AI models in model development, engine design/optimization, and control are still in their growing up stage. Interdisciplinary research on AI for internal combustion engines is needed to close this gap.

Here the emphasis is laid on the introduction of Microprocessor based Locomotive Control System along with the MCBG /Microcontroller based governor which not only reduces /avoids engine failure but increases the operational efficiency of the locomotives in actual service.

***Keywords**: Artificial Intelligence; Machine Learning; SDGs; Heat Transfer; Fluid Dynamics; Microprocessor; MCBG; Efficiency; Engine Failures*

INTRODUCTION

Before going ahead, it would be better to throw some light on Artificial intelligence.

Artificial Intelligence

Basically, artificial intelligence is the broad science of imitating human abilities, machine learning is a specific subset of AI that trains a machine how to learn.AI focusses with a promise of genuine human to machine interaction. When machine behaves like an intelligent person, request can be easily understood, data points connected easily and conclusions can be judiciously drawn. It can reason, observe & plan. We are at a new level of cognition in the AI field that has taken birth to be truly fruitful in our lives.

In other words, Artificial intelligence is a field of computer science which makes a computer system that can imitate human intelligence. AI system need not be pre-programmed. On the basis of capabilities, it can be further sub-divided into three types:

- Weak AI
- General AI
- Strong AI

Presently, AI has a great focus on various disciplines. The future of AI is strong. It is said that strong AI will be intelligent than humans.

Intelligent machines, can be created with a larger concept of AI, that can stimulate human capability, thinking and behaviour, whereas, ML is an application of AI which allows machines to learn from data without being absolutely programmed.

AI, ML & deep learning are corelated and are integrated at some level. The field of AI has a long history having with military science & statistics, along with contributions from psychology, philosophy, maths & cognitive science. AI initially set out to make computers more beneficial and capable of independent reasoning.

AI has originated from the Dartmouth Research project in 1956 that has explored the topics like solving problems and symbolic methods. The defence department of U.S had taken keen initiative (during 1960s) in this type of work and increased the focus on training computers in order to imitate reasonings of human beings., Defence Advanced Research Projects Agency (DARPA) completed street mapping projects in 1970s and produced intelligent personal assistants in 2003, long before Google, Amazon or Microsoft tackled similar projects in this area.

It has paved the route for the present automation and formal reasoning that we all observe in computers in this modern world. AI is on the path of changing the world. Actually, it already has our ability to consume and act on data is because of advancement in computing, complex algorithms and intelligent analytical output.

Machine Learning

It is about extraction of knowledge from the data. It can be defined as,

“Machine learning is a subfield of AI, that makes the machines possible to learn from past data or experiences without being absolutely programmed”.

Machine learning makes a computer system possible to make predictions for taking some decisions using historical data without being absolutely programmed. A large amount of structured and semi-structured data is used so that a machine learning model can generate accurate result or confirm the actual output based on that data.

Machine learning works on algorithm and uses her own historical data to learn. It works only for specific domains such as if we are creating a machine learning model to detect pictures of dogs, it will only give result for dog images, but if a new data is provided like image of a cat, then it will become unresponsive. Machine learning is being used in various places such as for online recommender system, for Google search algorithms, Facebook Auto friend tagging suggestion, Email spam filter etc.

It can be divided into three types:

- Supervised learning
- Reinforcement learning
- Unsupervised learning

Difference between AI & ML

S.No	Artificial Intelligence	Machine learning
1	Artificial intelligence is a technology which enables a machine to simulate human behaviour.	Machine learning is a subset of AI which allows a machine to automatically learn from past data without programming explicitly.
2	The goal of AI is to make a smart computer system like humans to solve complex problems.	The aim of ML is to permit machines to learn from data so that they can give correct output.
3	In AI, we make intelligent systems to perform any task like a human	In ML, we teach machines with data to perform a particular task and give an accurate result.
4	Machine learning and deep learning are the two main subsets of AI	Deep learning is a main subset of machine learning.
5	AI has a very wide range of scope.	Machine learning has a limited scope.
6	AI is working to create an intelligent system which can perform various complex tasks.	Machine learning system is meant to create machines which can perform specific tasks for which they are trained.
7	AI system is concerned about maximizing the chances of success.	ML is specifically concerned about accuracy and patterns.
8	The main applications of AI are Siri, customer support using catboats, Expert System, Online game playing, intelligent humanoid robot, etc.	Machine learning is being used in various places such as for online recommender system, for Facebook Auto friend tagging suggestion, Email spam filter, Google search algorithms, etc.
9	On the basis of capabilities, AI can be divided into three types, which are, Weak AI, General AI, and Strong AI.	It is of three kinds e.g.; Reinforcement learning, Supervised learning, Unsupervised learning etc.
10	It includes learning, reasoning, and self-correction.	In case of new data, it only includes learning and self-correction.
11	AI completely deals with Structured, semi-structured, and unstructured data	Machine learning deals with Structured and semi-structured data.

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Internal Combustion Engines

Internal combustion engines have powered on human interface since the second industrial revolution. Presently I.C Engines are near critical path and there is an immediate requirement of specialised technologies to produce HHP in addition to fulfil the near Zero carbon emissions targets. It is one of the biggest challenges for the engine industry around the world.

Artificial intelligence (AI), particularly with the advances in machine learning and deep learning, out-performs humans in solving many highly complex real-world problems as indicated above. The Internal combustion engines is a complicated system that involves fluid dynamics, combustion, heat transfer, catalysis, system control, and design, among other mechanisms, and thus provides a perfect yet challenging platform for AI applications. Testing and simulations of engine operations have generated a large amount of data that can be utilized to train AI models. Focus on the applications of AI in the field of internal combustion engines are of prime importance which include, but are not limited to:

- AI in engine design, including the combustion system, fuel and lubricant system, and after treatment system
- Development of data-driven operational performance for Internal combustion engines
- AI in fuel injection & heat transfer, etc
- AI in optimizations of internal combustion engines
- AI in engine speed control & other important aspects.

Micro Controller-based Governor MEG -601 [MCBG]

MCBG-MEG-601 has been developed conforming to RDSO Spec. No. MP.0.17.00.01 dated March 2002 (Rev-01) amendment 02 (June 2002).

Salient features of MCBG are enumerated as follows;

- The basic function of the governor is to control the speed of engine based on corresponding handle position (Notch) of the throttle. A micro controller-controlled DC stepper motor is used to control the fuel rack of diesel engine of the locomotive through a control linkage.
- A second function is load control through an interface with E-type excitation system, for maintaining a pre-set constant horsepower at each notch.
- The equipment also maintains air manifold pressure (air inlet pressure) bias fuel limiting to maintain air: fuel ratio.
- Third function is low lube oil pressure shut down. It is done through an OPS (oil pressure switch). OPS is set for drop out & pic up pressures.
- Necessary provision for reduction of excitation during wheel slip is also incorporated which can be done through user settable parameters.

Vacuum Fluorescent Display (VFD) is continuously used to display status of various engine parameters. Configurations of system through user settable parameters and reading of error log can be managed on line on the locomotive itself by using a laptop PC, even while the engine is running. The equipment is modular in construction and it has functionally separated plug-in modules for ease of servicing.

MCBG consists of two sub-assemblies namely:

(i) Control Unit (ii) Actuator Unit.

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Control Unit

It is mounted on the short hood side wall just below the existing location of lube oil, fuel oil & booster air pressure gauges in the driver's cabin, or any other suitable location as per design features of loco. Control unit accommodates all necessary electronic circuits for functioning of governor. Plug in modules of control unit are as under,

(a) Control Card

It is consisting of a 16-bit micro controller; its peripheral ICs and necessary system software for governor control. All other cards in the system are integrated with control card.

(b) Input Card

Utilized for monitoring,

- Engine speed signal from tacho generator.
- Position & pressure signals from the actuator unit.
- Notch input signals from throttle handle.
- All other high voltage input signals.

All the input signals are optically isolated surge protected and reverse polarity protected.

(c) Motor Control Card

It drives the stepper motor in actuator unit. Two identical cards are being used for this purpose.

(d) Load & Clutch Control

Meant for driving the clutch in the actuator unit and it also provides excitation voltage output for load control through an interface with E-type excitation system.

(e) Display Control Card

Main attribute of the card is to display the data on Vacuum Fluorescent Display in 20-character x 4 line receivedfrom micro controller. The card has its own micro controller to communicate with control card through serial communication.

(f) Power Supply Card

This card is suitable for converting 72 V locomotive battery voltage to different low voltage supplies required by the system. Switches for various functions like over speed test, Reset/start operation & booster air pressure bypass.

Actuator Unit

Location of Actuator Unit is exactly on the same engine base as in case of already existing mechanical Governors.

- The Governor controls the engine speed, based on throttle handle position (known as notch), position of notches is controlled & selected by the Loco pilot on the control Desk.
- Tachogenerator or speed sensor is mounted on the Engine to indicate relevant engine RPM.

  Digital PID* control is used to calculate desired fuel rack position dynamically, based on the selected notch on throttle handle and measured Engine RPM.

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[*A PID controller is an instrument used in industrial control applications to regulate temperature, flow, pressure, speed and other process variables. PID (proportional integral derivative) controllers use a control loop feedback mechanism to control process variables and are the most accurate and stable controller. PID control uses closed-loop control feedback to keep the actual output from a process as close to the target or setpoint output as possible.]

- Fuel rack of Diesel Engine is controlled by a stepper motor drive equipped in the actuator unit. Load on the engine is controlled by the governor electrically through an electrical interface with the excitation system of Locomotive. Thus H.P at each notch is monitored at a pre set level.
- A pressure sensor is mounted in the air manifold for measurement of booster (Turbo) air pressure. Movement of fuel rack is limited as a function of this pressure to prevent incomplete combustion of fuel, black smoke, excessive engine temperature, fuel wastage etc caused by lack of air to burn the fuel.
- Monitoring of engine lube oil pressure is continuously ensured. If the lube oil pressure is less than the specified pressure at each notch, engine is automatically shut down. Thus, consequential damages to the engine, due to malfunction of lube oil pump, are avoided.
- Vacuum Fluorescent Display continuously shows the status of various engine parameters.
- Built in fault diagnostic facility takes appropriate action immediately and displays relevant fault message on the display board for information to the loco pilot. It also records the fault with date and time stamp, to help the maintenance crew /staff later for analysis of the root cause.
- The Governor has number of user programmable parameters, which permits the system to be used on various types of engines/locomotives.
- Configuration of the system through user settable parameters for fine tuning of operation and reading fault messages of Error Log can be done, on-line on the locomotive, using a laptop PC, even while the engine is running.
- The equipment is modular in construction and has functionally separated plug-in modules for ease of repair and maintenance.

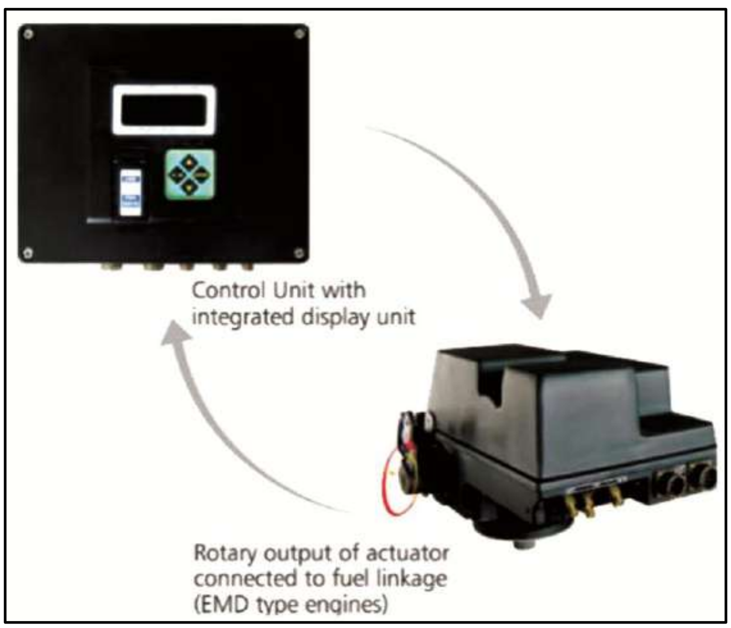

Figure 1 Rotary output of actuator connected to fuel linkage (for EMD Locomotives)

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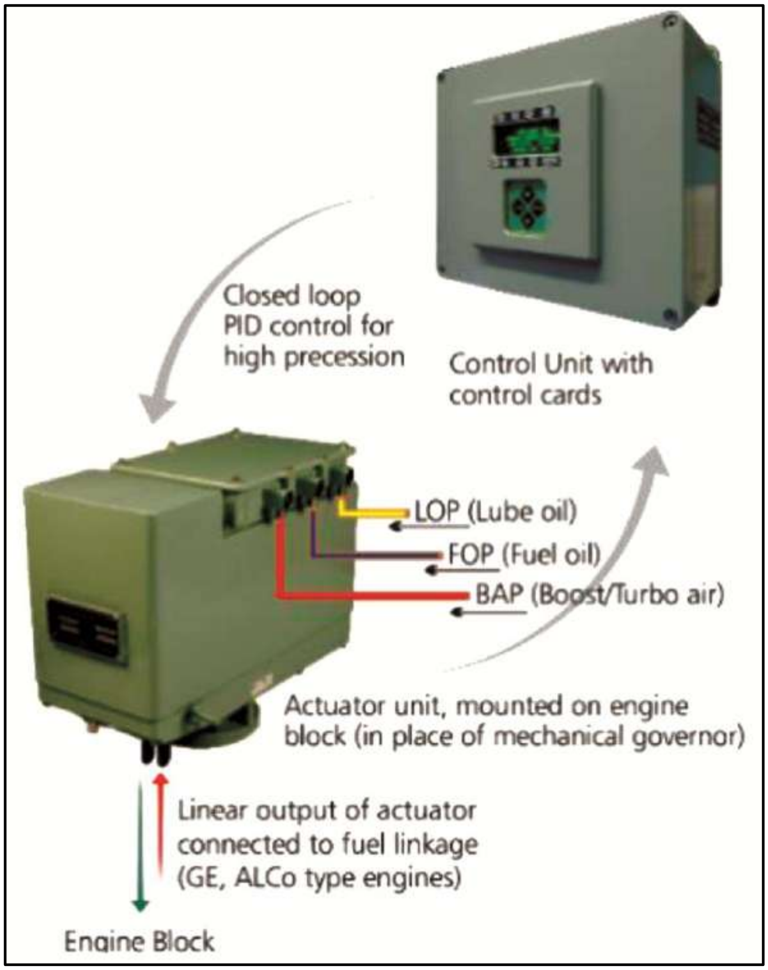

Figure 2 Linear output of actuator connected to fuel linkage (for GE/Alco type Locomotives)

Principle of Operation

The micro controller in control unit continuously measures the frequency signal from the existing Tacho- generator on loco.

(a) Engine RPM is calculated from this frequency signal. Desired engine RPM is determined from the selected notch on throttle handle. Comparing these two RPMs in a PID control loop the micro controller drives fuel rack of the engine through the actuator unit, so as to adjust the engine RPM equal to the set RPM for the given notch. PID parameters can optimised for each class of engines through user settable parameters using a laptop PC, so as to maintain stable engine RPM free from hunting.

(b) B.A. P is measured through a pressure sensor to limit the movement of fuel rack as a function of BAP.Thus supply of fuel to engine proportional to available air pressure is ensured which is helpful in preventing,

(i) Incomplete combustion

(ii) Smoky exhaust gases

(iii) Excessive engine temperature

(iv) Fuel wastage.

A toggle switch is equipped on control unit to bypass this feature. In case of bypass, speed variation between different notches is linearly based on acceleration and retardation rates specified in user settable parameters.

(c) Load control output is provided to maintain constant horse power output of the engine at each notch. Load control js done by changing the generator field excitation, from maximum to minimum or vice versa at a rate specified in user suitable parameters. BAP linked load control facility is also available.

(d) Lube Oil Pressure (L.O.P) is continuously monitored. Provision of sensing wheel slip and reduction of excitation to minimum is available which may be managed through a user settable parameter.

(e) Over Speed Trip assembly:

A 3- position key switch is provided to ensure testing of over speed trip.

Ist position on key switch: Selects a built-in feature of MCBG to test electronic overspeed trip RPM< mechanical OST.

In this case engine RPM is gradually increased above 8^{th} notch RPM, when engine RPM reaches a set RPM for electronic OST, the system shuts down the engine with proper display.

Second Position: Selects Mechanical OST where governor gradually increases engine RPM to maximum set limit and waits for a specified time. By this time mechanical OST device should operate & trip, even if it does not trip due to any reason- engine RPM reduces to idle. Display further indicates whether the test was successful/fail or needs adjustment.

(f) In addition to above, actuator unit is equipped with an electromagnetic clutch, which turns off automatically during loss of power and fuel rack is brought to no fuel position. It also gets deactivated in case of malfunctioning of the system. This will close fuel rack and engine will shut down.

A built-in fault diagnostic system continuously monitors the health of various peripherals.

In case of major faults, the engine is shut down automatically and displayed on display board with message. Fault is registered with time & date in error log for further maintenance /servicing. This aspect is of vital importance for preventing the engine with heavy detrimental damages.

User Settable Parameters

Different parameters of the MCBG are user settable by using a laptop computer. The software displays the range and default value for any parameter that is selected for any minor modification. These values differ from loco to loco depending on the design features. Laptop interfaces with MCBG through an RS 232 serial port. These parameters can be set while the engine is running, which is very useful for initial turning of engine. List of parameters that are user settable is as follows;

- Notch wise engine speed.
- Notch wise minimum LOP for loco shut down.
- Maximum permissible fuel rack at each notch.
- Fuel rack limit- BAP wise
- Setting of OST RPM
- Rates of engine acceleration & deacceleration.
- Load control minimum and maximum voltage & responsive time.

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- Fuel rack position for cranking.
- Misc. parameters e.g., wheel slip sense enable &BAP linked load control enable etc.

Merits of MCBG

- Control of engine RPM without hunting.
- Effective control for complete combustion of fuel, improvement in fuel efficiency and reducing pollution.
- Load control interface with excitation system for constant horse power control.
- User settable engine parameters for optimizing performance for different class of locomotive as per design features.
- 16-bit micro controller-based design.
- Use of stepper motor for high precision position control of fuel rack.
- Digital PID control, requires no adjustment throughout its life & no potentiometer settings involved.
- Continuous display of engine status parameters.
- Online fault diagnostics and fault message display.
- Error log with date & time stamp.
- User settable RPM & LOPs levels for each notch.
- Functional plug-in modules for ease of maintenance /service.
- Electronic & mechanical OST RPM setting through key lock switch.
- Fail safe shutting down of engine in case of any major malfunctioning of the equipment.
- Regular maintenance is not required however some schedules have been recommended for control & actuator unit for improved performance of the system.

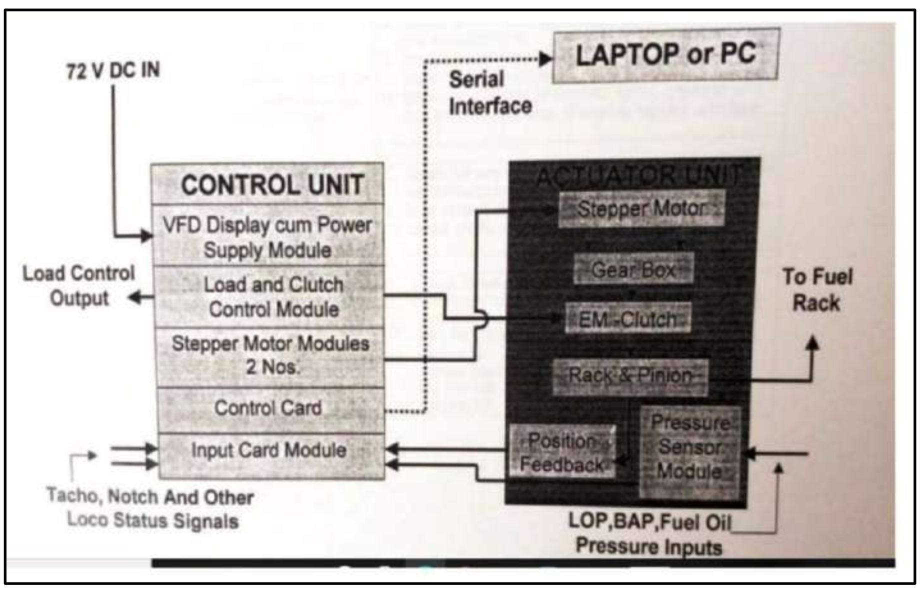

Figure 3 System block diagram

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Maintenance Schedule of MCBG

Sch.	Control Unit	Actuator Unit
Trip (20 days)	1.Check & ensure tightness of couplers available on back panel of control unit. 2.Visual inspection of wire shoes & connections on MCBG terminal board at CP backside for any looser disconnected wires. Ensure tightness of these connections as normal procedure.	1. Check & ensure tightness of couplers provided on the actuator unit. 2.Ensure any possible leakage from the pressure sensor pipeline. 3.Ensure availability of external spring provided on fuel control shaft arm, if missing provide new one.
M4	1.Conduct rack calibration test as per the annex-I available in MCBG operation & maintenance manual to ensure free movement of racks. If any racks are found sticky, re-test after lubrication of racks.	1.check for any damage to the rubber bellow provided on the output shaft. 2.If so replace the bellow to avoid dust entry on to the output shaft.
M24	1.Remove, clean and refit the unit. Replace (MCB MB gasket) if found on simulator set up. Damaged.	1.Unload, clean & refit the unit. Replace the following items if found damaged. (i)Actuator main cover gasket (ii)PRS box cover gasket (iii)Bellow AU (iv)Flange gasket (v) AU Mat-GB (vi) AU Mat-RP
M48	1.Remove, clean the control unit. 2.Visually inspect the individual modules for any damaged components. 3.Replace circuit breaker. 4.Replace gaskets as per companies guide lines. 5.Test the unit along with the actuator on simulator set up.	1.Unload the actuator unit and clean. 2. Check & fill the grease. 3.Clean the clutch plates with thin cloth soaked with isopropyl alcohol. 4.Replace the gasket as per standard practice. 5.Check calibration of pressure sensors. Replace sensors if damaged /deviated.
M96	1.Replace all interconnecting cables with couplers and loco connecting cables. 2.Replace all pressure sensors. 3. Replace OSTA test key assembly. 4.Replace all push buttons (Reset/Start and Acknowledge.)	
NOTE: (a) Schedule attention listed here is telescopic type hence all lower schedules have to be followed along with a higher sch. (b)I case of any control unit and actuator unit are interchanged, auto fuel rack sensor calibration has to be carried out as per procedure laid down in governor maintenance manual for efficient control of fuel racks. (C)M2 & M12 Sch. Are not shown as these are covered with next higher schedules.		

MICROPROCESSOR CONTROLLER UNIT

Medha's* Microprocessor based Loco Control System Type MEP 660 (Proprietary item of M/s Medha) being usedfor controlling diesel electric locomotives. This is an alternative to the E-type excitation system being used on WDM3 & other types of locomotives working over IR. This system is equipped for Excitation Control, Propulsion Control, Dynamic Braking Control, Wheel Slip Control, and Auxiliary Generator Control with digital PID controls.

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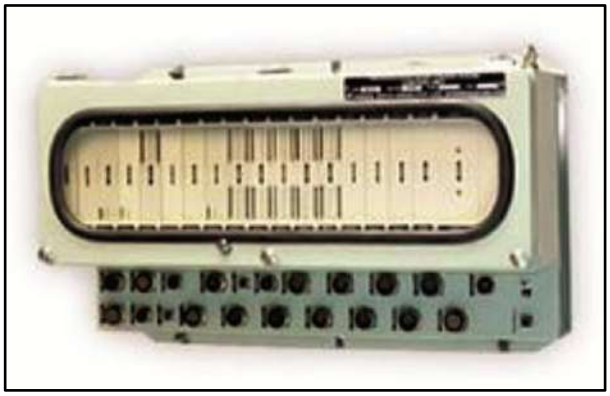

Pic 1 MEP660- Display

**Medha Servo Drives Pvt. Ltd. is focused on rail transportation. It is known for the product range, domain knowledge, design expertise, and manufacturing capabilities. Medha has proved to be a world leader in railway products and it has specialised in three areas, Control Electronics, Power Electronics and safety critical Signalling. They have designed and manufactured various high-tech electronics products for application on locomotives, coaches, railway stations and yards. Medha R&D Centre has all the infrastructure required for developing sophisticated products*

Microprocessor MEP- 660 (Ver2.0) WDM3A & WDM3G Locomotives

Microprocessor based control system have been introduced on Diesel Electric Locomotives.

Microprocessor Technology is new to our engineers/operating staff and, therefore, it is necessary that proper knowledge about troubles which everyone faces during service of locomotives should be disseminated properly.

Microprocessor Control System is the vital part of Diesel electric locomotive. The system is recently introduced on Indian Railways for ensuring higher reliability & better availability of locomotives.

Proper knowledge of system and troubleshooting is necessary to ensure reliability & availability of locomotive in sheds as well as on line.

Introduction of Excitation Control System

Excitation control system regulates the exciter field current through a transistor switch operated by the pulse width modulator basically a magnetic amplifier. The average current is decided by 'ON' to 'OF' ratio of PWM which is controlled by the mixer reference network basically a resister network with two saturable reactors and rectifiers. The mixer reference network receives proportionate feedback signals from TA voltage, TA current and engine speed. Based on the input signal levels, it sends a controlling signal to PWM, which controls the exciter field current and its output. The exciter output is directly connected to alternator field through GF contactor which is again controlled by propulsion control system. The traction alternator power is controlled to the required constant horse power at each notch.

INTRODUCTION OF MICROPROCESSOR BASED CONTROL SYSTEM (VER2.0) FOR WDM3A/WDM3G LOCOMOTIVES

The MEP-660 is a complete locomotive control system consisting of engine cranking, loco propulsion control, excitation control., auxiliary generator control & continuous monitoring of safety devices on the locomotives. Some of the improved features are the self-load test of the locomotives and inbuilt event recorder designed and developed as per RDSO specifications. MEP-660 loco control system is designed to replace the existing propulsion & E-type

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Excitation system. MEP-660 control system eliminates mechanical interlocking (sequential /timing) and uses microprocessor to control the locomotive through software logic.

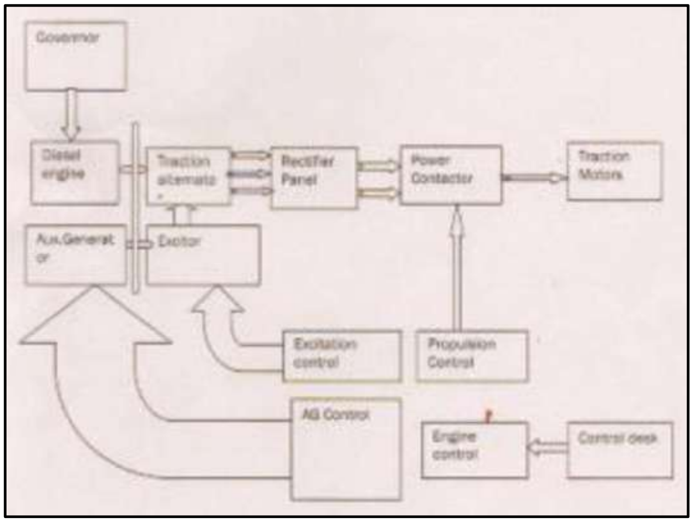

Figure 4 Excitation control system

Salient Features of Microprocessor Based control system (MBCS)

(a) Fault Diagnostics: Microprocessor based system has the fault diagnostics capabilities. The system continuously monitors various operational parameters and checks for abnormalities in the functioning of various traction equipment.

The fault is displayed on the display unit along with restrictions imposed because of the fault, for information of the loco pilot. Fault code along with real time & date stamp is logged in the Error Log Memory.

(b) Self-Diagnostics: This system keeps on monitoring its own modules and sensors, continuously for their healthiness.

(c) Fault Tolerance: Fault tolerance capabilities are existing in this system for certain faults. In such cases the operation of the locomotive continues in the normal way and the fault is logged in error log with data pack for later analysis.

(d) Automatic fault recovery

(e) Short Term rating of traction motors

(f) Self-test to digital input and output

(g) Self: Load Box test

(h) Event Recorder

(I) In the short-term memory - Various data are recorded in one second interval and latest 45 hrs data is available at any time to download.

(II) In the long-term memory - Only speed and distance along with date and time are recorded in 20 secs interval and Latest 225 days data is available at any time to download.

(i) Multi reset vigilance control device.

(j) Auto flasher light.

(k) Auto emergency brake system.

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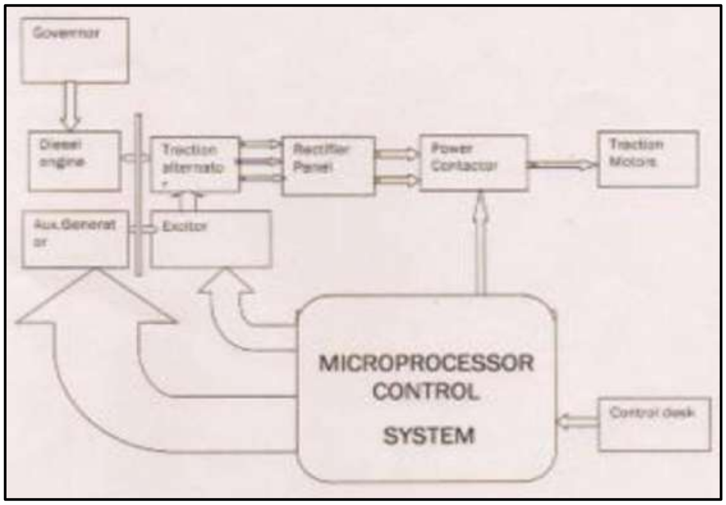

Figure 5 Microprocessor based control system

Additional Features

1. Engine shuts down with failure of Crankcase breaker.
2. Limitation of power to 4th Notch with failure of RBB or Diode HOT.
3. Power de-ration from T3 Setting to T4 Setting (90 to 95° C): The engine power is derated by 20% of the notch power for every degree raised from 90° onwards.
4. 8th Notch RPM at Hottest Temperature: Engine RPMs are raised to 8th notch automatically by cutting of power for faster cooling of engine in case the engine reaches to T4 setting (95°C).
5. Low Idle Feature: When the locomotive is in Idle for more than 10 minutes, the engine RPM is reduced to 350 for reducing the fuel oil consumption.

Pic 2 Diesel Locomotive

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Brief Details of Engine

Alco 251-C, 16 cylinder, 3,300 hp (2,500 kW) (2,430 hp or 1,810 kW site rating) with GE/ABB turbo supercharged engine. 1,050 rpm max, 400 rpm idle; 228 mm × 266 mm (8.98 in × 10.47 in) bore x stroke; compression ratio 12.5:1. Direct fuel injection, centrifugal pump cooling system (2,457 L/min (540 imp gal/min; 649 US gal/min) at 1,000 rpm), fan driven by eddy current clutch (86 hp or 64 kW at 1,000 rpm)

Conclusion: Thus, it is concluded that there is definitely the application of AI & ML with close integration with Microprocessor control based locomotive and Micro controller based governor with modified high horse power (HHP) turbo-superchargers because these system definitely contribute in reducing fuel consumption, maintaining proper air: fuel ratio, avoiding severe damages to engine power pack due to operation of over speed trip assy. electronically or otherwise by mechanical means, reducing exhaust emission by controlling incomplete combustion. These microprocessors governors & microprocessor control-based locomotive are supported by the design consideration and following points,

Durability, reliability and fuel economy(i.e specific fuel consumption) are the main considerations that limit the degree of supercharging of an engine.

- Because of the excessive heat generation and heat transfer,the valve overlap is usually designed greater in supercharged engines . The valve overlap may vary from approximately 80° to 160° of crank travel.
- Increased valve overlap permits greater time during which cooler air will flow past the valves and the piston crown. This cools the exhaust valve seat , the exhaust valves and the piston crown.Thus the thermal loading of cylinder head valves, valve seat & the piston crown is reduced to the extent possible.
- When inlet air is compressed, it becomes hot. When air charge leaves the compressor, it is at much higher temperature than ambient air. During supercharging, the temperature of air increases from 60° to 95° C. When air is heated, it expands and thereby density reduces. Because of this the mass of air entering the cylinder becomes lesser. This reduces availabilty of oxygen in the cylinder for combustion.Further supply of hot air to engine may increase engine operating temperature. As such charge is cooled by way of aftercooling to overcome this problem. In double discharge turbo of GE make, two aftercoolers are provided for cooling the charged air. However, it adds to the complexity of the system. It has been proved that HHP locomotives engines are having improved BAP by 46.8 % say 47 % or more aas compared to conventioinal TSCs of ALCO make.

The turbocharger may also be used to increase fuel efficiency without any attempt to increase power. It does this by recovering waste energy in the exhaust and feeding it back into the engine intake. By using this otherwise waste energy to increase the mass of air it becomnes easier to ensure that all fuel is burnt before being vented at the start of the exhaust stage.

The power of the engine can be increased by increasing the mean effctive pressure, this is being done by turbocharging.

- Volumetric efficiency of the engine is increased by 1.5% using turbochargiung compared to natural aspiration.
- Mechanical efficiency of the engine is increased by 12 % using turbocharger as compared to natural aspiration. Specific fuel consumption can be reduced by .020 Kg/KWH by providing turbocharging compared to natural aspiration.
- Turbocharging is economically better than the natural aspiration, because turbocharger can be driven by utilizing the exhaust gases. Air : fuel ratio is high in turbocharging as compared to natural aspiration. Diesel knocking is reduced by providing TSC. All the aboce parameters can be improved by extensive research in the relevant field.
- Design of turbosupercharger is basically based on following performance parameters

  (i) Increased gas loading and thermal stresses, enhanced booster air pressure.

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(ii) Durability, reliability anf fuel economy (i.e specific fuel consumption) .

(iii) The valve overlap may vary from approximately 80° to 160° of crank travel. Thermal loading of cylinder head valves, valve seat & the piston crown is reduced to the extent possible.

(iv) During supercharging, the temperature of air increases from 60° to 95° C.

(v) Reduced exhaust emission, better torque characteristics, tractive effort is iomproved.

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Comparison of Properties of SA213 T12 Tube Weldments by GTAW, ATIG, P-GMAW and Alternating Shielding Gas GMAW

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Abstract: *The composition Sa213 T12 chrome moly alloy steel Tubes make it ideal for use in power plants, refineries, Petro-chemical plants, and oil field services where fluids and gases are transported at extremely high temperatures and pressures. These tubes offer the advantages like Consistent Workability, Preferred Fabrication and better Mechanical Properties. These tubes are often used in the water wall tubes, reheater tubes and super heater tubes of super critical and ultra-super critical boilers. Conventionally, Pulsed Gas Metal Arc Welding (P-GMAW) and Gas Tungsten Arc Welding (GTAW) processes are used to join these tubes. Activated TIG (ATIG) and Alternating Shielding Gas GMAW (A – GMAW) are the emerging processes for higher quality and productivity. This paper compares the properties of weldments of SA213 T12 tubes welded by the above processes.*

Keywords: *T12; P GMAW; ATIG; GMAW; Alternating Shielding Gas; Power Plants*

INTRODUCTION

SA213 T12, the ferritic and austenitic alloy steel tubes are widely used in water walls, reheaters, heat exchangers, and condensers of power plants, marine application, refineries, paper pulping, petrochemical applications, pressure vessels and general engineering applications.

For boiler applications, these tubes are welded with Pulsed GMAW (P-GMAW) and Gas Tungsten Arc Welding (GTAW) processes to meet the requirements of higher quality and productivity. Activated TIG (ATIG) and GMAW with Alternate Shielding Gas (A-GMAW) are the new high productive processes with improved quality, reduced processing time, savings in energy and consumables, reduced arc time weldment, etc.

Butt joining of the tubes were carried out with optimized parameters and the mechanical and metallurgical properties are compared.

A. Alternating Shielding Gas GMAW (A-GMAW)

The operating point in GMAW process depends on the shielding gas used; besides the wire feed speed [current] and voltage settings [1]. However, the stable operating point for each shielding gas viz. Argon and CO_2 is located differently on the parametric window. By use of alternating shielding gases wherein two different shielding gases are alternatingly supplied to the torch for effectively protecting the weld pool from the atmospheric contamination. The arc dynamics changes alternately in tune with the alternating shielding gas supply. The frequently changing arc dynamics positively influences the weld pool thereby the incidence of defects like porosity and crack are decreased. Besides, it also results in improved weld metal mechanical properties in steel. Other factors such as flat bead profile

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and smooth weld metal transfer are considered to be beneficial aspects of gas pulsing in GMAW process. GMAW with alternating shielding gases is characterized by the switching of the transfer mode from spray to short circuiting type, which produces reliable fusion and penetration. Gas pulsing frequency and procedures have to be established to meet the quality requirements of tube butt joints. **Figure 1** shows the Principle of operation of Alternating Shielding gases GMAW.

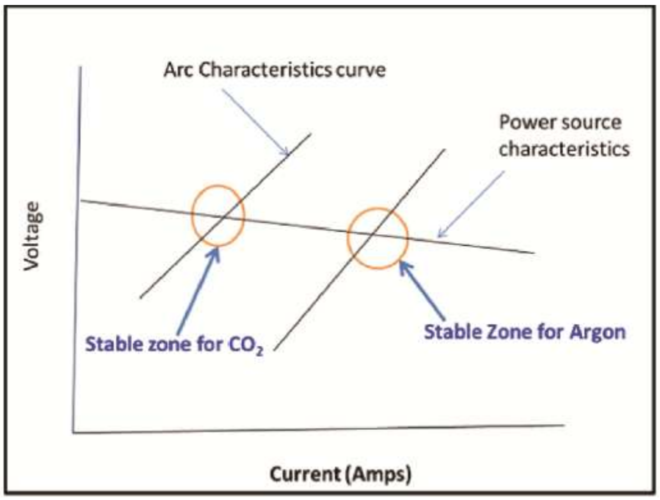

Figure 1 Principle of Operation of Alternating Shielding gases GMAW [1]

B. Activated TIG (ATIG)

The increased weld penetration in ATIG welding is attributed to reverse Marangoni effect. Marangoni effect is one of the penetration mechanisms which refer to the convective flow within the weld pool due to the surface tension gradient on weld pool surface. During TIG welding the surface tension gradient is negative and the convection movements are centrifugal leading to shallow penetration. The addition of activated flux induces an inversion of the convection currents changing the sign of the surface tension gradient, resulting convection movements changed to centripetal. Hence, the penetration depth increases [2].

EXPERIMENTAL WORK

The SA 213 T 12 tubes have been edge prepared by the facility available as per the requirement. Square butt edge preparation was carried out for TIG process and for other processes 70°V groove.

Number of experiments to optimize the parameters and the optimized parameters were used for welding trials. Preheating has been done as per requirement using LP gas before welding. After welding, the samples were subjected to Post Weld Heat Treatment (PWHT) also as per ASME code requirement. After PWHT, the joints were subjected to Radiographic Tests (RT). Transverse tensile and impact specimens have been extracted from the welded tubes and tested as per AWS standard. Microstructural studies have been observed in the base metal and weld metals. During welding of samples, the voltage and current waveforms were also recorded by using Analysator Hannover.

The surfaces of the tubes to be joined are cleaned to remove oxide films, oil coatings, etc. prior to welding. Día 0.8 mm ER 80 S B2 filler wire was used for all welding trials.

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Welded joints with GTAW process were carried out in orbital GTAW machines using Dia. 54 × 4 mm SA213 T12 tubes with 100% argon as shielding gas. The welding was completed in 3 passes.

Welding trials with P-GMAW process were carried out in the automated tube butt welding machines using Dia. 57.15 × 14.3 mm tubes with 95% argon and 5% CO_2 mixed gas, as shielding gas. The welding was completed in 5 passes.

C. ATIG Processes

After ensuring, right fit up of the square edge prepared tube joints, the activated flux paste (mixture prepared with flux powder and acetone) was applied on the joint area by using a smooth brush. The flux that was applied had major elements such as Silica, Titanium, Al, Fe, Calcium, Manganese, Nickel, Chromium and Copper. On applying the flux on the joint area, shielding gas, suitable welding current, welding voltage, welding speed, wire feed rate, gas flow rate, torch angle, torch position, polarity were set appropriate so that full penetration is obtained in a single pass.

D. Alternating Shielding Gas GMAW (A-GMAW)

Dia. 57.15 × 14.3 mm SA213 tubes were welded by using alternating shield gas GMAW process. The shielding gases argon and CO_2 are alternatingly fed into the weld pool through the gas alternator at the frequency of 0.02 sec and 0.04 sec respectively.

Figure 2 shows the welding set up for ATIG and A-GMAW processes.

Figure 2 Set up & Weld Joint for A-GMAW process and ATIG processes

RESULTS AND DISCUSSIONS

The mechanical properties of welds deposited by all the four types have been studied and compared.

E. Radiography Test (RT)

The welded samples were subjected to Radiography (RT) test to ensure the soundness of the joint. All the joints met the RT requirement as per ASME.

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F. Tensile Test

The tensile strength of the welds were determined by using UTM 600 kN. The transverse tensile test specimen is prepared as per the standard AWS B 4.0.

Table 1 shows the transverse tensile test results for SA213 T12 tube welds and compared with parent / base Material.

Table 1 Tensile test results

Description	UTS MPa	Position of Fracture
GTAW	474, 481	Base Metal
ATIG	491, 511	Base Metal
P-GMAW	467, 470	Base Metal
A-GMAW	470, 473	Base Metal
Parent Material	415	As per Literature

From **Table 1** it could be observed that the UTS values of all the four methods are above the minimum value of base material i.e., 415 MPa. The UTS values of ATIG welds are much higher than other processes. The A-GMAW also results in better UTS value than P-GMAW.

G. Guided Bend Test

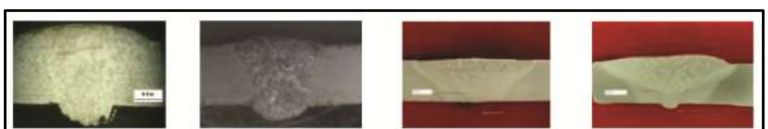
The welds were subjected to guided bend tests and test coupons were prepared as per AWS B 4.0. Both transverse face and root bend tests were carried out for GTAW and ATIG and side bend test for P-GMAW and A-GMAW, to evaluate both the ductility and soundness of the weldments. 180° bend tests with mandrel diameter equal to 4 t were carried out on all welded samples. Both the specifications were tested and the results are tabulated in **Table 2**. All samples passed the test without any discontinuitywhich ensures the ductility of the weld.

Table 2 Guided bend test results

Description	Face	Root	Side
GTAW	Passed	Passed	-
ATIG	Passed	Passed	-
P-GMAW	-	-	Passed
A-GMAW	-	-	Passed

H. Macrograph& HAZ

The macrograph of the joints and with of Heat Affected Zone (HAZ) are compared as detailed below.



A B C D

Figure 3 Macrographs

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Figure 3A shows the bead profile of GTAW, B shows the ATIG profile, C the P-GMAW and D the A-GMAW. Comparing the bead profiles ATIG produces deeper penetration and lesser bead width in single pass. The bead width of gas alternator is also uniform and lesser comparing with P-GMAW and A-GMAW. Further, it could be observed that the width of HAZ is 5.29 mm is for the weld with A-GMAW against 5.56 mm for P-GMAW and this may be due to the low heat input in A-GMAW to the weld pool.

I. Microstructure

The microstructural study was done under the optical microscope under proper illumination condition in the desired region, under 500X magnification for P-GMAW and A-GMAW joints.

The microstructure of base materials, HAZ and weld metal for SA213 T12 tube are shown in **Figure 4**.

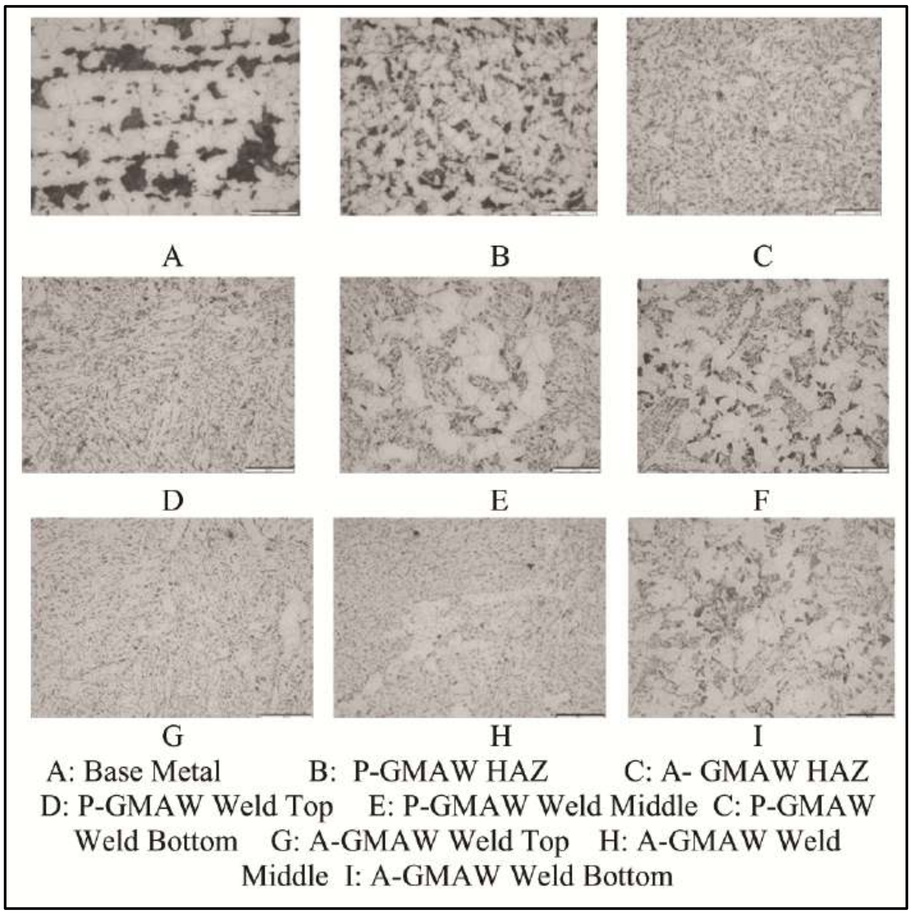

Figure 4 Micrographs of Welds

Equal amount of polygonal ferrite and bainite was seen in base metal. Hard martensitic phase was observed at the HAZ; also prior austenite grain boundary is seen.

It can be seen that the bainite structure is formed at the weld metal region in both gas mixer and gas alternator The coarse polygonal ferrite was noticed together with bainitic phase at middle and bottom of the weld metal of gas mixer when compared to gas alternator.

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J. Arc Characteristics

During the welding trials, the current and voltagesignatures were captured using the Analysator Hannover system, developed by Late Prof. Dr. Ing. Rehfeldt of Germany. The current and voltage transient signatures are shown in **Figure 5** and analyzed.

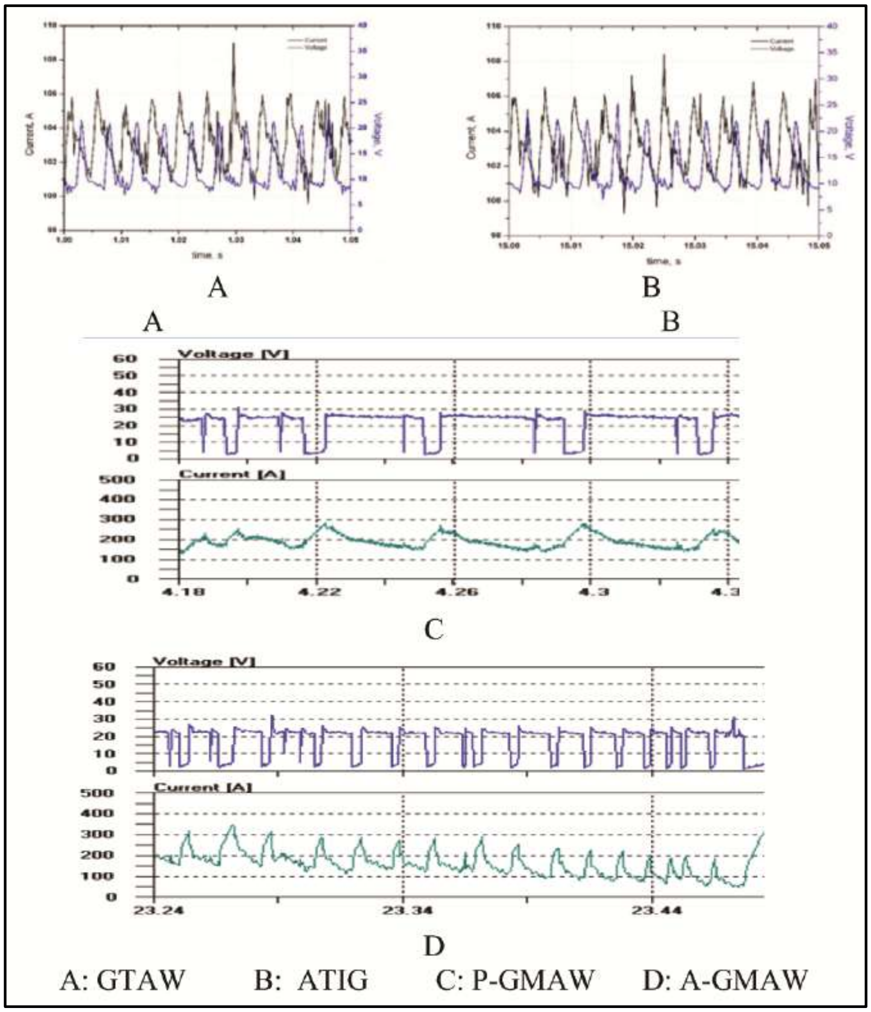

Figure 5 Current & Voltage Characteristics

From **Figure 5** A and B, It will be interesting to note that comparing to GTAW, in ATIG process, the arc voltage increases significantly. Further, the arc voltage is much more stable comparatively.

While comparing **Figure 5** C and D it can be observed that Combination of argon and CO_2 in A-GMAW for a shorter duration generate more pulses which enhance the metal deposition with reduced heat input, also enables to increase the welding speed during welding.

In the case of P-GMAW the occurrence of lesser peak current for a longer duration will drastically increase the instantaneous heat input.

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CONCLUSIONS

The weld metal deposited by all the methods is found to meet all mechanical properties viz. tensile and bend, as per ASME standards. ATIG and A-GMAW produces much better results than conventional processes.

- In ATIG process, the welding has been completed in single pass, whereas in other process it is multipass welds.
- The productivity of tube joints is increased by three times per shift in ATIG welding compared to GTAW method.
- The consumption of power, shielding gas, consumable wire came down to approx. 50% for ATIG.
- The gas consumption in A-GMAW is lesser comparing to P-GMAW.
- The current and voltage signature analysis proves that ATIG process results in more stable voltage.
- The A-GMAW produces more pulses and higher peak current which enable the process to increase the speed as well with reduced heat input.
- The bead profile of ATIG and A-GMAW are better than GTAW and P-GMAW.
- The microstructure of A-GMAW is better than P-GMAW.

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Contribution of Engineers in Reaching $5trilion Economy

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***Abstract**: Contribution of engineers in creating the nation's GDP is key to the technology centric activities of all sectors of economy in rapidly changing world economic scenarios. The VUCA world situations in the recent conditions created by onslaught of pandemic has made the this aspect more significant. Indian economy is no exception to this as economy is growing at a rapid pace with the policy impetus to the economic environment as envisioned by the government. Actualization of the policies into the real world economic scenarios to achieve the targeted results through the engineering skills and technological efforts are entrusted to the engineers of the nation. The opportunities available for contribution by the engineers in the three main sectors of the economy in the current economic environment is discussed in this paper. Engineering innovation to the existing practices and technological up gradation potential in the identified sectors are enormous for bringing the Gross Value Addition n the short period of time ahead. The present work identifies key drivers for GDP growth, includes critical analysis of sector wise financial investments that have impact on value addition and introduces scope on possible technological developmental strategies further implementation.*

***Keywords:** Productivity; Innovation; Technology*.

INTRODUCTION

India has set a ambitious goal to become USD 5 Trillion economy by the end of FY2025 and envisioned to become third largest economy in the world. The Government has several ongoing initiatives across sectors focused on growth and the role of Engineers in achieving these initiatives is significant and challenging after the lockdown imposed halted economic activities to prevent the spread of COVID-19. A faster rate of growth is required to be achieved after relaxation of restrictions imposed in lock downs to overcome the losses happened in output during previous two years. According to the recent trends to achieve the set targets, Engineers as nation builders must contribute as catalysts to initiate the basis for loss compensated faster growth during this year only. This can happen in the identified economic sectors by connecting growth aspirations with the skills of the engineers and by the development of improved technologies and further use them as fulcrum to leapfrog.

CONNECT GROWTH ASPIRATIONS WITH ENGINEERING SKILLS AND TECHNOLOGY

The focus on growth aspirations laid by economic policies in three broad segments of the economy- Agriculture and its related activities, Manufacturing in Industries and the Services need impetus by efforts of engineering skills in the forms of innovations and technological improvements in the existing practices. The typical compositions of the three sectors characterizing the economies in varying degrees for three countries is provided in **Chart 1** which indicates dominance of service sector in large GDP nations.

Service sector itself involves gross value additions done by core innovation and technological activities and it is the key for economic growth. Technological Innovation comes with the core feature of productivity growth which is "doing more with less". Growth in productivity improves the citizens' standard of living as greater number of services and products are generated by less production inputs compared to inputs required in the past. Activities done with productivity obviously bring greater value additions within a short time.

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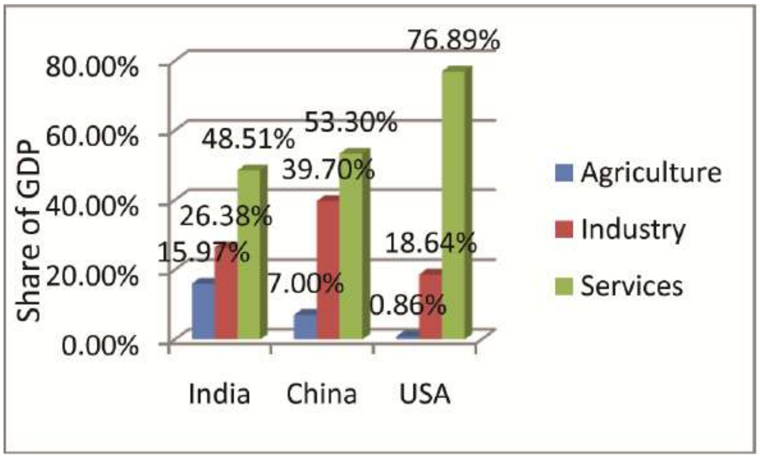

Chart 1 Distribution of the GDP across economic sectors-2018

Agriculture and Allied Activities

In the Indian economy labor force participation in agriculture sector is comparatively highest to the other sectors than that of India which indicate that enormous scope exists for use of innovations in the activities to improve productivity. It is also clear by the results that the main food grains contribution of in terms of acreage is 15 percent, while their contribution in production is less than 9 percent.

For Americans, agriculture was once a leading form of employment but now it is only a less than 2% of the population is engaged in activities of farming, even when output by Agricultural activities have increased. This is evident in the **Chart 2**. This also freed the major chunk of the labor community to search for other areas of production in manufacturing and services sector.

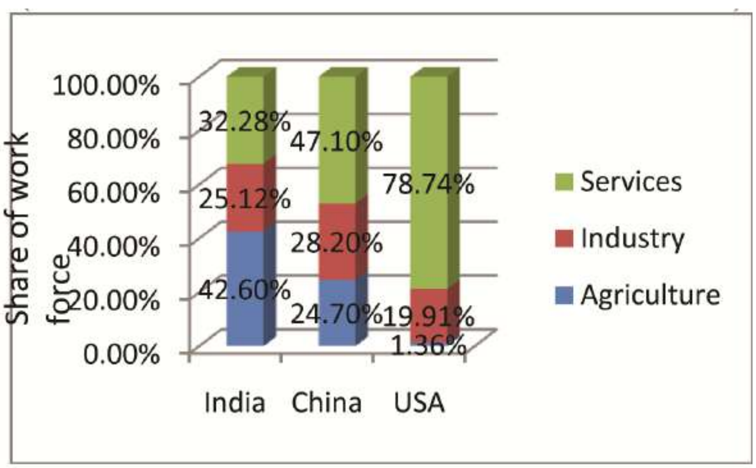

Chart 2 Distribution of the workforce across economic sectors-2019

Ways to Improve Productivity in Agriculture

Improving productivity requires engineers to adopt innovation throughfounding of start-ups in Agricultural activities. Start-ups with potential of human capital and intellects is the right approach for economic growth in the current Indian scenario comprising requirement of multi pronged approach solutionsfor creating the agricultural value chain and value addition. A key element in the improving competitiveness is the efficient use of this

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innovation led talents. In order to achieve the results faster, clear objectives to be set by use of technology collaborations and participation of stakeholders.

In India, agricultural start-ups are still at beginning stage and are started by some aspiring ‘agripreneurs’ with a aim to solve multiple problems inherent in the ecosystem of Indian agribusiness. The potential for scaling up and opportunity of disrupting the technologies is an advantage. In the global investments arena, during 2019, agri-tech start-ups from India contributed around $400 which is less than 10%. Technological interventions required in value chains in the knowledge areas of agricultural sciences like mobile apps for weather forecast, decision support systems for crops selling prices, soil management solutions, sowing techniques involving artificial intelligence and crop pest control systems. Educating farmers and get accustomed to the new technologies is also an area for policy reforms in adult education schemes which will benefit the farming community.Governmental policy frameworks to be revived through farm Co-operative sectors for promoting such educations to the majority of needy farmers community who are having technological generations gap issues.

Engineering Development of equipment and devices related to crop management, harvest management and transport is another area like Mobile controlled motor, UAVs for pest control spray, Drone services for crops management, technologies in irrigation systems for drip and sprinkler, GPS powered driverless tractors, Counting Machines for crop produces, algorithms usingMachine-learning to identify weeds, Imaging technologies to sorting crops based on size, type, colour, etc.

Development of marketing support based solutions for crops and producesdistribution, support on packaging technology and handling is in the urgent need looking to India’s vast imbalance territorial geographies for crops and seasonal changes to cropping.Also, a mobile applications to sell agricultural products, price forecasting models on controlling inflation, dynamic mechanisms on product pricing can be a game changer for vast Indian agriculture produces.

Success Story Models of Early Starters

On a market study of agriculture start-ups, a many of new start-ups have already embraced the innovation and technological route to solve climate change challenges of Indian farmers. One such start-up, Skymet Weather Services offers weather monitoring and predictingaimed at tackling the risks in farming. These solutions offer village level measurements and predictions on yield for any crop with accuracy and weather forecasting at local level in time ranges of short, medium, and long duration. Another start-up Ecozen Solutions is offering indigenously developed solar based products for crop irrigation and harvest storage for regions having issues of disruptions in electrical supply. Crop protection methods are offered by Barrix Agro Sciences with eco-friendly features like preventing water and soil contamination which are caused by use of chemicals to tackle damages by pests and diseases.

In an effort to connect marginal Indian farmers on value chain stake holders, online and mobile based solutions are provided by eKutir Global. They offer services to connect farmers with service providers for farm soil-testing , seeds and fertilizers supply, information on banks, food-processing centres,exporters and retailers. They offer a one-stop solution with field partners for training farmers to even use mobile applications. Some ventures initially ventured as start-ups are now turned out as medium-scale businesses owing to innovative solutions. One such company is EM3 AgriServices, which was started in 2014, has opted the farming-as-a-service business model. They offer machines on a pay-for-use basis to farm activities through their techno service centres called ‘Samadhan’.

These are the some examples of innovation and technology collaborations that are eventually turning out the business to successful ventures and making impact on economical landscape development. Indian agriculture has potential to replicate and improvise further on these business models to garner greater share in economy as it is characterised by vast variety of agricultural produces with varying geographically and climatically changing conditions.

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Industrial Manufacturing

Dan Scheinman, Former Senior Vice President of Cisco Systems' Media Solutions Group once said, "We originally came to India for the [low] cost. We stayed because of the quality, and now we're investing because of the innovation". Focus on existing high impact sectors in manufacturing is the key to achieve the target with advantages in cost, quality and scope for innovation.

Indian Industrial Sectors Requiring Engineering Skills

Defence sector in India is having 2nd largest standing military and its spending is fifth largest in the world. Almost 60% of defence requirements are met through imports and is largest spending of 30% of total budget for importing conventional defence equipment.Forging industry-academia-R&D lab collaborations is the opportunity in this sector which is open arena for the engineers and entrepreneurs. Some Indian private business houses like Adani have started their venture in defence and aerospace with encouraging government policy of indigenous manufacturing of defence equipment. These have come up with defence collaboration in technology with foreign companies.

The engineering sector accounts about 27% of total factories in the industrial sectors and comprises 63% of the foreign collaborations. Investment in infrastructure and industrial production over recent years made India's engineering sector witnessing a remarkable growth.It is associated with the manufacturing and infrastructure sectors which makes it a important contributor in India's economy mix and having advantage of 100% FDI approvals. Make In India initiative by the government has attractive support schemes for new technology absorption which needs to be fully utilised by the Indian engineers and industrialists.

Electronics System, Design & Manufacturing (ESDM) sector in India is the focus area for the engineers owing to its demand met by exports. More than 60 per cent of the products under total domestic demand for electronics and 70 per cent of the components demands are met by imports. This share of imports in this sector is further rising over the years to around 75% which is a indication of huge potential for development of electronic goods sectors in India.

A sizeable Automobile industry exists in India, contributing to more than 7 per cent of India's GDP. Indian auto industry is the sixth largest by production in the world but India's share in exports of auto-components is around 4 per cent and in exports of overall automotive sector share is about 1 per cent. This indicates there is a lot of scope for further integration with Global Value Chains. Its employment creation potential is also huge and currently provides direct employment to 1.5 million people and indirect employment of same quantity.

Apart from the above, there are 8 emerging sectors in the manufacturing which are expected contribute significantly where Indian engineers have to upscale their skills through academic involvement to meet the opportunities of promising technologies. Namely in the areas of Robotics, Unmanned Aerial Vehicles, Biotechnology, electric mobility are at nascent stage in India offering tremendous potential in the areas of employment generation and significant share in GDP. The renewed commitments of India during recently concludedclimate change conference COP26 has also opened vistas in large scale technology changes for Indian energy and environment industry.

The Services

In India's GDP, the services sector contribution being the dominant and attracting major foreign investments. It contributed significantly to exports and it is a source of large scale employment. It covers economic activities of real estate, construction, insurance, transport, personal and social related activities, hotel business and computer software and hardware development and testing. Service sector's share in economy has been steadily increased to 54 percent and almost 80 percent of FDIs are coming into service sector.

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Table 1 Services Sector Gross FDI equity inflows

Services Sub-sectors	Percentage Share 2019-20	Inflows (US$ million)	
		2018-19	2019-20
Financial, Business, Outsourcing, R&D, Courier, Tech Testing & Analysis	9.5	9158	7854
Computer Software & Hardware	74.3	6415	7673
Trading	4.0	4462	4574
Telecommunications	0.03	2668	4445
Information & Broadcasting	0.68	1252	823
Hotel & Tourism	1.2	1076	2938
Hospitals & Diagnostic Centres	0.69	1045	635
Education	2.56	777	3245
Retail Trading	5.21	443	472
Consultancy Services	0.46	411	1,047
Sea Transport	0.61	279	199
Air Transport	0.41	191	918
Agriculture Services	0.25	88	46
Gross FDI Equity Inflows into Services Sector (US$ million)		28265	34868
Change from Previous Year (per cent YoY)		(-)2.4	23.4
Gross FDI Equity Inflows into India (US$ million)		44366	49977
Share of Services Sector in Gross FDI Equity Inflows (per cent)		63.7	69.8

Significant Successful Initiatives for Value Creation

In India, the year 2020-21 marked with many important significant service sector structural reforms. Many of the service sector restricts are eased for investment by private and foreign investment like in space sector, telecom regulations are freed from BPO sector and regulations enforced for consumer protection for e- commerce services. So far, India was attracting and enjoying the benefit of low cost services in software support outsources but now time has to work on new technologies in digital revolution by making use of its talented pool resources. This will shift India's focus from doing cheaper works of outsources to large value based technology development activities in software sector. India has the largest youth population in the world, developed a robust start-up ecosystems and a huge chunk of population who are yet to orient their activities digitally. These can make India to emerge as a technological super power in spite of the current economic uncertainty situations.

Some Silver Linings

There are some silver linings to reaffirm India's capabilities to emerge as technological superpower. India's innovation capability measure in Global Innovation Index is improved to 48th rank in 2020 which was significant achievement when compared to its past position of 81st rank in the GII list It has maintained the top position for the Central and South Asia region countries and consecutively second position for five years duration among middle income category nations list for quality of innovations. India's stands among the top 25 category for quality of scientific publications and its quality of technical universities namely IITs and IISc.

Apart from IT-BPO sector, India is able to create engineering excellences to promote tourism sector, rejuvenation of holy places infrastructure development to bring value generation through national and religious vigour. Conceptualising and implementation of tourism promotion by construction of Statue of Unity is one of the such schemes where Indian engineers contributed to improve national economy on tourism with innovative conceptualisation. Such experiments of tourism promotion developments to be replicated in other parts of the country to promote Indian tourism to higher level.

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In efficiency improvement of goods handled for import and exports at Indian ports, there is significant reduction of the turnaround time to 2.62 days in the year 2020 from 4.6 days in year 2011. This will add efficiency and cost reduction to import and export activities of the nation.

In the start-up front, $28Bn has been raised till September 2021 for the 9 months and more number of start ups are entering the unicorn club. Start-up ecosystem unicorns comprised health-tech, social commerce and e-pharmacy making the total counts to 75 numbers in the unicorn club which is a encouraging sign in the service sector. With this rate of growth, there will be around 100 unicorns by end of 2023.Service sector in India is attracting more investments through start-up routes and companies are seeing good valuations for the growing demand in spite of the second Covid wave during this year. The service sector is expected further revival with the ongoing vaccination drive and ease of restrictions in contact intensive activities.

CONCLUSION

Connecting economic aspirations with engineering skills and technologies is the key factor for target achievement. Today engineering skills and technology bringing disruptions in all walks of the life. With the start of digital revolution, India is in forefront with its vast fraternity of young talented engineers who can make the dream come true in every sector of economy. The start-up hubs by the young engineers are making huge disruptions in the technology and digital landscape. They are changing the way of doing business in all sectors of the economy through e-commerce route. In agriculture they are providing real time data inputs on soil quality, weather status for increasing the productivity. Start-ups in health, education are processing information and data through artificial intelligence and machine learning to get better outcomes. The blend of government’s economy oriented policy measures, schemes on business promotion initiatives are helping the engineers to realise the ease of doing business and make full utilisation their skills. The nations engineer fraternity is fully equipped to bring positive turnaround in economy in spite of pandemic challenges created in the last two years through its vast skill base and innovative spirit.

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Challenges in Design of Positive Isolation System for Large Diameter Gas Piping in Steel Plants

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***Abstract**: In this era of heading to 5 trillion dollar economy, 'Safety' remains prime concern for any industrial establishment; steel plant is no exception. During reduction of iron ore, the blast furnace produces blast furnace gas, having considerable calorific value. The gas, however, is not only poisonous, but has potential to form explosive mixture. Apart from blast furnace gas, there are other hazardous gases such coke oven gas, mixed gas etc. which also run through piping system in steel plants. After utilizing optimum heat value of the gas in various shops/units inside the plant, it is often required to release unused/excess gas through flare system. While maintaining the line pressure, the process calls for extreme safety measures against any hazard. 'Water-seal' is a conventional requirement at the upstream of branch-out connections or flare stack, which avoids any accidental propagation of fire caused by ingress of air from top of the stack, or from any other source of leakage. In addition, 'positive isolation' during maintenance necessitates either U-seal (requiring considerable plant space) or a Goggle Valve (a costlier proposition), in lieu. Designing of the positive isolation for repair/maintenance in large diameter gas piping mains connected to different units/shops/equipment often possess a challenge to the consulting engineer. This paper articulates on those challenges and focuses on a cost-effective, efficient and innovative safety device for flare stack, which can be called 'Water-Seal-cum-Lock'*

***Keywords**: Steel; Gas; Flare; Water-seal; Positive-isolation; Safety*

INTRODUCTION

Firstly, the recommended/normative basic safety requirements in handling fuel gases such as Blast Furnace Gas (BFG), Coke Oven gas (COG), and LD gas (LDG) & their mixtures (MG) and Liquid Petroleum Gas (LPG) are discussed in this paper. It focuses briefly the precautions to be taken, safety appliances to be available and their use in working with above gas lines to prevent from their main hazards of fire, explosion & gas poisoning, within and outside iron & steel making sector.[1]

HAZARDS OF BY-PRODUCT GASES

Following **Table 1** indicates the hazardous properties of various by-product gases produced/used from/in various shops/units, shown in Safety Code for Iron & Steel Sector, published by Ministry of Steel, Govt. of India, Doc. No: SC/21: [1]

A. Effect of Carbon Monoxide (CO) on Respiratory System

Carbon monoxide when inhaled along with air is absorbed in blood and reduces the oxygen carrying capacity in blood, and forms carboxy-hemoglobin in place of oxy-hemoglobin, causing body tissues to suffer from anoximia (lack of oxygen), with symptoms such as Headache, Nausea, Vomiting, Feeling of giddiness, difficulty in breathing. [2]

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B. Effect of Carbon Monoxide (CO) in Blood

Following **Table 2** indicates the effect of different percentage levels of CO when absorbed in blood, shown in Safety Code for Iron & Steel Sector, published by Ministry of Steel, Govt. of India, Doc. No: SC/21:[1]

Table 1 Hazards of by-product gases

Limit	BFG	COG	LDG	MG
Toxicity	Highly toxic	Toxic	Extremely toxic	Highly toxic
Flammability	Inflammable	Inflammable	Inflammable	Inflammable
Carbon Monoxide percentage by volume	23 - 27	6 - 10	60 - 70	10 - 60
Explosiveness	Explosive	Explosive	Explosive	Explosive
Lower Explosive Limit (LEL)	35% in air	6% in air	15% in air	10 - 30% Depending on composition
Higher Explosive Limit (HEL)	73.5% in air	31% in air	72% in air	35 - 70% Depending on composition
Identification of gases (by smells)	Odourless	Burning tar Rotten egg or rotten fish	Odourless	Odourless

Table 2 Effect of Various percentages of CO in blood

CO Percentage in Blood	Effects
0 – 10	Shortness of breath on exertion
10 – 20	Increase in shortness of breath and slight headache
20 – 30	Headache is more pronounced, irritable, judgment impaired, vomiting
30 – 40	Becomes confused, faint
40 – 50	Above symptoms are intensified with increased pulse rate respiration
50 – 60	Unconsciousness
60 – 70	Respiration may fail, death may occur

C. Fire and Explosion Hazards

1) Due to presence of leakage in gas piping and presence of ignition source in near vicinity:

In case there is any ignition source such as gas cutting/ welding spatters, sparking due electrical short circuit as well as from tools and tackles, or thunder etc. in the vicinity of gas conveying piping/pipeline, and there is any event of leakage through flanged joint(s) of valve(s) or expansion/dismantling joint(s), severe fire and explosion can occur.

2) Spontaneous ignition of coke oven gas (COG):

Sometimes, in a steel plant, spontaneous ignition is experienced in coke oven gas (COG) deposits either on ground or inside piping running on overhead pipe-rack, in the form of white smoke or fire, particularly during shutdowns when COG piping/pipelines are opened for inspection or maintenance. Reason of this is the presence of pyrophoric iron sulfide (PIS), which is formed by the conversion of iron oxide (rust or corrosion deposits) into iron sulfide in an environment which is free from oxygen and/or where hydrogen sulfide gas is present with concentration more than oxygen. PIS, when exposed to the atmospheric air, oxidizes exothermically, resulting in the formation of excessive heat oxidation which can ignite nearby flammable material, substances or fuel-air mixtures.

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PREVENTIVE MEASURES & POSITIVE ISOLATION OF GAS MAINS

Fire occurred due to PIS can be avoided by preventing PIS from contacting air, by maintaining a continuous layer of liquid or inert gas between the by-product gas and the air, through following precautionary measures:

a) Always purging the gas piping/pipeline, preferably with nitrogen or steam, before dismantling it for maintenance.

b) Covering the open ends thoroughly immediately after dismantling the pipes, to prevent air ingress inside the pipe.

c) Keeping the deposits inside the pipe submerged in water, if capping of end is not possible.

d) Maintaining a positive pressure inside the pipe, if possible, preferably with nitrogen supply.

Due to the hazardous characteristics/features of by-product gases indicated in **Table 1**, it is an absolute 'safety-necessity' to provide a positive isolation in gas piping during shut-down/maintenance.

In steel plants, there are three conventional ways of achieving positive isolation of gas lines:

1. Water Seal (U Seal/ Quick Dump Seal
2. Blanking
3. Goggle Valve

Figure 1 shows means of positive isolation of gas piping main with both U Seal and Goggle Valve.

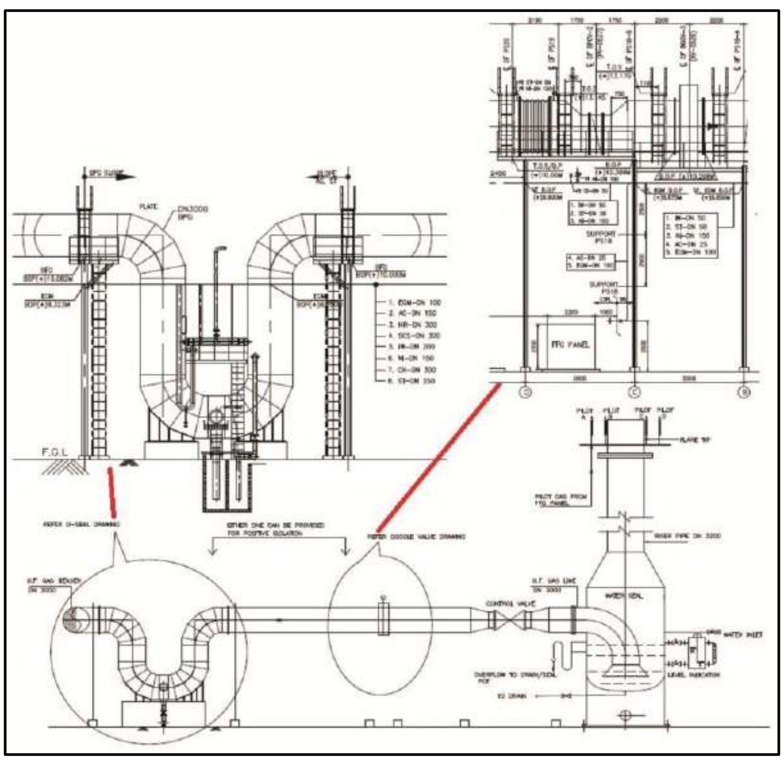

Figure 1 Positive isolation of gas main with U-seal / Goggle Valve.

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Figure 2 Typical installation of Goggle Valve in gas piping main.

Figure 3 Typical installation of U Seal in gas piping main.

ISOLATION WITH WATER SEALS

Water Sealing (**Figure 4**):

a) First, the Gas isolating valve ‘1’ is to be closed.

b) Next, the drain valves ‘4’& ‘5’ are to be closed and a blank is to be put additionally below the valve ‘4’.

c) It is to be ensured that there is sufficient water pressure in the water inlet line.

d) Then, water inlet valves ‘2’ and ‘3’ are to be opened.

e) Next, water overflow valve ‘6’ is to be opened.

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f) As soon as water starts coming from overflow line, water inlet valve '2' is to be adjusted in order to ensure continuous trickling through water overflow line.

g) Now, water sealing of U Seal is done.

h) From time to time the flow of water trickling from overflow line is to be kept under watch.

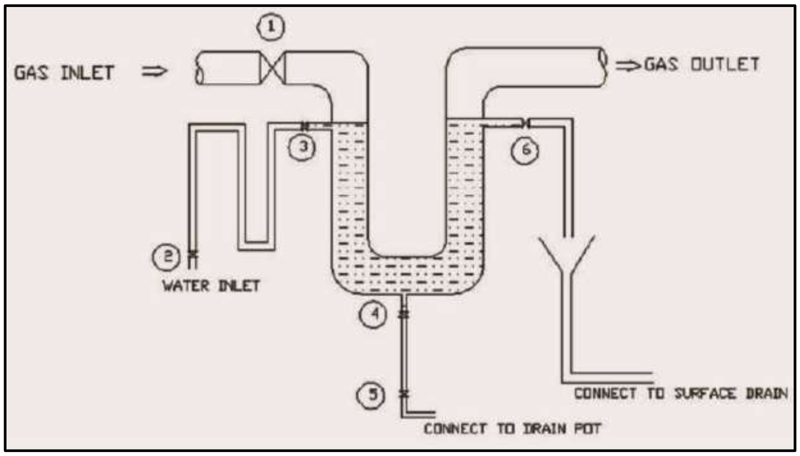

Figure 4 Scheme of U Seal in gas piping main.[2]

Purging of Gas Line with Inert Gas (**Figure 5**):

a) The gas incoming line valve, if provided, is to be closed.

b) The outlet gas line valve at consumer's side, if provided, is to be closed.

c) Water sealing in incoming line is to be done as per **Figure 4**.

d) Water sealing in outlet line (consumer side) is to be done as per **Figure 4.**

e) Bleeder/vent valve, just before first isolation device (valve or U seal) of downstream line of all consumers is to be opened, to depressurize the gas line and it is to be ensured that the line is completely depressurized before purging preferably with nitrogen.

f) During purging process, no personnel is to be allowed to stay near the vicinity of end bleeders due to presence of high concentrations of nitrogen.

g) Purging valve nearest to the isolation point is to be opened.

h) Line pressure is to be monitored and controlled by installing a manometer in one of the drip pots. This manometer should not be fixed very near to purge in and vent out point, in order to ensure accurate monitoring. Pressure in the gas line is to be controlled by throttling either purge-in or vent-out valves. Drip pot where manometer is placed must not be used as vent-out for controlling the line pressure.

i) For COG, purging is to be continued till carbon monoxide concentration at bleeder becomes less than 50 ppm. During checking of carbon monoxide concentration at bleeder, suitable gas mask must be used.

j) When carbon monoxide concentration at bleeder becomes less than 50 ppm, nitrogen purging valve is to be closed. Purging is now over and gas line work to be carried out from outside; however, personnel entry inside gas line must be prohibited still.

k) If any work which require entry of personnel inside the gas line, gas line is to be purged out with air (with suitable mechanical equipment (e.g. portable compressor or exhaust fan) till oxygen level goes above 20%, especially for BFG & LDG lines, as per the stipulations of confined space safety standard.

