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Performance Evaluation of a Biodiesel Engine Using Optimization Techniques

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ABSTRACT

Biodiesel, a renewable fuel, can be a substitute for fast depletion of fossil fuel as an alternative energy source.This work is aimed at investigating the effects of engine performance of a single cylinder 5 kW diesel engine.Simarouba oil which was extracted from seeds of simaroubatree.simarouba biodiesel obtained by transesterification process is blended with diesel at different percentages has its properties closer to that of diesel.The experiments were designed using a statistical tool known as design of experiments based on Taguchi. Four parameters compression ratio, injection pressure, load, blend proportions were varied at three levels and the responses brake power, specific fuel consumption, brake thermal efficiency. Results of conformation tests showed good agreement with predicted quantities.

KeyWords: *Diesel Engine, Simarouba oil, Transesterification, Biodiesel, Performance*

1. INTRODUCTION

The rapid depletion of petroleum fuels and their ever increasing costs have led to an intensive search for alternative fuels. Many alternative fuels are identified and tested successfully in the existing engine with and without changing engine specifications. The research is still continuing in this field to find the best alternative fuel for the existing petro fuel.

Simaroubaglauca L. commonly known as aceituno paradise tree or bitter wood is a medium sized evergreen tree of height 7-15 m. It grows well up to 1000m above sea level in all types of well drained soils (pH 5.5 to 8) and has been found to be established in places with 250 mm to 2500 mm annual rainfall and temperature going up to 45^0 C. As it withstands dry and semi dried conditions, it can be planted in areas where no other plants of economic value can be grown. In a hectare of land about 200 trees can be accommodated. It produces fruits similar in size, shape and colour to olives. The tree begins to produce fruit at about four years of age, but it comes to full production at six years of age.

Some optimization approach has to be followed so that performance of the engine has to be increased. The most common optimization technique used for engine analysis are Taguchi L9 orthogonal array. In this work involves four parameters such as blend, compression ratio, injection pressure and load at three optimum levels. So an attempt is made to carry out an optimization analysis of direct injection diesel engine run by simarouba biodiesel using a model in combination with Taguchi method.

2. EXPERIMENTAL SETUP

The experimental set up consists of a direct injection single cylinder four stroke cycle diesel engine connected to an eddy current type dynamometer used for loading. It is provided with necessary instruments for pressure and crank-angle dimensions. These signals are interfaced to computer through engine indicator for P-θ and PV diagrams. Provision is also made for interfacing air flow, fuel flow, and temperature and load measurements.

3. METHODOLOGY.

3.1 Materials

Simarouba seeds are purchased from Department of forestry & Environmental science UAS, GKVK and Bangalore. Simarouba biodiesel was prepared through Transesterification process from simarouba oil which was extracted from seeds of simarouba tree. The formation of methyl esters by transesterification of vegetable oil requires raw oil. 15% of methanol and 5% of sodium or potassium hydroxide on mass basis. The reaction mix is kept just above the boiling point of the alcohol (around 60° C) to speed up the reaction and the reaction take place. Suggested reaction time varies from 1 to 8 hours, and some systems suggest the reaction take place at room temperature. Overload alcohol is normally used to ensure total conversion of the fat or oil to its esters.

The glycerin phase is much denser than biodiesel phase and the two can be gravity separated with glycerin simply drawn off the bottom of the settling container. In some cases, a centrifuge is used to separate the two materials faster. Once the glycerin and biodiesel phases have been separated, the overload alcohol in each phase is removed with a flash evaporation process or by refinement. In others systems, the alcohol is removed and the mixture neutralized before the glycerin and esters have been divided. In either case, the alcohol is recovered using distillation equipment and is re-used. Care
Must be taken to make sure no water accumulates in the recovered alcohol stream.

The glycerin by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerin (water and alcohol are removed later, mainly using evaporation, to produce 80-88% pure glycerin). Once separated from the glycerin, the biodiesel is from time to time purified by washing gently with warm water to remove residual catalyst or soaps, dried, and sent to storage space.

3.2 Taguchi Method For Optimization

Taguchi method is a simplest method of optimizing experimental parameters in less number of trails. The number of parameters involved in the experiment determines the number of trails required for the experiment. More number of parameters led to more number of trails and consumes more time to complete the experiment. Hence, a method called 'Taguchi' was tried in the experiment to optimize the levels of the parameter involved in the experiment.

This method uses an orthogonal array to study the entire parameter space with only a small number of experiments. To select an appropriate orthogonal array for the experiments, the total DOF need to be computed. The DOF are defined as the number of comparisons between design parameters that need to be made. The present study uses four factors at three levels and thus, an L9 orthogonal array with four columns and nine rows were used for the construction of experimental layout shown in Table-1. The L9 has four columns and nine rows and the parameters such as blending, compression ratio, injection force, and load

Table 1. L9 orthogonal array design

Experiment	A	B	C	D
1	A1	B1	C1	D1
2	A1	B2	C2	D2
3	A1	B3	C3	D3
4	A2	B1	C2	D3
5	A2	B2	C3	D1
6	A2	B3	C1	D2
7	A3	B1	C3	D2
8	A3	B2	C1	D3
9	A3	B3	C2	D1

4. RESULTS AND DISCUSSIONS

4.1 Selection Of Control Parameters

The following control parameters as given in Table-2.Were selected for the investigation since they have influence on the objectives of improving brake power and BSFC. More parameters are related to the fuel injection and these parameters were found to be suitable for the experiment and could be done with available engine configuration. Three levels were chosen for this investigation.

Table 2. Setting levels for design parameters

Controlled Factors	Level 1	Level 2	Level 3
A: Blend	10	20	30
B: CR	17.5	20	23
C: IP	200	250	300
D: Load	13	19.5	26

This experiment has 4 variables at 3 special settings. A full factorial experiment would require 3^4 = 81 experiments. We tested a Taguchi experiment with a L_9 (3^4) orthogonal array (9 tests, 4 variables, 3 levels). The experiment design is shown in table-2.

Table 3. Experimental Design

Exp.no	Blend	CR	IP	Load	BP	BSFC	BTH%
1	10	17.5	200	13	1.87	0.76	12.53
2	10	20	250	19.5	2.78	0.96	9.93
3	10	23	300	26	3.57	1.13	8.40
4	20	17.5	250	26	3.62	1.27	7.49
5	20	20	300	13	1.86	0.72	13.14
6	20	23	200	19.5	2.75	0.96	9.93
7	30	17.5	300	19.5	2.77	1.06	9.01
8	30	20	200	26	3.77	1.33	7.18
9	30	23	250	13	1.84	0.93	10.24

Nine experiments, following the plan, were performed on the engine and the results were shown in table- 3and the S/N ratio is calculated and shown in table-4

Table .4. S/N Ratios of Emissions

Exps	BP	BSFC	BTH%
1	-27.60	-15.56	-7.95
2	-23.52	-16.90	-8.65
3	-16.90	-18.06	-9.36
4	-31.82	-20.00	-9.18
5	-28.29	-19.08	-7.23
6	-23.52	-15.56	-9.06
7	-25.10	-18.06	-8.53
8	-31.59	-15.56	-11.45
9	-24.08	-15.56	-8.33

4.2 Brake Power

Break Power (Kw): The Fig 1 shows the variations of Brake power from the interaction plot of Brake power. We conclude that the factors like load and blend should be increased, the compression ratio should be medium and injection pressure should be kept minimum in order to increase the brake power.

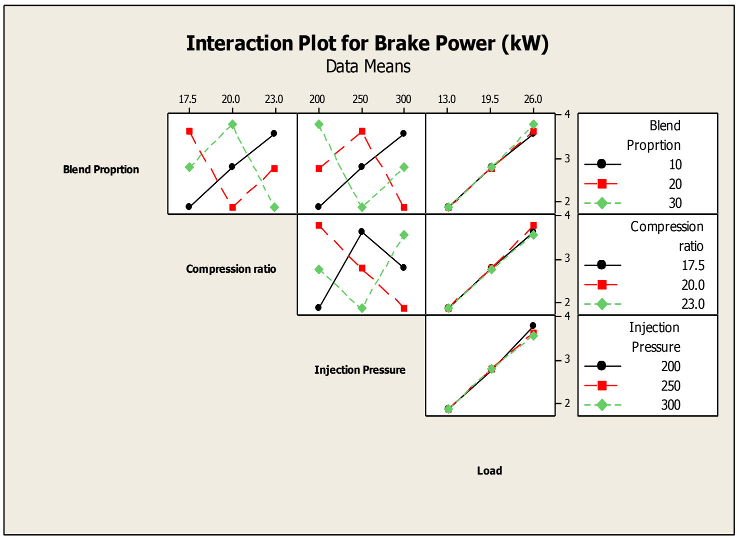

Fig.1 Variations of brake power

4.3 Brake Specification Fuel Consumption

Experimental results were substituted in DOE for optimization to calculate the S/N ratio for Brake Specification Fuel Consumption. For this calculation larger the better characteristic can used. From the value the optimization of engine parameters were obtained: Blend - 30, Compression Ratio – 17.5, Injection Pressure – 250, Load – 26. The figure-2 shows the variation of S/N ratio for Brake Specification Fuel Consumption

