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Analysis of CI Engine Parameters with Used Temple Oil Biodiesel Using Taguchi Method

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Abstract: Today's world is facing major environmental issue called global warming, the emissions of diesel fuel is one of the major source for the global warming and also for air pollution. The use of biodiesel can reduce diesel fuel consumption and emission of diesel engine, because biodiesel has been considered as a potential alternative fuel for CI (Compression Ignition) engines. Out of many biodiesel derived from various resources, present study deals with usage of Used Temple Oil have been considered as fuel for analysis. The transesterfication process was adopted to condition the raw oil to suit its properties. Properties are evaluated according ASTM standard and properties are found to be computable with diesel. The present work Used Temple Oil biodiesel bends are used to the run thesingle cylinder four strokes diesel engine at different injection opening pressure. To optimize thethree opening pressure, Taguchi method adopted. For forming orthogonal array the experiments have been designed using DOE in Minitab 18 and Taguchi's L9 array is employed. For identifying the contribution of various factors which significantly affects the response followed by regression analysis to validate the results at optimum set of selected control factors. This study deals with optimal values of BTE and NOx emission. From the results it reveals that NOx reduction is maximum at 200 bar injection pressure, B30 methyl ester blend at 50% load.

Keywords: Injection Pressure, UTO Biodiesel, Taguchi Method, ANOVA, Performance Parameters

1. Introduction

Various resources like non edible oil, animal fats and waste oil are the main sources of biodiesel. The best quality of all these sources is that, they all are renewable and do not influence any food security supply for human beings [1]. Biodiesel is considered as promising alternative fuel for CI engines, due to reduced smoke emission and with rich oxygen content. The 10% of oxygen content in biodiesel provides better combustion of fuel. To optimize operating and design variables of diesel engine for maximum Brake Thermal Efficiency, peak pressure, Temperature, IMEP, BMEP Taguchi method is used and improvement in above said parameters at optimal condition is reported [2]. Taguchi method is good to find optimal operating parameters for high BTE and low BSFC, NOx and smoke [3]. In investigation process Taguchi method was used to optimize three parameters such as injection pressure, injection timing and blend proportion [4].

The injector opening pressure, fuel injection timing and compression ratio on BTHE, BSFC and emissionswas able to identify the orders of significance or contribution of each parameters using Taguchi method along with grey relation analysis and ANOVA [5]. In terms of BTE and NOx emission Taguchi method provides the optimal setting of the engine for the set of control factors taken into consideration and tends to offer better engine performance with the confirmed results and regression analysis validate all the results predicted within specified range of limits, the predictions made by Taguchi parameters design technique found to be in good agreement of additive blended castor biodiesel blends [6]. Optimization of Taguchi method predicted optimum level of parameters within a trial and the 40 eucalyptus blend seen satisfactorily working at optimum setting slighter more in emission of NOx was seen [7].

Forimplementing operating parameters and to obtain best results Taguchimethod is well known. It is amethod of statistical and mathematical collection to optimum system performance. To solve the different types of problems of industries, this method is oftenly used. One of the main benefit to use of this method is the reductionof cost and time compared to the full factorial design experimentation [8-9]. From Sesame oil, it was found that Taguchi method (L9 parameter design) given the optimize process of biodiesel production. The contribution factor is higher for molar ratio is 78.09% for ester recoveryin transestrification process [10]. Taguchi analysis proved that methanol to oil ratio has maximum effect followed by temperature reaction and catalyst concentration [11].

To identify the order of contribution of each parameter (Injection opening pressure, fuel injection timing and compression ratio) on BTHE, BSFC and emission, further they reported that confirmation test results were good agreement with predicted values. Taguchi method along with grey relational and ANOVA was able [11-13].

Sesame oil yield 97.27% biodiesel production process parameters optimized using Taguchi method L9 parameter design with a 8:1 molar ratio and 0.34 catalyst concentration at 55°C reaction temperature [14].

The Taguchi and ANOVA techniques are used to determine the effect of experimental parameter and optimum level for load, injection pressure and blend percentage. And it identifies thatblend 40 of Jatrophacurcasmethyl ester at 25% of engine load and 220 bar injection pressure are the optimum parameters [15].

The single and combined effects of engine operating parameters on performance and characteristics of emission of the diesel engine employing Used Temple Oil bio diesel blend as fuel using approach in order to determine the optimal levels of load, biodiesel blend, injection pressure and optimal value of BTE, SFC, C, HC, NOx and smoke are the main objectives of this study.

