PERFORMANCE OF SINGLE CYLINDER CI ENGINE USING BLENDS OF RUBBER SEED BIODIESEL - TAGUCHI METHOD

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The objective of the study is to optimize the parameters such as rubber seed biodiesel blend %, injection pressure and applied load of the single cylinder diesel engine with respect to specific fuel consumption and brake thermal efficiency through the Taguchi and ANOVA techniques. The optimum values of the parameters were found using Signal - Noise ratio. Analysis of variance (ANOVA) was used to investigate the influence of parameters on the response. It was found that the applied load was the most dominant factor influencing the specific fuel consumption and brake thermal efficiency followed by injection pressure and biodiesel blend.

Keywords: biodiesel blend, injection pressure, applied load, Taguchi, Anova

1. Introduction

In the last few years, research work efforts have been made by several researchers in investigating the possibility of using alternate bio fuels instead of diesel. Among the vegetable oils and animal fats, vegetable oils seems to be promising alternative fuel because it has several advantages such as renewable, environmental friendly and can be produced easily in rural areas. Use of vegetable oils as diesel fuels is being promoted in many countries due to rapid decline in crude oil reserves.

Depending upon climate and soil conditions, different countries are looking in to different vegetable oils. Therefore in recent years systematic efforts have been made by several researchers [1-3] to use vegetable oils as an alternate fuel in engines. Puhan et al [4] investigated the effect of fuel injection pressures (200,220 and 240 bar) on a constant speed, diesel engine using Linseed oil as fuel and found that 240 bar injection pressure improved the engine performance considerably. Ganapathy et al [5] reported that compression ratio was the most significant parameter in the performance of Jatropha biodiesel engine. Banapurmath et al. [6] investigated the performance and emission characteristics of a diesel engine operating with different bio fuels.

Saravanan et al [7] investigated the combustion characteristics of a stationary diesel engine fuelled with a blend of crude rice bran oil methyl ester and diesel. Agarwal and Das [8] tested linseed-oil biodiesel blended with high sulfur diesel fuel in a single cylinder compression ignition engine and reported that thermal efficiency of the engine increased particularly at low loads.

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Altiparmak et al [9] tested the tall oil methyl ester–diesel fuel blends in a diesel engines and observed that both the engine torque and power output increased about 6%.

Hifjur Raheman et al [10] evaluated the single-cylinder water-cooled direct-injection diesel engine using blends of biodiesel (B10 and B20) obtained from a mixture of mahua and simarouba oils. They reported that blend B10 was found to be superior based on performance and emissions. Mohanraj and Murugu Mohankumar [11] conducted an experiment to obtain the operating characteristics of the variable compression ratio engine run by tamanu oil. They found that the engine performance is improved with significant reduction in emissions without any engine modification.

Gumus and Kasifoglu [12] studied the performance and emissions of a diesel engine using apricot seed kernel oil methyl ester and its blends. They reported that a lower concentration of apricot seed kernel oil methyl ester in blends provides better engine performance and exhaust emissions. Celikten et al. [13] studied the performance and emissions of diesel fuel engine using rapeseed and soybean oil methyl esters injected at different pressures (250, 300, and 350 bar) and they found that the torque and power of diesel engine were reduced with increasing injection pressure. Panwar et al. [14] conducted an experiment in single-cylinder variable compression ratio diesel engine to investigate the engine performance using castor methyl ester at different loads. They reported that the lower blends of biodiesel increased brake thermal efficiency and reduced fuel consumption. Semin et al. [15] investigated the effect of fuel injection pressure on power performance and fuel consumption of diesel engine. They reported that engine performance increased with increasing the injection pressure. Jindal et al. [16] studied the performance and emission characteristics for different compression ratios along with injection pressure, and the best possible combination for operating engine with Jatropha methyl ester. They reported that the combined increase in compression ratio and injection pressure results in an increased brake thermal efficiency and reduced brake specific fuel consumption. Celik and Simsek [17] conducted an experiment to determine the optimum injection pressure in an engine fuelled with soybean biodiesel/diesel blend .They reported that higher injection pressure decreases the specific fuel consumption and increases the power at all loads.

The rubber seed oil, a non-edible type vegetable oil is a potential alternative for producing bio-diesel. The annual rubber seed production potential in India is about 150 kg per hectare. Rubber seed kernels (50-60 % of seed) contain 40-50% of brown colored oil. At present rubber seed oil does not find any major application. The characteristics of the vegetable oils fall within a fairly narrow band and are quite close to those of the diesel oil. Hence it can be used as bio-fuel in compression ignition engines.

Jaichandar and Annamalai [18] reviewed the usage of bio diesel in diesel engines and reported that the high viscosity and the low volatility of bio diesel affects the atomization and spray pattern of fuel which caused incomplete combustion, severe carbon deposits and injector choking. Transesterification process was done to reduce the viscosity and fatty acid (FFA) content of rubber seed oil and make it suitable for compression ignition engines. This present work aims to investigate the an experimental study to determine the optimum percentage of rubber seed biodiesel blend, injection pressure and applied load of a single cylinder diesel engine using Taguchi and ANOVA methods in achieving the desired performance indicators such as specific fuel consumption and brake thermal efficiency.

