OPTIMIZATION OF INJECTION PRESSURE FOR A COMPRESSION IGNITION ENGINE WITH METHYL ESTER OF RICE BRAN OIL AS AN ALTERNATE FUEL

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Abstract. Extracting biodiesel from vegetable oil with additives is attracting increased attention for performance and emission improvement of diesel engines. Higher fuel injection pressure is an effective way to improve the performance and reduce Particulate Matter (PM) emissions. In this present work, the direct use of vegetable oils as fuel in the Compression Ignition engines due to their higher viscosity. The use of vegetable oil in the Compression Ignition engine interferes the fuel injection and atomization and contributes to incomplete combustion, nozzle clogging, excessive engine deposits, ring sticking, producing thick smoke, etc. The problem of higher viscosity of vegetable oils can be reduced by trans-esterification process with modification of injection system. In this investigation, tests were conducted with the use of transesterified rice bran oil called biodiesel in a single cylinder, four stroke, and direct injection diesel engine. To improve the combustion characteristics of direct injection diesel engine using methyl ester of rice bran oil in an unmodified engine, effect of increase in injection pressure was studied. The injection pressure was increased from 180 bar to 220 bar. The investigation revealed that the optimum pressure at 200 bar and comparison of the performance of the engine was studied in terms of brake specific fuel consumption, brake thermal efficiency, and mechanical efficiency(1).


I. INTRODUCTION:

More than 90% of world’s rice production coming from Asian countries. Rice production is first among agricultural commodity of the country. Rice bran is a brown layer present between rice and the outer husk of the paddy. Rice bran oil is an important derivative of rice. Depending on variety of rice and degree of milling, the bran contains 16-32 wt% of oil. About 60-70 wt% of the oil produced from this bran is non edible oil, due to the problems attributed to the stability and storage of the rice bran and the dispersed nature of rice milling. Rice bran oil (RBO) is considered to be one of the most nutritious oils due its favourable fatty acid composition and unique combination of naturally occurring biologically active and antioxidant compounds [2]. RBO has been difficult to refine because of its high content of free fatty acid (FFA), unsaponifiable matter and dark colour [3]. The results obtained show a 49% reduction in smoke, 35% reduction in Hydro Carbon and 37% reduction in Carbon Monoxide emissions for the blends whereas the brake power and Brake Thermal Efficiency are reduced by 2.4% and 3.2% respectively with 4.3% increase in the Specific Fuel Consumption. Therefore it is concluded from the present experimental study that the blend of rice
bran oil biodiesel with the Diesel fuel can successfully be used in Diesel engines as an alternative fuel without any modification.

II. THE BIODIESEL PRODUCTION AND CHARACTERIZATION:

A. Biodiesel Production Procedure

The biodiesel fuel used in this study was produced from the transesterification of raw rice bran oil with methanol (CH$_3$OH) catalyzed by potassium hydroxide (KOH). A titration was performed to determine the amount of KOH needed to neutralize the free fatty acids in raw rice bran oil. A 12 gram of KOH needed as catalyst for every liter of raw rice bran oil. For transesterification, 200 millilitre of CH$_3$OH plus the required amount of KOH were added for every liter of raw rice bran oil, and the reactions were carried out at 55°C for the period of one hour. The water wash process was performed by using a sprinkler which slowly sprinkled water into the biodiesel container until there was an equal amount of water and biodiesel in the container. The water biodiesel mixture was then agitated gently for 20 minutes, allowing the water to settle out of the biodiesel. After the mixture had settled, the water was drained out.

B. Biodiesel Properties

The fuels were characterised by determining their density, viscosity, flash point, fire point and lower calorific value. The important fuel properties of Petroleum Diesel and rice bran Biodiesel and ASTM standard specification for biodiesel[4] are given in Table 1.

It is shown that the viscosity of biodiesel is evidently higher than that of diesel fuel. The density of the biodiesel is slightly higher than that of diesel fuel. The heating value of biodiesel is more than that of diesel fuel. Therefore, it is necessary to increase the fuel amount to be injected into the combustion chamber to produce same amount of power. Fuels with flash point above 52°C are regarded as safe. Thus, biodiesel is an extremely safe fuel to handle compared to diesel fuel. Even 20% biodiesel blend has a flash point much above that of diesel fuel, making biodiesel a preferable choice as far as safety is concerned.