2. Materials Method

The fuel used in this present study was Used Temple Oil Methyl Ester (UTOME). The Used temple Oil collected from Hanuman and Marikamba Temple Sirasi, Uttarkannada, Karnataka. Used Temple Oil free fatty acid (FFA) content was found to be below 2%. Therefore direct transesterification with alkali catalyst was performed.

The physical properties of UOME (Used Temple Methyl ester) at different blends are determined at Bangalore Test House (An ISO 9001 Certified and NABL accredited laboratory) according to IS 1448 (P6, P66, P25, P32, and P66) and were compared with fossil diesel fuel as shown in the Table 1. The Values of UTOME have almost same properties as that of the diesel fuel and shows it can be used as an alternate fuel.

Table 1. *Physical properties of UTOME at differentblends.*

Properties	B20	B30	B40	B100
Density(kg/m^3)	825	830	840	870
Kinematic Viscosity@ 40°C cSt	2.8	3.0	3.2	5.1
Flash point °C	54	58	60	164
Calorific Value (MJ/kg)	42.881	40.231	39.423	39.080
Fire point °C	57	60	65	167

The experiments were carried out on AV1 Vertical, single cylinder, water cooled, 4-stroke, and compression ignition diesel engine was for the experiment. The technical specification of the engines is given in Table 2. Engine was operated at a constant speed of 1500 rpm. The load variation was done with the help of eddy current dynamometer. Initially the engine was tested with local diesel then with different blends like 20% UTOME+80% diesel fuel (denoted B20), 30% UTOME+70% diesel fuel (denoted B30) and40% UTOME+60% diesel fuel (denoted B40) at different engine loads from 25% to 100% and at Injection Opening Pressure (IOP) of 180 bar, 200bar and 220 bar.

Table 2. *Engine parameters.*

Sl No	Detail	Specification
1	Engine type	AV1 Vertical, single cylinder, water-cooled, 4-stroke, compression ignition diesel engine.
2	Make	Kirloskar
3	No. of Cylinders	1
4	Bore X Stroke (mm)	80 X 110
5	Compression Ratio	16.5:1
6	Rated Output kW (hp)	3.7 (5)
7	Rated speed rpm	1500
8	Dynamometer	Air cooled Eddy Current Dynamometer,

Taguchi orthogonal array method has been used for BTE and NOx for UTOME. Different parameters influencing the BTE and NOx of UTOME, the three most influencing parametersand three levels (L=3, L=3 as shown in Table 3) have been considered in this study.

Table 3. *Factor and Levels for BTE of UTOME.*

Factors	Level 1	Level 2	Level 3
IOP (bar)	180	200	220
Load (%)	50	75	100
Blend (%)	20	30	40

3. Results and Discussion

The adequacy and signification of the developed regression model was tested using Analysis of variance (ANOVA) method. In ANOVA factors with 95% is considered as significant. This provided information on relative influence of parameters and their interactions with respect to the various results. According to this analysis, the most effective parameters with respect IOP (bar), Load (%) and Blend (%) are mentioned. The effects of the three chosen parameters at three different levels have been studied by conducting only nine experiments as per L9 orthogonal array for BTE shown in Table 4.

Response table for S/N ratio generated using Minitab software and for analysis purpose in Taguchi Design the condition "Larger is better" is selected. The effects of each parameter on BTE at three different levels are shown in Figure 1 and the Table 5 shows the Response table for Means of Brake Thermal Efficiency. The maximum value in each graph specifies the optimum level of that particular parameter on the BTE.

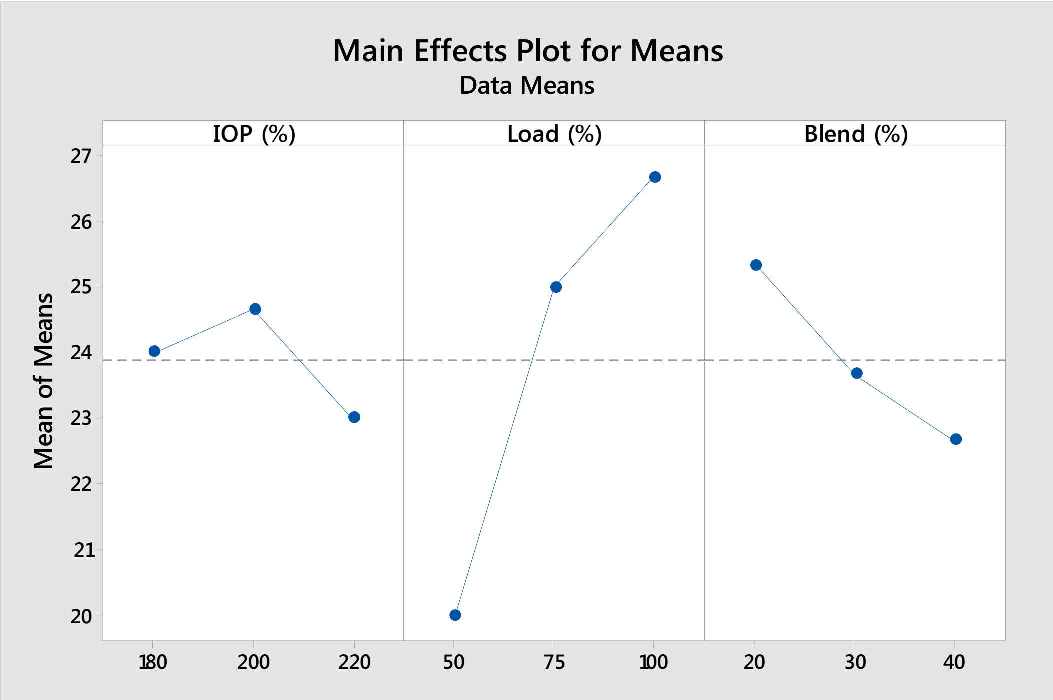

Figure 1. *Main Effect Plot for Means for the effectof Each Parameter at different levels.*

Table 4. *L9 Orthogonal Array for Design of Experiments with Three Parameters at Three levels for BTE of UTOME.*

IOP (bar)	Load (%)	Blend (%)	BTE (%)	S/N ratio
180	50	20	22	26.8484
180	75	30	25	27.9588
180	100	40	25	27.9588
200	50	30	20	26.0206
200	75	40	25	27.9588
200	100	20	29	29.2479
220	50	40	18	25.1054
220	75	20	25	27.9588
220	100	30	26	28.29947

The above Figure 1 shows that S/N ratio is maximum 24.67, 26.67 and 25.33 for 200 bar IOP, 100% load and 20% biodiesel blend respectively. And S/N ratio is minimum 23.00, 20.00 and 22.67 for 220 bar IOP, 50% load and 40% blend respectively.

Table 5. *Response Table for Means of Brake Thermal Efficiency.*

Level	IOP (bar)	Load (%)	Blend (%)
1	24.00	20.00	25.33
2	24.67	25.00	23.67
3	23.00	26.67	22.67
Delta	1.67	6.67	2.67
Rank	3	1	2

In the Table 5, Delta is the difference from maximum value and minimum value of mean of means for a particular parameter. The highest difference suggests that particular parameter has a greater effect. From the table it can see that load has maximum effect after that biodiesel blend ratio and lastly IOP on BTE.

The Figure 2 shows the Main Effect Plot for S/N ratio for the effectof each Parameter at different levels and Table 6 shows Response Table for Signal to Noise Ratios for Larger is better.