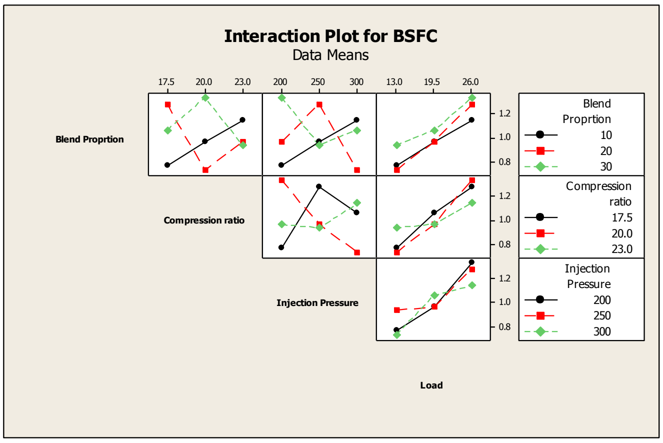

Fig.2 Variations of BSFC

4.4 BREAK THERMAL EFFICINCY

The figure-3 shows the variations of Break thermal efficiency from the interaction plot of brake thermal efficiency, we conclude that the following factors like load should be minimum and blend and compression ratio should be medium and injection pressure should be kept maximum in order to increase the Brake thermal efficiency.

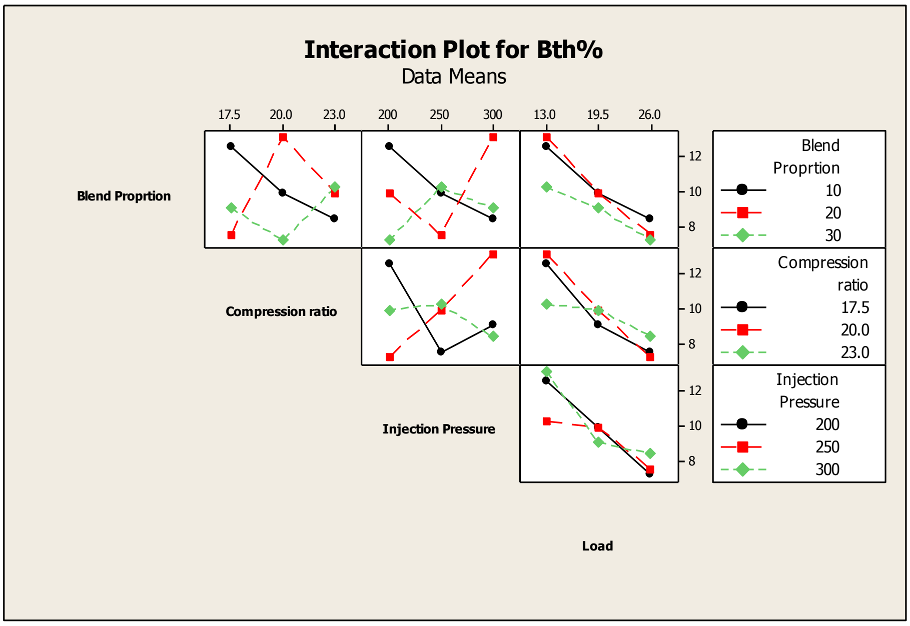

Fig.3. Variations of BTH%

Table .5 Optimum Parameters for each response variable

Factors	BP	BSFC
Blend Proportion	30	30
Compression ratio	20	17.5
Injection Pressure	200	250
Load	26	26

5. CONFIRMATORY TEST

After selecting the optimum levels of the engine, the final step is to verify the results using the optimum design parameter levels. Confirmation test for the combined objective is conducted by choosing four control parameters in multi optimization technique. The confirmation test was conducted are shown in table-6

Table 6. Confirmatory test results

Sl. No	Response Variable	Confirmation Test Values
1	Brake power	3784.57KW
	Brake specific fuel consumption	1.26KW
2	Brake power	3648.43Kg/hr
	Brakespecificfuel consumption	1.32Kg/hr

From these values it can be concluded that

1)From the above table-6 values it can be concluded that the brake power are increased for an optimal combination of Blend-30, Compression ratio -20, Injection pressure-200, load-26.

2) The Brake Specific Fuel Consumption are increased an optimal combination of Blend-30, Compression ratio 17.5, Injection pressure 250, and load-26.

6. CONCLUSION

Based on the experimental investigations conducted on a single cylinder DI diesel engine using simarouba oil mixed diesel fuel. The taguchi's approach analysis has been carried out for optimizing the emissions of simarouba biodiesel engine. The various input parameters have been optimized using signal to noise ratio.

The Larger-the-better quality characteristics have been used to maximize the performance. Based on this study we are conducted that performance of simarouba biodiesel are increased for the following optimal combination are

1) Brake power and Brake Thermal Efficiency increases in load with 30% Blend.

2) Brake specific fuel consumption increases in Load and Injection Pressure with 30% Blend.

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