Parametric Optimization of Single Cylinder CI Engine for Break Thermal Efficiency using Mahua Oil Blend

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Abstract— an experiment study has been carried out for MAHUA oil blended with diesel used in single cylinder CI engine. MAHUA oil is non-edible vegetable oil which is available in large quantities in India. Blending of mahua oil with diesel in maximum possible proportion helps to increase the break thermal efficiency of diesel fuel. This study applies the L16 orthogonal array of the Taguchi method to find out the best injection pressure blend proportion and load for maximum break thermal efficiency. The result of the Taguchi experiment identifies that 10% blend ratio, engine load 10 kg and injection pressure 180 bar are optimum parameter setting for maximum break thermal efficiency. Engine performance is mostly influenced by engine load and least influenced by injection pressure. Confirmation experiment was done using optimum combination showed that break thermal efficiency was found by experiment is closer to the predicated value.

Key words: Diesel, MAHUA Oil, Parametric Optimization, Brake Thermal Efficiency (BTE), Taguchi Method

I. INTRODUCTION

Recent survey on the world energy consumption highlights that a major portion of the total energy consumed is derived from the combustion of fossil fuels. Unfortunately, the reserves of fossil fuels, specially the liquid fuels are not unlimited and may exhaust, if not utilized economically, within few decades. Efforts are being made throughout the World to reduce the consumption of liquid petroleum fuels wherever is possible. Two general approaches are in use. First is to switch over the energy consumption devices on alternative energy source. The second is to enhance the efficiency of combustion devices the first one is quite easy to achieve.

When biodiesel is used as a substitute for diesel, it is highly essential to understand the parameters that affect the combustion phenomenon which will in turn have direct impact on thermal efficiency for which the other design and operating parameters have to be optimized. The most common optimization techniques used for engine analysis are response surface method, grey relational analysis [1], nonlinear regression[2], genetic algorithm[3] and Taguchi method. Taguchi technique has been popular for parameter optimization in design of experiments. DOE has introduced the loss function concept which combines cost, target and variations into one metric. The signal to noise ratio (S/N) is a Figure of merit and relates inversely to the loss function. It is defined as the ratio of the amount of energy for intended function to the amount of energy wasted [4]. Orthogonal arrays are significant parts of Taguchi methods. Instead of one factor at a time variation all factors are varied simultaneously as per the design array and the response values are observed. It has the ability to evaluate several factors in a minimum number of tests. Design of experiments (DOE) approach is cost effective and the parameters are varied simultaneously and then through statistical analysis the contribution of individual parameters towards the response value observed also could be found out. The engine operating parameters are the main factors responsible for the engine emissions and fuel economy. The fuel injection parameters like injection valve opening pressure and the compression ratio also have influence on emissions and fuel economy. In this work DOE approach is used to find the effect of design and operating parameters on brake thermal efficiency (BTHE).

A second order weight equation is formulated where several parameters are used to make sensitivity analysis. Design optimization is also done with several design parameters. BTHE varied widely with different injection timings than with different load, Static injection pressure, Compression ratio, were taken as parameters for the design optimization study. The effect of the parameters - injection pressure, Compression ratio, Load, and engine speed on brake power and smoke were investigated [5]. An increase in injection pressure contributes to fuel economy by improved mixing [6]. Optimal combination of design and operating parameters were identified that can improve brake thermal efficiency. This method was found to be useful for simultaneous optimization. It has been studied the effects of injection pressure load and biodiesel blend on brake thermal efficiency. Without considering the combustion parameters engine design and operating parameters can be optimized and engine efficiency can be increased by applying Taguchi method. It is known from DOE procedure that for 3 parameters with 4 levels, the number of trial runs will be 64. In this present work an attempt is made to carry out an optimization analysis of direct injection diesel engine run by MAHUA OIL blend using a model in combination with Taguchi method.

II. MAHUA OIL

Mahua oil (MO oil) is an underutilized non-edible vegetable oil, which is available in large quantities in India. The fuel properties of the MO Oil biodiesel were found to be within the limits of biodiesel specifications of many countries. Fuel properties of diesel, mahua oil and blends are comparable. The calorific value of mahua oil was found as 96.30% on volume basis of diesel. It was found that mahua could be easily substituted up to 20% in diesel without any significant difference in power output, brake specific fuel consumption and brake thermal efficiency. The performance of engine with mahua oil blends improved with the increase in compression ratio from 16:1 to 20:1. Based on this study, it has been observed that esters of mahua oil could be used as a substitute for diesel.