2. Experimental set up and testing procedure

The study was carried out on a direct injection single cylinder four stroke 18 HP diesel engine (Bore: 99mm, Stroke: 98mm, CC: 900cc, compression ratio 18:1). The rated rpm of the engine is 2000 rpm. The diesel engine is connected to a 3 phase 15 KVa. The experimental set up is shown in Figure 1. The properties of rubber seed oil are dynamic viscosity 6.82Cp @ 30 ^{o}C, Flash point 72^{o}C, Density 0.86 g / cc, Calorific Value 36500kJ/kg, Pour point 12^{o}C, Cetane number 45.

Fig.1 Experimental set up

Taguchi's method can be used to find the optimum parameters which have an effect on the performance measure. Orthogonal arrays can be employed to examine the affect of the factors on the mean and variance of a process performance characteristic. The selection of orthogonal arrays depends on the number of control factors and the levels of variation for each factor.

A Taguchi L9 orthogonal array was selected for this study as it can control three factors, each at three levels. In the present investigation, 9 tests were carried out according to the L9 array. The chosen factors are listed in Table 1 along with their codes and levels. Each test was repeated thrice in order to minimize the experimental uncertainties and mean value was considered.

In this study, “smaller is better” S/N ratio is used to predict the optimum parameters because lower specific fuel consumption was desirable. On the other hand “Larger is better” S/N ratio is used to predict the optimum parameters because higher brake thermal efficiency was desirable. In addition, the experimental results were analyzed using analysis of variance (ANOVA) to study the influence of the factors on the performance.

Table 1.

Factors and levels

Level	Fuel (A)	Injection Pressure (MPa) (B)	Load (%) (C)
I	Diesel (1)	180	20
II	B20 (2)	200	60
III	B50 (3)	220	100

Table 2.

Measured values and S/N ratios

Exp .No	Fuel (A)	Injection Pressure (MPa) (B)	Load (%) C)	SFC (Kg/ kw.h)	BTE %	S/N ratios	
						SFC	BTE
1	Diesel (1)	180	20	0.530	13.85	5.5145	22.8290
2	Diesel (1)	200	60	0.241	31.00	12.359	29.8272
3	Diesel (1)	220	100	0.350	22.00	9.1186	26.8485
4	B20 (2)	180	60	0.310	27.16	10.172	28.6786
5	B20 (2)	200	100	0.287	30.36	10.842	29.6460
6	B20 (2)	220	20	0.405	21.06	7.8509	26.4692
7	B50 (3)	180	100	0.470	18.55	6.5580	25.3669
8	B50 (3)	200	20	0.423	20.96	7.4732	26.4278
9	B50 (3)	220	60	0.271	28.10	11.340	28.9741

SFC (Specific Fuel Consumption); BTE (Brake Thermal Efficiency)

Table 3.

ANOVA analysis

Factors	DoF	Specific Fuel Consumption			Brake thermal efficiency		
		F	P value	Pc%	F	P value	Pc%
Fuel(A)	2	22.26	0.043	6.12	32.61	0.030	10.64
Injection Pressure (B)	2	113.36	0.009	31.14	98.04	0.010	31.99
Load (%) (C)	2	227.36	0.004	62.46	174.78	0.006	57.03
Error	2	-	-	0.274	-	-	0.326

DoF- Degrees of Freedom; Pc %-Percentage of contribution

3. Results of S/N ratio

S/N ratios which are expressed in a decibel scale, computed from the quadratic (quality) loss function. The S/N ratios are calculated for each experiment. Measured values and S/N ratios are presented in Table.2. The term 'signal' indicates the mean value and the term 'noise' indicates the variance value (undesirable) for the output response of the process. This technique is used to identify the controllable factors that reduce the effect of the uncontrollable (noise) factors on the response. The chosen factors with the highest S/N ratio would give the optimum quality with the least variance. Ranking of parameters using signal to noise ratios was obtained and the load was the dominant parameter followed by injection pressure and fuel blend. From the response diagram of S/N ratio (Fig.2 and Fig.3), it was found that the optimum parameters were load (60%), injection pressure (200 MPa) and fuel (B20%) for the both specific fuel consumption and thermal efficiency of the engine.

