PERFORMANCE ANALYSIS OF CI ENGINE USING BIODIESEL FROM PONGAMIA PINNATA

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ABSTRACT

The seed of Pongamia pinnata which is popularly known as Karanja in Hindi and Indian beech in English is very much available in region of the Assam, North-east India. The seeds of Pongamia pinnata were collected from the Assam Engineering College Campus, Jalukbari, Guwahati, Assam, India. The oil from the dried seed of Pongamia pinnata was extracted and then biodiesel is produced by transesterification method and blends with the petroleum diesel for five samples of B00, B10, B20, B30 and B100. The fuels were test in the single cylinder four stroke compression ignition engine for the purpose of performance analysis. The different properties like Brake power, specific fuel consumption, brake thermal efficiency, heat carried out by water from calorimeter, heat carried away by engine jacket, heat carried out by exhaust gases, heat lost in radiation and uncounted, volumetric efficiency and air consumption were calculated using the collected test data.

Key words: Biodiesel, blends of biodiesel, performance analysis, brake thermal efficiency, volumetric efficiency.

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1. INTRODUCTION

Majority of the world’s energy needs are supplied through petrochemical sources, coal and natural gases, with the exception of hydroelectricity and nuclear energy. The fossil fuel resources are dwindling day by day. However, these energy resources are non-renewable and will be exhausted in the near future. Biodiesel seem to be a solution for future or effective alternative to diesel.

A diesel engine is almost the same as a petrol engine but it burns a different type of fuel. Diesel is named after its inventor Rudolf Diesel, a German who first developed this type of fuel in the early 1900’s. Diesel engines have mainly been used in Lorries and buses because of their increased power and their reliability. They tend to be noisy and smelly compared to a petrol engine but are more economical to run. In a diesel engine the compression stroke only compresses air and not fuel. In the ignition stroke compressed air is present with very high pressure and then fuel is injected into the engine cylinder with the
help of an injector, resulting in generating enormous heat, which then ignites the fuel that is injected into the combustion chamber at that precise moment of maximum pressure. There is no need for a spark plug in a diesel engine. The compressed air is hot enough to cause the fuel to explode. This is because a diesel engine has a far higher “compression ratio” that does a petrol engine.

A literature survey has been done to examine the work done on performance analysis of a compression ignition engine of internal combustion engine. This has been carried out to get an idea on the different method used for the performance analysis of the compression ignition engine. Few of the important works of researchers are discussed below.

Lebedevas S et al research into the change of parameters concerning the fuel economy thrust and harmful components of exhaust gases was carried out to evaluate the efficiency of fuel replacement; and that is, mineral diesel fuel, which is normally used by diesel engine fleets of agricultural machinery in Lithuania, was replaced with biofuel (biodiesel), which is rapeseed oil methyl ester (RME) and the research was done on a model diesel engine F2L511 and a single section of diesel engine A41. Fuel blends of mineral diesel fuel and RME biodiesel fuel and pure RME were tested as B10, B15, B30, B100. A non-linear change of operational characteristics were determined depending on the loads of the diesel engine. Ozkan M did comparative study of the effect of biodiesel and diesel fuel on a four cylinder, four stroke, turbocharged IDI CI engine. The engine was operated with the same settings for both fuel types during the experiments and no alternation has been made in the fuel system elements.

In their study an oxygenated additive diethyl ether (DEE) was blended with biodiesel in the ratio of 5%, 10%, 15% and 20% and tested their performance in a computerized Kirloskar diesel engine of AVI model, four stroke, direct injection, naturally aspirated, water cooled engine. The diesel engine is coupled with an eddy current dynamometer and data acquisition system, for saving data.

Non-edible filtered viscous (72cst at 40°C) and high acid value (44mg KOH/gm) polanga (Calophyllum inophyllum L.) oil based monoesters (biodiesel) produced by triple stage transesterification process and blended with high speed diesel (HSD) (20%, 40%, 60%, 80% and 100%) were tested for their use at varying loads (0%, 20%, 40%, 60%, 80% and 100%) as a substitute fuel of diesel in a single cylinder diesel engine. The brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were calculated from the recorded data. The engine performance parameters such as fuel consumption, thermal efficiency, exhaust gas temperature and exhaust emission were recorded.

High viscosity, poor volatility and heavy chemical structure of vegetable oil are the main constraints to replace diesel fuel. Venkateswara Rao P. investigates the scope of utilizing biodiesel produced with ethanol and methanol as alcohols in the process of making biodiesel. Experiments were conducted on diesel engine with B20 of methyl and ethyl esters of Pongamia oil (POME20, POEE20), methyl and ethyl esters of Mahua oil (MOME20, MOEE20) and standard diesel fuel separately. The performance and emission characteristic results were compared with diesel fuel.

Ghosh S. et al states the Potential use of Pongamia oil methyl ester as a substitute for diesel fuel in diesel engine. Various proportions of Pongamia and Diesel (B25, B50, B75, and B100) are prepared by transesterification process on volume basis and used as fuels in a four stroke single cylinder direct injection diesel engine to study the performance of these fuels and compared with neat diesel fuel.

Experiments have carried out by Krishna A Gopala et al to examine the properties of palm oil biodiesel, performance and emissions of the engine with different blends (20%PBD, 40%PBD, 80%PBD, and 100% PBD) at different fuel injection pressures (190, 210, and 230bar) and the results obtained are compared with diesel (base line test values).

Dwivedi Gaurav et al discussed the comprehensive review of engine performance and emissions using biodiesel from different feedstock and to compare that with the diesel. However, many further researches about modification on engine, low temperature performance of engine, new instrumentation and methodology for measurements, etc., are recommended while using biodiesel as a substitute of diesel.
R. D. Gorle et al investigated the performance and emission characteristics of various blends of Jatropha biodiesel with diesel on a single cylinder four stroke diesel engine. The acquired data were analyzed for various parameters such as brake thermal efficiency (BTE), brake mean effective pressure (BMEP), brake specific fuel consumption (BSFC), exhaust gas temperature (EGT).

Rajesh Kumar et al studied the performance and emissions characteristics of methyl esters of Silk Cotton Oil (SCOME) and diesel blends in a diesel engine. For this study, methyl esters of Silk Cotton Oil were added to diesel by volume of 20% (B20), 40% (B40), 60% (B60) and 80% (B80), as well as a pure blend 100% (B100). Fuels were tested in single cylinder, water-cooled, direct injection Kirloskar diesel engine loaded by eddy current dynamometer. The effect of blends on engine performance, exhaust emissions were examined at different loads (0%, 25%, 50%, 75%, and 100%) at constant engine speed of 1500 rpm. Engine performance parameters namely brake power, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature were determined.

Mamilla Venkata Ramesh et al investigated the percentage substitution of jatropha methyl ester blends to diesel as fuel for automobiles and other industrial purposes. They analyzed the performance characteristics of the jatropha methyl esters and its comparison with petroleum diesel. The tests were carried out on a 3.7 KW single cylinder, direct injection and a water-cooled diesel engine. The fuels used were neat jatropha methyl ester, diesel and different blends of the methyl ester with diesel. The experimental result shows that 20% of the blend shows better performance with reduced pollution. The analysis shows that jatropha methyl ester blended biodiesel is a good substitute for pure diesel.

Mihir J Patel et al said that to meet increasing energy requirements, there have been growing interests in alternative fuels like biodiesel to provide a suitable diesel oil substitute for internal combustion engines. Biodiesels are offered a very promising alternative to diesel oil since they are renewable and have been similar properties. One of the economical sources for biodiesel production which doubles in the reduction of liquid waste and the subsequent burden of sewage treatment is waste cooking oil (WCO).

The biodiesel from jatropha oil is used in a M&M Turbo Charged make four stroke, four cylinders, and water cooled diesel engine in pure and blended form without any modification in engine design or fuel system. The performance characteristics of an engine are studied with different proportions of biodiesel and petro-diesel.

Kumar Sunil et al analyze suitability of petro-diesel blended with biodiesel in varying proportions in CI engines. For this purpose, a stationary single-cylinder four-stroke CI engine was tested with diesel blended with Jatropha biodiesel in 0%, 5%, 20%, 50%, 80% and 100%. Comparative measures of specific fuel consumption (SFC), brake thermal efficiency, smoke opacity, HC, CO₂, CO, O₂, NOₓ have been presented and discussed. Engine performance in terms of comparable brake thermal efficiency and SFC with lower emissions (HC, CO₂, CO) was observed with B20 fuel compared to petro-diesel. Volumetric efficiency showed almost no variation for all the blends. Important observations related to noise and vibrations during testing have also been discussed.

Using the combination of Castor Oil and Ethanol renewable fuel a Performance analysis has been forwarded using STAR-CD. A computational domain of the model geometry has been taken to analyse the combustion characteristics using this blends in diesel. The experimental investigation has been carried out on single cylinder CI Engine (Kirloskar high speed four stroke diesel engine with 4.4 KW,1500rpm.TAF Vertical air cooled engine) and the results has been recorded.

2. PERFORMANCE EVALUATION OF ENGINE

The engine performance tests were conducted with a single cylinder four stroke diesel engine Test Rig set up as shown in figure 1. The test rig arrangement mainly consists of loading arrangement, a fuel input measuring arrangement, air intake measuring arrangement, an arrangement for measuring the heat carried away by cooling water from engine jacket, an arrangement for measuring the heat carried away by cooling water from exhaust gases, a control panel. The specification of the test engine is as given below:
The parameters like fuel consumption, speed of engine, torque and etc. were measured at different loads for diesel and with various combinations of biodiesel from pongamia pinnata with the petroleum diesel. Brake power, brake specific fuel consumption, brake thermal efficiency, heat carried out by water from calorimeter, heat carried away by engine jacket, heat carried out by exhaust gases and air consumption was calculated using the collected test data (table 2).

![Figure 1 Set up of Single Cylinder Four Stroke Diesel Engine Test Rig (With Rope Brake Dynamometer)](image)

### 3. OBSERVATION

Data for water and the other samples of blends and the diesel were given below and in table 1:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Heat of water ( C_p )</td>
<td>4.186 kJ/kg°C</td>
</tr>
<tr>
<td>Density of air ( \rho_a )</td>
<td>1.21 kg/m³</td>
</tr>
<tr>
<td>Density of water ( \rho_w )</td>
<td>1000 kg/m³</td>
</tr>
<tr>
<td>Diameter of the brake drum ( d_B )</td>
<td>0.2 m</td>
</tr>
<tr>
<td>Diameter of the rope ( d_R )</td>
<td>0.012 m</td>
</tr>
<tr>
<td>Diameter of orifice ( d_O )</td>
<td>0.015 m</td>
</tr>
<tr>
<td>Diameter of piston ( D )</td>
<td>0.08 m</td>
</tr>
<tr>
<td>Stroke length of piston ( L )</td>
<td>0.11 m</td>
</tr>
<tr>
<td>Number of cylinder ( N_C )</td>
<td>1</td>
</tr>
<tr>
<td>Number of cycles ( n )</td>
<td>2</td>
</tr>
</tbody>
</table>

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Table 1 Data for different samples (diesel, blends of biodiesel and diesel, biodiesel)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Particulars</th>
<th>Sample 1 B00</th>
<th>Sample 2 B10</th>
<th>Sample 3 B20</th>
<th>Sample 4 B30</th>
<th>Sample 5 B100</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acceleration due to gravity, g (m/sec²)</td>
<td>9.81</td>
<td>9.81</td>
<td>9.81</td>
<td>9.81</td>
<td>9.81</td>
</tr>
<tr>
<td>2</td>
<td>Caloric Value of fuel C_v (kJ/kg)</td>
<td>43500</td>
<td>42738</td>
<td>41956</td>
<td>40995</td>
<td>35879</td>
</tr>
<tr>
<td>3</td>
<td>Co-efficient of discharge for orifice C_d</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
</tr>
<tr>
<td>4</td>
<td>Density of fuelρ_f (kg/m³)</td>
<td>828.9</td>
<td>832.4</td>
<td>836.3</td>
<td>839.3</td>
<td>857.2</td>
</tr>
</tbody>
</table>