The specific gravity of mahua oil was 9.11% higher than that of diesel. The kinetic viscosity of mahua oil was

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15.23 times more than that of diesel at temperature of 40oc. the kinetic viscosity of mahua oil reduced considerably with increasing the proportion of diesel in fuel blend.

A. Mahua Oil:

- Botanical name: - Madhuca indica
- Family: - Sapotaceae
- Color: - Pole Yellow
- Consistency: - Plastic

B. Property of Mahua Oil and Its Compression:

Property	Diesel	Mahua oil
Calorific value(KJ/Kg)	42,500	36,100
Viscosity(mm^2/s)(at40^{o}c)	4.3	24.58
Density (Kg/l)	0.815	0.960
Cetane Number	47	61.40
Flash Point(^{o} c)	58	232
Ash content %	0.01	0.09

Table 1: Property of Mahua Oil

C. Comparison of Mahua Oil with Diesel Oil:

Caloric value and carbon residue: The calorific value of mahua oil was observed as 88.26% of diesel on weight basis and 96.30% on volume basis. The calorific value of a mahua oil was found nearer to diesel fuel in comparison with other liquid fuel option like ethanol and methanol. The carbon residue of mahua oil was found higher than that of the limit specified for grade-A diesel and this may increase the chance of carbon deposition in the combustion chamber. The higher carbon residue may be due to the difference in chemical composition and molecular structure of mahua oil.

D. Flash Point:

The flash point of mahua oil was very high as compared to diesel thus indicating its low volatile nature. The result of increase in concentration of mahua oil in diesel revealed that the power output decreases at all compression ratios.

E. Brake Thermal Efficiency and A/F Ratio:

Brake thermal efficiency decreased with the increase of mahua oil in diesel at all compression ratio in comparison with pure diesel. Exhaust gas temperature increased with the concentration of mahua oil in diesel. The air-fuel ratio and volumetric efficiency decreased with increase in concentration of mahua oil in diesel

III. EFFECT OF PARAMETER

A. Injection Pressure:

Injection pressure is a pressure which is required to inject the fuel into cylinder. For smooth function of injector, it is required that the injection pressure is higher than cylinder pressure. Higher the injection pressure gives better the dispersion and penetration of the fuel into all desired locations in combustion chamber.As the piston moves approximately two-thirds of the way up in the cylinder on the compression stroke, the injector cam lobe begins to lift causing the injector rocker arm to push down on the follower and the plunger. Plunger return spring bring back to initial position.

How to vary the injection pressure?
On the upper part of plunger the adjustable screw is attached to the injector. By varying the position of plunger, change in the injection pressure is achieved. It is required to calibrate the screw or injector.

1) Effect Of Injection Pressure:

As with increasing fuel injection pressure can, at least up to some point, result in superior mixing of the fuel with the intake gas, ordinarily resulting in more complete combustion and thus more NOX, less particulate Metter and HC emission and greater cylinder pressure, fuel economy and power.

B. Engine Load:

As engine speed increases, the loss of heat during compression decreases with the results that both temperature and pressure of the compressed air tends to rise, thus the increase in turbulence, however may tend to increase the heat loss in some cases. when load increases brake thermal efficiency and mechanical efficiency also increase in proportion. Eddy type dynamometer is used for change the load on machine.

C. Bland Proportion:

Blend ratio is percentage of alternate fuel or additive in the convention fuel by V/V ratio. When bland ratio increase or decrease, its changes the fuel consumption and consequently brake power and mechanical efficiency also change in brake thermal efficiency. When alcohol is a content of blend, it provides oxygen. So that, combustion becomes smooth and complete. Sometimes due to additive in the blend, there may be decrease in CO and HC emission. Blend ratio is vastly influence on the combustion characteristics, performance and emission. So that, if change in blend ratio, it may be change in above characteristics.