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l) In no case any personnel should enter inside COG line.

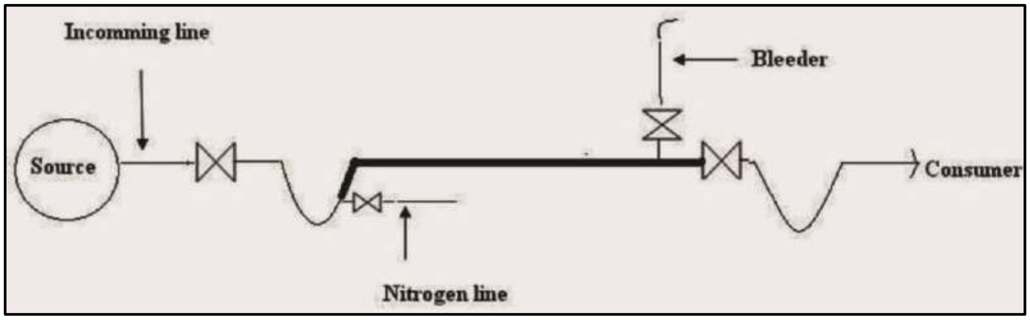

Figure 5 Purging of gas main with nitrogen.[2]

Water Seal Breaking (after necessary purging of gas line) (**Figure 4**):

a) Water inlet valves ‘2’ and ‘3’ are to be closed.

b) As soon as water trickling from overflow line stops, overflow valve ‘6’ is to be closed.

c) The blank below drain valve ‘4’ is to be removed and the drain valves ‘4’& ‘5’ are to be opened.

d) The gas isolating valve ‘1’ is to be opened.

e) Water seal breaking is now done.

ISOLATION WITH BLANKING

Following steps are to be followed for isolation of gas piping main with blanking:

a) Proper and safe location for inserting the blank in the gas line, preferably with nitrogen flooding arrangement, is to be selected/deigned.

b) Standard scaffolding with suitable platform, toe-guard, railing and proper approach is to be provided for overhead pipework.

c) Suitable gas mask/breathing apparatus (as required) are to be kept at site to meet any emergency situation, such as blower type gas mask. Carbon monoxide detector should be kept near the suction point of the blower during use to ensure that no carbon monoxide is sucked in the blower.

d) Fire tender is to be stationed near the blanking site.

e) Any possible presence of ignition source in the vicinity must be taken care off.

f) Blank of the right size to be kept ready along with gasket/ceramic rope/ring joint.

g) Gas line isolation valve is to be closed after getting clearance from consumer.

h) Water sealing of respective gas line is to be completed and the line is required to be depressurized by opening end bleeder at approachable and safe location.

i) Nitrogen/inert gas purging of gas line must be completed before doing blanking job in order to evacuate the toxic gas from the piping/pipeline.

j) Fasteners are to be opened, but without gas cutting or chiseling.

k) It must be ensured that isolation valves are fully shut-off; the amount of concentration of gas leakage, if any, must be under permissible limit (50 ppm). In case blanking is to done in the event/environment of gas leakage, it must be done by using appropriate gas mask.

l) All persons engaged for blanking/de-blanking job must wear fire-retardant cloth.

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m) Non-ferrous tools such as hydraulic flange spreader are to be used for making gap between the flanges.

n) While inserting the blank in the gas main, personnel working in the vicinity must unfasten their safety belt and stand away from the flange joint(s) on the scaffolding platform. This is for ensuring that they can escape away in case of any unwarranted fire hazard.

o) While blanking/de-blanking, sufficient of water must be sprayed over the flange joints.

p) Gasket/rope should be put on both side of the blank.

q) Same precautions are to be followed during removing of blank from gas line.

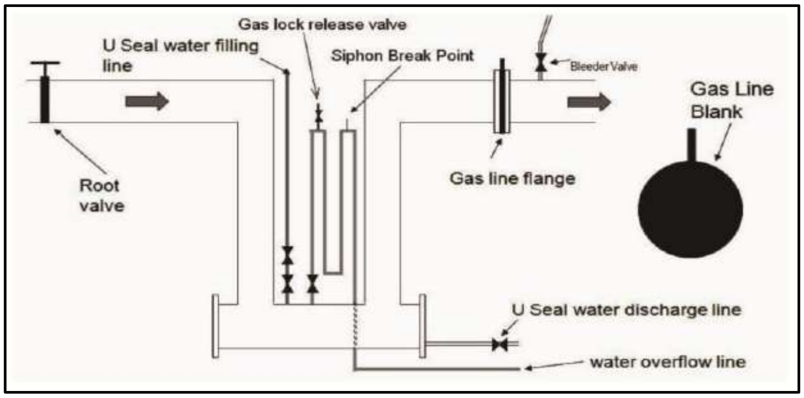

Figure 6 Purging of gas main with nitrogen.[2]

ISOLATION WITH GOGGLE VALVE

Goggle Valve is a positive isolation device, comprising of two components, a solid disc and an expansion joint. Operation of this valve requires that the faces of flanges are be separated by thermo-mechanical or hydraulic means, in order to allow the solid disc to be inserted into the gas stream flowing though conveying piping/pipeline, either manually or by a small electric motor. Once the solid disc has been inserted into the gas path, the separation means is reversed, which in turn seals up the flange faces.[3]

SAFETY ARRANGEMENT IN FLARE STACK

Prevention of Air Ingress in Flare System

Typically flare system operates at a low pressure close to atmospheric pressure. This pressure is actually the built-up back pressure due to continuous flared or purged gas flow in flare stack. Pressure at flare stack tip is atmospheric and back-pressure in the clean gas piping is atmospheric pressure plus frictional pressure drop from continuous venting/purging of gas. If flow of gas to flare stack stops for some reason, there is a possibility of air ingress into flare stack and subsequently into the clean gas piping. This can result in an explosive mixture of air and hydrocarbons in the flare network, which would perhaps be catastrophic.

Liquid (Water) Seal at Base of Flare Stack

Water seal at flare stack base is a cylindrical volume of liquid into which the gas inlet to flare stack is dipped. The 'seal-height' is so maintained (depending on network gas pressure) that it just allows the flow of flared gas from inlet pipe to the stack (initially by bubbling through the water, and then by dispersing the water from the inlet pipe level). Water seal does not permit air ingress into the gas inlet pipe. Liquid (water) also helps in extinguishing any fire that would have accidentally travelled up to the bottom of flare stack. This is already a proven arrangement (**Figure 7**).

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However, in the subject case, this common arrangement has been improvised further with additional safety feature working in tandem, with significant reduction of cost and plant area.

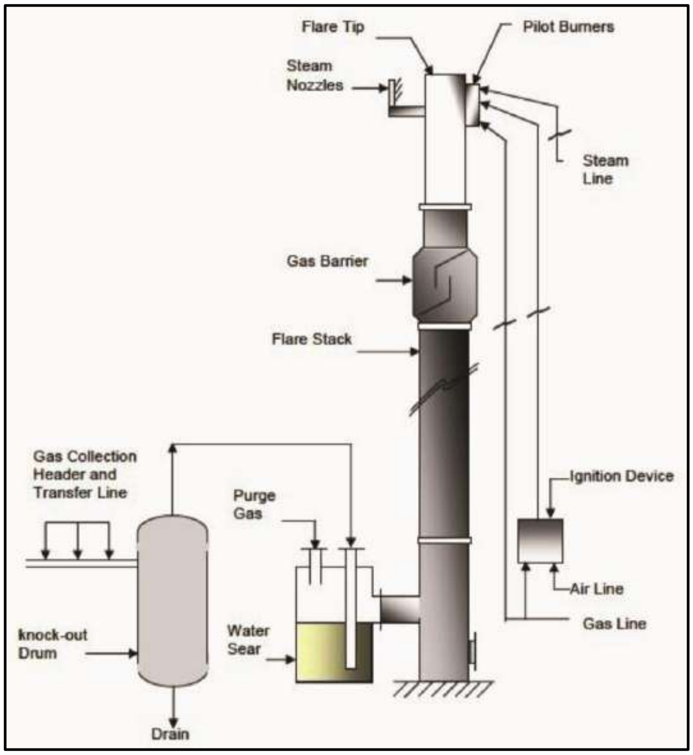

Figure 7 Common liquid seal arrangement at base of flare stack

Goggle valves (**Figure 2**) are heavy in construction and involve considerable cost, both in procurement and installation, as well. It requires a robust supporting structure and considerably big maintenance platform, with stair/ladder. On the other hand, U seals (**Figure 3**) are easier to design, install and operate, and ensuring 100% positive isolation. However, U seals require much larger space, in plant layout, compared to goggle valve.

Table 3 Indicates a comparison between two options

Table 3 Comparison Between Goggle Valve and U-seal

Sl. No.	Description		Features
1	Goggle Valve	Either of the two is a must technically	• Costly item • Heavy structure
2	U-seal (min seal height shall be '500 mm Water Col. plus actual gas pressure' or '2000 mm Water Col.', whichever is higher)		• Cost comparatively less than goggle valve • More space required

The 'constraints' gave rise to an 'innovation in design':

- To avoid Goggle Valve (high cost consideration)
- To avoid U-seal (space limitation)

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- To offer an alternative 'positive isolation' for blast furnace gas
- To retain conventional water seal

To overcome the constraints and satisfy technical/functional requirements, an 'out-of-the-box' solution had been designed and implemented, i.e. to merge conventional 'water seal' (to prevent air ingress and propagation of back fire) with a device (hereafter referred as 'water lock') to provide positive isolation (substitute of goggle valve and/or U-seal).

In this route, following challenges had to be overcome:

1. Pre-requisite of water seal: Height of water must be less than 900 mm, so that forward gas can bubble through towards stack, but any possible fire cannot travel backward.
2. Pre-requisite of water lock: Height of water not to be less than 2000 mm, which is a technical requirement, in order to prevent/isolate any flow of gas, whenever required.

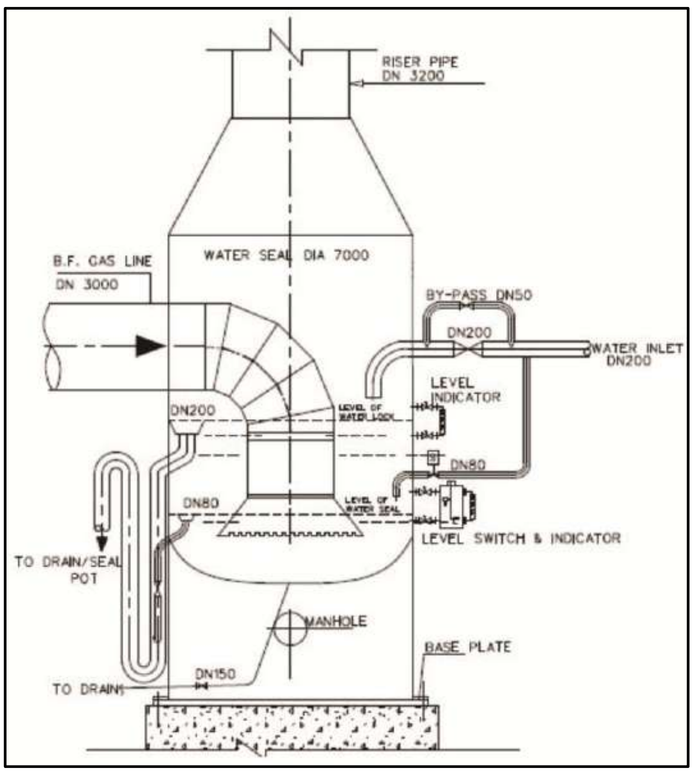

Figure 8 Combined 'water seal' cum 'water lock' arrangement.

From the above, it is evident that the above requirements are contradictory to each other under normal condition. Hence, the real challenge was to satisfy/incorporate both requirements simultaneously, after incorporating 'extra-ordinary' modifications, as required, in the system.

Features of 'water seal' cum 'water lock'

It is a combined equipment with inner diameter of the order of 7000 mm at the base of flare stack, with provision to maintain either of the two pre-defined levels of water inside the equipment by means of piping and valves:

- Lower level providing 800 mm Water Column, for 'water seal'

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- Upper level providing 2000 mm Water Column for ‘water lock’

To supply water, there would be a DN 200 water header for the equipment, along with two branches:

- DN 200 supply line for higher level i.e. ‘water lock’ with a bypass line with isolation valve of DN 50 - to be operated during maintenance period only, to maintain continuous supply of water, yet avoid its wastage during that period.
- Inlet branch line DN 80 with solenoid valve, which will be kept open during normal operation, to maintain the level in ‘water seal’

There would be a DN 200 overflow line for the equipment, discharging through drip pot (safety against possible gas leak). This overflow line would consist of isolation valve (manually operated). This valve is to remain open during normal operation of flare System, so that lower level of water is maintained inside the equipment, same functioning as normal ‘water seal’. When isolation of the blast furnace gas line would be required, this valve has to be closed to stop the lower level overflow and allow the level to increase (up to the pre-defined level, by means of overflow line), creating and maintaining water level required for ‘water lock’. Also, there would be a common drain valve of DN 150 at the bottom, for occasional cleaning of equipment. The material of construction of the seal is carbon steel as per IS 2062 Gr. B with Copper content of 0.25 - 0.35%.

VALUE ENGINEERING

This proposition reduced the installation cost of the flare system significantly, along with occupying much less plant area. **Table 4** shows the comparison of costs for different options.

Table 4 Comparison of costs for different options

Sl. No.	Description	Estimated Cost (INR Lakhs)	Remarks
1	Perforated gas inlet + base plate + shell with dished end	23.80	
2	Riser pipe and derrick structure	164.80	
3	BF Gas header with platform + 1 no. 4-legged tower + 1 no. 2-legged trestle	4.00	
4	Control valve 1 no.	16.00	
5	Flare tip + Panel + utility piping with valves + cabling	50.00	
6	Civil foundation for flare stack, 4-legged tower & 2-legged trestle	92.16	
	SUB TOTAL	350.76	
7	Goggle valve	100.00	Option-A
	TOTAL – Option-A (Sum of 1 to 7)	450.76	
8	U-seal with pipes & valves	13.20	Option-B
	TOTAL – Option-B (Sum of 1 to 6 plus 8)	363.96	
9	‘Water seal’ cum ‘water lock’ with piping, valves, level gauge and extension of perforated gas inlet	2.28	Option-C
	TOTAL – Option-C (Sum of 1 to 6 plus 9)	353.04	

Therefore, proposed arrangement yielded a cost savings of INR 97.72 Lakhs (21.67%) when compared with installation of goggle valve, and INR 10.92 Lakhs (3%) when compared with installation of U-seal. Further, intangible effect of value engineering is even higher (in case of the innovative safety device), if the requirement of lesser plant area is taken into account. However, it is to be noted that cost comparison presented in Table IV above is

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as of the year 2015, and a 15% – 20% escalation may be considered, if this proposition is to be implemented in any project today.

CONCLUSION

In upcoming and future steel plants in India and abroad, this integrated ‘water seal’ cum ‘water lock’ arrangement can open a new horizon in plant and process safety.

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Experience of Belt Jump and Sway in a Short Belt Conveyor

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Abstract: *A limestone handling belt conveyor intended to carry 200 metric tonnes per hour met challenges during the start of operation. Simple conveyor, simple design parameters and rather simple layout yet engineers were rather struggling to tame the running of the conveyor.*

This paper intends to provide the problems faced, analysis/diagnosis of the problem and remedial measures suggested. It is really an eye opener for young bulk material handling engineers working in the industry. It is also lesson learning for experienced engineers of the industry to create checks and balances in the working system to eliminate any lapse that can creep in but could be avoided.

Keywords: *Conveyor; Material handling; Belt; Troughability; Sway; Jump.*

INTRODUCTION

Bulk Material Handling Industry can't be thought of without Belt Conveyors. A Belt Conveyor consists of Idler, Pulley, Belt, Scrappers, Skirt Boards, Take Up, Protection & Safety switches, Couplings, Gear boxes, Motors, Drive options like Drive without soft start, Drive with soft start, Hydraulic Drive, VVFD drive, CST Drive, Gearless Drives and Supporting Structures. Experience would give us the clue that there is inherent and intrinsic tendency of Business Managers to make it too simplistic for short conveyors with small capacities thinking it to be too simple and trying to intrude in the design & operational features of Belt Conveyors sometimes unknowingly and unintended intrusion as well.

Associated with the above parts or components, some technical terms are Belt Speed, Troughing angle, Tensions (allowable, running, starting, empty belt), $e^{\mu\O}$, μ, TIR (total indicated runout) of an idler, troughability of the conveyor belt, allowable material cross sectional area of belt, cosine correction and some more.

There are number of established books, codes and standards available in the archives to enable the engineer to get into the design aspects of Bulk Material Handling Industry at large and belt conveyor in particular. While high capacity, high speed, long belt conveyors in complex layout feature with/without curvatures in vertical and/or horizontal plane with multiple drives with/without regeneration receives due attention from experienced engineers, the smaller ones are left to younger engineers and allowed to be released from designer table to site for installation. However, the intended example that is presented here shows that the industry engineers ought to exercise caution to obtain desired results of operations even for small conveyors like the one presented in this article.

BELT CONVEYOR IN DISCUSSION – ITS PARAMETERS

- Material handled – Limestone
- Lump Size – 50 mm and down
- Bulk density – 1360 kg/m^3

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- Angle of repose – 38^{O}
- Angle of surcharge – 20^{O}
- Rated Capacity – 200 MTPH
- Design Capacity – 230 MTPH
- Belt conveyor c/c – 180000 mm approx.
- Lift – 35 m (approx.)
- No of feed points – 2 (Two)
- Type of take up – Vertical Gravity
- Troughing angle – 35^{O}
- Drive margin – 1.36 at rated MTPH & 1.21 at design MTPH
- Type of Drive – Direct if selected motor is 75 KW or below
- Other stipulation – Top & bottom cover thickness of Belt shall not be less than 7 & 3.5 mm respectively.

LAYOUT DRAWING OF THE CONVEYOR

Following **Figure 1** indicates the layout (plan & profile) of the conveyor in discussion.

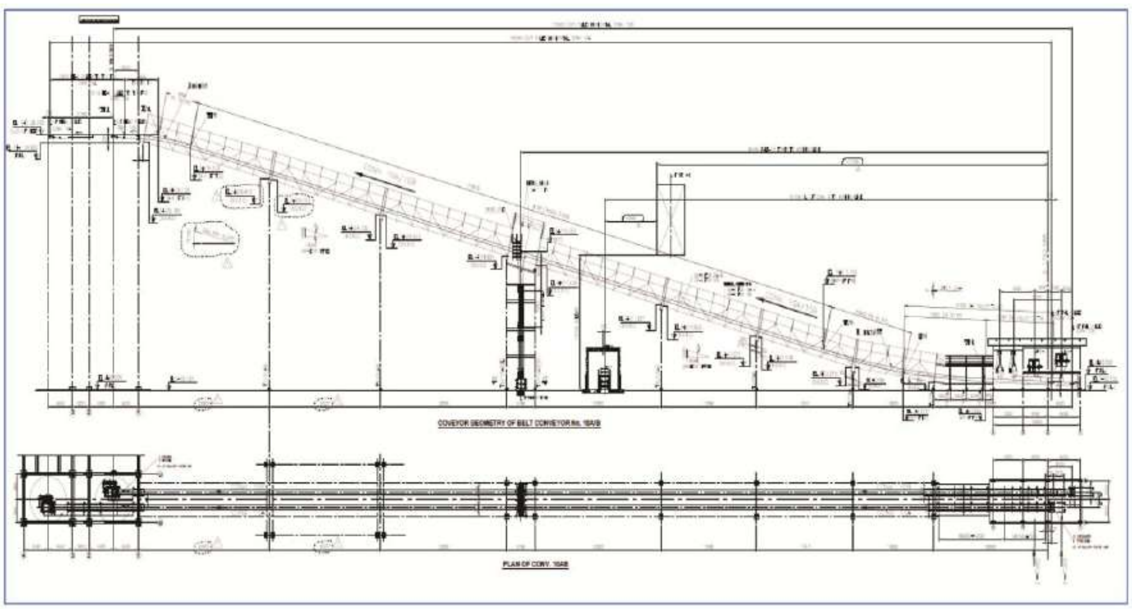

Figure 1 Conveyor Layout

Designed Parameters

- Belt – 600 mm wide, 35^{O} troughed, 630/4 with 7 mm top & 3.5 mm bottom EP belt
- 127 mm toughed equal roll idlers
- Drive – Snub drive with 45 kW Sq. Cage Induction Motor (with no soft start), Bevel Helical Drive, matching Pin Bush Coupling between Motor & Gearbox & Gearbox & Drive Pulley

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- Take up – Vertical Gravity

What was the Problem?

When the plant was taken up for operation, “no load” trials were being taken; the project site team noticed that:

- The belt is not touching the central idler. And the gap between belt and roller is uneven throughout the length of the belt conveyor.
- At the curvature zone, belt jumped quite a bit during no load trial.
- When the conveyor was taken for no load trial, the belt jumped & swayed too much on one side. There was no consistency in such sway i.e. sometimes it swayed on one side and in another time it swayed on opposite side. And the sway in carrying run was on one side where as the sway on return run was on the opposite side.
- During no load start, it appeared that the belt slipped a while and then the belt started running. Apparently, this introduced lagging wear rate more.

Figure 2 Belt jump

Figure 3 Belt sway

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And ironically, the problems listed above were visible at two Project sites where two separate site teams were working.

Since the problems were repetitive at both sites, installation errors were practically ruled out.

Figure 2 & **Figure 3** showing the ‘jump’ and ‘sway’ of the belt are given for the comprehension of the problem and visual understanding.

Design team studied the problem in detail and their findings are outlined below.

Analysis of the Problem

Careful scrutiny of the design revealed the following:

Empty belt power is hardly around double-digit mark. Whereas the motor selected was 45 kW. And the starting torque of motor of the selected vendor was 260% of full load torque (FLT) at rated voltage and rated frequency. Since Pin bush Coupling was installed between Motor & Gearbox, the starting torque of 260% of FLT was being witnessed by the belt resulting in abnormal jump of belt from the alignment.

And once belt jumped, the return of the belt was getting largely influenced by weight of the belt, behaviour of the belt in free fall condition and such other.

That explained the unpredictable sway of belt conveyor and the reason of the abnormal jump at curvature zone.

Layout of the belt conveyor would give a geometrical calculation of the maximum radius of curvature and that worked out as 309 m (when the belt is partially loaded up to the start of concave curve) though there are other conditions also that need checks.

Could the layout engineer have increased the radius of curvature feasibility at least geometrically without compromising the engineering norms of such layout engineering?

Answer is yes. Then why was it not done? Apparently, the engineer designed the conveyor preliminarily and did not refresh it with the actual equipment procured. May be it was too late to introduce any geometrical change in layout of the conveyor since the structural works proceeded much ahead without a room for trace back even if the plant engineer wanted to effect any change.

This is where the experience would have played a role. And that is why, this paper intends to bring it to the notice of the industry that small conveyors, be it small belt width, small capacity, short length and little height also deserve attention of experienced engineers.

The problem got complex since the base document stipulated direct drive for drives below 75 kW. And the young engineers who were a bit of inexperienced relied heavily on such stipulation and preferred not to raise the flag on the mother stipulation. One has to reckon the fact that the mother stipulation in the base document might have been done to cover most of the drives where such a stipulation might have proved to more than logical. That same needed a closer scrutiny is best realised by experienced engineers only. And that is why this deliberation stresses the need for checks & balances.

Second problem of troughability was looked at as follows:

Catalogues from reputed belt manufacturers provides recommendation for troughability purely on the bulk density (range given by belt manufacturer) and belt width (**Table 1**). From that consideration, the designer, due to his/her lack of experience, found it to be okay for troughability of 600 mm conveyor belt at 35^{O} for a bulk density of 1.36 t/m^3, and abnormal cover thickness was not given credence that ought to have been given.

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Table 1 Conveyor belt load support table[1]

Belt Rating	Minimum belt width for satisfactory troughing		Max. width for satisfactory load support		
	35^{O}	45^{O}	Upto 1 ton/m^3	Over 1 to 1.6 ton/m^3	Over 1.6 to 2.5 ton/m^3
kN/m			**mm**	**mm**	**mm**
315/3	500	600	1200	1000	800
400/3	500	600	1200	1050	900
500/3	500	600	1400	1200	900
500/4	500	600	1400	1200	900
630/3	600	650	1400	1200	1050
630/4	600	650	1600	1400	1200
800/4	650	800	1800	1600	1400
800/5	750	800	1800	1600	1400
1000/4	650	800	1800	1600	1400
1000/5	800	1000	2000	1600	1400
1250/4	800	1000	2000	1800	1600
1250/5	900	1050	2000	1800	1800
1400/4	1000	1200	2000	1800	1800
1600/4	800	1050	2000	2000	2000
1600/5	1000	1200	2200	2000	2000
2000/4	1050	1200	2000	2000	2000

Result: The practical experience showed that the belt is not touching the central idler. Some opinion was expressed that the belt would trough once the belt receives load and the troughability recommendation in the belt catalogue is with load.

Geometrical Dimensions

Resilience of the conveyor geometry with respect to its behaviour to radius of curvature was checked for below conditions for young engineers to take note of.

Radius of Curvature

- With direct drive considering the selected motor and its torque – speed characteristic curve:

✓ At no load belt

✓ At partially loaded belt up to the start of the curvature with design tonnage

✓ At fully loaded belt at design tonnage

✓ All the above conditions with 105% of rated frequency

✓ All the above conditions with 95% of rated frequency

- With soft start introduced between Motor & Gear box:

This soft start shall be considered as 150% of FLT irrespective of motor torque with 4% slip (an average of 3 to 5% slip recommended by Hydraulic Coupling manufacturer)

✓ At no load belt

✓ At partially loaded belt up to the start of the curvature with design tonnage

✓ At fully loaded belt at design tonnage

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- ✓ All the above conditions with 105% of rated frequency
- ✓ All the above conditions with 95% of rated frequency

One can also calculate the radii of curvatures with 3% slip and 5% slip. This slip largely depends on the Fluid Coupling model selected for a specific supplier

Loading cycle calculation for top cover thickness

Table 2 Recommendations for cold bulk materials with normal loading conditions[2]

Frequency Factor	Cover Grade (RMA)	Non Abrasive — Material such as lime, charcoal, wood chips, bituminous coal, grain — Material Class 5 (CEMA) — Lump size, inch				Abrasive — Material such as salt, anthracite, coal, phosphate rock, limestone, fullers earth — Material Class 6 (CEMA) — Lump size, inch				Very Abrasive — Material such as slag, copper ore, sinter, coke, sand, fine dust — Material Class 7 (CEMA) — Lump size, inch				Very Sharp Abrasive — Material such as quartz, some ore, foundry refuse, glass batch, iron borings — Material Class 8 (CEMA) — Lump size, inch			
		Dust to 1/4	1/2 to 1 1/3	2 to 5	6 and over	Dus tto 1/4	1/2 to 1 1/3	2 to 5	6 and over	Dust to 1/4	1/2 to 1 1/3	2 to 5	6 and over	Dust to 1/4	1/2 to 1 1/3	2 to 5	6 and over
0.2	2	3/32	3/16	3/16	3/8	3/16	3/8	-	-	3/16	-	-	-	3/8	-	-	-
	1	1/16	1/8	1/4	5/16	1/8	1/4	3/8	3/8	7/32	3/8	3/8	3/8	5/16	3/8	3/8	3/8
0.4	2	1/16	3/32	3/16	1/4	3/32	1/16	3/8	-	3/16	3/16	-	-	7/32	3/8	-	-
	1	1/16	3/32	1/8	3/16	3/32	1/8	1/4	3/8	1/8	1/4	3/8	3/8	3/32	5/16	3/8	3/8
0.6	2	1/16	3/32	1/8	3/16	3/32	1/8	1/4	3/8	1/8	7/32	3/8	-	3/16	3/16	-	-
	1	1/16	3/32	1/8	3/16	3/32	1/8	3/16	1/4	1/8	3/32	1/4	3/8	1/8	7/32	3/8	3/8
0.8	2	1/16	3/32	1/8	3/16	3/32	1/8	3/16	9/32	1/8	3/32	3/16	-	1/8	7/32	3/8	-
	1	1/16	3/32	1/8	3/16	3/32	1/8	3/32	3/16	1/8	1/8	7/32	3/8	1/8	3/32	5/16	3/8
1.0	2	1/16	3/32	1/8	3/16	3/32	1/8	3/32	7/32	1/8	1/8	1/4	3/8	1/8	3/16	3/8	-
	1	1/16	3/32	1/8	3/16	3/32	1/8	3/32	3/16	1/8	1/8	3/16	1/4	1/8	1/8	1/4	3/8
1.5	2	1/16	3/32	1/8	3/16	3/32	1/8	5/32	3/16	1/8	1/8	3/16	1/4	1/8	1/8	1/4	3/8
	1	1/16	3/32	1/8	3/16	3/32	1/8	5/32	3/16	1/8	1/8	3/16	7/32	1/8	1/8	3/16	1/4
2.0	2	1/16	3/32	1/8	3/16	3/32	1/8	3/32	3/16	1/8	1/8	3/16	7/32	1/8	1/8	3/16	3/8
	1	1/16	3/32	1/8	3/16	3/32	1/8	3/32	3/16	1/8	1/8	3/32	3/16	1/8	1/8	3/16	1/4
3.0	2	1/16	3/32	1/8	3/16	3/32	1/8	3/32	3/16	1/8	1/8	3/16	7/32	1/8	1/8	3/16	1/4
	1	1/16	3/32	1/8	3/16	3/32	1/8	3/32	3/16	1/8	1/8	3/32	3/16	1/8	1/8	3/16	1/4
4.0 and over	2	1/16	3/32	1/8	3/16	3/32	1/8	3/32	3/16	1/8	1/8	3/16	7/32	1/8	1/8	3/16	1/4
	1	1/16	3/32	1/8	3/16	3/32	1/8	3/32	3/16	1/8	1/8	3/32	3/16	1/8	1/8	3/16	1/4

Note: The frequency factor indicates the number of minutes for the belt to make one complete turn on revolution

Table 2 indicate that:

- 600 mm width is non-standard belt width in Indian context. Standard width is 650 mm
- 35^{O} troughing for such small width was a question mark. Designers relied too much on the customer requirement.
- Tension mandated that 630 kN/m shall have to be provided by the belt selected. Designer had the option of selecting 630/3 but designer selected 630/4 from other consideration that magnified the troughability issue of the belt not touching the central idler.
- Selection of EP belt instead of NN for the fabric of the belt also added stiffness.
- Loading cycle calculation indicated that 5 mm top cover would have been more than adequate. But customer stipulation of minimum top cover thickness indicated it to be 7 mm. That made the belt to be procured with top cover of 7 mm. And corresponding bottom cover though could have been made to be 3 mm to maintain the engineering practice of 1:3 between bottom & top cover but was selected as 3.5 mm based on customer

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requirement. Extra thickness also added stiffness to the belt for the flexural rigidity and thereby making trough further complex.

- Drive was stipulated as direct. That means the torque vs. speed in the transient period of the motor was being witnessed by the belt resulting lifting of the belt in no load condition. Procured motor was producing 260% of FLT at rated voltage and frequency. Torque speed characteristics curve of the motor is referred to.
- Critical look back of the conveyor calculation indicated that empty belt power was close to single digit and the loaded belt power with margin was close to 30 kW. But the designer selected a 45 kW drive presumably insisted upon by customer to make the selection extra safe.

Above would give the clue that the conveyor though small, in terms of layout parameters, width, capacity, belt speed and material conveyance, was installed with rather loaded parameters than required and without a soft start provision.

Design team of customer, contractor, component supplier and all other stakeholders have contributed in varying proportions to the parameters in building such over margin in the system.

MODIFICATION RECOMMENDATION

1. To introduce a fluid coupling of adequate rating to have smooth start with due checks for the space, ease of maintenance, finer parameters of bore checks of shaft (input & output) including tolerances
2. To reduce the trough angle of idlers to 20^{O}.
3. To introduce Guide roller in zigzag manner on both side of the conveyor at the cost of some additional wear at an interval of 20 m on carrying side and 40 m on return side

These modifications though not simple during commissioning phase because of time pressure were carried out successfully and the conveyors were running satisfactorily.

CONCLUSION

This paper is presented for young engineers to take cognizance of the inherent checks that they need to provide as also it is an eye opener for experienced belt conveyor specialists to properly guide young engineers to be aware of such complexities and raise flag at appropriate stage of execution so amends are possible avoiding loss of precious time of execution especially during end phase of a project when schedule is crashed.

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Overview of Wet Flue Gas Desulphurisation System and Condensate Flow Study in View of New Stringent Environment Regulations for Fossil Fuel based Power Plants in India

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Abstract: *In this article a general review of recent environment norms given by Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India to control the sulphur dioxide (SO2) emission generated from fossil-fuel based power plants are discussed. The leading technology for sulphur dioxide reduction i.e. limestone based Wet Flue Gas Desulphurisation (FGD) owing to its high desulphurisation efficiency and long term stability is reviewed. Issues like corrosion problem to the inner side of the stack wall, stack liquid discharge and plume downwash are presented. It can be stated that selection of liner material for chimney is a critical aspect while considering the wet FGD. Effect of condensate on liner material is analyzed to provide insights into selection of liner material for chimney operated under wet FGD. This work also includes the review of Condensate Flow Study (CFS)required to know the effect of acid condensation and presents viable means to minimize the effect of acid condensation by providing suitable condensate collection system.*

Keywords: *Carryover; Wet Stack; Re-Entrainment; Plumedownwash; Stack Liquid Discharge (SLD); Corrosion Resistant Material*

INTRODUCTION

The combustion of fossil fuels such as coal and Heavy Fuel Oil (HFO) emits three major air pollutants viz. sulphur dioxide (SO_2), nitrogen oxide (NOx), and particulates. SO_2 from the flue gas can be reduced at three stages, before combustion, during combustion and after combustion. Sulphur dioxide is a colourless & corrosive gas represents the major source of air pollution [1]. There is catastrophic effect of Sulphur dioxide (SO_2) on the environment and createsecological imbalance in the planet earth. To mitigate the problem of sulphur emissions, the Flue-Gas Desulfurization (FGD) system is utilized as an effective solution.

In recent times “Ministry of Environment, Forest and Climate Change” (MoEF&CC) has released notifications, making environment norms more stringent for thermal power plants which emits various pollutant through exhaust flue gas into the atmosphere. Our scope of discussion revolves around the effect of SO_2 present in the exhaust flue gas generated from fossil-fuel based thermal power plants. In this article the number of issues involved in wet FGD along with its benefits are discussed. A review of the Condensate Flow Study and its importance are presented in the work along with technical insights for chimney (stack) selection with respect to the current norms released by MoEF&CC, Government of India to curb the level of SO_2 in fossil-fuel based thermal power plants in India [5,6,10].

Commonabsorbent medium i.e. Limestone or lime in the form of slurry is sprayed over dry flue gas from boiler and forms gypsum as a byproduct in the scrubber also known as absorber. Independent of the classification, most of the available literature [1-3,5] conveys that most dominantly used FGD system i.e. 87 % is based on wet limestone and globally accepted in view of high SO_2 removal efficiency level and lower O&M cost [3].

This paper summarize a general review of the Condensate Flow Study and its methodology while implementing wet limestone based FGD technologies for the thermal power plants in India. The paper call attention to therequirement

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to study the wet stack in detail and address probable issues associated with FGD in view of the growing FGD market scenario in our country.

BACKGROUND

The FGD systems in the coal based thermal power plants emerged during the industrialera in the early 1970s majorly in the developed countries such as United States (US) and Japan, and swiftly utilized during 1980s in European market [3]. In order to reduce the emissions from power plants, countries, have formulated stringent regulations. Targets for greenhouse gas emission reductions has been set through International agreements such as the Kyoto Protocol. Moreover, in order to mitigate the sulphur oxide emissions, many countries emerged with enforcement of laws and regulations to protect the environmental damage. Clean Air Interstate Rule was launched by the government of US and subsequently after detailed review the Acid Rain Program was revised during 2005 to control the sulphur dioxideemissions. During 2008 the Large Combustion Plant Directive (LCPD) was reviewed and revised by UK, to set newsulphur dioxide emission limits. During 2005, China modified Atmospheric Pollution Prevention and Control Law (APPCL) and given directives for installation of flue gas desulphurization and dust separation equipment in all thermal power plants that exceed the set SO_2 emission levels [2]. In India, all stack emissions are measured in terms of concentrations only & not total emission per plant [11]. MoEF&CC vide Notification amendment as shown in **Table 1**, has set new emission norms for thermal power stations[5].

Table 1 Environmental (Protection) Amendment rules, 07 December, 2015

Pollutant	*TPPs (units) installed after 01.04. 2004 up to 31.12. 2016'	TPPs (units) to be installed from 01.01.2017
Sulphur Dioxide (SO_2)	600 mg/Nm^3 (< 500MW capacity units) and 200 mg/Nm^3 (≥ 500MW capacity units)	100 mg/Nm^3
	**TPP – Thermal power plant*	

Installation of flue gas desulphurization plant (FGD) has become essential in all thermal power plants already operating or under construction[5, 10]. These regulations have become more stringent as time progressed, leading to the new market for FGD systems.

Most of the thermal power plant stations in India are in operation without FGD. In view of recent stringent regulations for emission the market for FGD system is expected to grow rapidly. Demand for FGD will be substantial for both a new power plants or retrofitting in the existing power plants. Wet limestone FGD technology is going to dominate FGD market because of its high desulphurisation performance and low operating cost.

Globally reheat system were used in FGD plants to reheat the flue gas in order to make it dry before it exit the stack, by the utilizing Gas to Gas Heater (GGH). However, owing to need of decreased SO_2 emission in power plants and/or high energy consumption cost flue gas heating are not in use these days in the new plants.Thus, eliminated from existing plants in service[4].