4. RELATIONS FOR CALCULATIONS

The different relations for calculating the different performance parameters were given below:

Mean effective radius,

$$R_e = \frac{d_o + 2D_r}{2}$$ (m)

Torque,

$$T = (W_1 - W_2) \times g \times R_e$$ (N-m)

Brake Power,

$$BP = \frac{2\pi \times N \times T}{60 \times 1000}$$ (kW)

Fuel Consumption,

$$W_f = \frac{x \times P_f}{t \times 10^6}$$ (kg/sec)

Specific fuel consumption,

$$W_{sf} = \frac{W_f}{BP}$$ (kg/kW sec)

Heat supplied,

$$H_f = W_f \times C_v$$ (kW)

Brake thermal efficiency,

$$\eta_{BT} = \frac{BP}{H_f} \times 100\%$$

Mass of water entering the engine cooling jacket,

$$m_{ew} = \frac{V_E}{t_E} \times \frac{\rho_w}{10^3}$$ kg/sec

Heat carried out by water from engine cooling jacket,

$$H_{ecw} = m_{ew} \times C_p \times (T_2 - T_1)$$ (kW)

Mass of water entering the calorimeter,

$$m_{cw} = \frac{V_c}{t_c} \times \frac{\rho_w}{10^3}$$ kg/sec

Heat carried out by water from calorimeter,

$$H_{ccw} = m_{cw} \times C_p \times (T_6 - T_5)$$ (kW)

Heat carried out by exhaust gas,

$$H_{exh} = \frac{H_{ccw}}{T_3 - T_4} \times (T_3 - T_a)$$ (kW)

Heat lost in radiation and uncounted heat,

$$H_{un} = H_f - (BP + H_{ecw} + H_{exh})$$ (kW)

Cross sectional area of the orifice,

$$a_o = \frac{\pi d_o^2}{4}$$ (m²)

Head causing flow of air through orifice,
\[
H = \frac{h_1 - h_2}{100} \left( \frac{\rho_w}{\rho_d} - 1 \right) \text{ (m)}
\]

Air consumption,
\[
Q_a = C_d \times a_o \sqrt{(2gH)} \text{ (m}^3/\text{sec)}
\]

Swept Volume,
\[
V_s = \frac{\pi \times D^2 \times L \times N \times N_c}{4 \times 60 \times n} \text{ (m}^3/\text{sec)}
\]

Volumetric efficiency,
\[
\eta_{\text{vol}} = \frac{Q_a}{V_s} \times 100\%
\]

The different performance parameters were calculated at different load and samples and the results were shown in the table 2.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Particulars</th>
<th>Load (Kg)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>1</td>
<td>Brake Power (kW)</td>
<td></td>
<td>B00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>0.814</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>1.535</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>2.231</td>
</tr>
<tr>
<td>2</td>
<td>Fuel Consumption (kg/sec)</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>1.658x10^{-4}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>1.974x10^{-4}</td>
</tr>
<tr>
<td>3</td>
<td>Specific Fuel Consumption (kg/kWsec)</td>
<td>5</td>
<td>1.543x10^{-4}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>1.080x10^{-4}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>0.885x10^{-4}</td>
</tr>
<tr>
<td>4</td>
<td>Heat supplied (kW)</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>7.212</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>8.587</td>
</tr>
<tr>
<td>5</td>
<td>Brake thermal efficiency</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>21.28%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>25.98%</td>
</tr>
<tr>
<td>6</td>
<td>Heat carried out by water from calorimeter (kW)</td>
<td>5</td>
<td>0.427</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.427</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>0.555</td>
</tr>
<tr>
<td>7</td>
<td>Heat carried out by water from engine cooling jacket (kW)</td>
<td>5</td>
<td>3.052</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>3.052</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>1.846</td>
</tr>
<tr>
<td>8</td>
<td>Heat carried out by exhaust gas (kW)</td>
<td>5</td>
<td>0.606</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.636</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>1.089</td>
</tr>
<tr>
<td>9</td>
<td>Heat lost in radiation and uncounted (kW)</td>
<td>5</td>
<td>0.991</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>1.989</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>3.421</td>
</tr>
<tr>
<td>10</td>
<td>Volumetric efficiency</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>84.42%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>85.46%</td>
</tr>
</tbody>
</table>
Performance Analysis of CI Engine Using Biodiesel from Pongamia Pinnata