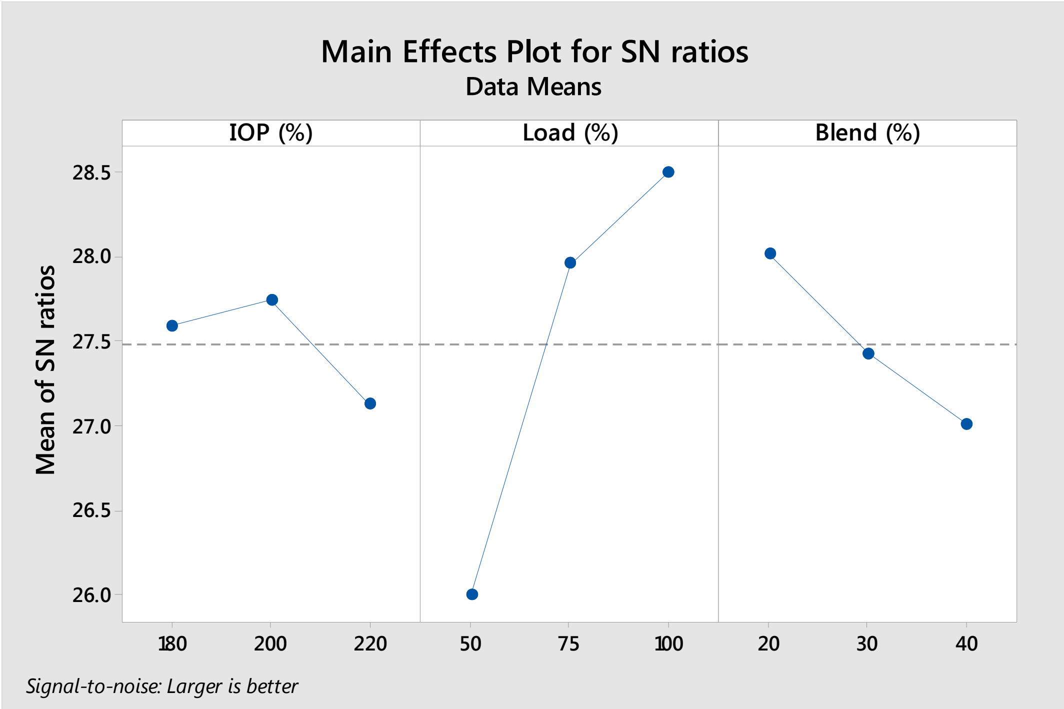

Figure 2. *Main Effect Plot for SN ratios for the effect of Each Parameter at different levels.*

The above Figure 2 shows that S/N ratio is maximum 27.74, 28.50 and 28.02 for 200 bar IOP, 100% load and 20% biodiesel blend respectively. And S/N ratio is minimum 27.12, 25.99 and 27.01 for 220 bar IOP, 50% load and 40% blend respectively.

Table 6. *Response Table for Signal to Noise Ratios for Larger is better.*

Level	IOP (bar)	Load (%)	Blend (%)
1	27.59	25.99	28.02
2	27.74	27.96	27.43
3	27.12	28.50	27.01
Delta	0.62	2.51	1.01
Rank	3	1	2

In Table 6, Delta is the difference between the maximum value and the minimum value and rank denotes the maximum and minimum effect of the parameters. It shows that the effect of load is more, whereas the effect of IOP is less on BTE. The Regression Equation of BTE is as follows, BTE (%) = 22.89-0.0250 IOP (bar) + 0.1333 Load (%) – 0.1333 Blend (%).

The S/N ratios and Mean values for NOx emission due to control parameters were computed using Minitab software and are presented in Table 7 and Figure 3. The S/N ratio of Smaller-is-Better option was chosen for the optimization of response parameter of NOx emission. The Table 8 shows Response table for Signal to Noise Ratios for smaller is better.

Table 7. *L9 Orthogonal Array for Design of Experiments with Three Parameters at Three levels for NOx of UTOME.*

IOP (bar)	Load (%)	Blend (%)	NOx (ppm)	S/N ratio
180	50	20	232	-47.3098
180	75	30	335	-50.5009
180	100	40	598	-55.534
200	50	30	145	-43.2274
200	75	40	272	-48.6914
200	100	20	425	-52.5678
220	50	40	182	-45.2014
220	75	20	316	-49.9937
220	100	30	450	-53.0643

It was noticed from the graphs of Signal-to-Noise ratio and the Mean that the NOx emission can be reduced to its lowest level when the test engine runs at 50% load condition with 200 bar IOP, when fueled with Blend 30% of UTOME.

Figure 5 shows the main Effect Plot for SN ratios for the effect of Each Parameter at different levels and Table 9 shows the Response table for Signal to Noise Ratios for smaller is better.

Table 8. *Response Table for Signal to Noise Ratios for smaller is better.*

Level	IOP (bar)	Load (%)	Blend (%)
1	-55.11	-45.25	-49.96
2	-48.16	-49.73	-48.93
3	-49.42	-53.72	-49.81
Delta	1.90	9.93	0.70
Rank	2	1	3

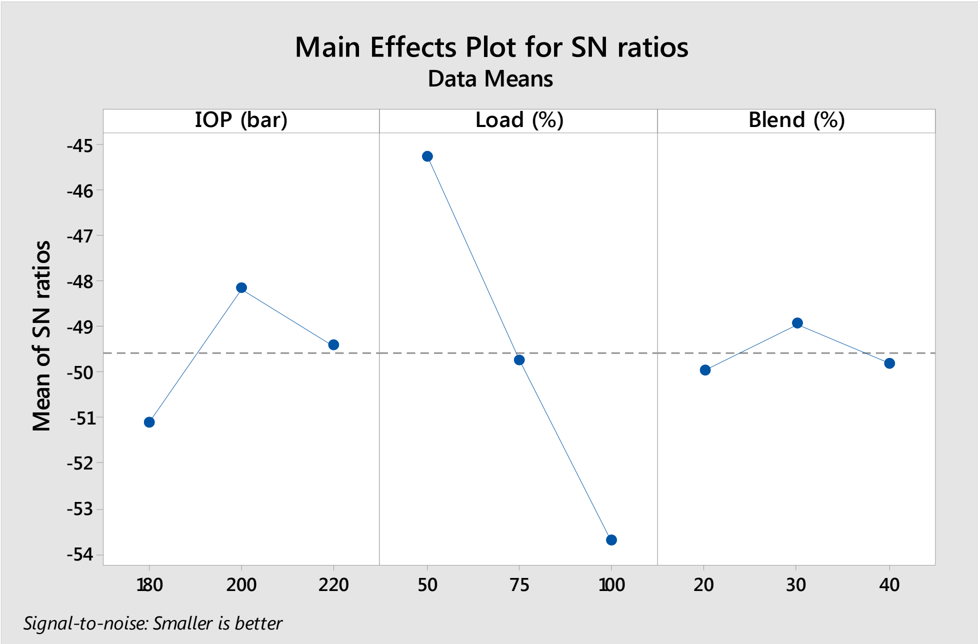

Figure 3. *Main Effect Plot for SN ratios for the effect of Each Parameter at different levels.*

From the Figure 3 and Table 8, Delta is the difference between the maximum value and minimum value. Rank denotes the maximum and minimum effect of the parameters. It shows that the effect of load is more, whereas the effect of blend is less compared IOP on NOx.

Figure 4 shows Main effect plot for Means for the effect of Each Parameter at different levels Table 9 shows Response Table for Means.

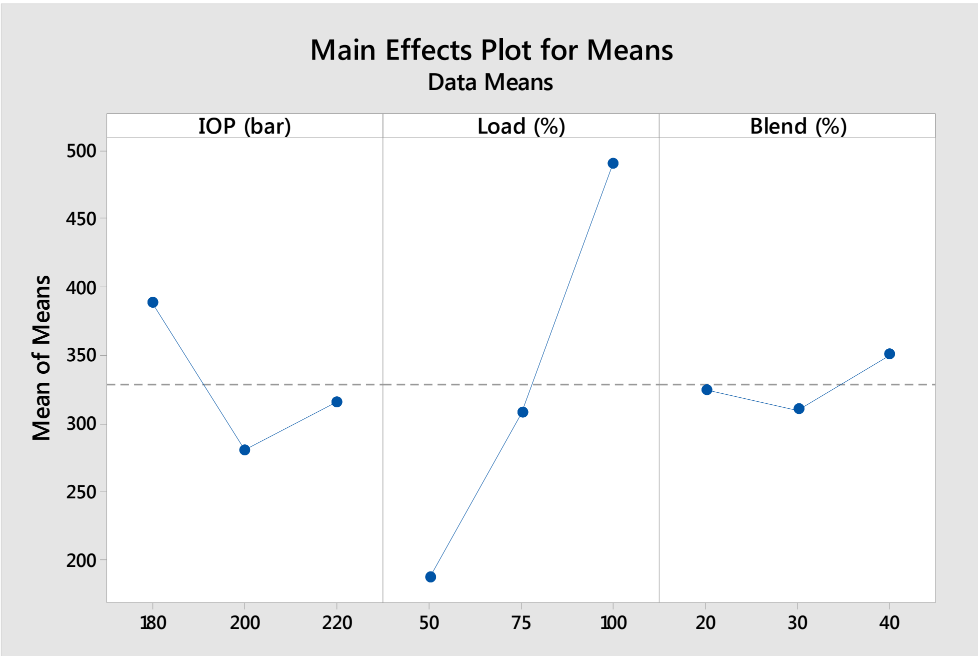

Figure 4. *Main Effect Plot for Means for the effect of Each Parameter at different levels.*

Table 9. *Response Table for Means.*

Level	IOP (bar)	Load (%)	Blend (%)
1	388.3	186.3	324.3
2	280.7	307.7	310.0
3	316.0	491.0	350.7
Delta	107.7	304.7	40.7
Rank	2	1	3

The above Figure 4 shows that S/N ratio is maximum 388.3, 491.0 and 350.7 for 200 bar IOP, 100% load and 20% biodiesel blend respectively. And S/N ratio is minimum 280.7, 186.3 and 310.0 for 220 bar IOP, 50% load and 40% blend respectively. The Regression Equation for NOx (ppm) is = 194 - 1.81IOP (bar) + 6.093 Load (%) + 1.32 Blend (%).

4. Conclusions

This study selected the optimum parameter for high percentage by varying parameters through Taguchi method. The Taguchi method was an accurate and one of the efficient methods of determining the optimum parameters for BTE and NOx of UTOME with an orthogonal array (L9) a total set nine experiments having three parameters each at three levels indicated. The contribution of each noise parameter estimated with the help of ANOVA. It shows that the effect of load is more, whereas the effect of IOP is less on BTE. The NOx emission can be reduced to its lowest level when the test engine runs at 50% load condition with 200 bar IOP, when fueled with Blend 30% of UTOME.

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