The dry stacks without FGD were designed for the higher flue gas velocity than the new wet stacks [19]. When operating these wet stacks often results in velocity higher than the recommended liner velocity, which makes the liquid collection difficult. Thus the majority of the liquid should to be collected in the absorber outlet ductwork [9].

MoEF&CC prescribed SO_2 emission limits to be mandated in all power plants at normal operating conditions. Suitable margins are considered by the purchaser in view of variable coal quality, peak load operation etc [10]. The proposed guaranteed SO_2 limit for clean flue gas after FGD system is to be mentioned by the purchaser in the bidas per **Table 2**.

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Table 2 Proposed guaranteed SO_2 limit in the clean flue gas under full load condition

SO_2 level stipulated by MoEF& CC	'Guaranteed SO_2 level in the treated flue gas under guarantee condition' (100% TMCR* load)
600 mg/Nm^3	500 mg/Nm^3
200 mg/Nm^3	150 mg/Nm^3
100 mg/Nm^3	70 mg/Nm^3

For many years wet FGD plants have been in use across the world,however, most of them were operated with dry stacks. However, to mitigate the unacceptable high levels of Stack Liquid Discharge (SLD) some power stations in late 1970s, have envisaged wet ducts and wet stacks [4].

LITERATURE REVIEW

A 'wet stack' commonly named as chimney which is enclosed with one or moreflue linerssubjected to wet (i.e. containing acid & moisture) exhaust flue gasesand is located downstream of FGD plant. These FGD plant utilizes absorber wherein generally limestone based slurry is sprayed over the incoming flue gases emitted after combustion of fuel in the boiler.This spraying action reduces the content of sulphur dioxide (SO_2) in the absorber but the flue gas gets saturated with water vapour and reduces the temperature of the flue gas in the range of 46°C to 55°C for bituminous and hard coals and in the range of 57°C to 63°C for lignite and sub-bituminous coals [9].

Wet limestone based FGD have advantages like high desulfurization efficiency, wide adaptation, long-run stability and low operating cost. However, it creates serious corrosion problems inside surface of stack wall[7]. Due to the high moisture content in the flue gas after the absorber, condensation occurs in these stacks during steady-state and start-up conditions[9]. Condensation will take place if the flue gas temperature gets lower than the acid dew point temperature resulting in chimney corrosion.The minor constituent in the flue gas is in the form of sulphur trioxide (SO_3). The SO_3 is due to oxidation of a small part of the more abundant SO_2 and owing to its greater affinity towards moisture, the traces of SO_3 present in the flue gas condenses in the form of fine mist [13].

Flue gas condensation occursdue to self or heterogeneous nucleation phenomena. Self-nucleation is defined as vapour condensation by collision of vapour molecules and the formation of tiny liquid droplets that grows by coagulation. Heterogeneous nucleation occurs at the surface of the dust particles. More complex situations can be arisen due to presence of two different molecular species [13]. Roedel (1979) studied formation of sulphuric acid whichtakes place due to collision of water & SO_3 molecules under saturated condition (high relative humidity). Theoretically condensation will also take place even when flue gas temperature is above dew point of sulphuric acid in case the relative humidityis higher approximately 80% or above [13].

A study by Dyna flow System Laboratory for Israel Electric Company (IEC) at Rutenberg power station found that the main source of liquid droplets is condensation. Mainly bulk & surface condensation processes are responsible to condense most of the water. Mist eliminator carryover is found to be less than 0.15 kg/s. While, the amount of condensation on liner wall is around 8.1 kg/s. The dew point calculation was carried out to know the condensation rate. To know the rate of condensation dew point of the flue gas at stack inlet was calculated 0.09 kg of water vapour is found to be present per kg of flue gas. Bulk condensation majorly contributes to 7.5 kg/s approximately, anda very small amount of thermal condensation will take place. The latent heat ofvapour is absorbed in the gas during bulk condensation. As no heat transfer takes place in this process it is termed as"adiabatic condensation" [16].

Thus, it is absolutely necessary to protect stack corrosion after the FGD installation. In 1980s Electric Power Research Institute (EPRI) has sponsored many programs to understand the wet FGD systems' process and to determine the key factors contributing to liquid entrainment [15]. By the late 1990s, power plants were installed with liquid collectors for wet stack & ductwork to understand the practical basis of Wet stack design guidelines, resulting in publication of second report by EPRI [4].

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PROBLEMS ASSOCIATED WITH WET FGD

The condensation in the duct and stack will not take place due to higher outlet temperature of flue gas coming out of Air preheater, which is in the range of 120°C to 140°C and exceeds the acid dew point (40°C to 60°C). Whereas, vice-versa will take place if the outlet temperature is lower than acid dew point resulting in chimney corrosion. Further, Internal pressure and irregular geometry of structure are also contributing to corrosion in Chimney [12].

The major factors of the chimney corrosion are:

Production of Corrosive Medium

Coal contains sulphur which is converted to sulphur dioxide (SO_2) during the burning process. Usually 1 to 5% of sulphur dioxide is converted to sulphur trioxide(SO_3) which has greater affinity to combine with water vapour in the flue gas to form gaseous sulphuric acid [14]. After the wet FGD, SO_2 and SO_3 conversion in the flue gas is 95% & 20% respectively [12]. Acid dew point is often 100°C to150°C considering H_2O & SO_3 concentration by volume. The outlet temperature of wet FGD are typically 80°C with GGH and 40°C to 50°C without GGH. Thus, the corrosive fluid medium will remain even after installation of GGH, however the situation gets worsen after elimination of GGH. If the chimney surface in contact with flue gas is cooler than the acid dew point, sulphuric acid can condense on it and is the majorculprit for corrosion in stack & ductwork [12].

The rate of deposition of acid (H_2SO_4) on the stack linerismore significant for corrosion because of the difference in temperature of acid dew point & liner [8]. The cooling effect of flue gas will take place due to leakage losses, heat conduction processthrough the surface of ducts & stacks and chimney draft [13].

Chimney Internal Pressure

An important factor in chimney design is gas temperature and pressure inside the chimney. Negative pressure is required inside the chimney to prevent the venting out of the corrosive and acidic flue gas to the ambient air through the cracks in the wall, various openings, manholes etc. provided in the concrete shell. If maintained with positive pressure inside the chimney it is not possible to prevent venting. Flue gas temperature is low for the FGD plants without GGH, density of gas & positive pressure region will expand [12].

WET STACK SELECTION

Chimney or wet stack in the industries is used for venting hot flue gases or smoke from a boiler to the outside atmosphere [18]. Maximum negative pressure to be obtained in the flue gas during Chimney selection [8]. Sizing of chimney depends on many factors that are difficult to quantify. Chimney is sized such that it can exhaust a given quantity of flue gases at suitable elevation with a velocity that will ensure the ground level concentration of pollutants within the prescribed pollution-regulation standards [19].

Chimney Diameter & Height Selection

The chimney flue internal diameter is selected based on exit flue gas velocity limitation, draft requirement, and environmental regulation consideration which in turn decides the major dimensions of the chimney concrete shell with the consideration of power station capacity and no. of the units. Sizing of chimney/flue depends on flue gas flow & temperature, ambient temperature, barometric pressure, available draft (see (1)), friction losses and exit losses of the chimney, future expansion and maintenance requirement [19].

Theoretical draft = pressure of air – pressure of flue gas (both at the level at which flue gas enter a chimney

$$= 0.029\ B \times Hd\{\vdash 1/(Va.Ta) - 1/(Vg.Tg)\}\dashv \text{ mm of Hg} \quad (1)$$

Chimney height is assumed and then mid-height elevation for portion H_d is determined, T_a is ambient temperature at this height and B is corresponding barometric pressure. T_g is average flue gas temperature at flue entry.

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Different chimney arrangements are commonly being employed in the power stations, single flue chimney & multi-flue chimney. Individual chimney arrangement where each unit of the power station has individual chimney and exit stack velocity is constant with an advantage of ease in maintenance during the annual shutdown or overhauling of the power station. Multi-flue chimney arrangement is common for two or more units of the power station. The flues of each unit is located inside the concrete shell which supports the flue and take care of the wind, seismic and provide structural stability [19]. There was no mandate for SO_2 emission but only stack heights are mandated to disperse far away diluting plume concentration. MoEF&CC directed power plants more than 500 MW to build 275 m stack height, those between 210 to 500 MW, stack height of 220 m height and for less than 210 MW, stack height (H) is calculated based on the SO_2 emission using H = ln (Q)^0.3 where Q is Emission rate of SO_2 (kh/hr)[11].

The required height of the chimney for thermal power stations fitted with FGD depends on flow rate of SO_2 being emitted from the chimney, stipulated by MOEF & CC notification [6], as shown in **Table 3**.

Table 3 Stack height in Thermal power plant with wet FGD

Power Generation Capacity	Stack Height
100 MW and above	$H = 6.902 (Q \times 0.277)^{0.555}$ or 100 m whichever is more
Less than 100 MW	$H = 6.902 (Q \times 0.277)^{0.555}$ or 30 m whichever is more
Q = Emission rate of SO_2 kg/hr H = Physical stack height in meter	

As the saturated flue gas enters the stack directly, water vapour content in the flue gas condenses creating a liquid film over the outlet duct and stack liner which needs collection and drainage system called as 'wet stack operation'.

In the event of no proper collection and drainage system being installed in the stack, results in the exit of large liquid droplets from the stack top to the ground resulting in the phenomena called Stack liquid discharge (SLD) or spitting or acid mist fall out or rain out. These large acidic droplets on reaching ground shall corrode the metallic structures and equipment in the vicinity of the stack. In view of this, there is a reduction in the allowable velocity in the range of 16.8 to 18.3 m/s for different types of liner materials being used in the wet stack such as C276, Titanium alloy, Fibre reinforced plastic (FRP) and Borosilicate materials resulting in the larger diameter chimneys[9]. Velocities recommendation values as shown in **Table 4** are based on the laboratory testing values by EPRI in the vertical wind tunnel under ideal condition of smooth surface without surface discontinuities in the liner considering the slight reduction in the velocities to accommodate practical constraints in the field erection quality.

Table 4 Recommended wet stack design velocity

Liner Material	(m/s)
Borosilicate Block	18.3
FRP	16.8
Alloy	16.8
Coatings	16.8
Acid Resistant Brick	13.7

The value of recommended design velocity is optimally selected in lower side to accommodate the increase in flow of flue gas due to increase in plant output, plant efficiency or change in the fuel source [9]. Earlier optimum chimney flue sizing is carried out considering the stack exit gas velocity without FGD system in the range of 20 to 25 m/sec. for mild steel flue lined stacks ensuring positive draft requirement [19].

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In India Central Electricity Authority (CEA) has suggested a standard technical specification for chimney height for retrofitted wet FGD in power plants installed as on 31st December, 2016 [10] as shown in **Table 5**.

Table 5 Suggested height of chimney, in meters in retrofitted wet FGD

Unit size	Stack Height	
	'No. of units connected to the chimney'	
	1	2
	'Suggested height of wet chimney' (m)	
< 250 MW	100	125
≥ 250 MW and < 500 MW	125	150
≥ 500 MW	150	150

However, the criteria are different for the new power plants which are going to be equipped with wet FGD after 1st January, 2017 as shown in **Table 6**.

Table 6 Suggested height of chimney, in meters, in new power plants with wet FGD

Unit Size	Stack Height	
	'No. of Units Connected to the Chimney'	
	1	2
	'Suggested Height of Wet Chimney' (m)	
< 250 MW	100	100
≥ 250 MW and < 500 MW	125	125
≥ 500 MW	150	150

Chimney Liner Material

The trend to use wet flue gas desulfurization (FGD) has had a great impact on the choice of chimney liners used today. With theresulting 49 – 54°C flue gas temperature, the use of induced draft fans rather than buoyancy moves the gas through the ductwork and chimney liner.

Wet lime/limestone based FGD system is a widely accepted FGD techniques in power plants industry worldwide. However, it comes with some serious issues like corrosion to the inside surface of stack due to three most common conditions in a FGD based power plant such as: (1) FGD with bypass fully open. In that case temperature of flue gas is above 120°C. Flue gas is completely dry which leave no chance of corrosion, which happens due to presence of water contents in flue gas at lower temperature. (2) Bypass is fully closed (FGD installed without GGH is completely in operation). Flue gas enters into the stack is at around 50°C with high humidity which leads to considerable acid condensation on the inside of stack liner (3) FGD in operation with partial opening of bypass which leads to cyclic wet-dry condition. Acid condensation occurs due to lower flue gas temperature in the both conditions (2) & (3) where FGD is used without GGH. This leads to corrosion which would generates a need for good corrosion resistant material [7].

Zhao (2016) in an experiment based analysis tested some corrosion resistant materials in real operation like in coal based thermal power station. As per literature laboratory experiments and prevailing engineering practices, materials selected such as epoxy glass coatings, corrosion resistant steels, fibre reinforced plastics (FRP), polyurea, titanium alloy& Borosilicate (i.e. foam glass blocks)are popularlyconsidered as corrosion resistant materials. In this study, six corrosion resistant materials are classified in three categories, such as coating materials includes Polyurea and vinyl ester glass flake (VEGF), lining materials includes ND steel (Fe, Mn, Cu, and Cr, etc), titanium alloy & fiberglass reinforced plastics (FRP) and the last category of lightweight insulation material include foam glass blocks. Even a short period of thermal shocks could make a significant impact on VEGF's the corrosion resistance property. FRP has also shown the sign of degradation under high temperature of above 180°C even for shorter duration. It was observed that vinyl ester glass flake can withstand upto 120°C temperature but it is not suitable for exhaust flue gas at high temperature as high as 180°C. FRP may cause corrosion failure under prolonged exposure in power plant stacks. On the other hand, weight & appearance of ND steel, Borosilicate and Titanium alloy remained almost same because of their high thermal conductivity, better heat resistant and excellent heat dissipation property[7].

Ghanem et al. (1996) demonstrated the heat resistant property of a low alloy steelby measuring the weight of the corrosion film over the material after an exposure for 480 hours within the temperature range of 75°C to 250°C. Cai et al. (2010) reported the significant increment of tensile ductility & thermal stability for the temperature above 150°C. Better anti corrosive behaviour of foam glass block at higher temperatures due to its low viscosity was noted by Song et. al (2010). Thus it was concluded that low alloy steel, Borosilicate and ND steel can be applied in higher temperature flue gas stacks in thermal power station[7].

During the tests at variable temperature, VEGF failed with significant mass loss on the other hand all other materials viz. polyurea, titanium alloy, ND steel and foam glass blocks did not fail in similar corrosive conditions, However FRP shown significant appearance change so not suitable with this standpoint. Thus, it was concluded that FRP & VEGF are not suitable for cyclic temperature change and high temperature. However, in long run corrosion failure may occur in FRP material. The three material viz. titanium alloy, Borosilicate and ND steel are able to withstand for variable temperature condition following wet stack operation in power station [7].

Bloyce et al. (1998) and Mabilleau et al. (2006) observed cracks with craters appeared on ND steel sample subjected to acid condition in cyclic wet-dry operation. However, nearly zero rate of corrosion for Titanium alloy was observed in samples during static & dynamic conditions, because of formation of oxide film on the material surface which prevented further corrosion. Unlike other materials, no significant change in colour or corrosion signs were observed which shows its good corrosion resistant property in acidic and cyclic conditions. The formation of TiO_2 layer on the metal surface of Titanium alloy makes it an excellent corrosion resistant material, thus can be used as material for stacksdespite being expensive [7].

Contrary to titanium's excellent performance under accelerated acid condition and variable & static high temperature condition its corrosion resistance was poor in sulphuric acid at high temperature. However, Borosilicate has not shown any significant impact due to exposure in acidic environment or cyclic wet & dry conditions. The formation of protective SiO_2 & B_2O_3 over the surface of borosilicate material makes it better resistant to corrosive environment during experiments explained by Soo Park et al. (1999) [7].

The comparative performance analysis of above mentioned six materials in respect of corrosion prevention in stacks due to acidic environment were evaluated for wet stacks in coal based thermal power station. To prevent corrosion Titanium alloy and Borosilicate glass blocks could be applied in the stack for the best performanceto prevent chimney corrosion [7].

In India, Alloy steel lining materials are found to be expensive for power generation chimney applications. However, the same is being used in various power plants such as 250 MW Rourkela project at Jharkhandand 2X800 MW NTPC Karimnagar project at Telangana in view of the long material life. However, FRP is being used as liner material in under construction 2X660 MW Maitree project at Bangladesh whereinitially no provision of FGD bypass was envisaged, so the flue gas inlet temperature is less hence FRP is suitable. Borosilicate block lining systems are also being installed in the short height chimney forpower station, despite having less life than alloy but comparatively cheaper option, such as in 2X490 MW NTPC Dadri project at Uttar Pradesh on a mild steel liner.

CONDENSATE FLOW STUDY

As per the two reports of EPRI as mentioned in the literature review, a detailed fluid dynamic analysis is required to design & install effective wet stack in wet FGD outlet ducting/stack system, liquid collectionand drainage system. The design of wet stack by the use of flow modelling is carried out in the laboratory. There are five different phases to carry out the complete wet stack study [4].

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Phase I - Initial review of the proposed system design

Phase II - Condensation calculations

Phase III - Design and development of the liquid collection system

Phase IV - Study of the plume downwash

Phase V - Field installation and operational inspections

The design of wet stack system can be finalized by using the results of above first four phases. and the same are being utilized to prepare technical bids & specification The liquid collection system is reviewed by field engineer during installation & inspection which is defined in fifth phase.The preliminary design review based on experience is carried out to review proposed geometry of absorber outlet duct and stack breach by analysing the change in system geometry such as breach aspect ratio and expansion joint locations. Comparison of gas velocities, breaching height to width ratio & size of liner with the existing plants that have effective wet stacks can be done. The liquid collection and preliminary evaluation of the condensation rate in the duct & stack is estimated [4,9].

Water droplet in wet stack system originates from two source, first from the mist eliminator at FGD absorber, and second & major sources of liquid droplet is flue gas condensation at FGD outlet ducting and stack liner wall. There are two kinds of condensation which are encountered in the wet stack and FGD outlet ductwork. Firstly, thermal condensationtakes place at the FGD outlet ducting and wet stack liner due to difference in the flue gas and ambient air temperature. The transfer of heat energy occurs from the flue gas through the liner, insulation, air in annular space and the outer concrete wall to the ambient air.The amount of thermal condensation changes with outsideair temperature, wind speed & direction, flue gas flow, thermal conductivity and stack geometry. Other kind of condensation is adiabatic condensation which takes place in the majority of the flue gas flow as a result of decrease in flue gas pressure along the stack height. However, it does not add up to the SLD as very small sized liquid droplet evaporates before it reaches the ground [15].

Physical model in the scale range of 1:8 to 1:16 is built fromoutlet of mist eliminator of absorber up to approximately four stack liner diameter above the top elevation of breaching duct. Physical model is fabricated from transparent thermoplastic i.e. acrylic or plexiglass which cater the requirement of the accurate visualization of flue gas and liquid droplet flow patterns. This allow better visual droplet trajectories, liquid film movements and flow pattern. Behaviour of liquid droplet in the flue gas flow and motion of liquid film on liner wall is evaluated by the physical model being fabricated in the laboratory [9]. On the basis of the flow pattern observed through physical model, Liquid Collection Systems (LCS) viz. gutters, ring collectors etc. are placed, fabricated and put in place. Commercial available materials such as FRP or Haste alloy (C276) are used to fabricate LCS.

Plume downwash is a phenomena of flue gas entrainment between the stack shell & liner in downwind side, normally occurs at stack top due to lower flue gas velocity and high crosswind velocity resulting in lower pressure region. The vertical component of flue acidic flue gas is deflected towards wind direction resulting of shell corrosion.If the system is designed considering the high flue gas velocity, it resulted in stack liquid discharge and if the system is designed at low flue gas velocity, it will result in plume downwash mostly at higher wind speed. It normally occurs due to lowerflue gas velocity during part load operation in power plant & high wind episodes. Plume downwash is more pronounced in multiple liners because of large size of shell enclosing multiple liners. During plume downwash condition, saturated flue gas enters into the extension, stack hood, and stack shell resulting in acidic corrosion [4].

To avoid plume downwash, momentum ratio should be above two for single flue chimney. Momentum ratio is calculated by knowing the ratio of vertical component of plume momentum to the horizontal component of wind momentum. The same can be achieved by increasing liner height above the shell or reduction of flue liner diameter or by installing a nozzle like geometry (known as 'Choke') at the top of stack liner[4].

Computational fluid dynamic (CFD) modelling is ideally suited for plume downwash study in different weather & plant operating condition. A study is conducted by constructing a 3-D model of the stack for the portion covering one-third from the stack top[9]. Small to medium sized droplet gets drifted at the liner surface while large droplet

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getsdeformed due to drag velocity of the gas and no longer have spherical shape [16]. Correlation explained by Ishii et al. (1979) predicted the distortion limit of 1.7 mm droplet diameter at the stack, so, droplets less than 1.7 mm flowin sphericalshape whilethe larger droplets are deformed or distorted. Drift velocity of distorted or deformed droplet is asymptotic & does not dependon droplet diameter. The droplet drift is simulated in the CFD model [16,17]. However, CFD model is incapable of accurately simulating the development of liquid film and its motion in the liner wall and ductwork are difficult to simulate accurately by the use of CFD models but it is useful to predict movement of the droplets and flow pattern [4,9].

The last phase includes the review and support of field construction and inspection. The correct installation of LCS is checked for proper installation and the changes / deviations at the site w.r.t the installation drawings are evaluated and rectified. Site inspection is highly recommended when 80-90% installation is complete to identify errors, on the spot modifications & corrective actions on site. Inspection of LCS need to be carried out during operation on routine basis to ensure satisfactory long term operation of LCS without plugging, deposition and drainage problems [4, 9].

The sole purpose of wet stack study is toensure maximum collection of moisture and acidic content in condensate formed inside the stack and ductwork through the help of liquid collection & drainage system and to prevent the stack liquid discharge (SLD) with least possible re-entrainment by the use of liquid collectors and the drain collected is connected to the absorber [4,9,15].

CONCLUSION

Alloys are expensive & can be operated at 16.8 m/s velocity. Acid resistance bricks are in use but has velocity limitation of 13.7 m/s as they have rough surfaces. Borosilicate lining can be effectively operated above 18.3 m/s velocity which can optimize the chimney diameter and found to be cheaper option as compared to the alloys. In India, most of the power generating industries have also followed for the non-reheat option in view of associated cheaper operation and maintenance cost, however there are some power plants which are still going for wet FGD with GGH in operation.

New FGD plant including a wet stack are designed to take care of chimney corrosion to prevent the stack liquid discharge, minimize potential for droplet re-entrainement & retrofit. Considering the outage time required for the lining modifications in the existing chimney, it is economical to build new low height stack & use existing chimney for emergency FGD bypass condition. One can opt for GGH as per the assessment on the basis of results of techno-economic analysis. Gas to gas heater (GGH) usage influe gas desulphurization plant requires additional space, more pressure drop leading to higher energy consumption with the leakage issues which makes it anunviable solution.

Technical specification for the design of effective wet stack system need to be prepared for complete FGD absorber outlet ducting to the stack top. Wet stack study is conducted for each unit if the layout of FGD ductwork up to the stack top is different. In order to control stack liquid discharge and corrosion problem, a proven liquid collection system is required to be designed for efficient chimney operation. Liquid collection system for the stack and ductwork is developed by considering different phases of the wet stack study as discussed in previous section.

This arrangement requires longer flue gas duct work from ID fan outlet resulting in the higher pressure drop and thereby increase in ID fan rating and thus, additional power consumption. Lastly, in India, in view of new stringent environmental norms it is imperative that a thorough study for implementation of wet FGD is required, to enable utility engineer for arriving at right techno-economical decision suited well in the project(s).

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Materials and Metallurgical Engineering

Optimization of Annealing Cycle and Microstructural Characterization of Cold Rolled Titanium-stabilized Interstitial Free Steel

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Abstract: *Interstitial free (IF) steels having carbon level at 30 ppm are extensively used for outer panel fabrication of four-wheeler. IF steel poses a mild strength with excellent elongation, high plastic strain ratio (r-bar; $\bar{r}$) and excellent formability. After hot rolling, the Ti-stabilized IF grade steel having Carbon around 30 ppm are cold rolled and annealed at different annealing temperature. Mechanical properties i.e. YS, UTS & % El are evaluated at every step for understanding the change of material behaviour in terms of their strength and other formable parameters. Hardness in HRB scale evaluated and $\bar{r}$ (plastic strain ratio) is calculated by using resonant frequency method in modul-$\bar{r}$ drawability tester. Cold rolled and annealed at 650°C, 700°C and 725°C samples shows the elongation 40% and above. Similarly, $\bar{r}$ are more than 2.0 for annealing temperature 650°C, 700°C and725°C. The best combination of properties achieved when cold rolled sheet was annealing at 700°C i.e. % elongation is 48% and $\bar{r}$ is 2.25.*

Keywords: *Interstitial Free Steels; Annealing; Plastic Strain Ratio and Formability*

INTRODUCTION

Industrial production of Interstitial Free (IF) steels began around 50 years back and in last two decades, the demand increased for IF steel due to their superior formability over conventional extra deep drawing (EDD) steel. IF steels having C in the range of 20-40 ppm, are extensively used for outer panel fabrication in automotive segment. Heat of IF steel are made by keeping interstitial elements i.e C and N below 30 ppm by refining liquid steel in vacuum degassers, and stabilizing these interstitial elements by micro-Alloying addition of Titanium or Niobium or both. Carbide and nitride precipitates of these elements makes matrix almost free from interstitial elements.

IF steel poses a typically non aging properties as no free C & N availableand have mild strength with excellent elongation, high plastic strain ratio and excellent formability. The minimum amount of Ti required for full stabilization, based on a stoichiometric approach[(1)], is:

$$Ti_{stab} = 4 \times \%\,C + 3.42 \times \%\,N + 1.5 \times \%\,S$$

Titanium precipitation took place in form of nitride and sulphide (TiN, TiS) at higher temperature and formed Ti-carbide and Ti-Carbo-Nitride at lower temperature i.e at inter-critical (austenite–ferrite transformation) temperature region during hot rolling transform to $Ti_4C_2S_2$, Ti-CN &TiC by the absorption of titanium and carbon[(2,3)].

Cold rolling plays an important role in the formation of favourable textures for deep drawing during annealing; however, has little effect on other properties[(4,5)].This was attributed to the fact that the precipitates formed during hot

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rolling and coiling were not large enough to compromise the $\bar{r}$ during annealing. A reduction of 90% produced the highest $\bar{r}$ in all the steels; however, these reductions were rarely achieved in practice, 75-80% being more common.

EXPERIMENTAL

2 nos. of hot rolled coiled samples of size 200 mm × 300 mm has been cold rolled at Experimental rolling mill, RDCIS, Ranchi (**Figure 4a**). The chemical composition of experimental IF steel (**Table 3**) was tested in Optical Emission Spectrometer(Model: Spectro-lab LAVMC05A).

Table 3 Chemical Composition of the IF steel

C	Mn	P	S	Si	Al	Ti
0.003	0.080	0.012	0.006	0.008	0.040	0.053

In both sheet, the reduction draft was kept 75% as per draft schedule shown in **Table 4**. The cold reduced sheet was shown in Figure **4b**.

Table 4 Draft schedule of hot rolled IF sheet in Experimental rolling mill, RDCIS

Sample No.	Initial Thickness	Final Thickness	% Reduction
15	4.8	1.2	75.0
18	4.8	1.2	75.0

Annealing of cold rolled sheet was carried out at different temperature in muffle furnace (KANTHAL make as shown in **Figure 4c**) as per chart given below in **Table 5**.

Table 5 Annealing Temperature given to IF cold rolled sheet

SN	Annealing Temp	Sample thickness	Sample Heating Rate	Holding time	Sample Cooling (f/c cooling)
1	550°C	1.20 mm	12°C/min	5 mnt.	10°C/min
2	600°C	1.20 mm	12°C/min	5 mnt.	10°C/min
3	650°C	1.20 mm	12°C/min	5 mnt.	10°C/min
4	700°C	1.20 mm	12°C/min	5 mnt.	10°C/min
5	725°C	1.20 mm	12°C/min	5 mnt.	10°C/min

Figure 4 Experimental set-up (a) Rolling of IF grade steel at Experimental Rolling mill, RDCIS; (b) Muffle furnace for annealing, Kanthal Make.

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The Tensile test was carried out in transverse direction of hot-rolled, un-annealed cold rolled and annealed cold rolled sheets. Hardness of samples annealed at different temperature was taken Rockwell cum Rockwell Superficial Hardness Testerin HRB scale. Tensile tests were performed on 50 mm gauge length sample as per the ASTM E8 standard using UTM having 5 Ton capacity at ambient temperature. The tensile and hardness values are reported in Table 6. Plastic strain ratio $\bar{r}$ is calculated by using resonant frequency method in modul-$\bar{r}$ drawability tester (Make: Tinius Olsen). Sample for $\bar{r}$ is cut by modul-$\bar{r}$ punch press in rolling direction (0^o), diagonal to rolling direction (45^o) & transverse to rolling direction (90^o).

Specimens of hot rolled sheet, un-annealed cold rolled sheet and annealed cold rolled sheet were investigated in optical microscope (Model: Olympus GX 71). Fracture morphology observation was made using an ASPEX scanning electron microscope.

RESULTS AND DISCUSSION

Mechanical Properties

The tensile strength of hot rolled IF grade steel was 308 MPa with around 40% elongation. The YS/UTS ratio is around 0.81. Cold rolled sample shows a 650 MPa of tensile strength withnegligible elongation which is due to high stress developed in material during cold rolling. After annealing, the stress incurred in material was released during recrystallization and regain its ductility as shown in **Table 6** and **Figures 5** & **6**. The most remarkable aspects are: the very low YS, ~ 121-132 MPa, the low ratio of YS/UTS (< 0.60) shown at annealing temperatures >700^oC to obtain $\bar{r}$ >2.20.

Table 6 Annealing temperature given to IF cold rolled sheet

SN	Particulars	YS, MPa	UTS, MPa	% El	Hardness, HRB	$\bar{r}$(r-bar)
1	Parent-HR	252	308	40%	52.0	----
2	Unannealed-CR	408	654	6%	86.6	----
3	CR-Annealing @ 550^oC	125	280	38%	36.2	1.61
4	CR-Annealing @ 600^oC	124	252	38%	36.8	1.47
5	CR-Annealing @ 650^oC	136	248	40%	28.3	2.20
6	CR-Annealing @ 700^oC	132	235	48%	24.7	2.25
7	CR-Annealing @ 725^oC	121	227	48%	24.9	2.23

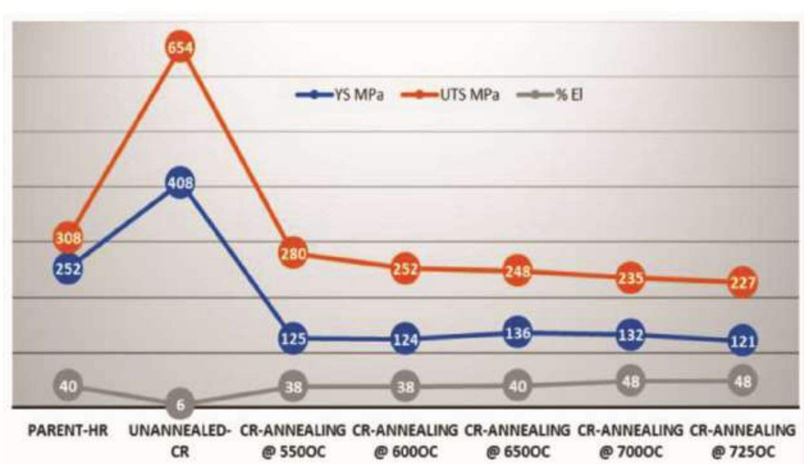

Figure 5 Variation of tensile properties w.r.t annealing time

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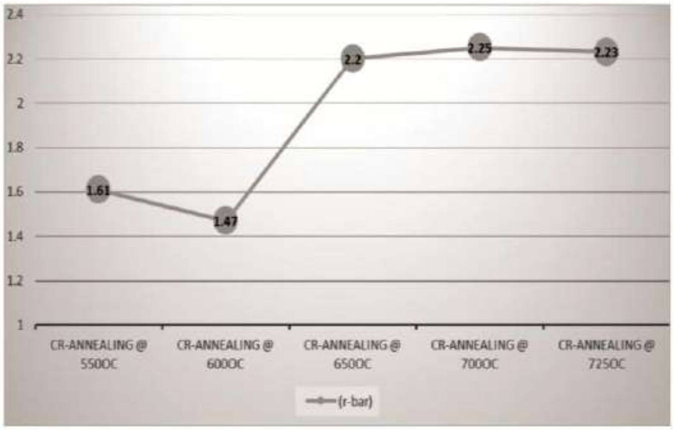

Figure 6 Variation of $\bar{r}$ w.r.t annealing time

Optical Microstructure

Optical Microstructure of hot rolled sheet (as shown in **Figure 7**) showing ferrite grains having a partially recovered, partially recrystallised and pancake microstructure, bearing evidence of the α-region hot-rolling schedule.

The cold rolled Unannealed sample shows an elongated grain of ferrite (in **Figure 8**).

Figure 7 Optical Micrograph of hot rolled IF steel sheet X200

Figure 8 Optical microstructure of Cold rolled-Unannealed IF steel sheet X200

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After annealing the recrystallization of elongated grains took place and observed in **Figure 9** to **Figure 13**. The scattered grains belong to the class of the smallest grains (approximately 10±20 μm) are observed in lower temperature annealing i.e annealing at 550°C, 600°C & 650°C. The size ferrite grains increased with increasing annealing temperature and almost equiaxed at 700°C.

Figure 9 Optical microstructure of Cold rolled-annealed at 550°C X200

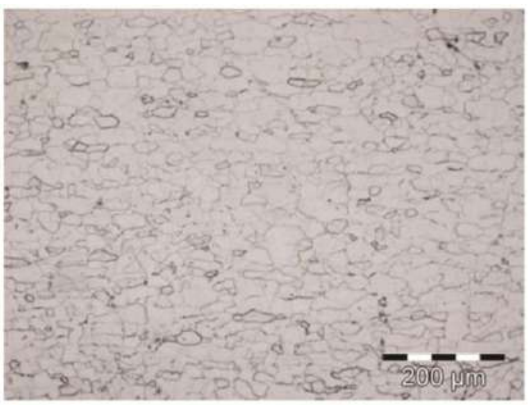

Figure 10 Optical microstructure of Cold rolled-annealed at 600°C X200

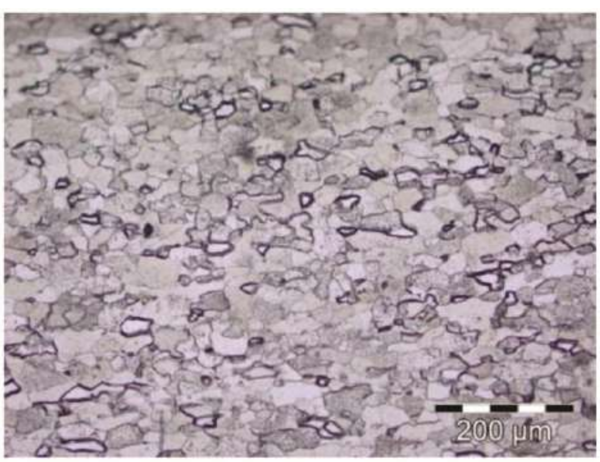

Figure 11 Optical microstructure of Cold rolled-annealed at 650°C X200

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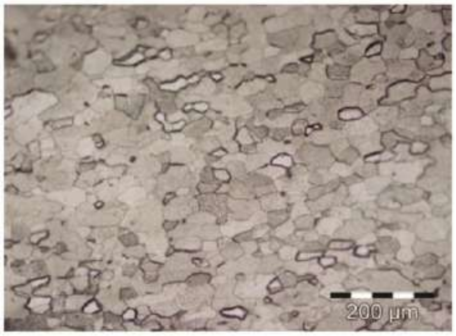

Figure 12 Optical microstructure of Cold rolled-annealed at 700^{o}C X200

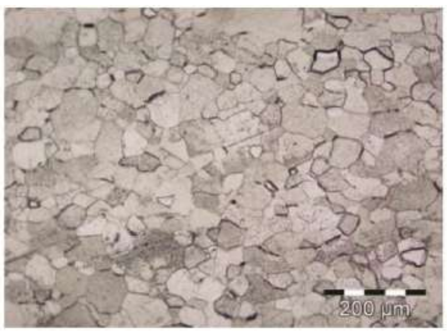

Figure 13 Optical microstructure of Cold rolled-annealed at 725^{o}C X200

Scanning Electron Microscope Image

Fracture morphology of tensile test sample of Hot rolled and cold rolled-annealed at 700^{o}C has been analyzed and shown in **Figures 14** & **15**. It is observed that the entire void formation is not of first generation but also smaller second-generation voids created in the matrix. In hot rolled sample the void size is as large as 117µm whereas void size in cold rolled annealed sample is smaller i.e. 32-38 µm.

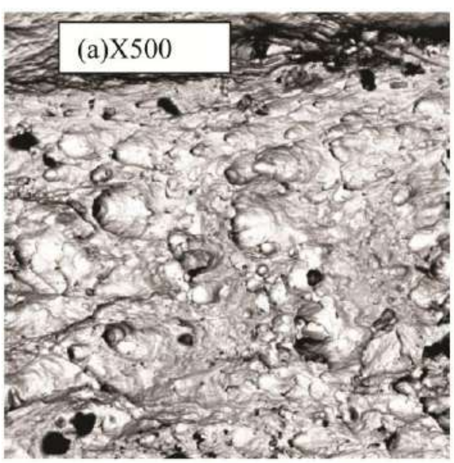

Figure 14 Fractographic image of tensile sample of Hot rolled steel

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Figure 15 Fractographic image of tensile sample of Cold rolled-annealed at 700^oC

CONCLUSIONS

Ti-stabilized interstitial free steel are applied for complex shaped part of inner and outer door panels, side partsetc in four wheeler. Carbon in the range of 20-40 ppm generally produced and stabilized by Ti for complete fixation of carbon and nitrogen and formed precipitates of nitrides (TiN), carbides (TiC), or carbo-nitrides (TiCN).This gives excellent formability, low yield points, and at the same time, high forminganisotropy.

Cold rolled and annealed at 650^oC, 700^oC & 725^oC samples shows the elongation 40% & above. Similarly, $\bar{r}$ are more than 2.0 for annealing temperature 650^oC, 700^oC &725^oC.

The optimized condition for annealing cycle was 700^oC, preceded by 75% cold reduction,which resulted in an $\bar{r}$ of as high as 2.25 & 48% elongation.