III. EXPERIMENTAL SETUP AND PROCEDURE:

The experimental setup used in the investigation is shown in Figure1. It consist of a single cylinder 4-Stroke, Direct Injection-Compression Ignition engine, an eddy current dynamometer to measure the brake power or load torque, data acquisition system, display panel, computer, pressure and temperature sensors are used. The detailed technical specifications of engine are described in
Table 2. The cooling water flow rate and temperature is maintained constant throughout the test. The engine was tested with rice bran biodiesel, petroleum diesel fuel used as a base line fuel to investigate the effect of injection pressure on performance and combustion characteristics. The engine was allowed to warm up until all temperature reaches steady state in each test. Engine was maintained at constant speed of 1500 rpm with fuel injection pump. To vary the engine load and to measure brake power, an eddy current dynamometer was used.

IV. RESULTS AND DISCUSSIONS:

A. Variation of Brake thermal efficiency with Brake power:

Brake power is the power output of the drive shaft of an engine without the power loss caused by gears, transmission, friction, etc. It's called also pure power, useful power, true power or wheel power as well as other terms. Due to increase in fuel temperature, brake thermal efficiency has increased substantially. It is due to the reduction in the viscosity, improved atomization and better combustion.

Figures 2. shows the variation of brake thermal efficiency with brake power for different injection pressures for the torque ranges from 0-30 N-m and the speed 1000 rpm. Brake thermal efficiency increases as the injection pressure increases from 180 bar to 220 bar, and then slightly decreases as the injection pressure is further increased. Brake thermal efficiency increases with the increase in brake power with the blend of 20% rice bran biodiesel mixed with the conventional diesel fuel.

From the figure, it was observed that the blend of B20 for the injection pressure of 200 bar is found to have the maximum thermal efficiency of 25.55% at a brake power of 7.19 kW while for diesel it was 20.95% at a brake power of 7.185 kw. It was observed that as the proportion of rice bran oil in the blends increases, the brake thermal efficiency decreases. The decrease in brake thermal efficiency with increase in rice bran oil concentration is due to the poor atomization of the blends due to their higher viscosity.

B. Variation of Brake Specific fuel consumption with Brake power:

Figure 3. shows the variation of brake specific fuel consumption with brake power for different injection pressures for the torque ranges from 0-30 N-m for the speed 1000 rpm. It was found that
the brake specific fuel consumption of rice bran biodiesel for the blend of 20% at 200 bar injection pressure is approximately close to diesel fuel. Higher proportions of rice bran biodiesel in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.

The brake specific fuel consumption, in general, is found to increase with the increasing proportion of fuel blends with diesel, where as it decreases with increase in speed for all fuels. The reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads. The higher densities of biodiesel blends cause higher mass injection for the same volume at the same injection pressure.

C. Variation of Mechanical Efficiency with Brake Power:

Figure 4 shows the variation of mechanical efficiency with brake power for the biodiesel blend of 20%, for the speed of 1000 rpm and at the torque ranges from 0 to 30 N-m. Mechanical efficiency increases with increasing injection pressures. The mechanical efficiency with the blend of the fuel is slightly lower than the diesel.

D. Variation of Brake Specific Fuel Consumption with Speed

Figures 5. shows the variation of brake specific fuel consumption with the different speeds of the engine running on the blend of 20% rice bran oil biodiesel.

From the figure, it was observed that the brake specific fuel consumption is based on the torque delivered by the engine in respect to the fuel mass flow. Brake specific fuel consumption is measured after all parasitic engine losses.

Brake specific fuel consumption has been seem to be higher (0.5 kg/kw-hour) for all the speeds and at the torque of 10 N-m. Brake specific fuel consumption decreases with increasing in engine speed and torque.

It was observed that at low speed and torque, heat losses from the combustion chamber walls is proportionately higher and combustion chamber efficiency is poorer, resulting in higher brake fuel consumption for the brake power produced. Brake specific fuel consumption decreases with the increase of the speed and the torque for the 20% blend of rice bran oil biodiesel.
E. Variation of Brake Thermal Efficiency with Speed

From the Figure 6, the following observations were made;

i) for the torque of 10 N-m, variation of brake thermal efficiency is between 16.92% to 18.85% for all the speeds and for all the injection pressures.

ii) for the torque of 20 N-m, brake thermal efficiency is approximately same for all the speeds, and for all the injection pressures.

iii) for the torque of 30 N-m, there is a uniform increase of brake thermal efficiency for all the speeds and for all the injection pressures.

