Performance and Emission Characteristics of Methyl Ester Mango Seed Biodiesel on Four Stroke Single Cylinder Diesel Engine with 200 bar Injection Pressure

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Abstract:
Petroleum based fuels worldwide have not only resulted in the rapid depletion of conventional energy sources, but have also caused severe air pollution. The search for an alternate fuel has led to many findings due to which a wide variety of alternative fuels are available at our disposal now. The existing studies have revealed the use of vegetable oils for engines as an alternative for diesel fuel. However, there is a limitation in using straight vegetable oils in diesel engines due to their high viscosity and low volatility. In the present work, neat mango seed oil is converted into their respective methyl ester through transesterification process. Experiments are conducted using various blends of methyl ester of mango seed oil with diesel in a single cylinder, four stroke vertical and air cooled Kirloskar diesel engine. The experimental results of this study showed that the MEMSO biodiesel has similar characteristics to that of diesel. The brake thermal efficiency, unburned hydrocarbon are observed to be lower in case of MEMSO biodiesel blends than diesel. The CO emission for B20, B40 and B60 are observed to be lower than diesel at full load, whereas for B100 it is higher at all loads. On the other hand, BSFC and NOx of MEMSO biodiesel blends are found to be higher than diesel. From this study, it is concluded that optimized blend is B20 and could be used as a viable alternative fuel in a single cylinder direct injection diesel engine without any modifications.

Index Term-- