OPTIMIZATION OF DIESEL ENGINE PERFORMANCE BY PALM OIL BIODIESEL

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ABSTRACT

Biodiesel was produced from edible and non-edible. Palm is the primary source of usage in India for cooking purposes. Waste cooking palm in a form of Palm Oil Methyl Ester used in various ratios of blends for measuring the engine performance measure parameters on a 4-stroke single-cylinder diesel engine. The present work involves experimental design to experiment. The Taguchi orthogonal array introduced to maximize the experimental data with a minimum combination of experiments. The solicitation of the Taguchi method in blend with grey relational analysis has applied for solving multiple response optimization problems. A grey relational grade, evaluated with grey relational analysis, has been espoused to conceal an optimal parameter amalgamation. Using grey relational class and signal to noise ratio as a performance index, finally performed the parametric optimization by predicting the results and then verified it with confirmatory experiment.

Keywords: 4-stroke single-cylinder diesel engine, Optimization, Palm Oil Methyl Ester, Taguchi Design of Experiments, Grey relational analysis

1. INTRODUCTION

The quest for useful energy and the desire to have a clean and green environment is always of great interest to any researcher. The rapidly declining petroleum reserves have already given the worldwide warning signal for alternative ways to meet rising energy needs. Furthermore, harmful emissions of fossil fuels must also take care of [1]. Biodiesel made from different renewable sources has become a viable alternative for use as a fuel in Compression Ignition (CI) engines. Biodiesel referred to as mono-alkyl esters of long-chain fatty acids. With the help of a chemical process known as transesterification, the biodiesel is produced from vegetable oils and used for compression ignition (CI) engines. The deviation of the percentage concentration of methyl esters in biodiesel from different sources leads to considerable changes in the physical and chemical properties of biodiesel, which in turn affects the characteristics of the engine used. Biodiesel from a choice of feedstocks has been tried by different researchers to learn and analyze the performance, emission, and combustion characteristics of the CI engine. Encouraging results such as the decrease in emissions like hydrocarbon (HC), a decrease in brake power (BP), and finally increase in brake specific fuel consumption (BSFC) has been reported [2]. However, the major obstacle in commercializing biodiesel produced from vegetable oil (PALM OIL) is the cost of its production.

Meanwhile, an enormous quantity of used cooking oil wasted worldwide. Disposal of such oil is again a concern as pollution problems arise when placing such materials in rivers and landfills. It can lead to problems in maintaining environmental balance. The best way to avoid contamination of the waste cooking palm oil used to produce biodiesel and use it in CI engines. Therefore, biodiesel produced from waste frying oil or junk cooking oil is the cheapest alternative to pure diesel in many parts of the world [3]. Waste cooking methyl esters oil from different origins used as fuel for diesel engines to study their effects. Experimented with waste cooking oil from palm oil and with blends of waste oil and pure diesel and analyzed the emission and performance characteristics of a single-cylinder four-stroke water-cooled diesel engine.

Waste cooking oil used as an exciting agent to reduce the overall viscosity and cloud point of the mixture as well as the ester. The purpose of the present work is to investigate the effects of palm oil-based biofuels on the performance and the emission characteristics of a diesel engine fuelled with those fuels. Preheated palm oil, PO/diesel blends, and methyl/ethyl esters of the PO mixture in different proportions used. Performance and emission tests performed at different engine loads and constant engine speed for each type of fuel. The cause that biodiesel is not utilizing usually in the region of the world is due to the high cost of raw materials. To overwhelm this, one can use lower worth oils, for example, waste cooking oils or animal fats that produced in excess in food processing trades. Utilize waste cooking oil can as well help to lighten the problem of waste oil disposal [4].

Much research has conceded out on the production of biodiesel from fresh vegetable and animal oil cradles, but the use of waste cooking oil, such as palm oil, where Malaysia is a leading manufacturer of palm oil, has not been well recognized, although frequently mentioned. The main objectives of the present research are to optimize the conditions for waste baking oil to biodiesel production, identify fatty acid methyl esters produced and classify them based on their viscosity, total acid count, elemental composition, emission rate and engine performance [5].

For biodiesel production, vegetable oil as an essential feedstock. Vegetable oil has collected from the from street shops in Kolkata has used for preparing biodiesel. Alcohol ratio, catalyst concentration, stirring rate, time, and temperatures are affected in transesterification. The process parameters were optimized, and the highest biodiesel capitulate of 94% has been achieved [6].