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Mining Engineering

Prediction of Roof Falls and induced Caving in Continuous Miner Panel using Machine Learning

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***Abstract**: Continuous Miners are deployed in underground mining for extraction of coal by caving method. The safety conditions require regular caving in the goaf to release the stress in the roof. These falls depend upon various geo-mining and specific characteristics in the area under extraction. Prediction of roof cavability is conducted by emprerical calculations and also numerical modeling. The cavability is assesed by monitoring of convergence in the front abutment zone. A threshold limit of 5mm convergence is considered for cavabilty in the goaf. In some cases, the roof fall does not occur beyond the threshold limit and requires induced caving of the roof in the goaf. In this paper 336 data sets of roof falls in five continuous miner panels were analyzed by logistic regression and machine learning algorithms, to predict the need for induced caving or not. The comparison of the field data in 336 sets, with the logistic regression was found to be about 74%. The variation is because of the varying depths and dimensions of the five panels in the mine under study. It is concluded that the logistic regression and machine learning algorithms of prediction is a useful tool for the decision of induced caving in a continuous miner panel based on the sufficient field data of 336 sets.*

***Keywords**: Continuous Miner Panel; Roof Falls; Induced Caving; Machine Learning; Logistic Regression*

INTRODUCTION

Coal seams at the deeper depths are suitable for underground mining technologies. It is suggested that, "the Power Roof Support Longwall mining and Continuous Miner technology" would be used successfully in several mines, and there is a requirement to propagate and develop it as the primary underground coal mining technique for mass production [1]. The Continuous Miner Technology has been used for development (i.e., virgin seam or developed pillar) and depillaring (i.e., split & fender or fishbone) with caving method for extraction of coal. In the case of the caving method after the extraction of coal from the developed pillars, the roof is allowed to fall into the goaf, this fall occurs periodically (i.e., periodical roof falls) [2]. But sometimes the roof will not fall periodically and increase the hanging goaf area which interrupts the mining operations and also cause problems like crushing of goaf edge pillar, air blast, trapping of machinery inside the goaf because of advanced fall and accidents in depillaring panels [3]. To avoid these problems induced blasting is conducted, if necessary for caving and filling the goaf. The caving due to natural or induced periodic falls will increase, the productivity, safety, and overall performance of mining activities in the panel. Prediction of roof falls in the goaf has been carried out in different approaches such as Experiences from previous panels, Empirical Formulas, Numerical Modeling methods, and Machine Learning Techniques.

In this paper, Machine Learning Techniques of Supervised Learning with Logistic Regression with 336 datasets of roof falls in five panels of continiuious miner working of GDK 11 Inc mine of SCCL is used for the prediction of roof falls in the goaf [4]. Factors considered for prediction of roof falls in the goaf are:

1. Extracted Area in the Panel in Sq.m (EA)
2. Hanging Goaf Area in Sq.m (HG)
3. Fall Area in Sq.m (FA)

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4. Roof Convergence before falling in mm (RC)
5. Induced Blasting (IB)

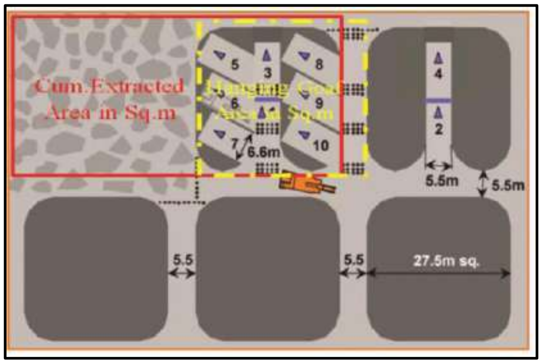

Figure 1 Extracted Area & Hanging Goaf Area

INDUCED BLASTING

Induced caving by blasting has received narrow attention. Induced caving by blasting (induced blasting) is critical to fetch downcast the hanging goaf roof area during the depillaring stage. In the mechanized bord & pillar system of coal extraction, a wide-ranging area of overlying roof strata is generally uncovered after depillaring. The weight accumulation characteristic ahead of the working face is neutralized by regular caving of underlying strata [5]. This is unlikely to happen if extraction is unfolding under a competent roof. Hard roof management schemes in underground coal mines could benefit from induced blasting.

The paramount purpose of induced blasting is to avoid rock bursts at the working faces, which is similar to pre-conditioning/distressing in deep mines [6]. By drilling holes into the uncaved roof and blasting with explosives, the roof rock can be brought down or fractured so that caving can be controlled. In the case of induced blasting, blast fragmentation is not the most important factor. However, the rock should be fractured by the induced blast to facilitate roof fall [7]. Once the roof span exceeds 120–190 Sq.m, induced blasting is commonly done regularly unless the overhanging roof does not fall inside the goaf by its weight. Roof convergence and stress on the goaf edge pillars are monitored continuously. Induced blasting will be used to avoid uncontrolled roof collapse with associated air blast once the daily rise in roof convergence is > 5 mm or the strata pressure increases by 2 t [8].

FIELD STUDY

The field study has done from GDK-11 Inc in Ramagudam-I Area, Singareni Collieries Company Limited where 1 seam is working with Continuous Miner Technology. Total Block-A property is divided into 6 panels for the continuous miner and 5 panels that have been successfully completed. Details of Continuous Miner Panels worked in 1 seam are:

Table 1 Details of Continuous Miner Panels worked in 1 seam

Panel No	Panel Size in Sq.m	Panel Depth in m		No of Pillars	Panel Dimensions in m (D x S)	Total No of falls
		Min	Max			
A-1A	98,980	160	217	74	157 x 630	81
A-1B	91,462	162	221	80	139 x 658	80
A-2	86,955	166	225	75	128 x 682	64
A-3	1,00,195	172	237	93	145 x 691	63
A-4	72,000	172	235	58	120 x 600	48
Overall Data	-	160	237	380	140 x 640	336

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In this paper, a statistical approach of Supervised Machine Learning's logistic regression using machine learning is adopted for the prediction of roof falls in the goaf.

Machine Learning

Machine learning technology-enabled computer programs to study without been explicitly trained. Machine learning is widely used in almost many fields in the world including healthcare sector. Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed [9]. Further, machine learning at its most basic is the practice of using algorithms to parse data, learn from it, and then make a determination or prediction about something in the world [10]. There are two major categories of problems often solved by machine learning i.e. regression and classification. Mainly, the regression algorithms are used for numeric data and classification problems include binary and multi-category problems [11].Machine learning algorithms are further divided into two categories such as supervised learning and unsupervised learning [12]. Basically, supervised learning is performed by using prior knowledge in output values whereas unsupervised learning does not predefined labels hence the goal of this is to infer the natural structures within the dataset [13]. Therefore, selection of machine learning algorithm need to carefully evaluated.In machine learning, data is the key driving element for analysis.

Data Collection

The data collected from the field study is formulated to a CSV file and imported to the machine learning program of Logisitic regression using liberires and Sklearn codes which are equipped with statistical paramters of different algorithms.

Table 2 Dataset Collected from Continuous Miner Panels

S No	Extracted Area in Sq.m	Hanging Goaf Area in Sq.m	Fall Area in Sq.m	Strata Parting in mm	Nature of Fall	Induced Blasting (IB)
1	5339	5339	684	6	Induced Fall	1
2	5829	5145	1017	5	Induced Fall	1
3	7970	6269	2459	5	Induced Fall	1
4	10663	6503	568	4	Periodic Fall	0
5	11953	7225	2410	25	Induced Fall	1
'	'	'	'	'	'	'
'	'	'	'	'	'	'
'	'	'	'	'	'	'
332	54692	1168	1168	5	Induced Fall	1
333	57794	3102	1570	5	Periodic Fall	0
334	58850	2588	818	3	Periodic Fall	0
335	58850	1770	1102	7	Periodic Fall	0
336	60996	2814	668	6	Periodic Fall	0

Analyzing Data

Data analysis is crucial in the area to identify challenges that such an organization has and to evaluate information in relevant ways. Data is nothing more than facts and numbers. Data analysis is the process of organizing, interpreting, structuring, and presenting a dataset into valuable evidence that gives meaning to the information[14].

Interpreted or combined graphs are used for the graphical representation of two or more variables in a single plot. Here induced blasting and strata parting readings are interpreted in count plot **Figure 3**. From the graphs, it is seen that the majority of induced blasting is conducted between the 0 to 6 mm strata parting and the periodical roof falls

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are noted between 5 to 8 mm and also in some cases periodical roof and induced blasting are correlated at the same strata readings which are difficult to predict. By combining variables of the induced blast with correlation graph of Hanging goaf and Fall area shows that the outliers are major problems in the depillaring stage with a large area of hanging goaf with fewer strata parting reading **Figure 3**.

Exploratory Data Analysis

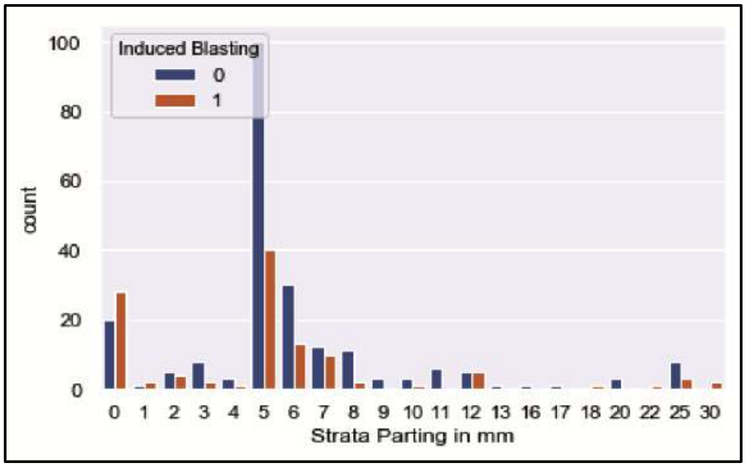

Figure 2 Count plot of Induced blasting and Strata parting

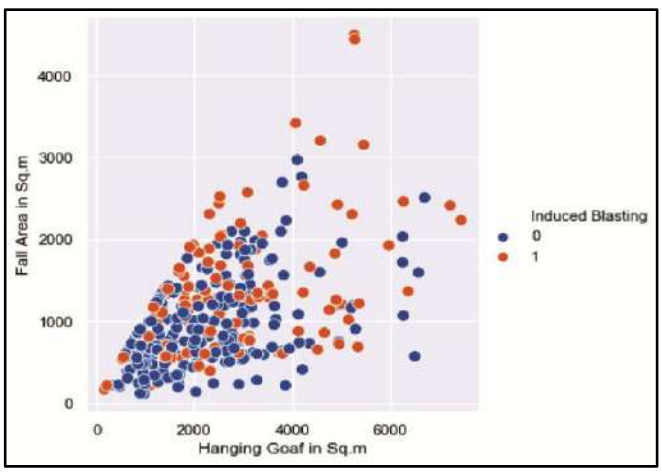

Figure 3 Correlation graph of Hanging Goaf and Fall Area Induced Blasting

Predictive Data Analysis

Predictive analytics is to establish the probability of upcoming occurrences depending on historical data. The purpose is to provide the best judgment of what will happen in the future, rather than actually acknowledging what has happened. Predictive models generate (or train) a model that could forecast values for various or new data based on previous findings shown in **Figure 4**. Modeling generates predictions, which indicate the probability of the response variable based on the anticipated consequence of a collection of input variables. In these models the training and testing data is divided into 70:30 ratio i.e., out of 336 datasets, 235 datasets are given to train the dataset to predict the dependent variable induced blasting, and the remaining 101 datasets are later used for testing of the model with its predicted values. In these 101 datasets, actual falls are 71 periodic falls and 30 induced falls but the

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model predictions are concluded that there are 89 periodic falls and only 12 were induced falls. So the evaluation of the model or program is validated based on the accuracy of predictive values to actual values in the testing dataset.

Model Building

Model Building

```
In [27]: from sklearn.linear_model import LogisticRegression

In [28]: lr=LogisticRegression()

In [29]: lr.fit(x_train,y_train)

Out[29]: LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
                            intercept_scaling=1, l1_ratio=None, max_iter=100,
                            multi_class='auto', n_jobs=None, penalty='l2',
                            random_state=None, solver='lbfgs', tol=0.0001, verbose=0,
                            warm_start=False)

In [30]: y_pred=lr.predict(x_test)

In [31]: y_pred

Out[31]: array([0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0,
                0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0,
                0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0,
                0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
                1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0], dtype=int64)

In [33]: y_test.values

Out[33]: array([0, 0, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 1, 0,
                0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0,
                1, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 1, 1, 0, 0, 1, 0, 1,
                0, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0,
                1, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0], dtype=int64)
```

Figure 4 Logistic Regression Predictive model

The roof falls are categorized according to the panels in which there are occurred. Predictions of these roof falls are also carried out panel-wise. This panel-wise roof falls analysis is carried out with 70% data with the training subset and 30% data for the testing purpose. The outcomes from the different panels are tested and predicted data values are given with no. of Periodical falls and no. of Induced falls occurring in their respective panels are shown in table 3. And the graphical representation of periodical falls and induced falls with the tested and predicted values according to the panels in which there are occurred in **Figures 5** & **6** respectively.

Table 3 Panel wise Predictive analysis of falls

Panel No	Total No of Falls	Total Train Data 70%	Test Data 30%	Test Data No of Periodic falls	No of Induced falls	Predicted Data No of Periodic falls	No of Induced falls
A-1A	81	56	25	20	5	19	6
A-1B	80	56	24	20	4	22	2
A-2	64	44	20	9	11	14	6
A-3	63	44	19	17	2	16	3
A-4	48	33	15	6	9	5	10
Overall Data	336	225	101	71	30	89	12

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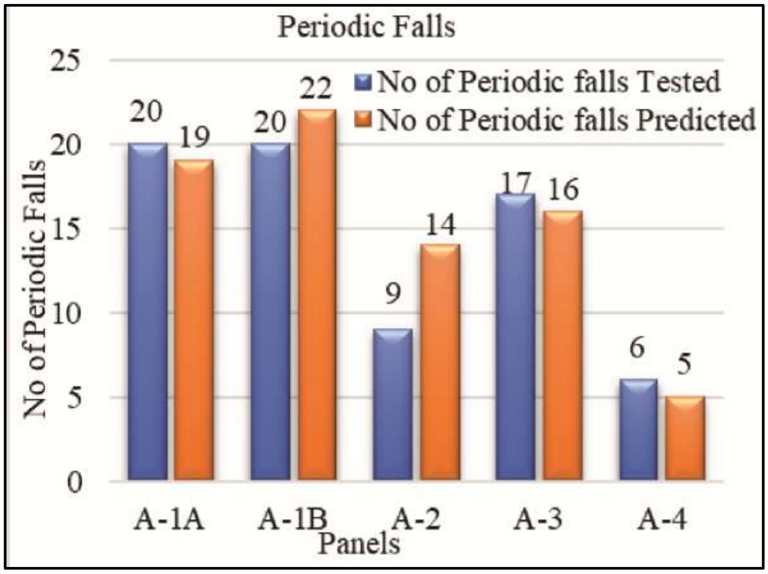

Figure 5 Panel wise Tested & Predicted Periodical Falls

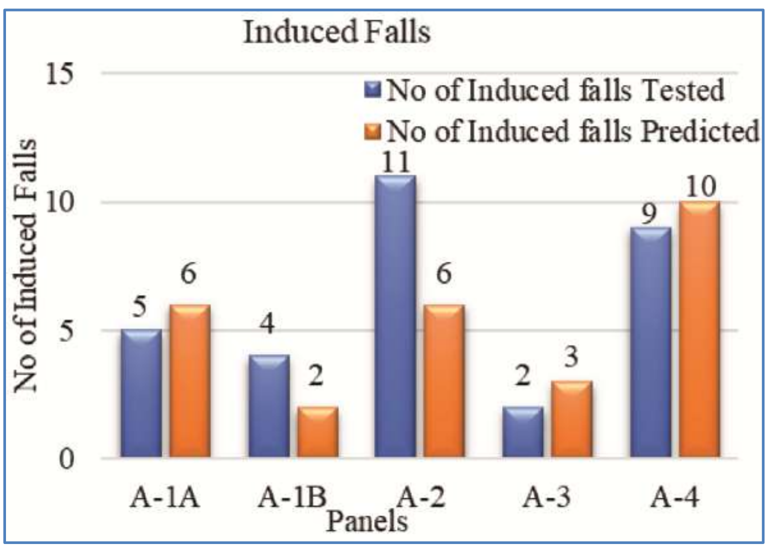

Figure 6 Panel wise Tested & Predicted Induced Falls

Confusion Matrix

The confusion matrix is used for the description of the relationship between the tested values and predicted values of the dependent variable i.e., Induced blasting. The confusion matrix and its heatmap of the above model are shown in **Figure 7**. And also the classification report of the model is provided along with the confusion matrix.

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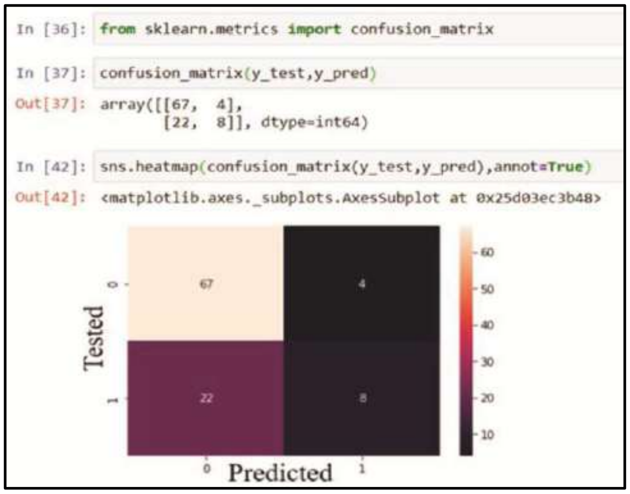

Figure 7 Confusion matrix

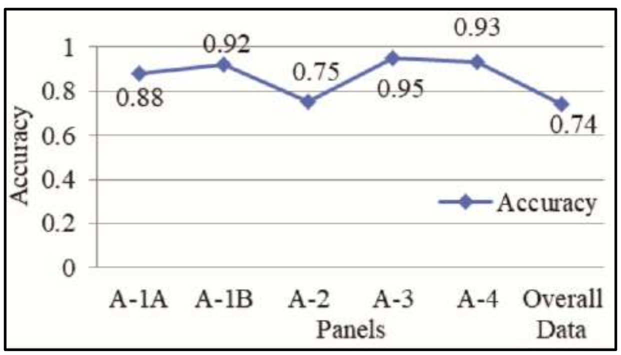

Figure 8 Panel-wise Accuracy of the prediction model.

In the case of panel-wise accuracy analysis, the accuracy levels of 4 panels i.e., A1-A, A1-B, A-3, A-4 are above 0.90 but for the A-2 panel, the accuracy is about 0.75 only. This A-2 panel's data result in the problem of decreasing the accuracy of prediction falls in the model [4].

CONCLUSIONS

1. Analysis of 336 falls in different depillaring panels of continuous miner working of GDK-11 Incline mine shows that there are 221 Periodic falls and 115 induced falls.
2. The induced falls reduce the overall hanging goaf area and avoid problems like crushing of goaf edge pillar, air blast, and accidents in depillaring panels.
3. The predictions model generated using logistic regression generates a decision to induce the roof or not.
4. The accuracy of prediction of roof falls by logistic regression model is 0.742 only. The predictive analysis is carried out panel-wise in which their are occurred and model accuracy levels of 4 panels are above 0.90 but for one i.e., A-2 panel the accuracy is about 0.75.

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Production Engineering

The Sustainable Development in Madurai Jewellery Cluster

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Abstract: *Global market for the Gold is estimated 3300 Metric Tons (in 2019). India is the 2nd largest consumer of the Gold followed by China. China (355 Tons) is the largest producer of Gold, followed by Australia (270 tons) and USA (237 tons) around 45% of total gold production. The Madurai Jewelry Cluster was formed during 2010 with 28 Micro Enterprises whose investment is less than Rs.1 crore with less than Rs. 5 crore turnovers as per MSMED Act 2006. The objective is to find the physical and financial the performance of Madurai Jewelry Cluster before and after Cluster Development Approach (CDA), to find the Productivity of the cluster by taking independent variable like No. of Units, Employment and Production and dependent variable like Turnover and to find performance of Madurai Jewelry Cluster before and after Cluster Development Approach. The methodology adopted by collecting the primary data like no of units [Un], employment in no's [En], production in crores [Pcr] and turnover in crores [Tcr]from the Madurai Jewellery Cluster before and after cluster development approach and analysing using Compound Annual Growth Rate (CAGR), Descriptive Analysis, Correlation Analysis, Trend Analysis, Regression Analysis and Structural Equation Modelling. There is increase in no. of units, employment, production and turnover after Cluster Development Approach when compared to before CDA and which leads to increase in productivity.*

Keywords*: Cluster Development Approach*

INTRODUCTION

Global market for the Gold is estimated 3300 Metric Tons (in 2019). India is the 2nd largest consumer of the Gold followed by China. China (355 Tons) is the largest producer of Gold, followed by Australia (270 Tons) and USA (237 Tons) around 45% of total gold production. The details of Jewellery Sector in India are given in **Table 1**.

Table 1 Gold Jewellery Sector in India

City	Jewellery
Jaipur	Polishing Precious & Semi Precious Gemstones
Surat	Diamond Processing Centre
Mumbai	Machine & Handmade Jewellery, Diamond Bourse,
Tiruchur	Gold Jewellery, Diamond
Delhi	Silver Jewellery Article
Kolkata	Light weight plain Gold Jewellery
Hyderabad	Precious and semi-precious studded Jewellery
Nellore	Handmade jewellery
Chennai	Gold Jewellery, Bangles
Coimbatore	Gold Chain, Bracelets, Studs, Ring

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TECHNICAL SURVEY

Tamil Nadu consumes about 175 Tons which is 17% of the gold consumption of the Country. Gold Jewellery manufacturing is led by Chennai, Coimbatore, Madurai, Trichy and Tirunelveli.

These 5 locations major manufacturing of the Gold Jewellery and their performance are shown in **Figure 1**.

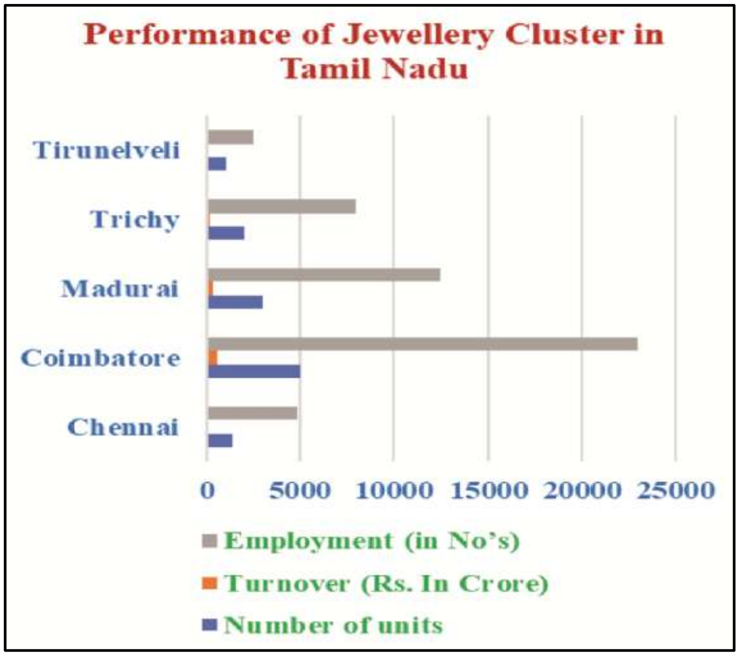

Figure 1 Performance of Jewellery Cluster in Tamil Nadu

The Madurai Jewellery Cluster was formed during 2010 with 28 Micro Enterprises whose investment is less than Rs.1 crore with less than Rs. 5 crore turnovers as per MSMED Act 2006. The status of the cluster is given in **Table 2**.

The Study was conducted to know the various interventions needed for empowering the entrepreneurs engaged in Jewellery Manufacturing in the areas of Social, Technological, infrastructure related, Financial and Marketing for the successful promotion of Cluster. [1] The Ministry of Micro, Small and Medium Enterprises (MSME), Government of India (GoI) has adopted the Cluster Development approach as a key strategy for enhancing the productivity and competitiveness as well as capacity building of Micro and Small Enterprises (MSEs) and their collectives in the country. [2]

Many studies have been made to identify performance for Clusters under Cluster Development Approach like Match, Printing, Auto components, Leather, Plastic, Hosiery, Textile, Lorry Body Building, Pharmaceutical, Ceramic, Wet Grinder, Jewelry and Rice Mill [3]. Tamil Nadu is first to implement 24 clusters in India which includes Jewellery Manufacturing Cluster [4][5][6]. A cluster is identified by two constituents – the product and the place, and is generally localized. [6] However the Jewellery Cluster is not studied yet and this leads to study on the performance of Madurai Jewellery Cluster before and after CDA.

Under Micro Small Enterprises Cluster Development Programme of Ministry of Micro, Small and Medium Enterprises, Government of India the Madurai Jewellery Cluster has got funding from Government of India, and Government of Tamil Nadu. The SPV also contributed and obtained bank loan to finish the project about Rs.3.56 crore. The details of project cost are given **Figure 2**.

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Table 2 Status of Madurai Jewellery Cluster

Name of the Cluster	Madurai Jewellery Cluster, Madurai
Created in	28-07-2010
Category of Products	Jewellery and Allied Services
Extent of Land	4200 Sq. Feet
No. of Units intended	28
No. of units created/established	46
No of occupancies	80
Present Board of Management	1.Managing Director 2. 6 Directors
Regularity of Conducting Meetings	Once in 2 months
No. of Members	31 MSMEs
Access to members/others (As per original plan)	SPV members and non-members
Existing facilities/Maintenance	1. Testing facility 2. Melting facility 3. Laser Marking and Soldering 4. Refining 5. Electro Plating 6. Hydraulic Pressing (Coins)
Financial Performance	Bank loan closed Self sufficient
Product refining etc as per original Proposal	As per the customer requirement model of design has changed.
Date of completion	24.10.2018

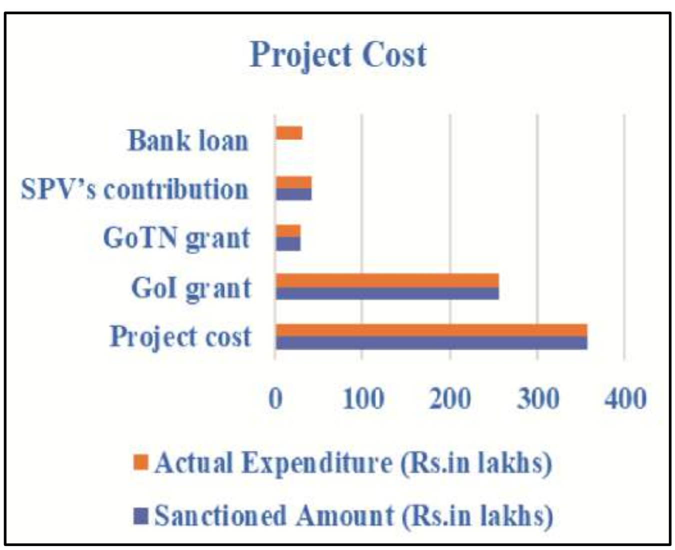

Figure 2 Project Cost of Cluster

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OBJECTIVE OF THE STUDY

The objective of study is to

1. To find the physical and financial the performance of Madurai Jewellery Cluster before and after Cluster Development Approach (CDA).
2. To find the Productivity of the cluster by taking independent variable like No. of Units, Employment and Production and dependent variable like Turnover.
3. To find performance of Madurai Jewellery Cluster before and after Cluster Development Approach.

METHODOLOGY OF THE STUDY

The methodology adopted by collecting the primary data like no of units [Un], employment in no's [En], production in crores [Pcr] and turnover in crores [Tcr] from the Madurai Jewellery Cluster before and after cluster development approach and analysing using Compound Annual Growth Rate (CAGR), Descriptive Analysis, Correlation Analysis, Trend Analysis, Regression Analysis and Structural Equation Modelling.

TECHNICAL ANALYSIS

Before adopting Cluster Development Approach, the Micro Enterprises manufacturing jewellery were manually doing different types of Jewellery.

- ❖ The cluster members do not use modern and sophisticated technology.
- ❖ Many Units still following traditional methods
- ❖ Household type of venture
- ❖ Unorganised sector
- ❖ Obsolete machineries with cluster members – Need for technology infusion.
- ❖ Limited market. Mostly doing job work to Traders and Wholesalers / Retailers.
- ❖ Over dependence on Traders
- ❖ Poor Backward (Raw material and Advanced machineries) and Forward integration (Job order, Design, whole sale market and Export)
- ❖ Poor R & D activity – No new design development by cluster units
- ❖ Lack of in-house testing facilities
- ❖ Lack of training to work with modern machineries

NEED FOR COMMON FACILITY CENTRE

- ❖ Need for modern machineries for product making which are capable of making large number of homogeneous products in short period.
- ❖ Lack of Credit / limited resources for Investment in Latest Technology Machineries
- ❖ Need for reduction in the cost of production and wastages to compete with big players.
- ❖ Investment in latest technology machineries for various activities like gold melting, sheet and wire drawing, different types of chain making, laser welding, laser marking, cutting, refining etc., are beyond the reach of these micro artisan goldsmiths.

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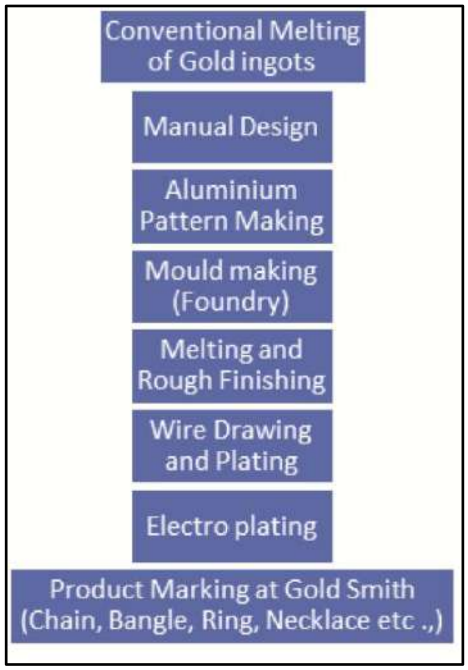
- Establishment of a Common Facility Centre for the cluster members will bring in radical change for the cluster members in terms of cost reduction, quality improvement, increased productivity, product diversification through design creation etc., and enable them to compete with organized players and create their own brand and market.

WORKS AT CLUSTER UNITS BEFORE CDA

The following process were done before CDA.



Facilities created in Common Facility Centre (CFC)

To improve productivity the following facilities were created in the cluster during 2018 and also shown in **Figure 3**.

1) XRF Machine
2) Laser welding Machine
3) Laser Marker
4) Induction Furnace
5) Coli Heating Machine
6) Assaying Furnace
7) Bangle Making Machine
8) Sheet, Wire & half round machine
9) Hydraulic press
10) Die Hand press
11) Hand Bali press
12) Pneumatic press

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Figure 3 CFC created in Cluster

The Value Chain Analysis after CDA is as follows and also shown in **Table 3.**

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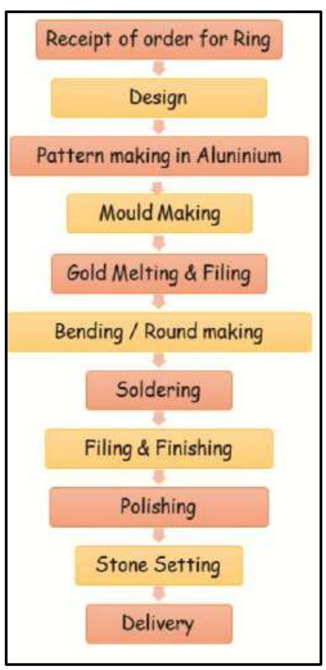
Table 3 Value Chain Analysis in Madurai Jewellery Cluster

S. No.	Type Of Product	Work At The Individual Units [Before Cda]	Value Addition At The Cfc	Post Cfc Work At The Unit Level [After Cda]
1	Jewelry Item Like Ear Ring, Bangles, Ring, Stud, Etc (Only One Piece / Set)	Goldsmith Workshop (Gold Melting, Sheet / Wire Drawing, Welding, Polishing, Stone Fixing, Enamel Work, Engraving Work Etc)	-	-
2	Mangal Sutra As Per Customer's Request	Entire Work Will Be Done At The Goldsmith Workshop	-	
3	Bulk Order (More Than 10 Numbers) Of Same Item (Homogeneous Product) – Like Same Type Of Chains, Bangles Etc.,	Order Procurement Gold Quality Assessment	Gold Melting Chain Making (Continuous Length) Bangle Making (Continuous Length) Hook Making	Machine Cutting, Hook Attachment, Pendent Attachment, Stone Fixing For Chain/ Bangles And Engraving Work On Bangles Back To Cfc For Buffing & Polishing Work
4	Bulk Order – Ring (Casting Type)	Order Procurement Gold Quality Assessment	Casting Working Gold Melting Polishing Work	Filing Work Stone Setting Finishing Work Engraving / Enamel Work Back To Cfc For Buffing & Polishing Work
5	Bulk Order – Ring	Order Procurement Gold Quality Assessment	Gold Melting Hollow Pipe Making	Cutting Into Requirement Sizes Design Work Back To Cfc For Polishing And Cutting Work

SOURCE: PRIMARY DATA

Manufacturing Process – Stone Fixed Ring



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PHYSICAL PERFORMANCE

The physical performance is shown in **Figure 4**

Figure 4 Physical performance

As per **Figure 4**, CAGR for Un = 19.13% and for En = 9.5%

FINANCIAL PERFORMANCE

The financial performance is shown in **Figure 5**

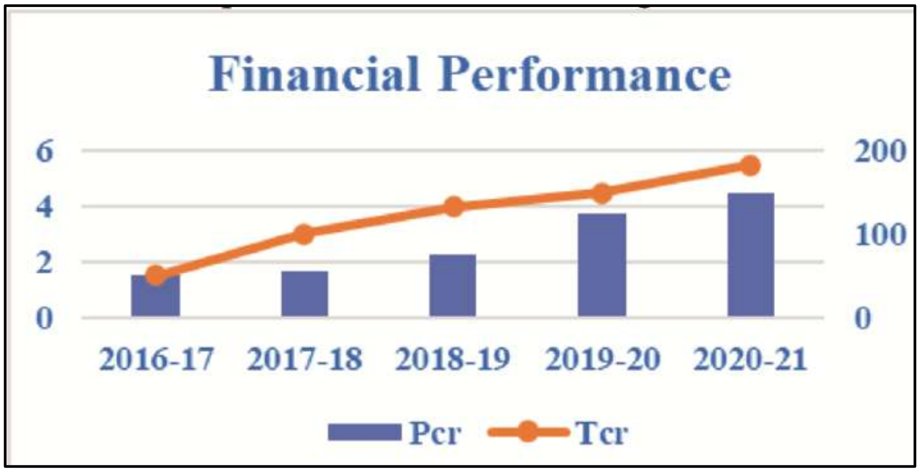

Figure 5 Financial Performance

As per figure 5, CAGR for Pcr = 24.57% and for Tcr = 26.57%

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DESCRIPTIVE ANALYSIS

Table 4

	Un	En	Pcr	Tcr
Mean	78.40	920.00	91.00	3.70
Standard Error	11.83	67.40	19.84	0.68
Median	72	960	75	4
Standard Deviation	26.46	150.71	44.36	1.52
Sample Variance	700.30	22712.50	1967.50	2.33
Kurtosis	1.38	0.31	-2.18	0.00
Skewness	1.05	-0.58	0.60	-0.54
Range	70	400	100	4
Minimum	50	700	50	1.5
Maximum	120	1100	150	5.5
Sum	392	4600	455	18.5
Count	5	5	5	5

TREND ANALYSIS

$Un = 30.4 + 16\ T\ [\ p = 0.01,\ R^2 = 0.91]$ [1]

The annual average increase in no. of units is 16.

$En = 641 + 93\ T\ [\ p = 0.01,\ R^2 = 0.95]$ [2]

The annual average increase in employment is 93.

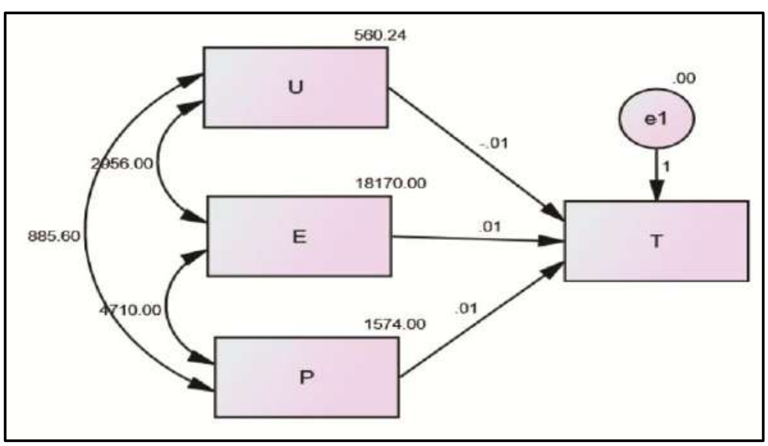
$Pcr = 10 + 27\ T\ [\ p = 0.01,\ R^2 = 0.92]$ [3]

The annual average increase in production is Rs.27 crores.

$Tcr = 0.85 + 0.95\ T\ [p = 0.002,\ R^2 = 0.97]$ [4]

The annual average increase in turnover is Rs.0.95 crores.

