

Optimization of Engine Performance through different piston shapes by Taguchi Method

V.Yalini, TTM.Kannan, D.Vincent H.Wilson



Abstract: The world's energy demand has increased drastically in the past and is likely to increase even more in the upcoming years. The fossil fuels are non-renewable energy, depleted at fast rate and this fact intensifies the need to look for alternative fuels to meet our day to day energy needs in all power sectors. The consumption rate of energy has increased tremendously and it necessitates increased supply of energy in all forms. The conventional energy resources like diesel, petroleum, gas and coal will soon be depleted. Hence there is a dire requirement to generate alternative sources of the fuel. Biodiesel is one of the best alternative and renewable fuel. It is oxygenate, Sulphur free and biodegradable. Oxygen content in biodiesel helps to improve the efficiency of the engine. Combustion chamber in compression ignition engine is one of the most important roles to enhance the fuel – air mixing rate (swirl) in short possible time. The turbulence is guided by the shape of the combustion chamber. The air swirl is created in combustion chamber, when the fuel air mixing rate increases. Hence the time duration of air fuel mixing rate decreases. The overall duration of the combustion process to shorten as swirl has leads to increases mechanical efficiency. In this work, in which biodiesel is prepared by transesterification process and engine performance is optimized by different parameters such as Piston shape, Load and Blend ratio and analyzed by Analysis of Variance.

Keywords: Transesterification, Castor methyl ester oil, Mechanical efficiency, Taguchi, Anova.

I. INTRODUCTION

Castor oil plant (*Ricinus communis*) is cultivated in India in large scale and has a high potential to become an alternative fuel to replace diesel fuel. Although there is a problem of high viscosity in vegetable oils, it can be reduced by heating, esterifying and blending them. If free fatty acid in oil is more than 1% it may lead to soap formation and that in turn may affect the transesterification process. This may be controlled by a few steps. In first step the amount of free fatty acid is reduces below 1% is by using acid catalyzed esterification. Next preheated oil is converted into biodiesel by using base catalyzed transesterification process. This two-step process gives an average yield of 90% [1]. The castor biodiesel is mixed with diesel on the volume basis in different quantities. The blend proportions of pure biodiesel and diesel was used in 25:75 (B25), 35:65 (B35), and 45:55 (B45).

Different blends of fuel were used to run a single cylinder four stroke compression ignition diesel engine. Piston head is one among the foremost advanced elements within the engine and it endures high thermal and mechanical stress throughout its operating cycles. The good combustion could also be influenced by empirical model of the combustion chambers. Piston may damage due to temperature, wear, fatigue etc. It is necessary to analyze the structure of the piston to know whether it gives the better engine performance and lower emissions to the atmosphere [6]. Hence toroidal, reenter and ordinary pistons are used to run a single cylinder four stroke diesel engine with biodiesel. The ideal values of the mechanical efficiency in different piston shapes were observed and to evaluate the performance of single cylinder four stroke diesel engine. The results showed that of different operating characteristics at different piston shapes are analyzed by ANOVA. In the present work the turbulence was induced by modifying the piston crown in combustion chamber, as shown in Fig 1.1 and 1.2.



Fig 1.1 Toroidal piston



Fig 1.2 Reenter piston

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II. METHODOLOGY

In this experimental work, investigation designed by Tauchi design of experiment using L9 orthogonal array. It provided 3 level and 3 factors for optimized effective higher mechanical efficiency derived from biodiesel and analyzed by using ANOVA technique.

2.1 Transesterification of castor oil

The flow diagram of basic transesterification process is shown in Fig 2.1

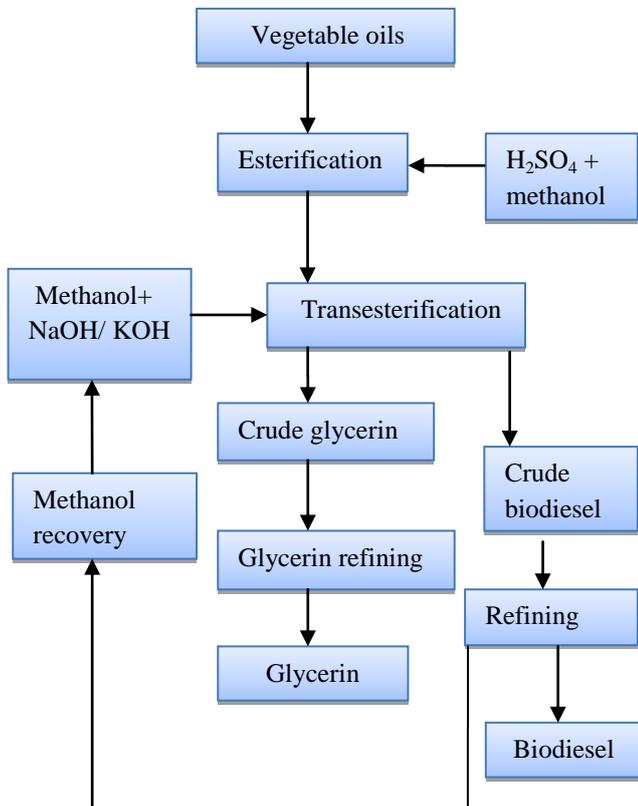


Fig 2.1 Basic transesterification process

The preparation of biodiesel procedure is as follows:

- For safety purpose safety glasses and gloves are worn during the process of making and testing the biodiesel.
- 300 ml of castor oil is poured in to a 1000 ml round bottom flask and concentrated H_2SO_4 acid (3 ml) is poured and heated up to $80^\circ C$ separately.
- 125 ml of methanol was added with 3gms of sodium hydroxide (NaOH) pellets and is mixed together until NaOH pellets dissolve in methanol. This mixture is called as methoxide solution.
- The above heated oil is normally cooled to $60^\circ C$ and it is mixed with methoxide solution in conical flask.
- The conical flask was closed with a cork and was mixed until heated oil and methoxide solution are mixed together.
- The above mixture is poured into the separator funnel and it was allowed to set for 24 hours when the ester and glycerin were separated.
- The upper layer of the separator funnel is ester and the lower layer of the separator funnel is glycerin.

2.2 Experimental set up

Experimental setup of transesterification process as shown in Fig 2.2



Fig.2.2 Experimental setup of transesterification process

2.3 Separation of biodiesel from byproducts

The separation of biodiesel from its by-products is done by washing of methyl ester with distilled water. This process is continued until the glycerin is removed. Filtered biodiesel was stored in a separate container.

2.4 Settling Process

Comparatively, glycerol density is higher than biodiesel density. Hence glycerol is settling down at the bottom of the container after transesterification process. The mixture should be left for 12 hours to make sure all of the glycerol has settled out. The extract glycerol is used for making soap and other cosmetic items. The viscosity difference between the two liquids that the difference in flow from the drain and finally get biodiesel.

2.5 Methanol Recovery

During esterification process the temperature should be maintained at $60^\circ C$. If the temperature reaches above $64.7^\circ C$ the methanol will be evaporated because the boiling point of methanol is $64.7^\circ C$. With the help of condenser the methanol is recovered and it is reused for esterification process. Methanol recovery is important to reduce the manufacturing cost of biodiesel.

2.6 Purification Process

Washing process of raw biodiesel is done carefully. The purpose of the washing process is to remove the remnants of the catalyst and other impurities from biodiesel. Finally get purified biodiesel. Distilled water is used for washing the biodiesel fuel. Washing process is shown in Fig 2.3



Fig.2.3 Washing process

2.7 Preparation of blends

Different ratios of diesel and biodiesel are mixed together to obtain different blends of biodiesel. Different ratios of blends are shown in Fig 2.4 and Table 2.1



Fig 2.4 Different ratio of blends

Table 2.1 Different ratios of blends

Blend	Percentage of Biodiesel (%)	Percentage of Diesel (%)
B25	25	75
B35	35	65
B45	45	55

III. ANALYSIS OF ENGINE PERFORMANCE BY USING TAGUCHI METHOD

Efficiency is the most important parameters in the internal combustion engines in which the other design and operating parameters have to be optimized. Response surface method, gray relational analysis, non-linear regression, genetic algorithm and Taguchi methods are the most common optimization techniques. Taguchi technique has been the best for optimization of parameters in design of experiments [9]. Less number of trial are used in Taguchi method and one of the simple methods of optimizing experimental parameters. The process parameters involved in the experimental work which determines the number of tests required for the experiment [10]. Taguchi Design of Experiment (L_9) has been used which has focused on the optimization of biodiesel production and engine performance parameters and analyzed by Anova.

IV. RESULTS AND DISCUSSIONS

4.1 Analysis of Engine performance using different piston shapes.

This section deals with engine performance of the different blends of biodiesel at various loads. The effects of load on performance like mechanical efficiency at different piston shapes were shown in table 4.1, 4.2 and 4.3.

Table 4.1 Evaluation of mechanical efficiency in Ordinary piston

Load	B25	B35	B45
50	23.0781	22.8763	21.9276
75	26.5378	25.7275	25.6932
100	28.0247	26.1668	22.4468

Table 4.2 Evaluation of mechanical efficiency in Toroidal piston

Load	B25	B35	B45
50	23.5169	22.4888	21.4862
75	27.4501	27.1869	25.3753
100	28.6977	27.0279	25.3111

Table 4.3 Evaluation of mechanical efficiency in Reenter piston

Load	B25	B35	B45
50	23.2248	22.4004	21.3733
75	27.1602	26.5132	24.2804
100	28.1441	26.3955	24.5415

Table 4.4 Layout of L_9 Orthogonal array for different piston shapes

Runs	Shapes	Load	Blend	Mechanical efficiency	SNRA1
1	1	50	25	23.078	27.264
2	1	75	35	25.727	28.054
3	1	100	45	22.447	27.214
4	2	50	35	22.489	27.039
5	2	75	45	25.375	28.082
6	2	100	25	28.697	29.156
7	3	50	45	21.373	26.567
8	3	75	25	27.160	28.678
9	3	100	35	26.396	28.43

Table 4.4 represents mechanical efficiency of different piston shapes using Taguchi L_9 orthogonal array, the optimized parameters of Engine efficiency were found that Second level of piston shape 100 N of load and 25 percentage of blend and produced 28.69 % of efficiency using alternative fuel.

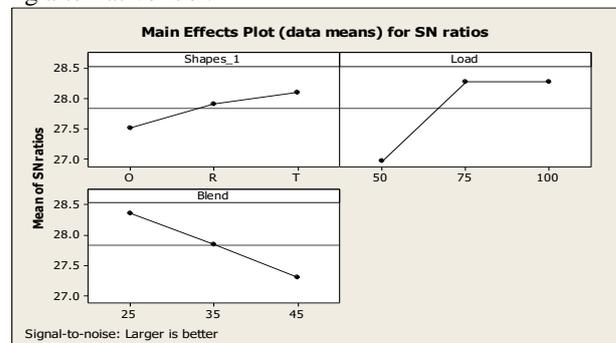


Fig 4.1 Main effect plot for mechanical efficiency of Engine

Figure 4.1 denotes the main effect plot for engine efficiency using different piston shapes with different process parameters of Engine performance. It represents 25 percentage of Blend, 100 N of load and Toroidal piston shape using larger the best concept of signal to noise ratio of process parameters of Alternative fuel.

Table 4.5 Analysis of variance for mechanical efficiency

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Shapes	2	4.8311	4.8311	2.4155	3.37	0.229
Load	2	26.8305	26.8305	13.4153	18.71	0.051
Blend	2	14.2367	14.2367	7.1184	9.93	0.091
Error	2	1.4337	1.4337	0.7169	-	-
Total	8	47.3320	-	-	-	-

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Table 4.5 represents analysis of variance for production of biodiesel using transesterification process and analyzed by signal to noise ratio then compared with significance value of 'F' which denotes load applied is an influencing parameter to achieve higher efficiency in four stroke diesel engine.



Fig 4.2 Contour plot of mechanical efficiency Vs blend and load

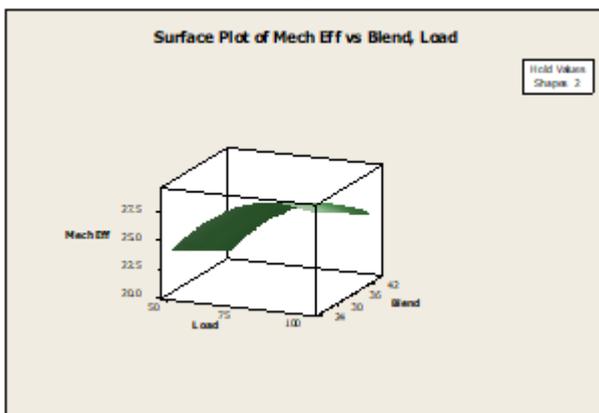


Fig 4.2 Surface plot of mechanical efficiency Vs blend and load

Fig 4.2 represents Contour plot of Process parameters such as piston shapes, load and Blend of Engine and indicate 100 N of load and 25 % of blend achieving higher engine efficiency. Similarly Surface plot mention higher efficiency of alternative fuel achieved by 100 N load of engine performance.

V. CONCLUSIONS

In this work, 25 % the castor methyl ester oil is blend with diesel and achieved maximum engine efficiency. It concludes the following

- Alternative fuel has been produced successfully by transesterification process
- Toroidal piston design give better performance in four stroke diesel engine
- Toroidal piston shape, 100 N of load and 25 % of Blended oil is optimized process parameters of Alternative fuel and Engine performance.
- When blend ratio increases, the efficiency decreases because of its higher viscosity.
- Higher viscosity oil (B35 and B45) has poor atomization due to combustion, because higher viscosity oil blocks the fuel injection lines and fuel injector.

- Main effect plot, Surface plot and Contour plots were represents 100 N of load and 25% of blended oil is optimum level to producing optimum engine performance.
- From Analysis of variance, Higher value (Load 100) of "F" denotes the influencing parameter of achieving better efficiency
- This derived blended biodiesel (B25) helps to increase the efficiency of the diesel engine and comparatively reduce the emissions.

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