They were agreed on experimental work to investigate the operating situations that maximize the biodiesel production after waste cooking oil. The conversion of waste cooking oil from the domestic dwelling by transesterification reaction is useful to obtain biodiesel. The tests carried out on waste cooking oil samples coming from domestic dwelling and characterized by an FFA content equal to 3%, have shown that NaOH concentration of 0.5% w/w oil and 100% of methanol surplus represent the best-operating conditions. Indeed they permit to obtain a reaction yield of 94.3% and a biodiesel density of 0.875 g/cm3 [7].

Leisurely the combustion characteristics and emissions of compression ignition diesel engines using biodiesel as an alternative fuel. The experiments are conducted at 4-stroke 1-cylinder diesel engine variable speed 1200-2600 rpm. They collected oil from the Tafila Technical University restaurant and converted it into biodiesel for experimentation. The test had conducted on B5, and the B20 blend without engine modification and observed emission reduced at satisfactory loads. The final results observed that while compared with diesel CO, HC significantly reduce, and NOx raised. Biodiesel has a 5.95 % increasing in brake-specific fuel consumption due to its worse heating rate. However, waste cooking oil blends B20 and B5 gave better performance and emissions. The experimental results illustrate that the fuel consumption rate, brake thermal efficiency, and exhaust gas temperature increased while the BSFC, emission indices of CO2, CO decreased with an increase of engine speed. Also, the engine power increased while increasing the biodiesel percentage; the brake specific power consumption varied from 16.8 to 13.81 MJ / kW kg for the standard diesel while the B20 for the standard diesel was between 16.8 and 13.81 MJ / kW for the B5. Biodiesel CO2, produced in conjunction with the peroxidation process, has the lowest equivalence ratio and emission index of CO [8].

A.M. Liaquat et al. [9] approved the experimental work to analyze engine performance and emissions characteristics for diesel engines using different blend fuels without any engine modification. A total of four fuel samples, such as DF, JB5, JB10, and J5W5 in that order, were used in this study. The test was conducted at full load at a variable speed of 1500 rpm to 2400 rpm to maintain a fully open throttle valve. Whereas, emission tests passed out at 2300 rpm at 100% and 80% throttle position. Finally, the investigators observed that JB5, JB10, and J5W5 show torque reduction of 0.6%, 1.6%, and 1.4% and power reduction 0.7%, 1.7%, and 1.5%, respectively. Average amplify in BSFC compared to DF was observed as 0.54%, 1.0% JB10, and 1.14% for JB5, JB10, and J5W5, respectively. In exhaust gas emission case, when compared with diesel observed average decrement in hydrocarbons for JB5, JB10 and J5W5 at 100% throttle position and 2300 rpm found as 8.9%, 11.3%, and 12.6%, whereas, at 80% throttle position, lessening was 16.3%, 30.3%, and 32% respectively. Near 2300 rpm CO reduced at fully open throttle position for JB5, JB10, and J5W5 found as 17.3%, 25.9%, and 26.99%, where, at 80% throttle position, the reduction observed 20.70%, 33.24%, and 35.57%. Similarly, for JB5, JB10, and J5W5, the CO2 reduction was 12.10%, 20.51%, and 24.91% compared to DF for 2300 rpm and 100% throttle position, while for 80% throttle position, the reductions were 5.98%, 10.38%, and 18.49% respectively. However, some NOx emissions increased for all composite fuels compared to DF. For fear that of noise emission, the sound level for all blend fuels was reduced compared to DF. Finally concluded that the JB5, JB10, and J5W5 blends could use in diesel engines. However, the W5B5 gave some excellent results compared to the JB10. Change in compression ratio ranges 14 to 18 resulted in 18.4%, 27.5%, 18.5%, and 19.8% increase in brake thermal efficiency in the case of B10, B20, B30, and B50, respectively. When the compression ratio increased from 14 to 18, CO2 emissions increased by 14.28%, HC emissions by 52%, CO emissions by 37.5%, and NOx emissions by 36.84%.

The purpose of this work is to determine the optimum mixtures of diesel and palm oil, resulting in improved performance of the engine along with minimum emissions.

Following the Gray-Taguchi approach, the multi-response problem converted into one using the weighting factors of the grey relational analysis. Finally, the validation results were carried out by experimentation results.

Table 1. Levels with parameters.