**Figure 2** Brake power for different sample at different load

![Brake power graph](image1)

**Figure 3** Fuel consumption for different sample at different load

![Fuel consumption graph](image2)

**Figure 4** Specific fuel consumption for different sample at different load

![Specific fuel consumption graph](image3)

**Figure 5** Heat supplied for different sample at different load

![Heat supplied graph](image4)
Figure 6 Brake thermal efficiency for different sample at different load

Figure 7 Heat carried out by water from calorimeter for different sample at different load

Figure 8 Heat carried out by water from engine cooling jacket for different sample at different load

Figure 9 Heat carried out by exhaust gas for different sample at different load
5. RESULT AND DISCUSSION

In a single cylinder four stroke diesel engine made of Kirloskar AK65 was run using different types of sample that is petroleum diesel, blends of diesel and biodiesel, pure biodiesel made from the seed of pongamia pinnata at different loads to analyse the performance of the engine. To determine the performance of the engine, the values of the brake power, specific fuel consumption, heat supplied, brake thermal efficiency, heat lost in radiation and uncounted, volumetric efficiency were calculated (table 2).

Brake power (kW) as shown in the figure 2 it is increases as load of the compression ignition engine increase. The values of brake power are small at the low load and at high load the brake power is higher. The brake power remain almost same for all the sample and from the figure 2 it comes to conclude that we may use the blend of diesel and biodiesel is B20 which is almost highest value among all the samples.

Specific fuel consumption is almost same for all samples to the respective load (figure 4). It is lowest for maximum load that at 15Kg and highest at lowest load (5Kg). The specific fuel consumption is better for the sample B10 and B20. Therefore B10 may be the best for the purpose of the practical application.

Heat supplied of the fuel of different sample from the figure 5 shows that the sample B00 fuel is better than the sample B100 fuel, where as in between these two the sample B20 gives more efficient heat supply of the fuel. With increase in load it is seen that B10 and B20 will remain same fuel heat supply. Therefore the sample B10 fuel is more efficient fuel for the compression ignition engine or any other engine run by the diesel fuel.

Brake thermal efficiency increases with respect to load increases as shown in the figure 6. The B100 or pure biodiesel gives better brake thermal efficiency with comparison to other sample. In between the sample B00 and B100, it is seen that with increase in load, the sample B10 gives good result of brake
thermal efficiency, therefore the B10 sample may be the better sample as compared to the other samples that is B00, B20, B30 and B100.

In reference to the figure 10, it is seen that the heat lost in radiation and uncounted increase with respect to load increases and it becomes slow increases with respect to high increase of load. In figure 10 it is seen that the heat lost decrease for the sample B10 with increase in load, therefore the sample B10 may be better as compared to the other remaining four sample.

The volumetric efficiency of the single cylinder four stroke compression ignition engine using the fuel of petroleum diesel, blends of diesel and biodiesel, pure biodiesel is shown in figure 11. The volumetric efficiency increases with respect to load, at low load the different sample shows the ups and down efficiency and with increase in load it becomes almost equal to all samples of the diesel, blends of diesel and biodiesel, biodiesel as shown in figure 11. With reference to the changes of efficiency the sample B10 gives uniform, therefore it may be useable for the practical purpose.

6. CONCLUSION

With reference to the result and discussion of different properties like brake power, specific fuel consumption, heat supply of the fuel, brake thermal efficiency, heat lost in radiation and uncounted, volumetric efficiency got from running the compression ignition engine using different sample from diesel and biodiesel, it may conclude that the sample B10 is the best among the fuel B00, B10, B20, B30, B100.

REFERENCES

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