STRUCTURAL EQUATION MODELLING



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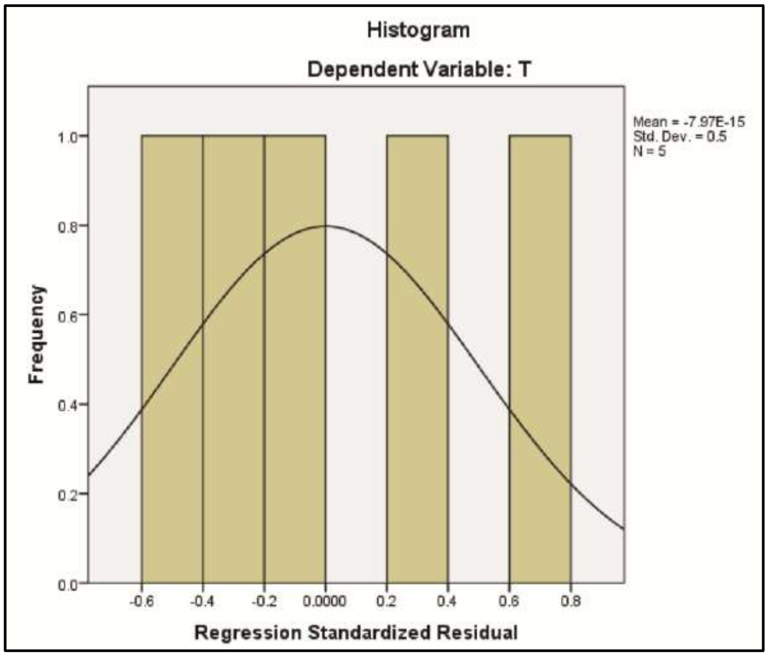
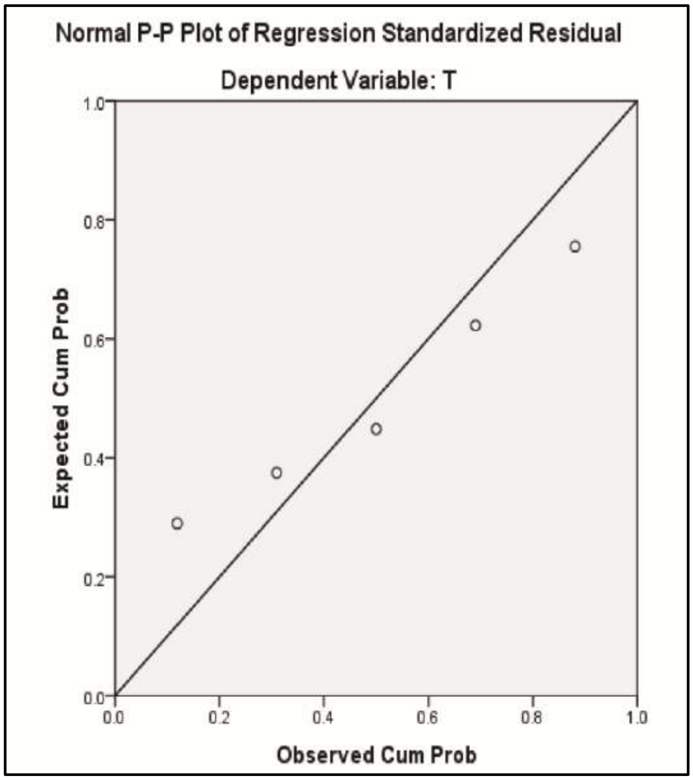
Tcr = -5.21-0.006 Un + 0.009En + 0.006 Pcr [$p= 0.03 < 0.05$, $R^2 = 0.99$] ……[5]

For one unit increase in turnover, production increases by 0.01 units, Employment by 0.01 units and there is decrease in no. of units.





REGRESSION ANALYSIS

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$Pcr = -40.27+1.5\ Un + 0.015En\ \ [\ p= 0.11 > 0.05,\ R^2 = 0.94]$ [6]

For one unit increase in production, employment increases by 0.02 units and no. of units by 1.5 units.

$Tcr = 0.88+0.03\ Pcr\ \ [\ p= 0.04 < 0.05,\ R^2 = 0.90]$ [7]

For one unit increase in turnover, production increases by 0.03 units.

T TEST

t-Test: Paired Two Sample for Means		
	Ua	Ub
Mean	92.33333	62.33333
Variance	616.3333	126.3333
Observations	3	3
Pearson Correlation	0.893539	
Hypothesized Mean Difference	0	
df	2	
t Stat	3.326496	
P(T<=t) one-tail	0.039857	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.079714	
t Critical two-tail	4.302653	

Ho: Ua = Ub , p = 0.03 < 0.05 (Rejected)
Ha: Ua # Ub (Accepted) Ua > Ub

t-Test: Paired Two Sample for Means		
	Ea	Eb
Mean	1015	838.3333
Variance	5575	17108.33
Observations	3	3
Pearson Correlation	0.893386	
Hypothesized Mean Difference	0	
df	2	
t Stat	4.22986	
P(T<=t) one-tail	0.025802	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.051604	
t Critical two-tail	4.302653	

Ho: Ea = Eb , p = 0.02 < 0.05 (Rejected)

Ha: Ea # Eb (Accepted) Ea > Eb

t-Test: Paired Two Sample for Means		
	Pcra	Pcrb
Mean	116.6667	60
Variance	1458.333	175
Observations	3	3
Pearson Correlation	0.866025	
Hypothesized Mean Difference	0	
df	2	
t Stat	3.564168	

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P(T<=t) one-tail	0.035248
t Critical one-tail	2.919986
P(T<=t) two-tail	0.070497
t Critical two-tail	4.302653

Ho: Pcra = Pcrb , p = 0.03 < 0.05 (Rejected)
Ha: Pcra # Pcrb (Accepted) Pcra > Pcrb

t-Test: Paired Two Sample for Means		
	Tcra	Tcrb
Mean	4.666667	2.833333
Variance	0.583333	1.583333
Observations	3	3
Pearson Correlation	0.953821	
Hypothesized Mean Difference	0	
df	2	
t Stat	5.5	
P(T<=t) one-tail	0.015752	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.031504	
t Critical two-tail	4.302653	

Ho: Tcra = Tcrb , p = 0.02 < 0.05 (Rejected)
Ha: Tcrb # Tcrb (Accepted) Tcra > Tcrb

FINDINGS, SUGGESTIONS AND CONCLUSION

A study was conducted to find the productivity of Madurai Jewellery Cluster before and after cluster development approach. There is increase in CAGR after CDA. There is increase in mean value after CDA. There exists strong relationship between dependent variables like turnover and independent variables like no. of units, employment and production. There is annual average increase in no. of units, employment, production and turnover. There is increase in no. of units, employment, production and turnover after Cluster Development Approach. There is cost reduction in individual unit after CDA. Due to CDA, The Jewellery products are diversified, new design has been developed, direct export by cluster units has taken place and brand creation has been developed in Madurai Jewellery Cluster.

ACKNOWLEDGMENT

The author acknowledges Department of Industries and Commerce, Government of Tamil Nadu for sending him for UNIDO cluster development training at EDII, Ahmedabad and acknowledges University of Madras for giving Ph.D. in Industrial Cluster Development Approach.

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Textile Engineering

Modelling Multi-phase Machine Repairable System for a Textile Industry

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***Abstract**: In this article, we analyse multi stages of service queuing model which undergoes multi-phases of repair due to active breakdown in a manufacturing industry like textile industry with restricted arrivals of unfinished products in line.. During each stage of manufacturing process, whenever breakdown of machine occurs, it is immediately sent for its corresponding repair stage. After repair completion, the machine resumes it's remaining service. We carried out the steady-state analysis of the system using the method of supplementary variable technique and important performance measures and stability conditions are obtained such as the expected que length and expecyed waiting time of the the orders. The results were reported with interesting illustrative numerical example.*

***Keywords**: General Bulk Service; Non-Markovian Queue; Multi Stage Service and Repair, Active Breakdown*

Mathematics Subject Classification: 60K25, 90B22, 68M20.

INTRODUCTION

The fabric enterprise imposes a number of constraints regarding the mixing of an usual scheduling procedure. For example, the weaving technique is characterized by using lengthy planning horizons and relatively slow speed of machines, very long setup instances, very huge manufacturing batches, and combined order and stock-based totally production. on the contrary, the warp making process is characterized by way of short planning horizons and excessive velocity of machines, short setup instances, small production batches and simplest orders-based manufacturing. The above phases pose the maximum complex production scheduling problems.

In any manufacturing industry, machine break-down during operation is a general phenomena that brings an impact on the system efficiency, productivity, job completion time, waiting time in the queue and system. In multi stage manufacturing process such as textile, Leather industries etc., the server provides N stages of heterogeneous service in succession. This types of model finds real time application in heterogenous multi stage manufacturing process. The server (machine) starts the first stage of service only, if minimum 'a' customers are in the queue. After first stage service completion, the server starts second stage service to the same batch of customers (unfinished product), then remaining stage of services are served to the same batch of customers to complete the production cycle. During this process. If the machine breaks-down at 'i'th stage, then it is immediately sent for repair. For each stage of service station, we have different break-down rates. This types of model finds real time application in heterogenous multi stage manufacturing process in textile industry from fibre to garment. Our major problem is to enhance the overall performance of multi-phase store manufacturing technique via way of means of disposing of the waiting time of every technique at some point of the breakdown. Bulk queueing systems with active server break-down of differing time interval following probabilistic phenomena are considered by several researchers.

In textile industries, the manufacturing machine requires immediate repair after breakdown for proficient output of the creation and delivery of goods as per schedule. Motivated through those observations, we've got advanced a model bulk service queue model with multiple stages of services and multiple repairs to complete the production process. We carried out the steady-state analysis of the system using the method of supplementary variable technique to obtain measures such as joint distribution of the server state, expected system size, expected queue size, availability of the server and failure frequency. The results were reported with interesting illustrative numerical examples. The brief outline of the present paper is presented here.

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LITERATURE REVIEW

Very few authors have dealt with the concepts of multi stages of service and breakdown server: Bagyam et al. (2018) and Radha et al. (2017). Zhou et al. (2017), Fazlollahtabar et al. (2019) and Vladimir Alexeev et al. (2020) have analysed a single server and batch arrival with a multiple stages of service queuing system and determined the various performance measures based on queueing characteristics.

Sethi et al. (2017) investigated transient evaluation of Markovian queue with multi stage service, finite capability and breakdowns. Runge-Kutta approach has been used to have a look at the transient analysis of finite Markovian queueing version. various overall performance measures like waiting time, queue duration, throughput, and service kingdom probabilities have additionally been obtained.Bogatyrev et al. (2017) designed answers on the employer of multi-degree redundant service of copies of requests in multi-tier cluster that makes it possible to boom the possibility of well timed servicing of requests crucial to the overall waiting time for all machine tiers (stages of protection). They derived the life of efficient redundant carrier of requests in multi-tier clusters, and the ultimate multiplicity of redundancy of request copies relying at the machine load and constraints at the allowable total time of staged ready inside the queues of the nodes within the clusters at all degrees.

A multi stage of heterogeneous service in a batch arrival queue is analysed through Vignesh et al. (2017). through employing producing features and supplementary variable strategies, the brief answer and the corresponding consistent kingdom results were acquired explicitly with practical rationalisation / validation model.Another application, of this type of Queue model is healthcare system. Wu et al. (2019) advanced two effective heuristics strategies to estimate the patient-blocking opportunity, which can be then used to broaden an included mathematical version for bed allocation and validated it with actual time data amassed from a tertiary hospital in China . They discovered that increasing the range of beds at some stage in the primary level is greater powerful in reducing blockage than doing so later in case of a confined number of beds.

Zhou et al. (2019) considered an appointment scheduling problem in multi-level sequential provider structures and hooked up linear relationships amongst waiting instances and idle times in unique ranges, and transform the stochastic application into a two-level software. And sooner or later, they behavior numerical experiments and shown that the optimal agenda famous a "dome" shape when service instances of all clients are unbiased and identically disbursed in every stage, and the "dome" form varies with specific parameters.

Klassen et al. (2019) considers the situations under which adding an Mid-degree provider carriers (MLSP) to a unmarried-physician outpatient workplace turns into the exceptional method for the sanatorium, and determines how scheduling guidelines from the widely-researched unmarried-stage surroundings must be adjusted for a multi-stage environment. They display that adding an MLSP can reduce patient waiting time, patient drift time, and health practitioner service time with sufferers. Ebadi et al. (2020) develops control charts for monitoring the provider instances on the exceptional degrees of a congested device that gives a multistage service to its clients and carried out this approach to a quick food eating place with waiting ranges. Thai et al. (2020) discussed the observe of multi-stage production with several service areas in order to in addition optimise the excellent of the control of the distribution of jobs. Modelling is carried out and methods of fixing the discrete optimisation hassle are proposed.

MATHEMATICAL DESCRIPTION OF OUR MODEL

A multi-stage service process in Textile industry is given in **Figure 1** for the understanding of the textile process to the reader. In this paper$M^{[X]}/G(a,b)/1$ queue model with single server, multi-stages service with customers arrive in batch according to a Poisson process with restricted arrivals is discussed. The server provides multiple stages of heterogeneous service in succession. Server serves the customers under General Bulk Service Rule (GBSR) with FCFS queue discipline. After first stage service completion, the server starts second stage service to the same batch of customers then depends upon request with probability p third stage or with probability q fourth stage service served to the batch after fifth, six and seventh stage of services are served to complete the production cycle. During this process. If the machine break-down, then it is immediately sent for repair. For each stage of service station we have different types of break-down rates. This types of model finds real time application in heterogenous multi stage manufacturing process in textile industry from fibre to garment. Our main concern is to improve the performance of

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multi-stage shop production process by removing the waiting time of each process during the breakdown. Seven stages of services and repair are assumed to follow general(arbitrary) distribution.

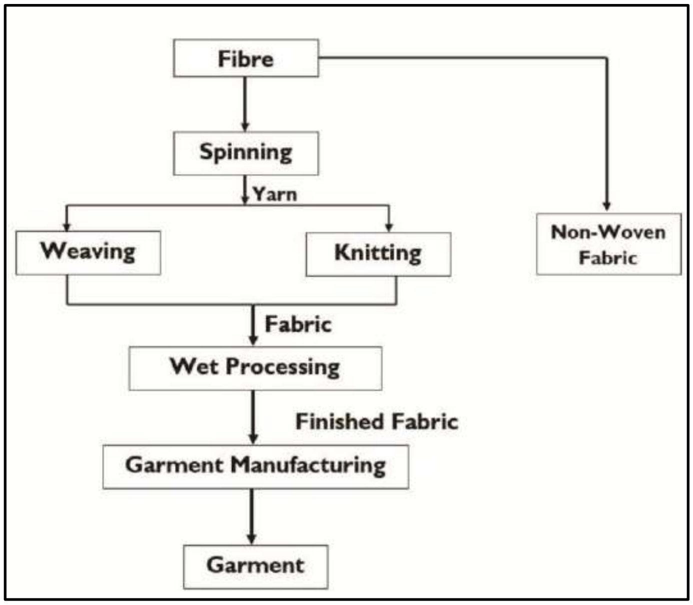

Figure 1 A multi-stage service process in Textile industry

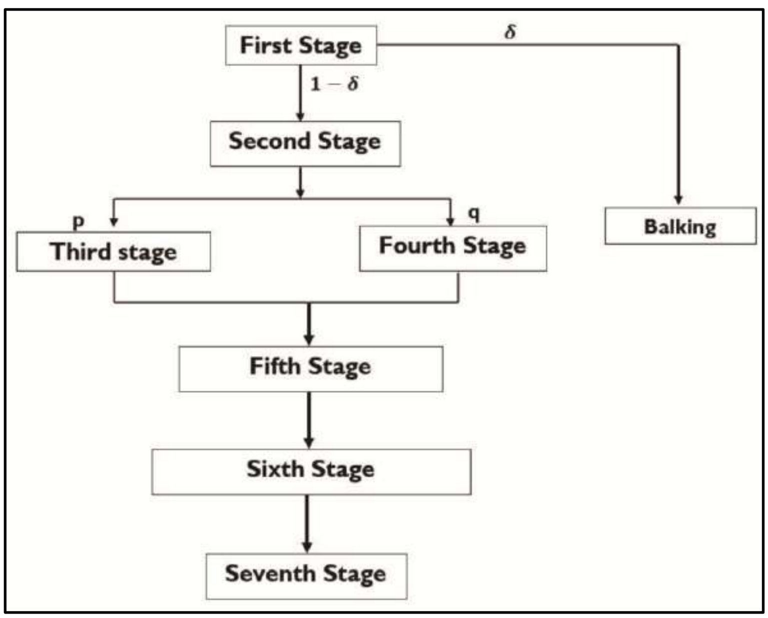

Figure 2 Schematic representation of the model.

Notations

• λ - Arrival rate.

• X- Group size random variable.

• $\Pr(X = k) = g_k$.

• $X(z)$ - the Probability Generating Function (PGF) of X.

• $\mathcal{S}_i(.)$, $\mathcal{R}_i(.)$ (i=1, 2,...,7) represents the Cumulative Distribution Function (CDF) of i^{th} stage service time, i^{th} stage repair time and their corresponding probability density functions are $s_i(w)$ and $r_i(w)$ respectively.

• $\mathcal{S}_i^0(t)$ and $\mathcal{R}_i^{(0)}(t)$ represents the remaining i^{th} stage service time, remaining i^{th} stage repair time at time 't' respectively.

• $\tilde{\mathcal{S}}_i(\tau)$ and $\tilde{\mathcal{R}}_i(\tau)$ represent the Laplace Stieltjes Transform (LST) of $\mathcal{S}_i$ and $\mathcal{R}_i$ respectively.

For the further development of the queueing system, let us define the following probabilities:

$\mathcal{I}_n(t)\Delta t = \Pr\{N_q(t) = n, \phi(t) = 1\}, n \geq 0,$

$\mathcal{M}_{i,n}(w,t)\Delta t = \Pr\{N_q(t) = n, w \leq \mathcal{S}_i^0(t) \leq w + \Delta t, \phi(t) = 2\}, n \geq 1$

$\mathcal{R}_{i,n}(w,y,t)\Delta t = \Pr\{N_2(t) = n,\ \mathcal{S}_i^0(t) = xy \leq \mathcal{R}_i^0(t) \leq y + \Delta t\phi(t) = 3\}, n \geq a.$

where $\phi(t) = (1), (2)$ and (3) denotes server is in idle, busy in i^{th} stage service and i^{th} stage repair respectively.

$N_q(t)$, be number of customers in queue at time 't' respectively.

QUEUE SIZE DISTRIBUTION

The Kolmogorov backward equation governing the system for the proposed model is:

Server is in idle

$$\lambda \mathcal{I}_0 = \mathcal{M}_{7,0}(0), \tag{1}$$

$$\lambda \mathcal{I}_n = \mathcal{M}_{7,0}(0) + \sum_{k=1}^{n} \mathcal{I}_{n-k}\lambda g_k, 1 \leq n \leq a-1, \tag{2}$$

Server is in service

$$-\mathcal{M}_{1,0}^{'}(w) = -(\lambda + \alpha_1)\mathcal{M}_{1,0}(w) + \sum_{d=a}^{b} \mathcal{M}_{7,d}(0)s_1(w) + \mathcal{R}_{1,0}(w,0)$$

$$+ \sum_{k=0}^{a-1} \sum_{d=a}^{b} I_k \lambda g_{d-k} s_1(w) + \lambda\delta\mathcal{M}_{1,0}(w), \tag{3}$$

$$-\mathcal{M}_{1,n}^{'}(w) = -(\lambda + \alpha_1)\mathcal{M}_{1,n}(w) + \lambda\delta\mathcal{M}_{1,n}(w) + \mathcal{R}_{1,n}(w,0)$$

$$+\mathcal{M}_{7,b+n}(0)s_1(w) + \sum_{k=0}^{a-1} I_k \lambda g_{b+n-k} s_1(w)$$

$$+(1-\delta)\sum_{j=1}^{n} \mathcal{M}_{1,n-j}(w)\lambda g_j, n \geq 1, \tag{4}$$

$$-\mathcal{M}_{2,0}^{'}(w) = -(\lambda + \alpha_2)\mathcal{M}_{2,0}(w) + \mathcal{M}_{1,0}(0)s_2(w) + \mathcal{R}_{2,0}(w,0) + \lambda\delta\mathcal{M}_{2,0}(w) \tag{5}$$

$$-\mathcal{M}_{2,n}^{'}(w) = -(\lambda + \alpha_2)\mathcal{M}_{2,n}(w) + \lambda\delta\mathcal{M}_{2,n}(w) + \mathcal{R}_{2,n}(w,0)$$

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$$+\mathcal{M}_{1,n}(0)s_2(w) + (1-\delta)\sum_{j=1}^{n} \mathcal{M}_{2,n-j}(w)\lambda g_j, n \geq 1 \quad (6)$$

$$-\mathcal{M}_{3,0}^{'}(w) = -(\lambda + \alpha_3)\mathcal{M}_{3,0}(w) + p\mathcal{M}_{2,0}(0)s_3(w) + \mathcal{R}_{3,0}(w,0) + \lambda\delta\mathcal{M}_{3,0}(w) \quad (7)$$

$$-\mathcal{M}_{3,n}^{'}(w) = -(\lambda + \alpha_3)\mathcal{M}_{3,n}(w) + \lambda\delta\mathcal{M}_{3,n}(w) + \mathcal{R}_{3,n}(w,0)$$

$$+p\mathcal{M}_{2,n}(0)s_3(w) + (1-\delta)\sum_{j=1}^{n} \mathcal{M}_{3,n-j}(w)\lambda g_j, n \geq 1 \quad (8)$$

$$-\mathcal{M}_{4,0}^{'}(w) = -(\lambda + \alpha_4)\mathcal{M}_{4,0}(w) + q\mathcal{M}_{2,0}(0)s_4(w) + \mathcal{R}_{4,0}(w,0) + \lambda\delta\mathcal{M}_{4,0}(w) \quad (9)$$

$$-\mathcal{M}_{4,n}^{'}(w) = -(\lambda + \alpha_4)\mathcal{M}_{4,n}(w) + \lambda\delta\mathcal{M}_{4,n}(w) + \mathcal{R}_{4,n}(w,0)$$

$$+q\mathcal{M}_{2,n}(0)s_4(w) + (1-\delta)\sum_{j=1}^{n} \mathcal{M}_{4,n-j}(w)\lambda g_j, n \geq 1 \quad (10)$$

$$-\mathcal{M}_{5,0}^{'}(w) = -(\lambda + \alpha_5)\mathcal{M}_{5,0}(w) + (\mathcal{M}_{3,0}(0) + \mathcal{M}_{4,0}(0))s_5(w)$$

$$+\mathcal{R}_{5,0}(w,0) + \lambda\delta\mathcal{M}_{5,0}(w) \quad (11)$$

$$-\mathcal{M}_{5,n}^{'}(w) = -(\lambda + \alpha_5)\mathcal{M}_{5,n}(w) + (\mathcal{M}_{3,n}(0) + \mathcal{M}_{4,n}(0))s_5(w)$$

$$+\mathcal{R}_{5,0}(w,0) + \lambda\delta\mathcal{M}_{5,n}(w) + (1-\delta)\sum_{j=1}^{n} \mathcal{M}_{5,n-j}(w)\lambda g_j, n \geq 1, \quad (12)$$

$$-\mathcal{M}_{6,0}^{'}(w) = -(\lambda + \alpha_6)\mathcal{M}_{6,0}(w) + \mathcal{M}_{5,0}(0)s_6(w) + \mathcal{R}_{6,0}(w,0) + \lambda\delta\mathcal{M}_{6,0}(w) \quad (13)$$

$$-\mathcal{M}_{6,n}^{'}(w) = -(\lambda + \alpha_6)\mathcal{M}_{6,n}(w) + \lambda\delta\mathcal{M}_{6,n}(w) + \mathcal{R}_{6,n}(w,0)$$

$$+\mathcal{M}_{5,n}(0)s_6(w) + (1-\delta)\sum_{j=1}^{n} \mathcal{M}_{6,n-j}(w)\lambda g_j, n \geq 1 \quad (14)$$

$$-\mathcal{M}_{7,0}^{'}(w) = -(\lambda + \alpha_7)\mathcal{M}_{7,0}(w) + \mathcal{M}_{6,0}(0)s_7(w) + \mathcal{R}_{7,0}(w,0) + \lambda\delta\mathcal{M}_{7,0}(w), \quad (15)$$

$$-\mathcal{M}_{7,n}^{'}(w) = -(\lambda + \alpha_7)\mathcal{M}_{7,n}(w) + \lambda\delta\mathcal{M}_{7,n}(w) + \mathcal{R}_{7,n}(w,0)$$

$$+\mathcal{M}_{6,n}(0)s_7(w) + (1-\delta)\sum_{j=1}^{n} \mathcal{M}_{7,n-j}(w)\lambda g_j, n \geq 1, \quad (16)$$

Server is on repair

$$-\frac{\partial R_{i,0}(w,y)}{\partial y} = -\lambda R_{i,0}(w,y) + \alpha_i\mathcal{M}_{i,0}(w)r_i(y), i = 1,2,\ldots,7, \quad (17)$$

$$-\frac{\partial R_{i,n}(w,y)}{\partial y} = -\lambda R_{i,n}(w,y) + \alpha_i\mathcal{M}_{i,n}(w)r_i(y) + \sum_{k=1}^{n} \mathcal{R}_{i,n-k}(w,y)\lambda g_k,$$

$$i = 1,2,\ldots,7, n \geq 1. \quad (18)$$

While applying LST to the above equations (2) to (18), we get,

$$\tau\widetilde{\mathcal{M}}_{1,0}(\tau) - \mathcal{M}_{1,0}(0) = (\lambda + \alpha_1)\widetilde{\mathcal{M}}_{1,0}(\tau) - \sum_{d=a}^{b} \mathcal{M}_{7,d}(0)\tilde{\mathcal{S}}_1(\tau) - \tilde{\mathcal{R}}_{1,0}(\tau,0)$$

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$$-\sum_{k=0}^{a-1}\sum_{d=a}^{b} I_k \lambda g_{d-k}\tilde{\mathcal{S}}_1(w) - \lambda\delta\widetilde{\mathcal{M}}_{1,0}(\tau), \tag{19}$$

$$\tau\widetilde{\mathcal{M}}_{1,n}(\tau) - \mathcal{M}_{1,n}(0) = (\lambda+\alpha_1)\widetilde{\mathcal{M}}_{1,n}(\tau) - \lambda\delta\widetilde{\mathcal{M}}_{1,n}(\tau) - \tilde{\mathcal{R}}_{1,n}(\tau,0)$$

$$-\mathcal{M}_{7,b+n}(0)\tilde{\mathcal{S}}_1(\tau) - \sum_{k=0}^{a-1}\mathcal{J}_k\lambda g_{b+n-k}\tilde{\mathcal{S}}_1(\tau)$$

$$-(1-\delta)\sum_{j=1}^{n}\widetilde{\mathcal{M}}_{1,n-j}(\tau)\lambda g_j, n \geq 1 \tag{20}$$

$$\tau\widetilde{\mathcal{M}}_{2,0}(\tau) - \mathcal{M}_{2,0}(0) = (\lambda+\alpha_2)\widetilde{\mathcal{M}}_{2,0}(\tau) - \mathcal{M}_{1,0}(0)\tilde{\mathcal{S}}_2(\tau) - \tilde{\mathcal{R}}_{2,0}(\tau,0) - \lambda\delta\widetilde{\mathcal{M}}_{2,0}(\tau) \tag{21}$$

$$\tau\widetilde{\mathcal{M}}_{2,n}(\tau) - \mathcal{M}_{2,n}(0) = (\lambda+\alpha_2)\widetilde{\mathcal{M}}_{2,n}(\tau) - \lambda\delta\widetilde{\mathcal{M}}_{2,n}(\tau) - \tilde{\mathcal{R}}_{2,n}(\tau,0)$$

$$-\mathcal{M}_{1,n}(0)\tilde{\mathcal{S}}_2(\tau) - (1-\delta)\sum_{j=1}^{n}\widetilde{\mathcal{M}}_{2,n-j}(\tau)\lambda g_j, n \geq 1 \tag{22}$$

$$\tau\widetilde{\mathcal{M}}_{3,0}(\tau) - \mathcal{M}_{3,0}(0) = (\lambda+\alpha_3)\widetilde{\mathcal{M}}_{3,0}(\tau) - p\mathcal{M}_{2,0}(0)\tilde{\mathcal{S}}_3(\tau) - \tilde{\mathcal{R}}_{3,0}(\tau,0) - \lambda\delta\widetilde{\mathcal{M}}_{3,0}(\tau) \tag{23}$$

$$\tau\widetilde{\mathcal{M}}_{3,n}(\tau) - \mathcal{M}_{3,n}(0) = (\lambda+\alpha_3)\widetilde{\mathcal{M}}_{3,n}(\tau) - \lambda\delta\widetilde{\mathcal{M}}_{3,n}(\tau) - \tilde{\mathcal{R}}_{3,n}(\tau,0)$$

$$-p\mathcal{M}_{2,n}(0)\tilde{\mathcal{S}}_3(\tau) - (1-\delta)\sum_{j=1}^{n}\widetilde{\mathcal{M}}_{3,n-j}(\tau)\lambda g_j, n \geq 1 \tag{24}$$

$$\tau\widetilde{\mathcal{M}}_{4,0}(\tau) - \mathcal{M}_{4,0}(0) = (\lambda+\alpha_4)\widetilde{\mathcal{M}}_{4,0}(\tau) - q\mathcal{M}_{2,0}(0)\tilde{\mathcal{S}}_4(\tau) - \tilde{\mathcal{R}}_{4,0}(\tau,0) - \lambda\delta\widetilde{\mathcal{M}}_{4,0}(\tau) \tag{25}$$

$$\tau\widetilde{\mathcal{M}}_{4,n}(\tau) - \mathcal{M}_{4,n}(0) = (\lambda+\alpha_4)\widetilde{\mathcal{M}}_{4,n}(\tau) - \lambda\delta\widetilde{\mathcal{M}}_{4,n}(\tau) - \tilde{\mathcal{R}}_{4,n}(\tau,0)$$

$$-q\mathcal{M}_{2,n}(0)\tilde{\mathcal{S}}_4(\tau) - (1-\delta)\sum_{j=1}^{n}\widetilde{\mathcal{M}}_{4,n-j}(\tau)\lambda g_j, n \geq 1, \tag{26}$$

$$\tau\widetilde{\mathcal{M}}_{5,0}(\tau) - \mathcal{M}_{5,0}(0) = (\lambda+\alpha_5)\widetilde{\mathcal{M}}_{5,0}(\tau) - (\mathcal{M}_{3,0}(0) + \mathcal{M}_{4,0}(0))\tilde{\mathcal{S}}_5(\tau)$$

$$-\tilde{\mathcal{R}}_{5,0}(\tau,0) - \lambda\delta\widetilde{\mathcal{M}}_{5,0}(\tau) \tag{27}$$

$$\tau\widetilde{\mathcal{M}}_{5,n}(\tau) - \mathcal{M}_{5,n}(0) = (\lambda+\alpha_5)\widetilde{\mathcal{M}}_{5,n}(\tau) - (\mathcal{M}_{3,n}(0) + \mathcal{M}_{4,n}(0))\tilde{\mathcal{S}}_5(\tau)$$

$$-\tilde{\mathcal{R}}_{5,n}(\tau,0) - (1-\delta)\sum_{j=1}^{n}\widetilde{\mathcal{M}}_{5,n-j}(\tau)\lambda g_j - \lambda\delta\widetilde{\mathcal{M}}_{5,n}(\tau), n \geq 1, \tag{28}$$

$$\tau\widetilde{\mathcal{M}}_{6,0}(\tau) - \mathcal{M}_{6,0}(0) = (\lambda+\alpha_6)\widetilde{\mathcal{M}}_{6,0}(\tau) - \mathcal{M}_{5,0}(0)\tilde{\mathcal{S}}_6(\tau) - \tilde{\mathcal{R}}_{6,0}(\tau,0) - \lambda\delta\widetilde{\mathcal{M}}_{6,0}(\tau) \tag{29}$$

$$\tau\widetilde{\mathcal{M}}_{6,n}(\tau) - \mathcal{M}_{6,n}(0) = (\lambda+\alpha_6)\widetilde{\mathcal{M}}_{6,n}(\tau) - \mathcal{M}_{5,n}(0)\tilde{\mathcal{S}}_6(\tau) - \lambda\delta\widetilde{\mathcal{M}}_{6,n}(\tau)$$

$$-\tilde{\mathcal{R}}_{6,n}(\tau,0) - (1-\delta)\sum_{j=1}^{n}\widetilde{\mathcal{M}}_{6,n-j}(\tau)\lambda g_j, n \geq 1 \tag{30}$$

$$\tau\widetilde{\mathcal{M}}_{7,0}(\tau) - \mathcal{M}_{7,0}(0) = (\lambda+\alpha_7)\widetilde{\mathcal{M}}_{7,0}(\tau) - \mathcal{M}_{6,0}(0)\tilde{\mathcal{S}}_7(\tau) - \tilde{\mathcal{R}}_{7,0}(\tau,0) - \lambda\delta\widetilde{\mathcal{M}}_{7,0}(\tau)$$

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(31)

$$\tau\widetilde{\mathcal{M}}_{7,n}(\tau)-\mathcal{M}_{7,n}(0)=(\lambda+\alpha_7)\widetilde{\mathcal{M}}_{7,n}(\tau)-\mathcal{M}_{6,n}(0)\tilde{\mathcal{S}}_7(\tau)-\lambda\delta\widetilde{\mathcal{M}}_{7,n}(\tau)$$

$$-\tilde{\mathcal{R}}_{7,n}(\tau,0)-(1-\delta)\textstyle\sum_{j=1}^{n}\widetilde{\mathcal{M}}_{7,n-j}(\tau)\lambda g_j,\, n\geq 1 \quad (32)$$

$$-\frac{\partial\widetilde{R}_{i,0}(\tau,y)}{\partial y}=\lambda\widetilde{R}_{i,0}(\tau,y)-\alpha_i\widetilde{\mathcal{M}}_{i,0}(\tau)r_i(y), i=1,2,\ldots,7, \quad (33)$$

$$-\frac{\partial\widetilde{R}_{i,n}(\tau,y)}{\partial y}=\lambda\widetilde{R}_{i,n}(\tau,y)-\textstyle\sum_{k=1}^{n}\widetilde{R}_{i,n-k}(\tau,y)\lambda g_k-\alpha_i\widetilde{\mathcal{M}}_{i,n}(\tau)r_i(y), i=1,2,\ldots,7, n\geq 1. \quad (34)$$

Again applying LST to the above equations (33) and (34), we get,

$$\theta\widetilde{R}_{i,0}^{\ *}(\tau,\theta)-\widetilde{R}_{i,0}(\tau,0)=\lambda\widetilde{R}_{i,0}^{\ *}(\tau,\theta)-\alpha_i\widetilde{\mathcal{M}}_{i,0}(\tau)R_i^{\ *}(\theta), i=1,2,\ldots,7, \quad (35)$$

$$\theta\widetilde{R}_{i,n}^{\ *}(\tau,\theta)-\widetilde{R}_{i,n}(\tau,0)=\lambda\widetilde{R}_{i,n}^{\ *}(\tau,\theta)-\sum_{k=1}^{n}\widetilde{R}_{i,n-k}^{\ *}(\tau,\theta)\lambda g_k-\alpha_i\widetilde{\mathcal{M}}_{i,n}(\tau)\tilde{\mathcal{R}}^{\ *}(\theta), i=1,2,\ldots,7, n\geq 1.$$

(36)

Let us define the following PGF's:

$$\widetilde{\mathcal{M}}_d(z,\tau)=\sum_{j=0}^{\infty}\widetilde{\mathcal{M}}_{d,j}(\tau)z^j,\ \ \mathcal{M}_d(z,0)=\sum_{j=0}^{\infty}\mathcal{M}_{d,j}(0)z^j, 1\leq d\leq 7,$$

$$\widetilde{R}_d^{\ *}(z,\tau,\theta)=\textstyle\sum_{j=0}^{\infty}\widetilde{R}_{d,j}^{\ *}(\tau,\theta)z^j,\ \widetilde{R}_d(z,\tau,0)=\sum_{j=0}^{\infty}\widetilde{R}_{d,j}(\tau,0)z^j, 1\leq d\leq 7. \quad (37)$$

Simplifying equations (19) to (32), (35) and (36) using (37), we get,

$$\widetilde{\mathcal{M}}_1(z,0)=\frac{(1-\tilde{\mathcal{S}}_1(u_1(z)))}{z^b u_1(z)}f(z) \quad (38)$$

$$\widetilde{\mathcal{M}}_2(z,0)=\frac{(1-\tilde{\mathcal{S}}_2(u_2(z)))}{u_2(z)}\mathcal{M}_1(z,0) \quad (39)$$

$$\widetilde{\mathcal{M}}_3(z,0)=\frac{p(1-\tilde{\mathcal{S}}_3(u_3(z)))}{u_3(z)}\mathcal{M}_2(z,0) \quad (40)$$

$$\widetilde{\mathcal{M}}_4(z,0)=\frac{q(1-\tilde{\mathcal{S}}_4(u_4(z)))}{u_4(z)}\mathcal{M}_2(z,0) \quad (41)$$

$$\widetilde{\mathcal{M}}_5(z,0)=\frac{(1-\tilde{\mathcal{S}}_5(u_5(z)))}{u_5(z)}(\mathcal{M}_3(z,0)+\mathcal{M}_4(z,0)) \quad (42)$$

$$\widetilde{\mathcal{M}}_6(z,0)=\frac{(1-\tilde{\mathcal{S}}_6(u_6(z)))}{u_6(z)}\mathcal{M}_5(z,0) \quad (43)$$

$$\widetilde{\mathcal{M}}_7(z,0)=\frac{(1-\tilde{\mathcal{S}}_7(u_7(z)))}{u_7(z)}\mathcal{M}_6(z,0) \quad (44)$$

$$\tilde{\mathcal{R}}_i(z,\tau,0)=\alpha_i\mathcal{R}_i^*(v(z))\widetilde{\mathcal{M}}_i(z,\tau), 1\leq i\leq 7. \quad (45)$$

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$$\tilde{\mathcal{R}}_i(z,0,0) = \frac{\alpha_i \mathcal{R}_i^*(v(z))\widetilde{\mathcal{M}}_i(z,0)}{v(z)}, 1 \le i \le 7. \tag{46}$$

where

$$f(z) = z^b \sum_{r=a}^{b} \mathcal{M}_{7,r}(0) + \mathcal{M}_7(z,0) - \sum_{n=0}^{b-1} \mathcal{M}_{7,n}(0) z^n$$

$$+ z^b \sum_{r=a}^{b-1} \sum_{k=0}^{a-1} \mathcal{J}_k \lambda g_{r-k} + \sum_{n=b}^{\infty} \sum_{k=0}^{a-1} \mathcal{J}_k z^k \lambda g_{n-k} z^{n-k}. \tag{47}$$

PROBABILITY GENERATING FUNCTION OF QUEUE SIZE

The PGF of the queue size at an arbitrary time epoch

Let P(z) be the PGF of the queue size at an arbitrary time epoch.

$$P(z) = \sum_{i=1}^{7} \widetilde{\mathcal{M}}_i(z,0) + \sum_{i=1}^{7} \tilde{\mathcal{R}}_i(z,0,0) + \mathcal{J}(z). \tag{48}$$

$$P(z) = \frac{\begin{array}{l} A(z)[\sum_{n=a}^{b-1}(z^b - z^n)m_n + \sum_{n=a}^{b-1}\sum_{k=0}^{a-1}\mathcal{J}_k\lambda g_{n-k}(z^b - z^n)] \\ I(z)[-v(z)A(z) - D(z)] \end{array}}{D(z)}. \tag{49}$$

where

$m_n = \mathcal{M}_7(z,0)$,

$u_i(z) = \lambda + \alpha_i - \lambda\delta - (1-\delta)\lambda X(z) - \alpha_i \mathcal{R}_i^*(v(z))$,

$u(z) = u_1(z)u_2(z)u_3(z)u_4(z)u_5(z)u_6(z)u_7(z)$

$S(z) = [z^b - \tilde{\mathcal{S}}_1(u_1(z))\tilde{\mathcal{S}}_2(u_2(z))[p\tilde{\mathcal{S}}_3(u_3(z)) + q\tilde{\mathcal{S}}_4(u_4(z))]\tilde{\mathcal{S}}_5(u_5(z))\tilde{\mathcal{S}}_6(u_6(z))\tilde{\mathcal{S}}_7(u_7(z))]$

$\mathcal{R}_i^*(v(z)) = \mathcal{R}_i^*(\lambda - \lambda X(z))$,

$D(z) = v(z)u(z)S(z)$

$$A(z) = u_2(z)u_3(z)u_4(z)u_5(z)u_6(z)u_7(z)[v(z) + \alpha_1(1 - \mathcal{R}_1^*(v(z)))](1 - \tilde{\mathcal{S}}_1(u_1(z)))$$

$$\begin{aligned} & u_1(z)u_5(z)u_6(z)u_7(z)\tilde{\mathcal{S}}_1(u_1(z))[u_3(z)u_4(z)[v(z) + \alpha_2(1 - \mathcal{R}_2^*(v(z)))](1 - \tilde{\mathcal{S}}_2(u_2(z))) \\ & \quad + u_2(z)\tilde{\mathcal{S}}_2(u_2(z))(u_4(z)[v(z) + \alpha_3(1 - \mathcal{R}_3^*(v(z)))]p(1 - \tilde{\mathcal{S}}_3(u_3(z))) \\ & \quad + u_3(z)[v(z) + \alpha_4(1 - \mathcal{R}_4^*(v(z)))](1 - \tilde{\mathcal{S}}_4(u_4(z))))] \\ & \quad + \ u_1(z)u_2(z)u_3(z)u_4(z)\tilde{\mathcal{S}}_1(u_1(z))\tilde{\mathcal{S}}_2(u_2(z))[p\tilde{\mathcal{S}}_3(u_3(z)) + q\tilde{\mathcal{S}}_4(u_4(z))] \\ & \quad * (u_6(z)u_7(z)[v(z) + \alpha_5(1 - \mathcal{R}_5^*(v(z)))](1 - \tilde{\mathcal{S}}_5(u_5(z))) \end{aligned}$$

$$u_5(z)u_7(z)[v(z) + \alpha_6(1 - \mathcal{R}_6^*(v(z)))](1 - \tilde{\mathcal{S}}_6(u_6(z)))\tilde{\mathcal{S}}_5(u_5(z))$$

$$u_5(z)u_6(z)[v(z) + \alpha_7(1 - \mathcal{R}_7^*(v(z)))](1 - \tilde{\mathcal{S}}_7(u_7(z)))\tilde{\mathcal{S}}_5(u_5(z))\tilde{\mathcal{S}}_6(u_6(z)))$$

PGF of queue size at various completion epochs

<u>Server is busy:</u>

$$M(z) = \frac{Nr(z)}{u(z)S(z)} \tag{50}$$

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Where

$$Nr(z) = g(z) * [u_2(z)u_3(z)u_4(z)u_5(z)u_6(z)u_7(z)S(z)(1 - \tilde{\mathcal{S}}_1(u_1(z))) +$$

$$\tilde{\mathcal{S}}_1(u_1(z))[u_5(z)u_6(z)u_7(z)(u_3(z)u_4(z)(1 - \tilde{\mathcal{S}}_2(u_2(z)))$$

$$+pu_2(z)u_4(z)\tilde{\mathcal{S}}_2(u_2(z))(1 - \tilde{\mathcal{S}}_3(u_3(z)))$$

$$+qu_2(z)u_3(z)\tilde{\mathcal{S}}_2(u_2(z))(1 - \tilde{\mathcal{S}}_4(u_4(z))))$$

$$+u_2(z)u_3(z)u_4(z)[p\tilde{\mathcal{S}}_3(u_3(z)) + q\tilde{\mathcal{S}}_4(u_4(z))]$$

$$* (u_6(z)u_7(z)(1 - \tilde{\mathcal{S}}_5(u_5(z)))$$

$$+u_5(z)u_7(z)\tilde{\mathcal{S}}_5(u_5(z))(1 - \tilde{\mathcal{S}}_6(u_6(z)))$$

$$+u_5(z)u_6(z)\tilde{\mathcal{S}}_5(u_5(z))\tilde{\mathcal{S}}_6(u_6(z))(1 - \tilde{\mathcal{S}}_7(u_7(z))))]],$$

$$g(z) = z^b \sum_{r=a}^{b-1} m_n - \sum_{n=0}^{b-1} m_n z^n + z^b \sum_{r=a}^{b-1} \sum_{k=0}^{a-1} \mathcal{J}_k \lambda g_{r-k}$$

$$+ \sum_{n=b}^{\infty} \sum_{k=0}^{a-1} \mathcal{J}_k z^k \lambda g_{n-k} z^{n-k}.$$

Server is on repair:

$$R(z) = \frac{\sum_{i=1}^{7} \alpha_i (1-\mathcal{R}^*(v(z)))\widetilde{\mathcal{M}}_i(z,0)}{v(z)} \tag{51}$$

Steady State Condition

The PGF of the queue length has to satisfy "$P(1) = 1$, for that we apply L' Hopital's rule and evaluating $\lim_{z\to1} P(z)$, then equating to 1, we have, $N'' = D''$.Since m_i and I_i represents the probabilities of $'i'$ customers waiting in the queue, it follows that N'' must be positive. Thus $P(1) = 1$ is satisfied iff $D'' > 0$". If

$$\rho = \frac{S_{11}+S_{21}+pS_{31}+qS_{41}+S_{51}+S_{61}+S_{71}}{b} < 1 \tag{52}$$

is the traffic intensity for the model.

Computational Aspects

Equation (49) has b unknowns $m_a, m_{a+1}, \ldots, m_{b-1}, I_0, I_1, \ldots, I_{a-1}$ Now from equation (49) which is PGF of number of customers involves b unknowns. By Rouches's theorem "S(z) has one zero on the boundary and b-1 inside the unit circle. Due to analyticity of P(z) the numerator must vanish at these points and gives b equations with b unknowns", which can be solved by numerical technique.

Expected Queue Length

The mean queue length E(Q) at an arbitrary time epoch is given by

$$E(Q) = \frac{Nr^{(X)}Dr^{(IX)} - Nr^{(IX)}Dr^{(X)}}{10Dr^{(IX)}Dr^{(IX)}}, \tag{53}$$

Expected Waiting Time

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The expected waiting time is obtained by using the Little's formula as;

$$E(W) = \frac{E(Q)}{\lambda E(X)} \qquad (54)$$

NUMERICAL EXAMPLE

A numerical illustration of our above discussed model is analysed for a specific case with the following assumptions:

1. Service time distribution is 2-Erlang (For all stage of service).

2. Batch size distribution of the arrival is geometric with mean 2.

3. Repair time is exponential with parameters η

4. E (Q) and E (W) presets are calculated and the results are tabulated for different arrival rates and service rates.

Table 1 Arrival Rate vs Service rate vs Performance measures

If $a = 8, b = 15, \mu = \mu_i, i = 1,2,\ldots,7, \delta = 0.2, \alpha = 1, \eta = 5$

μ	λ	ρ	E(Q)	E(W)
40	2	0.8428	0.9848	0.2462
	7	0.8998	3.4375	0.2148
	8	0.9112	3.4139	0.2439
50	4	0.8565	2.2032	0.2754
	7	0.8838	3.3154	0.1972
	9	0.9021	3.5487	0.2368
60	4	0.8504	1.7696	0.2212
	7	0.8732	3.0908	0.1942
	9	0.8884	3.4949	0.2208
70	4	0.8461	1.3839	0.1730
	7	0.8656	2.8203	0.1856
	9	0.8786	3.3410	0.2014
80	2	0.8314	0.5881	0.1470
	7	0.8599	2.5399	0.1744
	9	0.8713	3.1398	0.1814

Table 2 Breakdown rate vs Performance measures

$a = 8, b = 15, \lambda = 5, \mu_i = 20, i = 1,2,\ldots,7, \delta = 0.2, \eta = 7$

α	ρ	E(Q)	E(W)
0.0	0.5323	1.1346	0.1135
0.5	0.5459	1.5043	0.1504
1.5	0.5730	1.9421	0.1942
2.0	0.5866	2.4543	0.2454
3.0	0.6137	2.7409	0.2741
4.0	0.6409	3.3827	0.3383
5.0	0.6680	3.7419	0.3742

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CONCLUSION

In this article, multi stages of service queuing model which undergoes multi-phases of repair due to active breakdown in a manufacturing industry like textile industry with restricted arrivals is anlysed to arrive at expected waiting time and quelength in each and every process of the manufacturing system. Probability generating function of distribution of queue length at an arbitrary time is obtained. Some important performance measures and particular case of the model are also presented. From the numerical results, it is observed that the performance measures E(Q) and E(W) decreases as service rate increases by quick repair of the system. It is also observed that if the breakdown rate decreases, then the performance measures also decreases.

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Appendix

The expressions used in (53) are defined as follows:

$$Nr^{(IX)} = 9A^{(VIII)}[B_1 - I.v_1] - I.Dr^{(IX)}$$

$$Dr^{(IX)} = -362880.\lambda X_1 u_{11} u_{21} u_{31} u_{41} u_{51} u_{61} u_{71} l_1$$

$$Nr^{(X)} = 45A^{(VIII)}[B_2 - I.v_2 - 2.I'.v_1] + 10A^{(IX)}[B_1 - I.v_1] - 10.I'.Dr^{(IX)} - I.Dr^{(X)}$$

$$Dr^{(X)} = -1814400[\lambda X_1 u_{11} u_{21} u_{31} u_{41} u_{51}[u_{61} u_{71} l_2 + l_1[u_{62} u_{71} + u_{61} u_{72}]]$$

$$+u_{61} u_{71} l_1[\lambda X_1 u_{11} u_{22} + u_{21}(\lambda X_2 u_{11} + \lambda X_1 u_{12})]u_{31} u_{41} u_{51}$$

$$+[u_{31} u_{41} u_{52} + u_{51}(u_{32} u_{41} + u_{31} u_{42})]\lambda X_1 u_{11} u_{21}]$$

$$l_1 = b - S_{11} - S_{21} - pS_{31} - qS_{41} - S_{51} - S_{61} - S_{71}$$

$$l_2 = S_{12} + 2S_{11}S_{21} + S_{22} + 2(S_{11} + S_{21})(pS_{31} + qS_{41}) + (pS_{32} + qS_{42})$$

$$2(S_{51} + S_{61} + S_{71})[S_{11} + S_{21} + pS_{31} + qS_{41}] + [S_{52} + 2S_{51}S_{61} + S_{62}]$$

$$+2S_{71}(S_{51} + S_{61}) + S_{72}$$

$$A^{VIII} = J^{VIII} + K^{VIII} + L^{VIII}$$

$$J^{VIII} = 40320 u_{21} u_{31} u_{41} u_{51} u_{61} u_{71} S_{11}[\lambda X_1 + \alpha_1 R_{11}]$$

$$K^{VIII} = 40320 u_{11} u_{51} u_{61} u_{71}(u_{31} u_{41} S_{21}[\lambda X_1 + \alpha_2 R_{21}] + u_{21} *$$

$$(pu_{41} S_{31}[\lambda X_1 + \alpha_3 R_{31}] + qu_{31} S_{41}[\lambda X_1 + \alpha_4 R_{41}]))$$

$$L^{VIII} = 40320 u_{11} u_{21} u_{31} u_{41}[u_{61} u_{71} S_{51}[\lambda X_1 + \alpha_5 R_{51}] + u_{51} u_{71} S_{61}[\lambda X_1 + \alpha_6 R_{61}]$$

$$+u_{51} u_{61} S_{71}[\lambda X_1 + \alpha_7 R_{71}]]$$

$$A^{IX} = J^{IX} + K^{IX} + L^{IX}$$

$$J^{IX} = 181440[(u_{41} u_{51}[u_{22} u_{31} + u_{21} u_{32}] + u_{21} u_{31}[u_{42} u_{51} + u_{41} u_{52}])$$

$$* u_{61} u_{71} S_{11}[\lambda X_1 + \alpha_1 R_{11}]$$

$$+u_{21} u_{31} u_{41} u_{51}(S_{11}[\lambda X_1 + \alpha_1 R_{11}][u_{62} u_{71} + u_{61} u_{72}]$$

$$+u_{61} u_{71}(S_{11}[\lambda X_1 + \alpha_1 R_{12}] + S_{12}[\lambda X_1 + \alpha_1 R_{11}]))]$$

$$K^{IX} = 756.[10.l_3[.u_{61} u_{71}(u_{11} u_{52} + u_{12} u_{51}) +.u_{11} u_{51}(2.S_{11} u_{61} u_{71} + 3(u_{62} u_{71} + u_{61} u_{72}))]] + 6.2.2.u_{11} u_{51} u_{61} u_{71} l_4$$

$$l_4 = 60.[[S_{21}(u_{32} u_{41} + u_{31} u_{42})[\lambda X_1 + \alpha_2 R_{21}]$$

$$+u_{31} u_{41}(S_{21}[\lambda X_2 + \alpha_2 R_{22}] + S_{22}[\lambda X_1 + \alpha_2 R_{21}])]$$

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$$+[u_{22} + 2u_{21}S_{21}][pu_{41}S_{31}[\lambda X_1 + \alpha_3 R_{31}] + qu_{41}S_{31}[\lambda X_1 + \alpha_4 R_{41}]]$$

$$+pu_{21}[u_{41}S_{32}[\lambda X_1 + \alpha_3 R_{31}] + S_{31}[u_{42}[\lambda X_1 + \alpha_3 R_{31}] + u_{41}[\lambda X_2 + \alpha_3 R_{32}]]]$$

$$+qu_{21}[u_{31}S_{42}[\lambda X_1 + \alpha_4 R_{41}] + S_{41}[u_{32}[\lambda X_1 + \alpha_4 R_{41}] + u_{31}[\lambda X_2 + \alpha_4 R_{42}]]]]$$

$$l_3 = 24.[u_{31}u_{41}S_{21}[\lambda X_1 + \alpha_2 R_{21}]u_{21}[pu_{41}[\lambda X_1 + \alpha_3 R_{31}]S_{31} + qu_{31}S_{41}[\lambda X_1 + \alpha_4 R_{41}]]]$$

$$L^{IX} = [24(u_{61}u_{71}S_{51}[\lambda X_1 + \alpha_5 R_{51}] + u_{51}u_{71}S_{61}[\lambda X_1 + \alpha_6 R_{61}]$$

$$+u_{51}u_{61}S_{71}[\lambda X_1 + \alpha_7 R_{71}])$$

$$* (120u_{11}u_{21}u_{31}u_{41} * [S_{11} + S_{21} + pS_{31} + qS_{41}]$$

$$+60.(u_{11}u_{21}[u_{32}u_{41} + u_{31}u_{42}] + u_{31}u_{41}[u_{12}u_{21} + u_{11}u_{22}]))$$

$$+24.u_{11}u_{21}u_{31}u_{41}l_5]$$

$$\begin{aligned} l_5 = 60.[u_{61}u_{71}(S_{51}[\lambda X_2 + \alpha_5 R_{52}] + S_{52}[\lambda X_1 + \alpha_5 R_{51}]) + S_{51}[\lambda X_1 + \alpha_5 R_{51}][u_{62}u_{71} + u_{61}u_{72}] \\ + u_{51}u_{71}(S_{61}[\lambda X_2 + \alpha_6 R_{62}] + S_{62}[\lambda X_1 + \alpha_6 R_{61}]) + S_{61}[\lambda X_1 + \alpha_6 R_{61}][u_{52}u_{71} + u_{51}u_{72}] \\ + 2.u_{51}u_{71}[\lambda X_1 + \alpha_6 R_{61}]S_{61}S_{51} \end{aligned}$$

$$+u_{51}u_{61}(S_{71}[\lambda X_2 + \alpha_7 R_{72}] + S_{72}[\lambda X_1 + \alpha_7 R_{71}]) + S_{71}[\lambda X_1 \alpha_7 R_{71}][u_{52}u_{61} + u_{51}u_{62}] + 2.u_{51}u_{61}[\lambda X_1 + \alpha_7 R_{71}]S_{71}(S_{61} + S_{51})]$$

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Interdisciplinary

Atmanirbhar Bharat: Indigenization for Defence Forces

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Abstract: *Self sustenance in terms of 'Atmanirbhar Bharat' is a delayed need for Indian subcontinent. The slogan of "Make in India" and the reality of "Made in India" are the matter of intensive realization for actual need based implementation. A missing link between above two realities are visible on ground. Professional affiliation with national and international institutions, capital expenditure for capacity enhancement in terms of machineries, test equipments and single window hassle free clearance are the challenges encountered by Atmanirbhar Bharat Aviyan in general and indigenization program for defence sectors in particular. Transfer of Technology (ToT), Memorandum of Understanding (MoU) with Original Equipment Manufacturers (OEMs) for sustenance, Capacity Requirement Planning (CRP), Research and Development (R&D) entities for time bound desired deliverables are the critical issues of 'Atmanirbhar Bharat' realization. Vendor developments, Affillate Marketing, Automation and Modernization of industries, Adoption of IoTs, uses of AI & ML with effective data analytics are key criteria of success to Indinigesation for Defence forces in particular. Under 'Atmanirbhar Bharat' program. Additive manufacturing, 3D printing, non conventional machining , global marketing , alternative fuel source identification and Industry-Academia integration for research advancement for gap filling with respect to conventional entities like CSIR, DRDO, RDSO and others.*

Keywords: *Make in India, Made in India; International Standards; Industrial Best Practices; Participative Management and Single Window Clearance*

INTRODUCTION

The steps taken by Indian subcontinent on "Make in India" and "Made in India" are two mile stones of " Atmanirbhar Bharat" . However "Make in India" is a concept and "Made in India" is the reality. The challenges encounter by Defence forces and associated manufacturers for spares and equipment indigenization are unique in terms of technology infusion, war field requirements, matching performance with advance countries products and the most important is capital expenditure requirements. The aspects of vendor developments, acquisition of state of art plant and machineries including test and diagnostic equipments, Up skilling and Re skilling facilities and adopting international standards with industrial best practices are the other areas of critical concern. Further the self sufficiency in Defence forces is critical time bound requirement but other sectors like health care, educational facilities, agricultural upliftment, infrastructure provisioning and creation of world class centre of excellence R & D institutions are the pressing requirements to realize desired deliverables.

NEED FOR ATMANIRBHAR BHARAT

Few good examples of emerging needs which are in current demand for sustainable Atmanirbhar Bharat are as follows:

- PPP models
- Disinvestment of non performing assets
- Organisation to be headed by domain experts
- Autonomy
- Intensive Industry – Academia interface for mutual developments

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- Affiliate Marketing
- Adaptability
- Artificial Intelligence and Machine Learning
- Blockchain
- Cloud Computing
- Coding
- Creativity on Ideas and innovations
- Cyber Security
- Telemetry and Data Analytics
- Dedicated Funding Institutions
- Prescriptive Maintenance
- Participative Management in decision making
- Professional Affiliations
- Continual Up skilling and Re skilling
- Close monitoring of R & D institutions

INDIGENISATION IN DEFENCE FORCES

Keeping in view of diversified unique nature equipment used in depth and range by Armed Forces having most origin to advance nations and rapidity of modernization taking place in short span of time, the Atmanirbhar Bharat program is a critical time bound compulsion for Indian Subcontinent. The technical features required by Armed Forces during field trials and war situations demands customized specification changes and design modifications. Eventually these aspects calls for complete dependency on foreign manufacturers and involves higher expenditure and foreign currency drain. Therefore all out efforts are being made to carryout substantial indigenization on defence requirements. Both government and private entities are involved to accelerate the indigenization program under Atmanirbhar Bharat initiatives.

SCOPE OF INDIGENISATION IN DEFENCE FORCES

The scope of indigenization in respect of Defence forces of Indian Sub continent is intensive and extensive as well. The facilities and equipment required for day to day activities and war requirements are all high end techno dependent. The priority requirement of indigenization are in the domain of the following:

- Armoured Technology and Autonomous Vehicles
- Secured Communication Devices
- Radars , Interceptors and Surveillance systems
- Guns and Ammunitions
- Unmanned Arial Vehicles and Drones
- Night Vision and Optical Devices
- Solider comfort equipments
- Rare Earth Material Applications
- Non Conventional and Additive Manufacturing
- Test and Diagnostic Equipment
- AI & ML
- Cloud Computing, Quantum computing and Data Analytics
- Cyber Security for protection from cyber attacks
- Nano Materials and Sensors with Telemetry
- Laser Beam Technology as war head
- Simulator developments for Augmented Reality and Virtual Reality
- Identification of Foe and Friend in War field
- Camouflaging and Image Analysis Technology
- R & D set up
- Nuclear, Biological, Chemical and Radiation Protection
- Prescriptive Maintenance on IoT platform

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- Integrated Tactical Power Management System
- Uninterrupted Navigation
- Blockchain
- Non Lethal Weapon

ORGANISATIONS CONTRIBUTING TO DEFENCE INDIGENISATION PROGRAM

Due to restrictions on commercial exploitation front and stringent requirements on field trials, very limited government and private entities are engaged in Indigenisation support program in particular in product development and manufacturing. The rate of failure of prototypes are nearly 50% and time required to complete different rounds of pilot testing , user extensive validation and maintenance trials is unexpectedly high. The cost factor involved during these validation processes are much beyond anticipated project cost. Further by the time all set to roll on indigenized product, there is every possibilities of modification required keeping in view of current situations. Keeping in view of above attributes the following entities are engaged in indigenization support work:

- Dedicated eight Army Base Workshops
- Directorate of Indigenization under Army HQ
- Ministry of Science and Technology, Govt of India through Council of Scientific and Industrial Research (CSIR).
- Defence PSUs like MIDHANI, BEL,GRSE,BDL,BEML, MDL,Hal
- Defence Laboratories
  - Advanced Centre for Energetic Materials
  - Defence Metallurgical Research Laboratory
  - Defence Research and Development Laboratory
  - Research Centre Imarat
  - Naval Science & Technology Laboratory
  - Combat Vehicles Research & Development Establishment
  - Microwave Tube Research & Development Centre
  - Solid State Physics Laboratory
- Restructured Ordnance Factories into seven DPSU clusters of specialization
  - Munition India Limited
  - Armoured Vehicle Nigam Limited
  - Advance Weapons and Equipment India Limited
  - Troops Comfort Limited
  - Yantra India Limited
  - India Optel Limited
  - Gliders India Limited
- Other Prominent Institutions extending support
  - International Advanced Research Centre for Powder Metallurgy and New Materials
  - Raja Ramanna Centre for Advanced Technology
  - Indian Rare Earths Limited (India)
  - Semiconductor Complex limited

PROGRESS MADE ON INDIGENISATION PROGRAM

The deliverables of above mentioned entities are restricted due several intrinsic factors of unique nature involved since war like equipments and associated components are under indigenization. Athugh the program is exhaustive and time consuming, following definite progress were achieved in recent past:

- Manufacturing of Special Maintenance Tools and Special Test Equipments in respect of most of foreign origin equipment
- Spares manufacturing in respect of routine maintenance requirements of imported equipments

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- Establishing facilities for Metallurgical investigation as per international standards, product development using additive manufacturing and 3 D printing. Also creating facilities for non contact quality assurance systems and progressing product development on Rare Earth Elements.
- Restructuring of 41 Ordnance Factories to seven specialized clusters with effect from 01 October 2021 as DPSUs having autonomy to carry out intensive indigenization activities.

PRIORITIES OF INDIGENISATION

The basic elements of indigenization under Atmanirbhar program in Defence sector are summarized below:

- Self Sufficiency in all fronts (Atma Nirbhar)
- Made in India Realization (MSMEs)
- Export Orientation (Up Skill, Re Skill)
- Import Substitution (Alternatives)
- Infrastructure Development (R & D, Reverse Engg , Vendor Development)
- Special Economic Zones (SEZs)
- Dedicated Financial Institutions (EXIM, SIDBI, NABARD, ICICI, DIC, IDBI, IFC)
- Professional Affiliation with Standards bodies
- Resource mobilization
- Adoption of Green Technology
- Identification of Alternative Fuels
- Emphasis on Reuse, Re cycle and Reduce
- Eco compatibility
- Academia – Industry interface

FEATURES OF INDIGENISATION

- Continuous Evolution
- Intermittent Evaluation
- Mechanization & Automation
- Security Classification
- Unique Coding for Defence Applications
- Capacity Requirement Planning (CRP)
- Coded Design Communication
- Shop Floor Control (SFC)
- Material Requirement Planning (MRP)
- Computer Aided Process Planning (CAPP)
- Concurrent Engineering
- IT Enabled Service (ITES)
- Discrete & Continuous Manufacturing
- Simulation
- Aesthetic Approach as per Defence Requirement
- Reliability Assessment at Field level
- Creative & Innovative Design
- Brain Storming & Participative Management
- Quality Cycles
- Ergonomic Approach

INDIGENISATION CYCLE FOR DEFENCE FORCES

As the indigenization activities is unique to Defence requirements , hence following customized cyclic steps are used in product development:

- Need Analysis of Product or Service

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- Formulation of Blue Print of Model
- Prototype or Pilot Sample
- Prototype Trial on Select Users in field formation
- Amendment to Design Parameters on the basis of user trial
- SWOT Analysis on the basis of friendly foreign countries
- Continuous Vendor Rating
- Bulk or Mass Production
- Warehousing by supply chain
- Packaging & Preservation for extreme temperature and weather conditions
- Shipment and Customized Delivery in remote locations and diversified terrains
- User Feedback after field use or exercises
- Competitors SWOT Analysis
- Need Analysis for Continual Improvements on user feedback
- Design Modifications as per real time threat perceptions
- Discard Policy for implementing new features on time bound manner and prevailing threats

CHALLENGES IN INDIGENISATION PROCESS

As the indigenization process in India may upset many potential countries in terms of supplying defence items hence many challenges are created by those countries and few limitations are inherent in our system. Few extreme challenges encountered by various entities are mentioned below for immediate attention and follow up remedies:

- Cyber Security since indigenization programme is intensively IoT dependant
- Data capturing, Telemetry and Data Analytics are techno intensive hence requires required infrastructure and experts for handling systems
- Adequate dedicated funding
- Uses of Predictive & Prescriptive Maintenance to keep functioning Plants, Machineries and Specialist Equipment meant for indigenization
- Participative Management to share ideas & smooth functioning
- Adequate professional affiliation with standards bodies, Academia & R & D institutions
- Continuous Upgrdation & Reskilling to match with competitors
- Development of in lieu materials to reduce cost and making ease of functioning
- Introduction of Alternative fuels and Non Conventional energy source during indigenization process to adhere green technology requirements and eco balance

CONCLUSIONS

Keeping in view of current hostile situations and strained relationships with neighbors, it is felt by higher leadership to go for indigenization program in war footing manner under Atmanirbhar Bharat Aviyan to develop technology, infrastructure, best practices, trained highly skilled manpower, working ambience and above all making government entities autonomous. However the under mentioned critical aspects are required to be I fore front always:

- Field users first
- Continuous Requirement Assessment as per ground reality
- Identification and up keeping of Skills for Sustenance
- On Job Training for Up Skilling and Re Skilling
- Affiliation with Professional Institutions like BIS , CII, FICCI, CSIR, DRDO and others
- Global Standards Adoption
- Set Up SEZs to support indigenization and substantiate foreign currency reserve
- Single Window Clearance for rapid materialization of projects

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The author was posted as OIC manufacturing in Army Base Workshop for more than two decades and intensively involved in indigenisation and method engineering, process planning, formulation of operation planned schedule and trial evaluation of indigenized products of Defence equipments. The author was posted as Deputy Director , IHQ (Army), MoD New Delhi during 2015 to 2020 dealing with HR issues and skill development of civilian workforce engaged in indigenisation activities. Presently the author is posted as course control officer in premier Military College of Electronics and Mechanical Engineering of Indian Army where besides routine work, established modern manufacturing training facilities which involves Additive manufacturing, 3 D printing, powder metallurgy, Rare Earth Materials applications in collaboration with IREL(India), CSIR-IMMT, DRDO, MIDHANI, ARCI and Ordnance Factories. The technical papers of the author were selected and presented during 34th and 35th Indian Engineering Congress and 35th National Convention of Production Engineers (35Th NCPE) conducted by The Institution of Engineers (India) . The author also contributes technical articles regularly to EME journal published by Military College of EME Secunderabad.

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Expertise Collaboration and Data Integration in Industries

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Abstract: *Tracing clues of revolutionary moments in the recent past that have given economic development a breakthrough leap worldwide, one cannot forget to mention the phrase Fourth Industrial Revolution (4IR or Industry 4.0) which was introduced by a team of scientists developing a high-tech strategy for the German government and was later introduced to a wider audience through including it in the theme "Mastering the Fourth Industrial Revolution" of World Economic Forum Meeting for the year 2016 held in Switzerland.*

While institutionalizing new ventures of innovation is widely being considered as the way ahead for India to achieve its aspirations of becoming a $5 trillion economy, exploring ways towards extracting maximum yield out of its existing industrial resources is another important pillar which is needed to be given equal attention upon.

Undoubtedly, the next leap of industrial transformation lies in combining the power and value of data. Interestingly, data is already there, industry owners have struggled to see through or make sense, to access or harness its value.

As the theme here is Engineers for Viable Technology and $5 Trillion Economy, which is a Techno-Philosophical subject, let's explore the correlation between the technical human resource and their scientific deliverables.

Keywords: *Expertise Collaboration; Data Integration; Shared Supervision*

INTRODUCTION

The existing practice of supervising operation and maintenance of all machines including rotating machines in major industrial institutions have infamous stream wise departmental segregation that too in a multilayer manner which is there because of few of its well justified administrative reasons that are mainly aimed at setting accountability and authority in order to get precise and efficient functioning. There is no problem with this approach as far as the administrative control is concerned but, there is this fact cannot be denied that midst long run of discharging this methodology somewhere an invisible boundary line gets drawn unintentionally in the delivery approach of the personnel involved at all layers. Not to blame anyone of these departmental verticals since this conduct is a natural outcome of the established framework that they are bound to adhere with. However, here comes the need of envisioning a solution that can address this immeasurable problem in a précised way and chalk out a platform where deliverables of all involved stakeholders can be defined and integrated in a measurable manner. Once all such streams & verticals come together and join hands not only for solving problems but also for developing new techniques capable of mitigating the root causes, it is then only our aspirations can come true.

CASE STUDY

While this is a popular phenomenon happening across all segments of industries, here for better understanding of the subject and it's detailed analysis purpose we will consider the case of rotating machines (pumps & blowers) in industries.

Few of the outlined demerits of not having a digital mechanism of integrating the outlooks of all stakeholders at a common platform, are as follows:-

1) No digital tracking system for supervising the running pattern of rotating machines.

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2) Total continuous running hours of these vital rotating machines are not known in lack of digital record system. Even if it is available in some of the upgraded PLCs[2] (Programmable Logic Controller) realizing them into useful data is still a complex process.
3) No robust reference for supervising timely changeover of pumps & blowers in lack of a guiding feedback system.
4) No tracking system for supervising the frequency of breakdown of a particular pump or blower leading in ambiguity of corrective action.
5) No tracking system for ensuring whether timely preventive maintenance of a particular rotating machine has been performed or not.
6) Sometimes few of the above inputs are available in the manual log-books but owing to their scattered possession and that too across a wider timeline, combining them manually in the form of a useful data is totally impractical.

SOLUTION

Digitization of the above referred activities and statistics by feeding them in the DCS[3] (Distributed Control System) and their integration in the form of Timer and Trend can dramatically improve the practice of supervising the service pattern of rotating machines with respect to their maintenance events which ultimately will result in optimization of their usability for a comparatively extended life span, which is usually not harnessed otherwise. Salient features of implementing integrated timelines of rotating machines in industries are as follows:

1) The Timer on DCS will instantly guide the operating personnel to changeover the pumps & blowers upon attaining the preset standardized running hours for respective rotating machines.
2) The Trend which is produced by data logging of multiple activities taken place across the timelines of respective rotating machines can be used for producing self generated preventive maintenance calls in the form of alarms, which will also eliminate the delayed preventive maintenance due to human errors or overlooking.
3) Additional provision of tagging events of all repair & maintenance jobs performed on the respective rotating machine's trend in the forms of color coded pegs will be of great use in assessing the machine's performance as well will be helpful in planning suitable future course of action. Kindly refer **Figure 1** for typical view of activity timeline of a rotating machine.

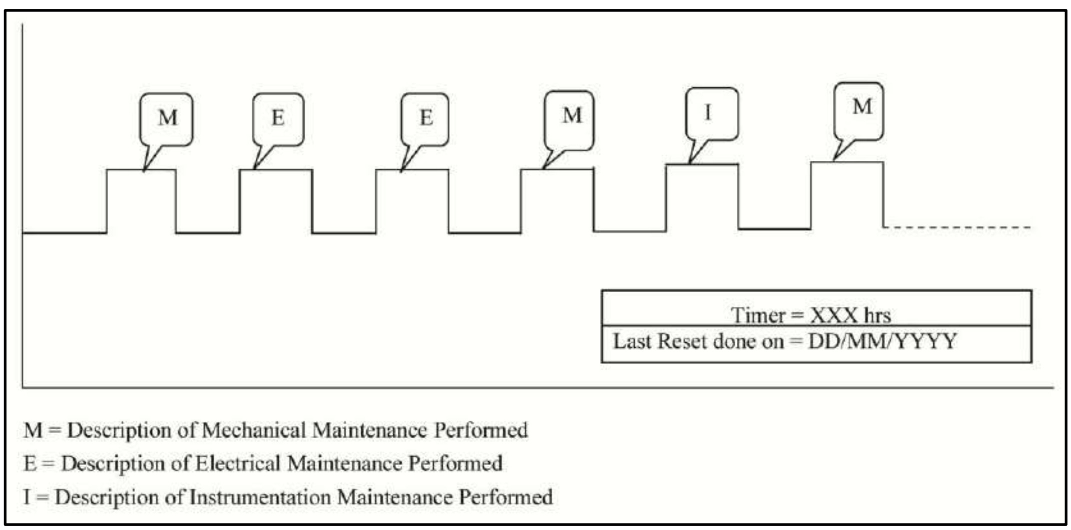

Figure 1 Typical view of an activity timeline

4) Further, drop down selection provision will instantly provide list of all previously performed maintenance activities of specific category for a particular rotating machine, during any desired period.

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5) These above provisions altogether will largely enable engineers in reaching data driven decision making s.

BENEFITS

Few of tangible & intangible benefits of implementing the integrated timeline scheme are enlisted as follows:

1) Huge financial savings can be made on account of avoiding the maintenance cost by preventing the rotating machines from premature breakdown through ensuring timely “changeover” and “preventive maintenance”, which otherwise happen due to continuous overrun.

2) Financial savings in terms of protecting opportunity loses which otherwise happen if breakdown of rotating machines occur resulting in production interruption and material wastage which were under process chain at that particular time.

3) Lifecycle enhancement of rotating machines.

4) By tracking preventive maintenance of equipments on their own timeline with the facility of producing self-generated preventive maintenance calls, will raise the practice of comprehensive monitoring & TPM[4] (Total Productive Maintenance) to next level.

5) Facility of tracking records for all repair & maintenance jobs performed on a particular rotating machine in a trend form will be largely helpful in better assessment by engineers across department verticals. This collaboration of expertise and knowledge sharing will also help engineer’s develop their problem solving skills.

CONCLUSION

It is widely known that major technology suppliers across the globe these days are pushing for inclusion of artificial intelligence, advance robotics & IIOT[5] (Industrial Internet of Things) in their technology packages as much as possible, in order to uphold their competitiveness in luring industries by providing all in one solutions. In fact, many of the contemporary economists have already termed this ongoing business strategy in their references as a data driven economy.

From the above explained case study we saw how sharing data & their useful integration can help & guide us in deciding the right course of action. It is therefore true need of the hour for the Indian engineers to realize this transforming trend of swift transition of technology and should come forward in joining hands across streams & functional verticals to collaborate and share their expertise making value addition in their existing resources and yield more returns.

ACKNOWLEDGEMENT

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Opportunity for Made in India Medical Devices in Global Markets: Role of Quality

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Abstract: *Medical Device industry consist of a large number of small and medium enterprises that produce a wide variety of heterogeneous products known as medical devices. Medical devices play an important role in healthcare delivery and has a growing global demand. The domestic manufacturers of medical devices in India have a good opportunity to supply to the increasing demand in expanding global market with made in India medical devices. The quality of medical devices made in India will determine the success of Indian medical device manufacturers to become a global player.*

Keywords*: Medical Device; Quality; Medical Device Industry*

INTRODUCTION

The current pandemic has brought out the significant role played by medical devices in healthcare delivery in the modern world. Even though modern healthcare system is dependent on hundreds of products coming under the category of medical devices, these products are not known much to people at large and remain confined to the professionals within the healthcare system. These products at times significantly impact the healthcare costs as well. The products are of diverse nature, utilising different technologies from different disciplines, with varying role in prevention, diagnosis or therapeutic use and interaction with the patients. These products are made in large numbers by a thriving industry, known as medical device industry, in different parts of the world, employing a large number of people and contributing to the economy. Yet just like the medical devices, the medical device industry is also not in the limelight unlike other industry segments such as automobile or consumer electronics etc in India. The medical device industry in India is still in a nascent stage, yet to make use of the emerging opportunity. This paper attempts to analyse the factors that herald the growing opportunity for made in India medical devices to capture a growing demand world wide and the role of quality in facilitating the Indian medical device domestic industry manufactures to capture the global market.

MEDICAL DEVICES AND INDUSTRY SCENARIO IN INDIA

Healthcare industry is generally considered as a recession free industry and medical products are always in demand. The market growth rate of medical products including medical devices is generally very positive and encouraging for the manufacturers. The market is always expanding irrespective of the cycles of growth and slump in other industry segments. Access to good quality, affordable and appropriate medic products is essential for good health care delivery system. There are a large number of products, from seemingly simple items such as a bandage to ubiquitous products such as a stethoscope or a thermometer to highly complex equipment like an X ray or CT imaging device that are considered broadly as a medical device. There are products like a syringe that temporarily go inside the body to implants like knee joint that are placed permanently inside the body. All these hundreds of myriad products that interact with a patient for a short/long duration in an invasive/non-invasive mode and which have different roles such as for prevention, diagnosis or treatment, are broadly termed as a medical device. In a modern world, it would be impossible to imagine any healthcare delivery without the use of one or other kind of medical device. It is estimated that there are over a million different kinds of medical devices in the global market, which are divided into intosome 7000 generic devices groups. Medical devices also include reagents for in vitro diagnosis and software used in medical application. For the sake of regulation purposes, the vast number of medical devices are classified based on the risks associated with the use of such devices.

Medical devices are made by manufacturers which belong to the medical device industry. With the exception of some large multinational corporations, globally, medical devices are made by small and medium scale enterprises.The worldwide medical device market was estimated to be US$455.34 billion in 2021 and is estimated to be growing at the rate of 5% [1]. The major market share of the global market is addressed by medical device manufacturers located in the USA. The Indian medical device market is estimated to be worth US$ 10 Billion in 2021. Most of the demand for the medical devices in India is said to be through import. Medical devices worth about US$ 2.1 Billion was exported from India in 2019 [2]

There is a growing domestic medical device manufacturing company base in India. These are mainly small and medium size enterprises and present in some prominent informal clusters in different parts of the country. Most of Indian domestic manufacturers are engaged in manufacturing of low value low technology disposables, medical electronics based devices etc. There are some areas in which India is already exporting in a big way and this includes Intraocular lenses and coronary stents Now we are witnessing a trend of startups coming with innovative devices trying to address unmet needs. These startups are employing new and emerging technologies like artificial intelligence, machine learning etc and using Industry 4.0 technologies. India is suited for medical device innovation and manufacturing. India offers natural advantages such as lower manufacturing costs and availability of skilled manpower. Specifically for medical device manufacturing, there is a need to implement standard operating practices (SOPs) and personal hygiene is essential for implementing a good manufacturing practice environment, for which it is important that the people are educated and able to understand the importance of these factors and not to cut corners. In spite of these positive factors, in India medical device manufacturing has been a lowkey affair in the past.

However, in the recent times, due to several initiatives, there is a push towards increasing domestic or make in India for medical devices. New medical device parks are being announced in several regions of the country. These exclusive parks will provide the right ecosystem for medical device manufacturing and will have tie up scientific and technological institutions, incubators, testing houses, certification bodies etc. The regulatory system in India was not adequate and was often cited as the reason for lack of domestic manufacturers to export or capture global markets. However, the regulatory system for medical devices in India is set to change for better with the publication of medical devices rules 2017 by Central Drugs Standards Control Organisation (CDSCO). The new regulatory system will make it necessary for the Indian medical device manufacturers to adopt quality management systems for their operations. For gaining market acceptance, medical device manufacturers must adhere to safety standards and performance benchmarks in their products. These are to be established through rigorous testing and validation processes followed by a regulatory approval.

ROLE OF QUALITY IN MEDICAL DEVICE MANUFACTURING INDUSTRY

Quality is not an accident. It comes by design and willingness of top management to implement a quality management system in the company. Indian manufacturers of medical devices need to understand the various benefits of implementing quality management system and not just as a pre requisite to meet the regulatory requirements. Improving quality can bring costs down significantly and will help in more customer acquisition and market expansion. The need for quality in the design, manufacture, and distribution of medical devices is today much more relevant than ever before for the medical device manufacturers in India. Good quality practices in manufacturing operations alone can save revenue losses due to defects and rejections. Manufacturers may adopt several practices that lead to good quality outcomes in their products. These include training and implementation of right quality tools that are widely applied in other manufacturing enterprises such as automobile or consumer electronics sectors. Application of proper quality tools and techniques in manufacturing will lead to reduced manufacturing costs and reduced lead times. A robust quality culture and practice across the organisation can transform the quality outcomes. Quality control tools are building blocks for any quality improvement project and with proper methods to collect and analyse data, process improvements can be achieved. Selection of the right set of quality control tools such as pareto analysis, fish bone diagram etc are simple, easy to implement yet powerful in bring out a quality change. Reducing variation by capturing and analysing data using process control charts can be effective in reducing rework and wastages. The cost of ensuring good quality is only a fraction of the loss due to poor quality. In the case of medical devices, poor quality may be at times life threatening and may have wider implications such as regulatory actions such as recalls, shutting down of facility etc. These have much more implications than direct costs and indirectly affect the image and brand.

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Medical device manufacturers can adopt the ISO standards which serve as valuable guides to achieving quality goals of an organisation and product. ISO 13485 is a standard that specifies the quality management system specifically for manufacturers of medical devices. This standard sets out the requirements that a manufacturer of medical devices must adhere to in order to demonstrate that it is capable of producing medical devices that meet both customer requirements and regulatory requirements where applicable. This standard covers the entire lifecycle of a medical device right from design stage to production and manufacturing, logistics operations, installation and after sales servicing. This is a standard that can be applied by all types of manufacturers of medical devices irrespective of the size or nature of product. This standard is a specific standard applicable for medical device manufacturers and emanates from the generic ISO 9000 quality management system standard that can be applied across all industry segments. Like in ISO 9000, this standard also is process oriented and gives thrust on instilling a process-based quality management system

CONCLUSION

Indian manufacturers of medical devices have a growth led market demand, cost competitiveness, skilled manpower and an emerging world class infrastructure and regulatory regime. Therefore, now it is an opportune time for Indian manufacturers of medical devices to focus on quality. This can open up to the opportunity to get a share of the growing global market for medical devices. The healthcare industry has been witnessing unprecedented attention due to pandemic and has expanded the scope of the industry. There is a great need and opportunity to cater to unmet clinical needs of the world with good quality affordable products. Medical device companies that embrace the quality and emerging demand will be able to grab the emerging opportunities. It is an opportune time for Indian companies to not only meet the customer expectation, but to exceed them. By giving quality its due in medical device manufacturing, Indian companies are well poised to become a supplier to the world thereby creating huge economic benefits to the country

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Drastic Change in Technical Education in India

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***Abstract**: There is lack of Holistic approach in our education system to prepare entrepreneursfor manufacturing and service sectors required in line with our national objectives. The present Education system neither motivates nor train or provide assistance to students to start their own venture after graduation or make them employable.*

If we have to achieve the desired growth rate to become 5 trillion-dollar economy, every Government unit shall work in unison focusing on total needs and demands of products and services in each sector for the coming decade. Based on demand and available capacity, the short fall shall be estimated for each sector and translated into skills demand and a holistic planning model shall be prepared for every sector.

Accordingly, whole education system shall be planned to fill the gap by skills development and engaging students in above chosen field after finishing their education.

Technical Colleges shall become the hub for turning engineers into entrepreneurs and also for supply of any kind of technical skills manpower to the industry and service industries.

The salient features of new education system are discussed in this article to fulfill above objectives.

There will be two streams of education and training. One for entrepreneurship and the other for employment.

The group selected for entrepreneurship goal is to set up the industry after the completion of the course. The choice of the industry/industries will be madeat the beginning of the course.

The group opting for employment the goal is to getthem trained for joining the industry as operating engineers in proposed and existing industries as per planned requirements received by University in advance so that immediately after study/training they can straight way be employed without any further training.

The technical university will have two distinct departments. One will be for training entrepreneurs the other will be for technical employment both working in unison.

The objective of the Entrepreneurship department is to develop multi-disciplinary skills so students can start their own industry (manufacturing or service) after finishing the education.

The objective of the Employment Generating department is toenhance the standard of technical education and training so students become immediately employable in the industries being started by fellow student entrepreneur or full fill the demand of the existing industries communicated to them at the beginning of the course.

These schools will become the main platform for accessing the skills required to get into industry.

This will also meet the needs of unemployed and non-employable engineering graduates and to improve their communication as well as technical skills.

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Keywords: *Entrepreneurship; Employment; Technical; Education; System; Training; Holistic Approach; Skills Development; Manufacturing; Service Industry*

INTRODUCTION

As per the present economic industrial scenario and based on experience of last 50 years, it is found that there is acute shortage of engineers in core disciplines. Even if fresh engineers from core branches are available they require extensive training for 2-3 years to take up assignment in the field of technology (know how), process engineering, design & engineering, operation, maintenance, manufacturing, production, procurement, logistics, technical marketing, construction, erection testing and commissioning, Techno Economics , Finance andCosting.

There is huge gap between the need and demand placed by the fast-technological changes and the emerging global market trends that are making the growth of core industries brings out the demand for complementing and supplementing the formal education through the non formal education and training

The profiles of the career opportunities keep dynamically changing as newer and newer technologies emerge and the global market requirements change.

The formal education focuses on the too much theory and fundamental concepts in different subjects and does neither inculcate any kind of entrepreneurship skills to prepare them to set up their own industries nor prepare them with practical skills to make them directly employable in any manufacturing, construction or service industry. This calls for urgent need for bringing drastic changes in technical education to bridge the gap that existing between the needs of the industry and the academic curricula.

With the increase in population, increase in urbanization and service industry, the basic needs of the masses like Food, Clothing, Housing, Telecommunication Information highway, Transport, Education, Health & Hospitality Sectors, Insurance, Entertainments, Tourism & Event Management, Digital Marketing & Payment, Pharmacy, House Hold appliances, the demand for products related to above (For example Food grains, Pulses, Vegetable Oils, Fruits & Vegetables, Houses, House hold appliances like Smart TVs, Air Conditioners, Refrigerators, Ovens, Lighting Equipment, Water Supply & Sanitation wares, Furnitures, Smart Mobile Phones, Tablets, Smart Televisions , Two & Four wheelers, Petroleum Products, Chemicals & Fertilizers, Hospitals, Schools, Banking , Entertainment games, movies) are bound to increase and it shall be the duty of the Central/State Government Agencies to estimate the short term, medium term and long term demands in each sector. Based on the demand estimated by these agencies and available capacity, the short fall shall be estimated for each sector. These short falls shall be translated into skills demand and a holistic planning model shall be prepared for every field right from Agriculture to space industry. Accordingly, whole education system shall be planned to fill the gap by skills development and engaging students in production activities after finishing their education. Technical Colleges shall become the hub for turning engineers into entrepreneurs and also for supply of any kind of technical skills manpower to the industry and service industries.

The salient features of new education system will be:

For BE Students

1. There will be two streams of education and training. One for entrepreneurship and the other for employment.
2. Those who chose entrepreneur ship will choose any four industries out of listed industries pertaining to various disciplines.
3. Each student will be trained for setting up of these four industries for full four years.
4. Each student will start any one of the four industries after graduation.
5. He will help and guide to start other three industries to his family members, friends and other members of the community in which he lives and will be their mentor and guide.

6. The other group who opt for employment will be trained for joining the industry as operating engineers in those industries started by fellow students as above or as per the planned and demand requirements of the manufacturing, construction and service industries received by Colleges in advance so that immediately after four years of study/training they straight way join the industry as working engineer without any further training.

For Diploma Holders

1. There will be two streams of training. One for entrepreneurship and the other for employment.
2. Those who chose entrepreneur ship will choose any Two industries out of listed industries pertaining to various disciplines.
3. Each student will be trained for setting up of these two industries for full three years.
4. Each student will start any one of the two industries after graduation.
5. He will help and guide to start other industry to his family members, friend and other member of the community in which he lives and will be his mentor and guide.
6. Those who chose employment as their career will be trained as supervisors, operators, foreman, inspectors or such fields needed for those industries started by Graduate Engineers and Diploma holders as per the needs/requirements sent to them from engineering colleges and Polytechnics and existing industries as per planned forecasting.
7. The other group who opt for employment will be trained for joining the industry as operating engineers in those industries started by fellow students as above or as per the demand of the Industry received by Colleges in advance so that immediately after three years of study/training he straight way join the industry as working supervisors, operators, foreman, inspectors or such fields needed by those industries without any further training.

For ITI Students

1. There will be two streams of training. One for entrepreneurship and the other for employment.
2. Those who chose entrepreneur ship will choose one industry (Small scale industries, Kutir Udyog or small scale venture based on forest produce, food processing, masala udyog, mason, cycle & two wheeler mechanic, plumber, tyre tube repairing, house hold appliances' repairing, metal art work, tailoring, knitting, tile work, painting, polishing work, growing mushrooms, vegetables, fruits, herbs and similar items not requiring higher skills).
3. Such student will be trained for setting up of above such industry.
4. Those who chose employment as their career will be trained as masons, fitters, mechanic, skilled workers, electrician, machinist, data entry operators, CAD operators, or such fields needed for those industries started by Graduate Engineers and Diploma holders as per the needs/requirements sent to them from engineering colleges and Polytechnics and existing industries as per planned forecasting so that immediately after one year of training he straight way join the industry as needed by those industries without any further training.

Common to All

1. There will be a technical university under which all the three streams BE, Diploma and ITI will be functioning.
2. There will be two distinct departments. One will be for training entrepreneurs the other will be technical employment. Both working in unison.
3. The department will work in close coordination with Neeti Aayog and various chambers/federations ofCommerce and Industries, Central & State Industries Departments, Technical Consultancy Organizations, WTO, Import/Export Cell and all other such departments/companies who will supply them List of Industries to be setup in near future (Next Five years) for which demand outstrips supply or import outstrips exports. Based on this, departments will freeze/short list items for manufacturing or skill sets require for service industries

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which will be taken up for start up by their students. This list can be further classified based on investment required under three categories (May be more). First category may be those industries (manufacturing or service requiring investment of Rs 50 lakh or less) and run by Single student entrepreneur trained by them. The other group may be run by two students with investment limits of Rs 1 Crore and similarly other group of 3 or more students with an investment of more than one crore.

4. There will be a lead bank or more than one bank in the University who will be responsible for disbursing the loans to those students at the end of their study who opt for entrepreneurship and choose to start any one of the chosen industries trained by the college/university
5. The guarantor of the student for recovery of the loan will be the Technical University as University is solely responsible for imparting such education and training that will train such students to venture for entrepreneurship.
6. The loan returned will be kept in separate account maintained by the University. This will become future corpus for distribution of loans to student entrepreneurs. This will receive donations from industries, old student entrepreneurs and aid from World Bank, Asian bank, Bricks, Mudra Bank and ultimately become self fund generating body.

The main objectives of the entrepreneurship department will be as follows:

1. To develop entrepreneur skills in the students so that they can to start their own industry (Manufacturing or Service) in their chosen field of specialization immediately after graduation.
2. To train StudentEntrepreneur in all the gamut of the chosen industries (Four for BE, two for Diploma and one for ITI) to enable him to start the industry at the end of his course.
3. The whole education will be based on imparting such multi disciplinary subjects as may be required to help him starting the newventure (Manufacturing or service industry)
4. Normally disciplines /subjects required to start an industry are given in Annexure-1, This is only indicative and not exhaustive and will depend upon the industry chosen for start up. Once the above engineering and managerial concepts are taught there is nothing additionally is required to run an industry. There is no reason for any failure. (except red tapism-but this can be taken care by university being guarantor, mentor and guide and any problems faced by student entrepreneur can be promptly taken up by university with respective Government/Chancellor)

The main objective of the Employment Generating department will be as follows:

- To enhance and guaranteethe employability of technical students.
- To enhance the standard of technical education and training so that he becomes immediately employable in the industries being started by student entrepreneur or full fill the demand of the respective specific industry already communicated to the department by the industries at the beginning of the first year session as per skill gap supply demand requirements given by industries (Manufacturing or Service)
- To reinforce the student skills and acquire industry–specific knowledge from trained faculty and experts from industries.
- To identify and inform the concerned industries about the selected candidate for their requirements as per skill demand supply gap furnished by them.
- To prepare and finalize the broad syllabus for study and training in consultation with concerned industry. To provide both technical and soft skills to the students as required.
- Performance appraisal of the student after each semester will be done jointly by College and the concerned industry to ensure that the training is undergoing in line with the needs of the industry. If required mid course changes may be carried out.

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- Such students are required to go for internship after each semester in the concerned industry who will give them a feel what is expected from them after completion of their course.
- After the completion of the course concerned industry will give them employment on the terms and conditions pre-finalized in consultation with Industry as per Govt formulated norms.
- In case any further special training is required the same can be given after employment by the concerned industry. (However, in most of the cases it may not be required)
- To bridge the gap between industry and technical institutions fully.
- This will be the only platform for accessing the skills required to get into industry.
- To meet the needs of unemployed and non-employable engineering graduates and to improve their communication as well as technical skills.
- To offer suitable candidates to different industries.
- To help young graduates to find jobs through appropriate training.
- To run finishing school to impart above training for those engineers/technicians who have finished their education earlier and need such skills to make them employable or who want to start their own industry.

Financing

(i) By Banks situated in the university

(ii) Loan to be disbursed by the University bank.

(iii) University to be Guaranteer.

(iv) Loan will be return to university by student entrepreneurs.

(v) Loan refunds, grant from Government, Asian Dev Fund/World bank/BRICKS,Donations from old student Entrepreneurs, Industries/Individuals/Foundations all will contribute to corpus fund.

(vi) After sometime this will become Corpus fund of bank of the university.

Training of Faculty members

(i) Existing to be retained for theory and its application to real life situation

(ii) New faculty from Industry

(iii) Services of Retired Professionals/businessman/professors/Technicians/engineers to be utilized for finishing school

Annexure-I

Basic Entrepreneurship/Engineering Skill (Common to All)

1. Site Location & Layout Considerations

A. Site: Location for Minimization of Total “t.km” route length and cost, rail road, power, water, gas, soil condition,

Layout:Rational flow of materials, Provision for future expansion, Shortest possible communication network, entry gates., existing terrain, Roads & Drainage system, Road & Rail linkage Seismic design, Environmental factors, Water Reservoir, Rain Harvesting, Switch Yard, Segregation, Minimum Over head & Ground Clearances.

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2. Technological Considerations

Process Selection, Basic Engineering

3 Design Considerations

Desired Production, Quantity/Quality, Modular Design , Standard Spacing of columns, building sizes Productivity of machines, Inbuilt capacity for future expansion, Safety Factors/Dynamic Loading Factors/Slope Factors/Filling Factors/Free Board, Availability of machines per year, Life span of plant/machines, Materials Characteristics, Specific Consumptions of utilities, Checking for Strength, Stability & Deflection, Requirements of all utilities, auxiliary facilities, power, water, air, gases, hoisting & handling, mounted electrics, instruments., Provision of Ramps, Lifts, Platforms, stairs, doors, corridors, restrooms of desired slopes, widths & dimensions considering normal persons, disability and old age.

A holistic design is a solution that is greater than sum of its parts.

4. Operation Considerations

Ease of operation,Flexibility in operation. Degree of automation desired, Degree of protection desired, duty cycles, all weather operation,quick changeover of parts, Comfortable environment, Lower pollution –Air, Water & Noise, Operators manuals

5. Maintenance Considerations

Should require lesser maintenance, Minimum Down time, Fit & forget concept, easily approachable-all parts needing maintenance to have proper hoisting and handling with adequate headroom, Easy lowering & lifting into Truck/Trailer, Corrosion & Abrasion prevention, Repair Workshop, Maintenance Manuals etc.

6. Standardisation/Interchangability

BIS Codes & Standards. Must comply to some reputed standards –Firstly it shall comply with Indian Standards. If the same is not available, the it may comply with any International standards acceptable., IRC Codes & Standards,National Building code Of India, Piping, Pressure Vessels codes, TAC Rules for firefighting facilities.

7. Safety Requirements

All the buildings, plant & equipment shall comply with all the safety requirements for the Safe & accident free operation.

8. Statutory Requirements

All plants, Buildings, equipment must comply with the law of the place where it is being erected/constructed/installed. Each State may have different provisions pertaining to same requirements.

9. Erection Considerations

Erection Sequence, Erection Methodology, Special Requirements /OD consignment, building roof erection, Minimizing Erection Time. In situ,Temp Protection Batching Plants-Capacity & Number, alignment, lining, levelling & grouting, Inserts Placements, Water requirement, Temporary Power requirement, Manpower requirements, Interfacing with other units, Welding requirements, Space requirements-Fabrication, storage and temp assembly.

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10. Project Management

Financial tie-up, Finalization of modus-operandi for project, Clearance from statutory authorities, Land acquisition

Estimation of duration of construction period of the project, implementation schedule, resources requirements, Quality Control, ProcurementServices, Selection of Vendors, Cost and Time Control, Project Monitoring, Specialist Supervision,Enabling Works, Construction Planning

Measurement and Certification, Safety & Security Management, Store & inventory management

Site survey and soil investigation

Completion of basic engineering, detailed Engineering, Tendering &Procurement, Civil& Structural work, Erection of Equipment, Commissioning

11. Ergonomics

Ergonomics is the science of making things simple, comfortable and efficient.If a plant or machine is simple to operate, it will be more acceptable.Comfort in the human-machine interface and the mental aspects of the product or service.

12. Transportation Logistics

Ship/Rail/Road/Air/ Conveyor, Pipeline, Water way transport, OD Size of consignment, Packaging, Container or Loose,Special Requirements-Special Bogie, Trailer,

13. Normal Spares Two Years, Commissioning & Insurance Spares

14. Financial Management: Capital Cost, Operating Cost, Profit & Loss, Financial Indices, IRR, DSCR, Pay Back Period.

15. Contracts Management

Legal aspects of contracts: definition of contracts, elements of a valid contract, offer and acceptance, capacity of the parties to the contract, types of mistakes encountered in contracts, misrepresentation, consideration, express and implied terms and statute of limitations. Contract documents: drawings, specifications, bill of quantities, General conditions of Contracts, Special Conditions of contracts.Types of Contracts-Supply, Semi Turn key, Turn Key contracts.

16. Marketing Research

Demand-Supply analysis Identification of potential markets, Analysis of Competitors' positioning Pricing trends Performance-gap analysis Formulation of growth strategy

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Basic Engineering Considerations for Engineers and Entreprenures

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Abstract: *Paradigm shift in technical education is needed to bridge the gap existing between the needs of the industry and the academic curriculum.During50 years of engineering practice author hasfound that our engineers are not trained to think in holistic engineering manner. This led author to write a book (under publication) on the above subject. The purpose of this article is to highlight such basic engineering considerations and skills to be included in the engineering curriculum for all engineering and technical education for developing "holistic engineering and entrepreneurship thinking" This approach means that once any engineer applies the basic engineering considerations given in this paper to any project/venture/ system then it is ensured no major technical glitch is left.*

Even non-technical persons can benefit by learning these principles and apply them in their day to day working in industrial and service sectors or even buying any equipment.

The following 16 basic skills need to be learned by every engineer to train him for holistic thinking.

1. Marketing considerations
2. Site location & layout
3. Technological
4. Design
5. Operation
6. Maintenance
7. Standardization/interchangeability
8. Safety requirements & considerations
9. Statutory requirements
10. Erection considerations
11. Implementation / project management
12. Ergonomics
13. Transportation logistics
14. Normal, commissioning & insurance spares
15. Financial management
16. Contracts management

It is recommended that all the above concepts shall become part of curriculum of all hard-core degree and diploma engineering courses. Also, this shall form part of one-year entrepreneurship course to be introduced as finishing school for the engineering graduates and diploma holders who have already finished their education and wish to become entrepreneurs in near future.

Keywords: *Marketing; Site Selection; Layout; Technological; Technical; Design; Operation; Maintenance; Standardization; Interchangeability; Safety; Statutory; Erection; Implementation; Project Management; Ergonomics; Transportation; Logistics; Spares; Financial Indices; Legal; Contracts; Capital Cost; Operating Cost; IRR; DSCR; Pay Back*

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INTRODUCTION

During my 50 years of engineering practice author has learnt that our engineers are not trained to think in holistic manner. There exists a wide gap in our technical education between the needs of the industry and the academic curriculum. Almost all fresh as well as experienced engineers from core branches require extensive training for 2-3 years to take up assignment in the field of technology (know how), process engineering, design & engineering, operation, maintenance, manufacturing, production, procurement, logistics, technical marketing, construction, erection testing and commissioning, Techno Economics , Finance and costing.This prompted him to write a book on the above subject.

The purpose of this article is to highlight such basic engineering considerations and skills to be included in the engineering curriculum for all engineering and technical curriculum for developing **"holistic engineering and entrepreneurship thinking".**

These considerations can then be applied to tackle any kind of engineering challenges with ease, for setting up of any industry, service organization. Once any engineer applies these basic engineering skills given in this paper to any project/venture/ system then it can be ensured that no major technical glitch has been overlooked/omitted

The following basic engineering considerations have been given in brief here and are taken from my forthcoming book on the same subject. Full description of each consideration is beyond scope of this article due to its length.

Following are the Sixteen Basic Engineering/Entrepreneurshipskills

1. Marketing
2. Site Location & Layout
3. Technological
4. Design
5. Operation
6. Maintenance
7. Standardization/Interchangeability
8. Safety
9. Statutory Requirements
10. Erection
11. Implementation / Project Management
12. Ergonomics
13. Transportation Logistics
14. Normal, Commissioning & Insurance Spares
15. Financial Management.
16. Contracts Management

MARKETING

Any engineer/ entrepreneur must have basic knowledge of following aspects of marketing considerations before setting up of a new industry or recommending the same for others.

- Challenges facing the given industry

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- Key drivers for stimulating growth
- Demand – Supply analysis
- Identification of potential markets
- Analysis of Competitors' positioning
- Pricing trends
- Performance-gap analysis
- Formulation of growth strategy
- Export Potential
- Market Share & Inter Shifting of demands

An engineer/entrepreneur must be able to comprehend the challenges being faced in the present industry at macro & micro level.

An engineer must be able to recognize the key drivers of the industry to estimate demand forecastingbefore venturing out for any new industry/project.

Conventional demand forecasting methods like Time Series Analysis, Trend Projection, A Barometric Forecasting, Casual Forecasting, Expert Demand forecasting are useful but becoming less relevant due to growth of e commerce, on line marketing, B2B Marketing, B to C marketing.

The other factors to be considered are Pricing, Growth, Marketing / Distribution Channels, Trade Practicesand Export Potential.

SITE LOCATION & LAYOUT

Every engineer shall be given an exposure for site selection and preparation of layout for any new venture whether small, medium or large industry. If due attention is not paid for this, it may have serious techno economic, commercial, social and environmental considerations after the investment is made and the factory/shop/industry is set up.

Site Selection

Following aspects shall be studied and looked into before any site is chosen.

1. Location proximity to Raw Materials & Market. Minimization of Total "t-km" route length and cost.
2. Proximity to Rail connection
3. Road Connection: Proximity to all weather road,
4. Proximity to airport &Sea Ports.
5. Easy all-round availability of Water& Power
6. Skilled Manpower:
7. Metrological data
8. Soil Conditions

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Layout

Finalization of the layout of plant is an important area needing attention.If proper or optimum layout is not made, it may result in higher capital cost, higher handling and operating cost. Following factors need attention for the preparation of layout.

1. The layout must ensure Rational flow of materials.
2. The types of layouts-Horse Shoe Type, Straight, L shapedParallel/Parallel,Parallel Perpendicular Oblique angle,Saw Tooth typeas per shape and size of plot.
3. Provision for future expansion
4. Shortest possible communication network.
5. Predominant wind direction.
6. Existing road around the plot & exit & entry gates.
7. Existing Terrainand slope avoid large scale cutting and filling of soil.
8. Roads & drainage system inside the plant.
9. Soil conditions
10. Direction of possible railway link/yard for receipt and dispatch of goods.
11. Landscaping & Green Belt (33% as per Statutory Requirements)
12. Water Reservoir&Rain Harvesting.
13. Switch Yard near to the external HT tower.
14. Vaastu Requirements
15. Space for Construction, Fabrication, Steel storage & Pre assembly yard
16. BIS:8091 Code of Safe Practice forIndustrial Plant Layout
17. Segregation –Explosives/hazardous to be isolated.
18. Minimum Over head & Ground Clearances to be maintained
19. Seismic design of buildings
20. Environmental factors.
21. Miscellaneous Facilities such as fire station, fire water pump house, fire water tanks, fire fighting network, security office, medical post, parking facilities, welfare facilities like Canteens, rest rooms, recreation rooms, crèche shall be planned

TECHNOLOGY

Selection of technology plays crucial role for setting up of any venture/plant/industry as there may be many available technologies, processes, methods to produce the desired end products.

Technology Selection Parameters

- Grade and quality of finished product desired. Higher Productivity
- Process Control& Equipment Design
- Desired Mechanical, Chemical, Metallurgical properties
- Flexible to suit fluctuations in input raw materials quality

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- Selection of single machine/unit carrying multiple operations.
- Economics of scale of Production
- Better yield of product
- Lower Downtime, Capital &Production Cost
- Minimum Specific consumption of Raw Materials, Water, Energy, Fuel, Power, auxiliary facilities,
- Minimum Generation of waste materials/recycling orZero discharge
- Minimum Air Water and Noise Pollution.
- Commercially Proven Technology.
- Minimum Space requirement
- Gestation Period

Design

Design Considerations is the soul of engineering.Any lapse will result in tangible and intangible losses which cannot be made up after the plant is set up and commissioned. Major design considerations are briefly given below:

1. Desired Production, Quantity/Quality
2. Raw Materials, Water Balance, Energy Balance
3. Sizing and balancing of Plant Capacities
4. Modular Design
5. Numberand productivity of machines
6. Inbuilt capacity for future
7. Rated Capacity & Design Capacity
8. Safety Factors, Dynamic Loading Factors, Slope Factors, Filling Factorsetc.
9. Availability of machines per year.
10. Life span of Plant/machines.
11. Materials Characteristics
12. Specific Consumptions of utilities, power, water, fuel, refractories, spares, grinding media per t/unit
13. Checking for Strength, Stability & Deflection
14. Degree of automation.
15. Requirements of Inserts.
16. Check for installed power, weight of plant& equipment
17. Man power for operation and maintenance
18. Requirements of all utilities, auxiliary facilities, power, water, air, gases, hoisting & handling, mounted electrics, instruments.
19. Check for painting requirements
20. Provision of Ramps, Lifts, Platforms, stairs, doors, corridors, restrooms of desired slopes, widths & dimensions considering normal persons, disability and old age
21. Nature of the Project: Category as per as per the prevailing EIA Notification, dated 14th September 2006.

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22. Use of Thumb rules for Checking weight, horse power, capacity

Operation

Any plant or equipment shall be selected for ease and simplicity of operation, with minimum man power, pollution and maximum safety. Following operating parameters to be considered while selecting a plant and equipment:

1. Ease of operation
2. Flexibility in operation. (Increase decrease capacity, flow rate, product mix, ambient conditions)
3. Degree of automation desired
4. Degree of protection desired
5. Type of duty-Light, Medium, Heavy
6. Quick changeover of parts or streams
7. Comfortable environment
8. Lower pollution Noise
9. Easy access to control switches, pedals
10. Operators manuals
11. Operators Room

Maintenance

The plant or equipment shall be selected which need minimum maintenance&less downtime. Following are the maintenance aspects

1. Should require lesser maintenance, Minimum Down time, Fit & forget concept
2. Easily approachable-all parts needing maintenance
3. Proper hoisting and handling facility with adequate headroom, within easy reach of part. Weight of heaviest part/equipment to be lifted
4. Easy lowering & lifting into Truck/Trailer
5. Inspection covers, manholes, lifting lugs provision
6. All main & Auxiliary buildings Junction Houses, Pump Houses, MCC, ECRs to be within road approach.
7. Choice of lubrication system
8. Repair Bay/Repair station/Workshop/stores
9. Maintenance Manuals/ Quality Assurance Plans (QAPs), Inspection Reports

Standardization/Interchangeability

The plant and equipment to be procured, manufactured shall conform to national or international standards. It must comply with BIS Codes & Standards or some other reputed standards.

To the extent possible every endeavor shall be made to limit the type of equipment by selecting similar types e.g. Motors, Gear Boxes, Couplings, Bearings, Idlers, Beltings, Pumps, Sections of Steels, Steel Plate Thickness and sizes, Reinforcement bars diameters, doors & windows sizes,pipes and their diameter, flanges, gaskets etc.This will reduce the cost of inventory.

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Safety

Safety requirements for all the buildings, plant & equipment as specified by State & Central Government bodies/agencies shall be strictly complied for the Safe & accident free operation.

All buildings /plant/equipment shall be provided withRamps, Elevators, Toe Guards & Handrails. Operating and maintenance Platforms, Walkways, Stairs & landings, Doors/Windows, Ventilation/Air Conditioning, Fire Protection, Escape & exits, Earthing, Lightening protection/Civil aviation lights, Under/over voltage/current. Frequency/Load protection (As required)

Apart from above every engineer shall have knowledge of safety requirements during construction of plant & buildings.

Statutory Requirements

All plants, Buildings, equipment must comply with the law of the place where the plant is being erected/constructed/installed. Each State may have different provisions pertaining to same requirements.

Some of the important laws for Industrial Buildings and installation of equipment thereinare given below:

1. Factories Acts for approval
2. CPCB, CEA, IEGuidelines & Rules
3. Indian Boiler Acts & BoilerInspector approval for Steam & HP pipelines, pressure vessels and boilers
4. Fire safety TAC Rules
5. Min Widths, Overhead Clearances, Curvatures for road/rail etc. as per IRC/RDSO
6. Doors & windows Sizes
7. MCC Rooms, Switch Yards, Overhead HT Lines –Minimum side, front, back & OH clearances Special requirements for the above shall be checked pertaining to Central and Concerned State rules.

Erection

It is seen that if proper erection sequence and methodology is not followed, it may result in time and cost overrun, duplication of jobs, dismantling & re-erection, accidents, loss of life and property. The following erection considerations shall be taken into account

1. Erection Sequence&Erection Methodology
2. Special Requirements/OD consignment,
3. Minimizing Erection Time
4. Erection of Cranes-Tower Cranes, Jib Cranes
5. Batching Plants-Capacity & Number
6. Alignment, lining, levelling & grouting
7. Inserts Placements
8. Rate of RCC, fabrication, Structural, Refractories, Piping, mechanical electrical equipment erection per month
9. Water, Manpower & Power requirements Peak &Average
10. Interfacing with other units

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11. Space requirements-Fabrication, storage and temp assembly.
12. Safety considerations in erection/construction

Project Management

Basic knowledge of project management for the smooth implementation of the project is necessary to identifymajor activities involved in the implementing of the project and to estimate average completion time for each of the activities. This ensures estimated ratesof construction work required and proposed time schedule for completion of project.

Project Implementation

For the project to be commissioned within schedule, the following advance actions have to be initiated by Project Authority to meet the proposed schedule.

- Financial tie-up and modus-operandi of project
- EMP/EIA approval
- Leveling, Cutting & Filling
- Selection of Technology Supplier, Consultant, Contractors for civil, structural, mechanical electrical works
- Quality Control set up
- Planning for enabling works at site
- Planning and organizing structural steel availability

Enabling facilities at site include construction of temporary offices, open and covered storage, fabrication yard, temporary firefighting construction water and power and drainage facilityetc.

After above zero activities the following activities are taken up in sequence or in parallel

- Basic Engineering
- Tender Specification, placement of orders for Main & Auxiliary Equipment
- Issue of Civil buildings Drawings
- Site Preparation for civil & steel fabrication work
- Issue of Structural Design and fabrication Drawings.
- Civil Construction Work
- Receipt of load data and issue for equipment Foundationdrawings
- Fabrication and erection of Steel Structures
- Issue of installation drawings for equipment and electrical
- Inspection & supply of equipment at site
- Erection of mechanical equipment, electrical equipment, instrumentation and cable laying work
- Cold start,Testing, trial run and commissioning

The timely completion of the project depends on the association of proven construction agencieswho can mobilize requisite resources of men, materials and construction machinery as well as construction and erection expertise to execute the above project.

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An engineer must have basic knowledge of Bar Charts, CPM/PERT Network (Master Network L1, L2, L3 types) for project monitoring and controlling time and cost overruns.

ERGONOMICS

Every engineer and entrepreneur must have a basic understanding of Ergonomics principles.Ergonomics is the science of making things simple, comfortable and efficient& more acceptable.

Following are the prime ergonomic considerations:

- Reducing the number of steps in a task makes it quicker to complete.
- Reducing the nos. parts, switches, gadgets, manual effort, soothing ambience, optimum temperature and humidity, less noisy atmosphere increase the efficiency of operation
- Reducing the amount of training needed,

Transportation Logistics

An engineer should have knowledge of transportation logistics to understand the economics of transport of material within and outside plant. Whereas for longer distances Rail, Ship Inland Water Ways and Pipe Line transport are cheaper, for shorter distances Road, Conveyor, Aerial Ropeway, Pneumatic Transport may be cheaper. The manta is that total tonne-km cost must be minimum.

Similarly, before ordering an engineer must have the knowledge of overall dimensions and size of equipment (OD Dimensions) so that the same can be freely transported to site by rail or road without any obstruction/hinderance on the way.

Similarly, due attention shall be paid to packaging considering the nature of material, and equipment with respect to damage due to breakage, humidity, self-ignition, loss due to evaporation, pilferage, hazardous nature of substance, parts identification etc.

Spares

Spare part for two Years Normal Operation shall be considered.

All spare parts and consumables required for Construction, Pre-Commissioning, and Commissioning shall be identified and ordered

Insurance spare parts are those parts of equipment, equipment assemblies or complete items of equipment that are required for replacement of items not subject to deterioration by normal use, but failure of which is critical for continued and safe operation of equipment or plant.

FINANCIAL MANAGEMENT

Engineer shall have knowledge to enable him to carry out Estimation of capital cost of Project, Working capital, margin money, Interest during construction, term loan interest, Cost of Raw materials, Energy, Utilities, power, water, fuel, consumables, manpower cost, repair and maintenance costs, production cost, Sales realization, profit & loss statements, payback period, internal rate of return, Debt Service Coverage Ratio, Break Even Point.

Capital Cost

Estimation of capital cost, cost of capital, interest rates, duration of payment are the factors to be considered:

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There are various ways to calculate the capital cost.

1 From the budgetary offers.
2 From historical costs.
3 From similar cost of recently constructed plants
4 Detailed estimation
5 By indexing
6 Byadopting Percentage Cost Method
7 By relative cost index method

Methods from 1 to 5 are common but the method at 6 & 7 are new and developed by author over a period spanning 50 years of Consultancy Practice.

Percentage Cost method is based on the analysis of historical data of similar plants. It is discovered that cost of various activities of a plant fall within some percentage of total cost of Mechanical Equipment.

Relative Cost Ratio/Index Method

This is another interesting and novel method developed by author and is based on the concept that relative cost of any plant and equipment/industrial products remain constant and fixed over the period of time and place. For example, relative cost ratio of motor and matching gear box is constant not affected by time or place. Similarly, relative cost ratio of one Million Tonnessteel plant &four MT steel plant is constant. By knowing the cost of one the cost of other can be easily calculated.

Operating Cost

This consists of Fixed Cost and Variable Cost. Fixed costs are those business costs that are not directly related to the level of production or output. Variable costs are those costs which vary directly with the level of output..

Profit & Loss

Every engineer/entrepreneur must learn to calculate profit and loss for the industry being set up and this shall be part of curriculum.

Financial Indices

Knowledge of following financial indices is important for taking investment decision.

Debt-Service Coverage Ratio, Internal Rate of Return, Break-Even Capacity,Pay Back Period

CONTRACTS MANAGEMENT

Engineer shall have following basic knowledge of managing contracts:

- Definition of contracts, elements of a valid contract, offer and acceptance, capacity of the parties to the contract, types of mistakes encountered in contracts, misrepresentation, consideration, express and implied terms and statute of limitations.
- Contract documents: drawings, specifications, bill of quantities.

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- General&Special Conditions of contracts.clauses of conditions, quality of work during construction, contractor duties, site engineer contractual job, costs of construction, essence of time factor of construction, insurance and bonds and arbitration
- Types of Contracts-Supply, Semi Turn key, Turn Key
- Contracts on BOO, BOOT etc.

CONCLUSION

All the aspects discussed above are necessary to be learned during course of technical education for development of entrepreneurshiptemperament.Onceany entrepreneur/engineer applies above concepts for implementing any project, then it can be ensured that the project has been taken care holistically and nothing more is left to chance. Thisall-round approach can turn all young engineers to think in holistic sense or “Engineered Thinking”

It is recommended that all the above concepts shall become part of curriculum of all hard-core degree and diploma engineering courses.Also, this shall form part of one-year entrepreneurship course for the engineering graduates and diploma holders who havealready finished their education and wish to become entrepreneurs in near future.

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