Design factor	**Levels**				
	1	**2**	**3**	**4**	**5**
Load	0	25	50	75	100
Blend	0	20	40	60	80

2. EXPERIMENTAL SETUP

The experiment beleaguered on a single-cylinder four-stroke diesel engine. A gas analyzer used for the measurement of carbon monoxide (CO), oxides of nitrogen (NOX), unburned hydrocarbon (HC), oxygen O2), and carbon dioxide also. CO measured as percentage volume, and NO, HC measured as n-hexane equivalent, parts per million (ppm). The engine was subjected to different loads (0 kg, 3 kg, 6 kg, 9 kg, and 12 kg), corresponding to load ranging from 0% at the lowest level and 100% at the highest level. The experiments were conducted using B 0 (0% PO, 100% diesel),B20 (20% PO, 80% diesel), B40 (40% PO, 60% diesel), B60 (60% PO, 40% diesel), and B80 (80% PO, 20% diesel) under different load conditions on the engine and the results are noted. Engine speed kept constant 1500 rpm. While at the time of experimentation, whenever the blend has changed, the fuel supply line was clean and left the engine on a no-load condition for a half-hour. By AVL DIG AS 444, five gas analysers used for analysing engine emissions.

Table 2. Specifications of engines and instruments

Manufacturer	Kirloskar Oil Engines Ltd.
BHP	5 HP
Speed	1500 rpm
Number of cylinders	One
Compression ratio	16.5:1
Bore diameter	80 mm
Length of stroke	110 mm

Type of loading	Rope brake
Method of cooling	Water cooling
Method of ignition	Compression ignition
Specifications of the AVL gas analyser	
Manufacturer	AVL India Pvt. Ltd.
Type	DiGas 444
Model	5 gas analyser

Figure 1. Single-cylinder 4-stroke diesel engine.

Table 3. Fuel property table of diesel and biodiesel blends

S.No	Fuel tested	Kinematic viscosity at (cSt)	Flash and fire point(^{o}C)	Specific gravity (gm/m^3)	Calorific value(kJ/kg)
1	B0	3.7	54&63	0.83	41500
2	B20	4.9	59&70	0.84	38237
3	B40	6.2	65&77	0.87	36908

4	B60	6.9	73&89	0.88	35783
5	B80	7.3	89&102	0.89	34863

3. DESIGN OF EXPERIMENT

Taguchi Method of DOE [10]

The Taguchi method helps to design a minimum possible number of experiments. Taguchi method uses a unique design of orthogonal arrays to study the entire restriction space with a small number of trials. For more accurate resulting Signal to Noise (S/N) ratios are was planned for analyzing the performance. Based on the Taguchi design, the L25 orthogonal array has selected for the experiments in MINITAB 17. All of this data used for the analysis and evaluation of a combination of optimal parameters.

Grey Relational Analysis [11]

In this analysis, maintain responses first normalized range 0 to 1. Based on these statistics, grey relation coefficients are premeditated to represent the correlation between the ideal (best) and the actual normalized experimental data. Then the average grey correlation is determined to the selected responses by overall grey relation grade. For calculating the grey relation grade, it depends on the multi-response process and its characteristics.

Normalization

Normalization of the signal to noise ratio performed to prepare raw data for the analysis where the original sequence transformed into a comparable sequence. Generally, a linear generalization is necessary since the range and unit in one data series may differ from the others [12].

If the bull's eye value of the original order is infinite, it has the characteristic of "higher is the better one." The original sequence can be generalized as follows:

$$X_i^* = \frac{X_i^0(k) - minX_i^0(k)}{maxX_i^0(k) - minX_i^0(k)} \longrightarrow (1)$$

When "small is better" is a characteristic of the original sequence, the original sequence should be generalized as follows:

$$X_i^* = \frac{maxX_i^0(k) - X_i^0(k)}{maxX_i^0(k) - minX_i^0(k)} \longrightarrow (2)$$

Though there is having a definite desired value (target value) to attain, the normalizing sequence is in the form of:

$$X_i^* = 1 - \frac{|x_i^0(k) - x^0|}{X_i^0(k) - x^0} \longrightarrow (3)$$

Otherwise, the unique sequence can simply normalize by the elementary method, i.e., let the values of the original sequence divided by the first value of the sequence [13]:

$$X_i^* = \frac{x_i^0(k)}{x_i^0(1)} \longrightarrow (4)$$

Where i = 1 . . . m; k = 1. . . n. m is the number of experimental data items, and n is the number of parameters. $X_i^o(k)$ denotes the original sequence, X_i^* the sequence after the data pre-processing, max X_i^o (k), the largest value of X_i^o (k), min X_i^o (k) the smallest value of X_i^o (k) and X^o is the desired value.

(1) Determination of deviation sequences Δ0i(k):

The deviation categorization, Δ0i(k), is the obvious difference between the reference sequence x0*(k) and the comparability sequence xi*(k) after normalization. It is determined using the equation:

$$\Delta 0_i(k) = |x_0^* - x_i^*(k)| \longrightarrow (5)$$

(2) Calculation of grey relational coefficient (GRC)

GRC for all the sequences expresses the relationship between the ideal (best) and actual normalized S/N ratio. If the two orders approve at all points, then their grey relational coefficient is 1. The grey relational coefficient ξi(k) for the kth performance characteristics in the ith experiment can express as:

$$\xi(k) = \frac{X_i^0(k\Delta \min + \xi \, \Delta\max)}{\Delta 0_i(k) + \xi \, \Delta\max} \longrightarrow (6)$$

Where Δ0i is the aberration sequence of the reference. The value of ζ is the smaller, and the unique ability is the larger. ζ = 0.5 is generally used. Grey relational coefficient for 27 comparability sequences.