F. Variation of Mechanical Efficiency with Speed:

Figure 7. shows the variation of mechanical efficiency with speed for the torque of 10 N-m, 20 N-m, and 30 N-m respectively. From the figure, following observations were made;

i) for the torque of 10 N-m, mechanical efficiency is 30% which is more or less equal to all the speeds.

ii) for the torque of 20 N-m, mechanical efficiency is 45 - 50% which is remains same for all the speeds.

iii) for the torque of 30 N-m, mechanical efficiency is highest (55%) at the speed of 1000 rpm – 1300 rpm. At the speed of 1400 rpm, mechanical efficiency is decreases to 50%.

V. Conclusions:

1) It is generally accepted that blends of diesel fuel, with up to 20% bio-diesels and vegetable oils, can be used in existing diesel engines without modifications.

2) Due to increase in fuel temperature, brake thermal efficiency has increased substantially. It is due to the reduction in the viscosity, improved atomization and better combustion.

3) Higher proportions of rice bran oil biodiesel in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.

4) i) Brake thermal efficiency substantially increases with the increase in fuel temperature.
ii) Brake thermal efficiency increases with the increase in injection pressure and slightly decreases with the further increase of injection pressure.

iii) Brake thermal efficiency increases with the increase in brake power.

iv) In general, brake specific fuel consumption increases with the increasing proportion of fuel blends with the diesel.

v) Brake specific fuel consumption is based on the torque produced is measured after all parasitic engine losses.

vi) Brake specific fuel consumption is directly proportional to the engine volume; as the engine volume decreases, brake specific fuel consumption is also decreases. This is due to the heat losses from the end gas to the cylinder walls.

Table 1. Properties of fuels

<table>
<thead>
<tr>
<th>I</th>
<th>Properties</th>
<th>Unit</th>
<th>Conventional Diesel fuel</th>
<th>Rice bran Bio-diesel</th>
<th>ASTM Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Density</td>
<td>gm/cc</td>
<td>0.831</td>
<td>0.881</td>
<td>0.88-0.90</td>
</tr>
<tr>
<td>III</td>
<td>Kinematic Viscosity @ 40°C</td>
<td>Cst</td>
<td>2.58</td>
<td>4.77</td>
<td>1.21 – 6.3</td>
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<tr>
<td>IV</td>
<td>Calorific Value</td>
<td>KJ/kg</td>
<td>42500</td>
<td>39798.5</td>
<td>38500</td>
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<tr>
<td>V</td>
<td>Flash Point</td>
<td>°C</td>
<td>50</td>
<td>165</td>
<td>137 min</td>
</tr>
<tr>
<td>VI</td>
<td>Fire Point</td>
<td>°C</td>
<td>56</td>
<td>163</td>
<td>--</td>
</tr>
<tr>
<td>VII</td>
<td>Cetane number</td>
<td>----</td>
<td>48</td>
<td>50</td>
<td>48 - 70</td>
</tr>
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</table>
Table 2. Technical specifications of the Engine

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>Kirloskar Oil Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>Single Cylinder D I Compression Ignition</td>
</tr>
<tr>
<td>Admission of air</td>
<td>Naturally aspirated</td>
</tr>
<tr>
<td>Bore</td>
<td>80 mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>110 mm</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>17:5</td>
</tr>
<tr>
<td>Maximum power</td>
<td>7.4 KW (10 BHP)</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1500 rpm</td>
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<tr>
<td>Dynamometer</td>
<td>Eddy Current Dynamometer</td>
</tr>
<tr>
<td>Method of cooling</td>
<td>Water cooled</td>
</tr>
<tr>
<td>Type of starting</td>
<td>Manual cranking</td>
</tr>
<tr>
<td>Governor</td>
<td>Mechanical governing (Centrifugal type)</td>
</tr>
<tr>
<td>Type of pressure sensor</td>
<td>Piezo-electric type</td>
</tr>
<tr>
<td>Pressure sensor resolution</td>
<td>0.1 bar for cylinder pressure, 1.0 bar inj. Pressure</td>
</tr>
<tr>
<td>Crank angle sensor resolution</td>
<td>1 degree</td>
</tr>
</tbody>
</table>
Figure 1. Schematic Diagram of Experimental Setup

Figure 2. Variation of Brake Thermal Efficiency with Brake power
Fig 3. Variation of Brake Specific Fuel Consumption with Brake power

Fig 4. Variation of Mechanical Efficiency with Brake power
Figure 5. Variation of Brake Specific Fuel Consumption with Speed

Figure 6. Variation of Brake Thermal Efficiency with Speed
Figure 7. Variation of Mechanical Efficiency with Speed

VI. REFERENCES:


