THE PERFORMANCE OF BIODIESEL MIXTURES IN A VCR ENGINE

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ABSTRACT

In recent years alternate fuels have received much attention because the world is confronted with the twin crisis of fossil fuel depletion and environmental degradation. The biodiesel produced from Jatropha oil by transesterification process represents one of the most promising options to reduce the use of conventional fossil fuels. The present work studies the performance and emission characteristics of a single cylinder water cooled variable compression ratio engine using jatropha biodiesel and its mixtures as fuel in a direct injection diesel engine. An additive DEE (Di-ethyl ether) is used to enhance the combustion properties of biodiesel. A total of 3 samples of fuels are used such as diesel, BD25 (Jatropha biodiesel 25%), BDM (Biodiesel mixture). The performance and emission characteristics are measured at compression ratios of 16, 17 and 18 by varying the load and maintaining the speed constant at 1500 rpm. From the study results it has been found that better results are obtained at a compression ratio of 18. At this best compression ratio the performance and emission characteristics of biodiesel mixture is compared with BD 25 and Diesel Fuel (DF). It is observed that the use of additive have improved the performance and emission characteristics of biodiesel mixture and can be used as a substitute for diesel.

Key words: Alternate fuel, BD25, Biodiesel mixture, Variable Compression Ratio and DEE


http://www.iaeme.com/IJARET/issues.asp?JType=IJARET&VType=6&IType=8
1. INTRODUCTION
The need for air quality improvements to cater latest pollution norms and the current cost of crude oil demands the use of alternative fuels for automobiles/IC engines. The past and the present day civilization are closely interwoven with energy and future; our existence will be even more dependent upon it. The conventional sources of energy are being depleted at a faster pace and the world is heading towards a global crisis. The greatest task today is exploiting the non-conventional energy resources for power generation.

The transesterification of low quality crude jatropha oil to biodiesel using modified natural zeolite as a solid catalyst can be done and the effects of various factors consist of the reaction time, molar ratio of methanol to oil, reaction temperature, mass ratio of catalyst to oil and catalyst reusability can be investigated[1]. Also Calcined sodium silicate can be used to rapidly catalyze the transesterification of rapeseed and Jatropha oils to biodiesel under microwave irradiation. By using calcinated sodium silicate biodiesel yields of 95.8% and 92.8% were achieved from rapeseed and Jatropha oils, respectively [2]. The performance of a diesel engine operated with Jatropha and Palm biodiesel blends at high idling conditions HC and CO emissions of both blends decreases, however, NOx emissions increases compared to pure diesel fuel [3]. Also when an emulsified fuel containing 10% and 15% water by volume, prepared from a diesel blend with 10% Jatropha biodiesel (JB10) the combustion characteristics of a10.3 kW, single cylinder, 4-stroke, water cooled, direct injection (DI) diesel engine showed considerable improvement [4]. The effect of blending ratio and compression ratio on a diesel engine performance using the different blends (B10, B20, B30, and B50) and normal diesel fuel (B0) shows considerable improvement in performance and emission characteristics. The compression ratio used varies from 16 to 18 [5].

2. EXPERIMENTAL SETUP AND PROCEDURES
In this experimental study the variable compression ratio engine was run with three different fuels; diesel, BD25 ((25 % jatropha biodiesel + 75 % diesel)and BDM (Biodiesel Mixture; DEE 5%, Jatropha biodiesel 25%, 3 ml raw rubber seed oil + 5% rubber seed oil biodiesel) at different compression ratios varying from 16 to 18. The chosen fuel for the study was biodiesel mixture (BDM). From the test the best compression ratio for the chosen fuel was found out. Then the results were compared with the diesel and jatropha biodiesel at that compression ratio.

2.1 Experimental Setup
The study was conducted in the laboratory on an advanced fully computerized experimental engine test rig comprising of a single cylinder, water cooled, four stroke, and VCR (variable compression ratio) diesel engine. “Figure 1” shows a single cylinder, four stroke, VCR diesel engine connected to eddy current type dynamometer for loading. The compression ratio can be changed only after stopping the engine. A locknut arrangement is provided on the top of the cylinder head to change the clearance volume thereby changing the compression ratio. The setup is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for Pθ − PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The set up consists of a standalone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit with sensors and fuel module, transmitters for air and
fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement. ‘K’ type thermocouples are used to measure the corresponding temperatures.

![Experimental setup](image)

**Figure 1** Experimental setup

Engine Performance Analysis software package “Engine Test Express V 5.76” is used for line performance evaluation. The specifications of the engine and dynamometer are given in “Table 1”.

<table>
<thead>
<tr>
<th>Engine specification</th>
<th>Dynamometer Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make</td>
<td>Legion Brothers</td>
</tr>
<tr>
<td>No. of Cylinder</td>
<td>Single</td>
</tr>
<tr>
<td>Cubic Capacity</td>
<td>553 cc</td>
</tr>
<tr>
<td>Cooling</td>
<td>Water</td>
</tr>
<tr>
<td>Fuel</td>
<td>Diesel</td>
</tr>
<tr>
<td>Speed</td>
<td>1400–1500 rpm</td>
</tr>
<tr>
<td>HP</td>
<td>5 HP</td>
</tr>
<tr>
<td>Starting</td>
<td>Crank</td>
</tr>
<tr>
<td>Lubrication</td>
<td>Forced</td>
</tr>
<tr>
<td>Type</td>
<td>Make</td>
</tr>
<tr>
<td>Load Measurement method</td>
<td>Strain Gauge</td>
</tr>
<tr>
<td>Max. Speed</td>
<td>1500 rev/min</td>
</tr>
<tr>
<td>HP</td>
<td>Direct</td>
</tr>
<tr>
<td>Type</td>
<td>Eddy current</td>
</tr>
<tr>
<td>Cooling</td>
<td>Air</td>
</tr>
</tbody>
</table>

The exhaust gases were sampled from exhaust line through a specially designed arrangement for diverting the exhaust to sampling line without increasing the back pressure and was then analysed using a portable gas analyzer (make –AVL digas 444).

The gas analyzer measures carbon monoxide (CO), carbon dioxide (CO₂), hydrocarbons (HC), oxygen (O₂) and nitrogen oxide emissions (NOx).

### 2.2 Fuel Used

All the biodiesel are procured from Southern Biotechnology Pvt Ltd, Chennai. The fuels used in the study are diesel, Jatropha biodiesel, Rubber seed oil biodiesel, Rubber seed oil. In addition an additive DEE (di-ethyl ether) is used to improve the properties of biodiesel. There are three combinations of fuel used in the study; BD0 (Pure diesel), BD25 (25% jatropha biodiesel) & biodiesel mixture BDM (DEE 5%, Jatropha biodiesel 25%, 3 ml raw rubber seed oil + 5% rubber seed oil biodiesel.). “Table 2” shows the various properties of fuel used for the study. In this study main focus is given to BDM (biodiesel mixture).
Table 2 Properties of fuels

<table>
<thead>
<tr>
<th>Properties</th>
<th>Jatropha biodiesel</th>
<th>Biodiesel mixture</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, g/ml</td>
<td>0.865</td>
<td>0.88</td>
<td>0.841</td>
</tr>
<tr>
<td>Viscosity @ 40 °C, cSt</td>
<td>5.2</td>
<td>5.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Calorific Value, MJ/kg</td>
<td>39.2</td>
<td>40.0</td>
<td>42.0</td>
</tr>
<tr>
<td>Flash point, °C</td>
<td>175</td>
<td>160</td>
<td>50</td>
</tr>
<tr>
<td>Cloud point, °C</td>
<td>13</td>
<td>12</td>
<td>9</td>
</tr>
</tbody>
</table>

2.3 Experimental procedures
Initially the engine was started at no load condition for a compression ratio of 16. The experiment was carried out by maintaining the speed constant at 1500 rpm and varying the load. A self governing mechanism was used for adjusting speed. All the performance and emission characteristics of the three fuel proportions were recorded before shifting to next compression ratio. The same procedure was conducted for compression ratios 17 & 18. From the base results it has been found that the better results for BDM (biodiesel mixtures) is obtained for a compression ratio of 18. The final results of BDM were compared with BD 25 & Diesel at CR 18. The performance of the engine at different loads and settings was evaluated in terms of SFC, BTE, volumetric efficiency, mechanical efficiency and emissions of carbon monoxide, carbon dioxide, un-burnt hydrocarbon, oxygen, and nitrogen oxides. The SFC is evaluated by the software on the basis of fuel flow and brake power. Similarly, BTE is also evaluated by software.

3. RESULTS AND DISCUSSIONS
3.1 Performance
3.1.1 Average cylinder pressure
In a compression-ignition engine, the peak cylinder pressure depends on the burned fuel fraction during the premixed burning phase, i.e. the initial stage of combustion. The variations in the cylinder pressure with crank angle for all the blends at different engine operating conditions are shown in “Figure 2”. It is clear that the peak pressure increases as the engine load increases.

Figure 2 Average cylinder pressure Vs Crank Angle (Load = 0 Kg & 9 Kg)
The use of DEE as an additive improved the cetane number of biodiesel and biodiesel mixtures also it is an excellent ignition enhancer and has low ignition temperature thereby reducing the ignition delay.

3.1.2 Brake Thermal Efficiency
The variation of brake thermal efficiency with respect to brake power is shown in “Figure 3”. It can be seen that for all the fuel samples the brake thermal efficiency increases with brake power. It is seen that BTE is higher for biodiesel blends and biodiesel mixtures when compared to diesel. The reasons for this improvement of Brake thermal efficiency is better combustion and better lubricity of biodiesel. The maximum brake thermal efficiency is obtained at a compression ratio of 18, due to the superior combustion and better intermixing of the fuel. Also the use of the additive DEE in biodiesel mixture has improved the calorific value and oxygen content of the fuel which in turn increases the brake thermal efficiency.

3.1.3 Specific fuel consumption
SFC is an important parameter that reflects how good the engine performance is. The variation of SFC with BP for different fuels is shown in “Figure 4”. Generally the SFC decreases with increase in load due to fact that the ratio of increase in brake power is more as compared to increase in fuel consumption. SFC is more for biodiesel mixture and BD 25 due to lower calorific value of the biodiesel. For biodiesel mixture SFC is close to diesel because DEE in the mixture has improved the calorific value of the fuel.
3.1.4 Volumetric Efficiency

The volumetric efficiency of the diesel engine mainly depends upon the combustion chamber temperature. “Figure 5” shows the variation of volumetric efficiency with brake power. It is clear that for jatropha biodiesel blend the volumetric efficiency is very low. The increase in availability of oxygen reduces the air intake. Biodiesel mixture has higher volumetric efficiency when compared to biodiesel blend.

![Figure 5 Volumetric Efficiency Vs BP](image)

3.1.5 Mechanical Efficiency

It has been observed that as the BP increases, mechanical efficiency for all the blends are also increases in a steady rate. Biodiesel mixture has higher mechanical efficiency when compared to BD 25 and diesel. The reason is that the presence of rubber seed oil in the mixture increases the lubricating property of the fuel thereby reducing the frictional power. “Figure 6” shows the variation of mechanical efficiency with brake power.

![Figure 6 Mechanical Efficiency Vs BP](image)

3.2 Emission

3.2.1 CO Emission

CO emissions are mainly due to incomplete combustion of fuel and it is produced most readily from petroleum oils, which contain no oxygen in their molecular structure. “Figure 7” shows the variation of CO emission with brake power. It is seen
that with increase in BP the CO emission is lower for both BD25 and biodiesel mixtures due to complete combustion of fuel taking place because of the availability of extra amount of oxygen. It is seen that the biodiesel mixture has more CO emission when compared to BD25. The reason is that Biodiesel mixture contains 5% rubber seed biodiesel which produces more CO than BD 25%. But when compared with diesel CO emission is much lower for biodiesel mixture due to complete combustion of fuel taking place.

3.2.2 HC Emission
It can be observed that HC emissions decrease with increase in blend proportion at a constant load. “Figure 8” shows the variation of HC emission with brake power. The trend can be attributed to the higher oxygen content of Jatropha biodiesel and biodiesel mixtures due to which complete combustion takes place inside the cylinder.

![Figure 7 CO emission Vs BP](http://www.iaeme.com/IJARET/index.asp)

![Figure 8 HC emission Vs BP](http://www.iaeme.com/IJARET/index.asp)

The HC emission of the jatropha biodiesel (BD25) and biodiesel mixture is less than that of diesel fuel due to higher cetane number and inherent presence of oxygen in the molecular structure of the jatropha biodiesel. The biodiesel mixture has more
CO₂ emission when compared to BD25 due to the presence of rubber seed oil biodiesel in the mixture.

3.2.3 CO₂ Emission
The higher CO₂ emission in the exhaust of internal combustion engine is indication of better combustion of fuel. “Figure 9” shows the variation of CO₂ emission with brake power. It is observed that the CO₂ emission of jatropha biodiesel and biodiesel mixture is higher than that of diesel fuel due to complete combustion of fuel taking place because of the extra availability of oxygen. Biodiesel mixture contains DEE which improves the cetane number of fuel leading to complete combustion.

3.2.5 NOx Emission
The mean high temperature inside the combustion chamber and availability of oxygen are the two factors responsible for NOx emission. “Figure 10” shows the variation of NOx emission with brake power. The jatropha biodiesel produces slightly more NOx than diesel due to increase in oxygen content because biodiesel contain many mono-unsaturated and poly-unsaturated fatty acids. Biodiesel mixture has lower NOx emission when compared to BD 25% and diesel. This is due to the effect of the additive DEE which reduces the mean temperature inside the combustion chamber thereby reducing NOx emission.

4. CONCLUSION
The following conclusions are drawn from the study.
Peak cylinder pressure is lower for biodiesel mixtures at higher and lower loads due to decrease in delay period. The high in-cylinder temperature existing during fuel injection, biodiesel may undergo thermal cracking resulting in lighter compounds leading to shorter ignition delay.

Brake thermal efficiency for biodiesel mixture is higher than diesel and BD 25. The reasons for this improvement of Brake thermal efficiency is better combustion and better lubricity of biodiesel.

SFC is higher for biodiesel mixture and BD25 when compared to diesel due to lower calorific value. But it has seen that SFC for BDM is almost close to diesel when compared to BD25. The reason is that DEE in the mixture plays an important role in increasing the cetane number and calorific value of the fuel.

Volumetric efficiency is found to be lower for biodiesel mixture with DEE which may be due to the effect of higher thermal efficiency leading to increase in the density of air sucked in.

Mechanical efficiency is higher for biodiesel mixture which may be due to increase in lubrication effect of fuel. The rubber seed oil in the mixture enhances the lubricity of the fuel and decreases the frictional power.

CO, HC emission is lower for biodiesel mixture because it contains extra amount of oxygen for complete combustion of fuel.

CO2 emission is higher for biodiesel mixture due to complete combustion of fuel taking place. All the unburned HC and CO are converted to CO2.

NOx emission is slightly lower for biodiesel mixture because DEE in the fuel provides a cooling effect which reduces the mean gas temperature inside the combustion chamber thereby reducing NOx emission.

REFERENCES