(3) Calculation of grey relational grade (GRG) [14]

After the grey relational coefficient is consequent, it is customary to take the average value of the grey relational coefficients as the grey relational grade. The grey relational grade is defined as follows:

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k) \longrightarrow (7)$$

However, in a real manufacturing system, the importance of several factors varies. Through various diseases of ineffective weight, the grey relational grade define as chronic and above. The grey relational grade γi epitomizes the level of correlation between the position sequence and the comparability sequence. If the two sequences are indistinguishable, then the value of grey relational grade is equal to 1. The grey relational grade also qualifies the level of motivation to which the comparison sequence applies rather than the reference sequence. Then, if the comparison sequence is more important than the other comparison sequences for the reference sequence, the grey relational grade for that comparison sequence and the orientation sequence is higher than the other grey relational grades [15].

4. ANALYSIS AND DISCUSSION OF EXPERIMENTAL RESULTS

The grey relational grade γi signifies the near of correlation between the positioning order and the comparability sequence the weighted grey relational grade calculated for each sequence has taken as a response for the further analysis. The large-is-better attribute used to analyze the GRG because the considerable value indicates the improved performance of the process. The number of repetitive tests is one since only one relational grade assimilated in each group for this calculation of S/N. Grey relationship grades have analyzed with Taguchi in the Minitab 17 software.

The corresponding main effect plots are shown on the next page. In the main effect plot, if the line for the parameter is nearly horizontal, the parameter has a less significant effect. On the other hand, the highest tilt parameter for the line has the most significant effect. From the main effect plot, parameter A (load) has the most significant effect among these two parameters [16].

The optimum process parameter combination for minimum emission and improved engine performance is the maximum value for the noise ratio and the grey relational grade for the signal. Thus, from the 2 plots of means, the optimum process parameter combination is found to be A5B2, i.e., load (A) at 100%, blend of fuel (B) at B 20.

In other words, the optimum combination is B 20 (diesel 80% + biodiesel 20%), 100 % engine load, where engine performance is maximum, and the exhaust emission is minimum.

The optimal combination obtained from the S/N ratio Fig.2. is shown in below Table 4.

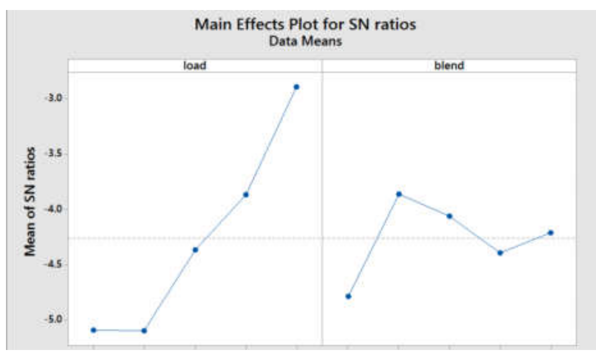

Figure 2. Main effects plot for SN ratio and Grey relational grade for optimum conditions.

Table 4. Optimal combinations of process parameters.

Factor	Load	Blend
Level	100% (12kg)	20%

5. CONCLUSIONS

This work, it appears that biodiesel is going to be a natural choice for our future transportation fuel. The other combination of experience and reasoning is possible to distill some conclusions about biodiesel as an automotive fuel, particularly in a developing country like India. The present work establishes the following facts.

From the above study, the multi-response parameters (engine performance and emission study) are optimized using grey relational analysis and converted into a single response. Then Taguchi's methodology is used to analyze the experimental data. The main effects plot for both mean of average grey grade and signal to noise ratio the optimized combination is found to be A5B2. In that combination, it predicts from the experimental data that the engine performance is comparable to that of diesel. Moreover, the emissions are less than that for diesel. That means from the used blends of biodiesel and diesel, and the B 20 blend found to be the most suitable blend for use in the diesel engine without any engine modification. The corresponding load applied on the engine is 100% load, I .e.12 kg load. The confirmation test is also carried out to verify it and finally observed the improvements of grey relational grade and signal to noise ratios.

Finally, it can conclude that without any engine modifications, biodiesels can use. And from our experimental view, the best blend is the B20 blend, where the engine performance is comparable to that of diesel, and the emissions are less than from diesel.

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