IV. METHODOLOGY

The problem of increasing demand for high brake power and the fast depletion of the fuels demand severe controls on power and a high level of fuel economy. Many innovative technologies are developed to tackle these problems. Modification is required in the existing engine designs. Some optimization approach has to be followed so that the efficiency of the engine is not comprised. As far as the internal combustion engines are concerned the thermal efficiency is the important parameters for which the other design and operating parameters have to be optimized. The most common optimization techniques used for engine analysis are response surface method, grey relational analysis, nonlinear regression, genetic algorithm and Taguchi method.

A. Taguchi Method:

The Taguchi method provides simple and effective solutions for investigating the effect of parameters on the performance as well as in the experimental planning. In this method, the signal -to-noise (S/N) ratio is used to represent a performance characteristic and the largest value of the S/N ratio is required. There are three types of S/N ratios-the lower-the better, the -higher-the better and the-more-nominal -the – Better.

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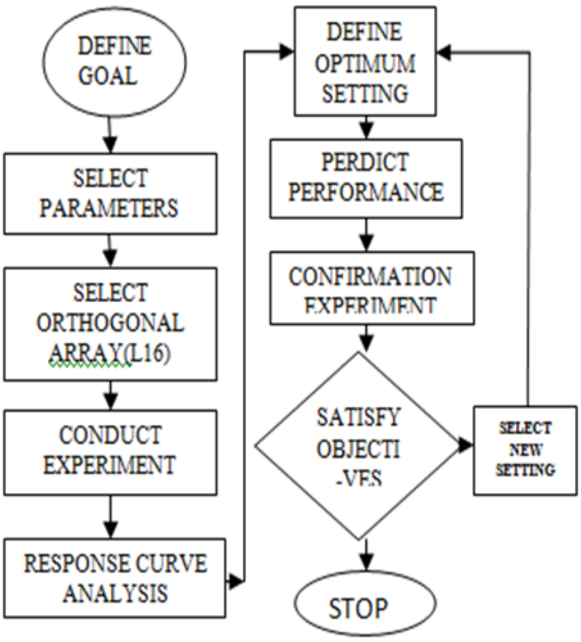

Fig. 1: Flow Chart of Taguchi Method

The objective of the work is to investigate the engine operating and injection parameters having maximum potential for increasing brake power and for improving the fuel economy and to identify the optimized range of input parameters for better fuel economy. DOE technique is used to identify the key factors that make the greatest contributions to the variation in response parameters of interest. It introduced the loss function concept which combines cost, target and variations into one metric. The signal-noise ratio is a Figure of merit and relates inversely to the loss function. It is defined as the ratio of the amount of energy for intended function to the amount of energy wasted. DOE recommends orthogonal array (OA) for lying out of the experiments which is significant part of this method. Instead of varying one factor at a time, all factors are varied simultaneously as per the design array and the response values are observed. It has the ability to evaluate several factors in a minimum number of tests. In the present study uses three factors at four levels and hence, an L16 orthogonal array was used for construction of experiment lay out (Table 2 column -1, 2, 3). The L16 has the parameter such as load, injection pressure and blend proportions are arranged in column 1, 2 and 3. (Table -2).

B. Selection of Factor Levels and Orthogonal Array:

In this experiment, three parameters for four levels were consider (table-1). Control parameter and their level are given in table L16 single orthogonal array shown in table-2(column- 1, 2 &3) was selected for the experimental investigation. “Larger is better” is being taken as quality characteristics since the objective function is to find maximum break thermal efficiency.

Controlled factors	**Injection pressure**	**Blend ratio**	**Engine load**
Units	Bar	% MAHUA oil in diesel	Kg
Level 1	160	0	1
Level 2	180	10	4
Level 3	200	20	7
Level 4	220	30	10

Table 2: Process Parameters and Their Level

V. EXPERIMENTAL SET UP

The experimental set up consists of a four stroke, multi-fuel, direct injection single cylinder research engine connected to an eddy current type dynamometer for loading which is shown in figure. 1. Details of the engine specification are shown in table.

The injection point and spark point can be changed for research tests. Setup is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle measurements. These signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The set-up has stand-alone panel box consisting of air box, two fuel flow measurements, process indicator and hardware interface. Rota meters are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement.

Fig. 2: Experimental Setup

The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance and combustion analysis. Lab view based Engine Performance Analysis software package “Engine soft” is provided for on line performance evaluation.

VI. EXPERIMENTAL INVESTIGATION

Experiment was done for the three parameter which we are selected and sets of parameters by Minitab software and find

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break thermal efficiency for those sets of parameters. Brake thermal efficiency for those sets are given in the table.