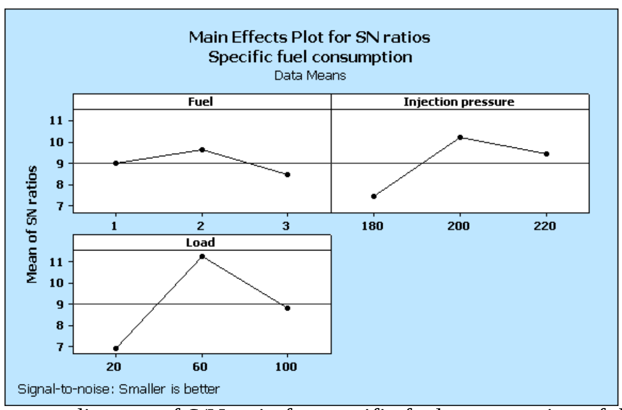

Fig.2 Response diagram of S/N ratio for specific fuel consumption of the engine

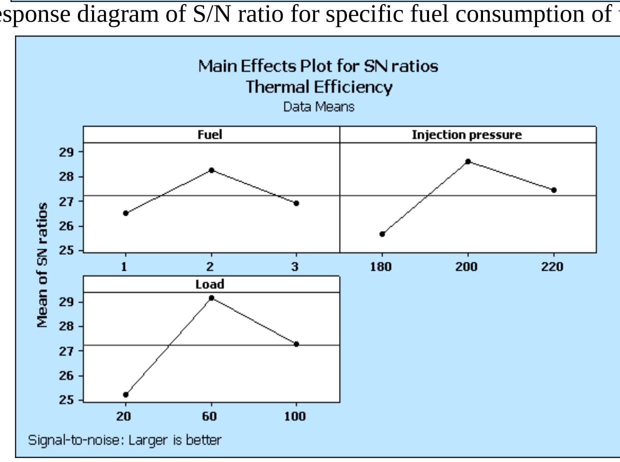

Fig 3 Response diagram of S/N ratio for brake thermal efficiency of the engine

4. Results of Anova

ANOVA which is a statistical technique can be employed to identify the significant parameters and to find the percentage contribution of parameters on the performance characteristic. ANOVA was performed by employing MINITAB16 software for a level of significance of 5% to study the contribution of the parameters. In the ANOVA analysis Table 3, there is a P-value which is computed from the F ratio for each independent parameter in the model. If P-value is less than 0.05, the parameter can be considered as statistically highly significant. Since P- value for all the three parameters have less than 0.05, they are highly significant at 95% confidence level for the specific fuel consumption and brake thermal efficiency of the engine.

It can be observed from the Table 3 that the percentage contribution (Pc %) of each variable in the total variation indicating their degree of influence on the specific fuel consumption of the engine. Load (62.46%) was the major contributing factor followed by injection pressure (31.14%) and finally fuel (6.12%) influencing the specific fuel consumption of the engine. A similar trend was observed in thermal efficiency of the engine.

5. Discussion

From the Taguchi results, the minimum specific fuel consumption and higher brake thermal efficiency were observed at a load of 60%. When the load on the engine increases beyond 60%, thermal efficiency tends to decrease and specific fuel consumption tends to increase. It may be due to the availability of oxygen is relatively less while more fuel is injected into the engine cylinder at higher loads.

B20 provides the lower specific fuel consumption and higher brake thermal efficiency than B50 and standard diesel at 60 % load. It can be attributed to the fact that the biodiesel blends have more oxygen content than that of standard diesel and it ensures the complete combustion process. Moreover, the hydrogen flow rate is low for biodiesel compared to diesel, reduces the specific fuel consumption of bio diesel. On the other hand, the specific fuel consumption increased with the addition of biodiesel content beyond 20 %. Since the calorific value of biodiesel is lower than that of diesel, increase in rubber seed oil percentage in the blends, the calorific value of blended fuel decreases resulting in increase of the specific fuel consumption. Thermal efficiency of the engine drops with increase in biodiesel content beyond 20 % due to its high viscosity, lower calorific value and poor atomization.

It can be inferred from the results that the injector pressure of 200 MPa was found to be the optimum pressure. 200 MPa injection pressure improves the atomization of fuel and reduces the physical delay period, resulting in better combustion. This is indicating the fact that higher injection pressure ensures the better mixing of fuel with air. Thus, at the prevailing conditions, an injection pressure of 200 bar yielded lower BSFC and higher brake thermal efficiency. The obtained outcomes are in line with the other research findings [16-17].

On the other hand the brake thermal efficiency at 220MPa injection pressure was observed to be low. It can be attributed to the fact that though the very high injection pressure produces very fine fuel spray, it affects the thermal efficiency due to the lowered momentum and penetration ability of the fuel droplets. Conversely, lower injection pressure (180 MPa) causes the incomplete and improper atomization of the fuel which affects the thermal efficiency considerably. Fuel injection pressure was found to be the one of the important parameters which has about 30% contribution on the performance of a diesel engine.

6. Conclusions

Based on this study, the following conclusions have been summarized.

It was found that the optimum parameters for minimum specific fuel consumption and higher thermal efficiency of the engine were applied load (60%), injection pressure (200MPa) and fuel (B20% blend). It was also observed that the load (62.46%) was the major contributing factor followed by injection pressure (31.14%) and finally fuel (6.12%) in influencing the specific fuel consumption of the engine. Load (57.03%) was the major contributing factor followed by injection pressure (31.99%) and finally fuel (10.64%) in influencing the brake thermal efficiency of the engine. From the above conclusions, the appropriate percentage (20%) of rubber seed oil can be blended with diesel to increase the thermal efficiency and reduce the specific fuel consumption of the engine without any engine modifications.

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