EXP NO	Pressure	Blend	Load	BTHE
1	160	B0D100	1	6.462
2	160	B10D90	4	20
3	160	B20D80	7	26.66
4	160	B30D70	10	28.85
5	180	B0D100	4	20.674
6	180	B10D90	1	9.39
7	180	B20D80	10	29.11
8	180	B30D70	7	24.17
9	200	B0D100	7	26.7
10	200	B10D90	10	28.45
11	200	B20D80	1	6.39
12	200	B30D70	4	17.96
13	220	B0D100	10	30.866
14	220	B10D90	7	24.84
15	220	B20D80	4	17.55
16	220	B30D70	1	6.45

Table 3: Result Table for Brake Thermal Efficiency

A. *Response Curve Analysis:*

Response curve analysis is aimed at determining influential parameters and their optimum levels. It is graphical representations of change in performance characteristics with the variation in process parameter. The curve give a pictorial view of variation of each factor and describe what the effect on the system performance would be when a parameter shifts from one level to another. Figure- 4 shows significant effects for each factor for four levels. The S/N ratio for the performance curve were calculated at each factor level and average effects were determined by taking the total of each factor level and dividing by the number of data points in the total. The greater difference between levels, the parametric level having the highest S/N ratio corresponds to the parameters setting indicates highest performance.

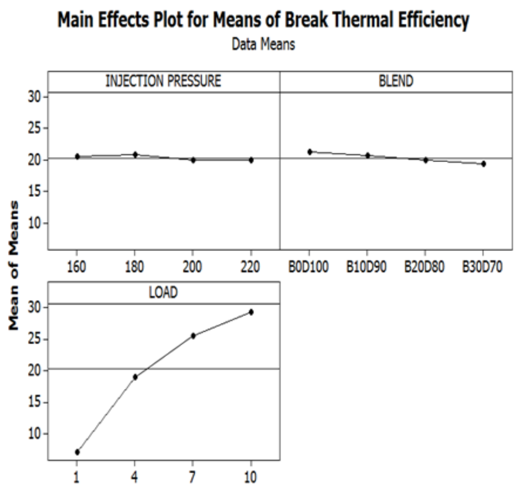

Fig. 3: Main Effects Plot for Mean Ratios of Brake Thermal Efficiency

From above figure-3, mean is an average value for reading taken for particular parameter. From graph, mean value is maximum (21.176) for 0% and minimum (19.875) for 30% blend. Mean value is maximum (20.836) for 180 bar injection pressure and minimum (19.875) for 200 bar injection pressure. Mean value is maximum (29.319) for 10 kg load and minimum (7.173) for 1 kg engine load

Delta is difference of maximum value and minimum value. Delta value is maximum for load parameter (22.145) and minimum (0.961) for Injection pressure. Delta value for diesel blend is between other two parameter and it is (1.818).So that effect of load is maximum and effect of Injection Pressure is minimum on Brake thermal efficiency.

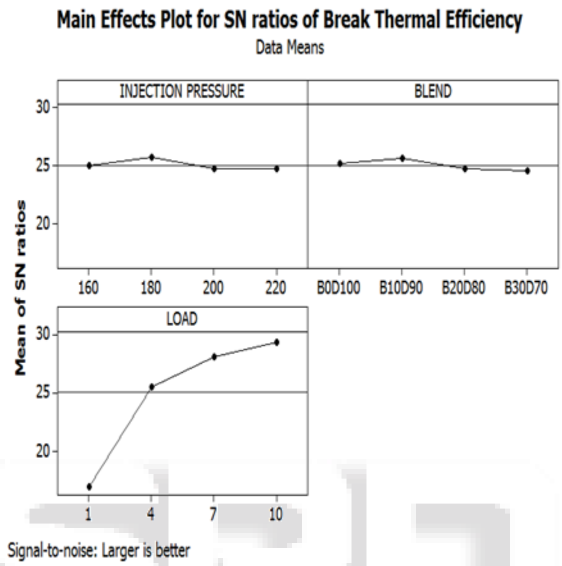

Fig. 4: Main Effects Plot for SN Ratios of Brake Thermal Efficiency

Referring (Fig.4), the response curve for S/N ratio, the highest S/N ratio was observed at 10% blend ratio (25.61), engine load 10kg (29.34) and injection pressure 180 bar (25.68), which optimum parameter are setting for maximum break thermal efficiency. From delta values as mention above, maximum (13.191) for engine load and minimum (0.180) for bland ratio. Parameter engine load is most significant parameter and bland ratio is least significant for brake thermal efficiency.

The term optimum set of parameters is reflects only optimal combination of the parameters defined by this experiment for highest break thermal efficiency. The optimum setting is determined by choosing the level with the highest S/N ratio.

LEVEL	INJECTION PRESSURE	BLEND	LOAD
1	24.99	25.21	16.99
2	25.68	25.61	25.58
3	24.70	24.70	28.15
4	24.69	24.54	29.34
DELTA	0.98	1.08	12.35
RANK	3	2	1

Table 4: Response Table for Signal to Noise Ratio

Referring fig-4 and table-3, the response curve for S/N ratio, the highest performance at set 10% blend ratio, engine load 10kg, and injection pressure180 bar, which is optimum parameter setting for highest brake thermal efficiency.

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B. Predict Performance at Optimum Setting:

S/N RATIO	BTHE (%)
30.60	30.25

Using optimum set of parameters, which was achieved by response curve analysis was used for prediction by Minitab software. Minitab software for Taguchi method of optimization was suggested break thermal efficiency 30.2567% and S/N ratio was 30.6012 for optimum set of parameter as shown in table 4.

VII. CONCLUSION

The results of the taguchi experiment identifies that injection pressure 180 bar, blend 10% and engine load 10 kg are optimum parameter setting for highest break thermal efficiency. Engine performance is mostly influenced by engine load and is least influenced by injection pressure.

REFERENCE

[1] Karnwal, M. Hasan, N. Kumar, A.N. Siddiquee and Z.A. Khan. 2011. Multi- response optimization of diesel engine performance parameters using Thumba biodiesel -diesel blends by applying the Taguchi method and grey relational analysis-International Journal of Automotive Technology. 12(4): 599-610.

[2] N. Maheswari, C. Balaji and A. Ramesh. 2011. A nonlinear regression based multi-objective optimization of parameters based on experimental data from an IC engine fueled with biodiesel blends. Biomass and Bio-energy. 35: 2171-2183.

[3] Alonso JM, Alvarruiz F, Deantesjm Hernandez. L, Hernandez V and Molto G. 2007. Combining neural networks and genetic algorithms to predict and reduce diesel engine emission. IEEE Trans. 11: 46-55.

[4] T. Ganapathy, K. Murugesan and R.P. Gakkhar. 2009. Performance optimization of Jatropha engine model using Taguchi approach. Applied Energy. 86: 2476- 2486.

[5] Cenk sayin and Metin gumus. Impact of compression ratio and injection parameters on the performance and emissions of a DI diesel engine fueled with bio-diesel. Blended Fuel.

[6] Jinlin Xue, Tony E. Grift and Alan C. Hansen. 2011. Effect of biodiesel on engine performances and emissions. Renewable and Sustainable Energy Reviews. 15: 1098-1116.

[7] Gupta, Ashok Kumar, Dilip Gehlot, and Mr Akhilesh Mishra. "Optimum fuel injection timing of direct injection ci engine operated on karanja oil investigation."

[8] Kannan, G. R., and R. Anand. "Effect of injection pressure and injection timing on diesel engine fuelled with biodiesel from waste cooking oil." Biomass and bioenergy 46 (2012): 343-352

[9] Patel, Sejal Narendra, and Ravindra Kirar. "An Experimental Analysis of Diesel Engine Using Biofuel at Varying Compression Ratio." International Journal of Emerging Technology and Advanced Engineering: 2250-2459.

[10] Pavanendra kumar,niraj kumar,vineet tirth "comparative analysis of performance and emission of diesel engine by varying compression ratio using different fuels" MIT international journal of mechanical engineering, vol. 3, no. 2, august 2013

[11] Patel, M. K. B., Patel, T. M., & Patel, M. S. C. (2012). Parametric Optimization of Single Cylinder Diesel Engine for Pyrolysis Oil and Diesel Blend for Specific Fuel Consumption Using Taguchi Method. IOSR Journal of Mechanical and Civil Engineering, 6(1), 83-88.

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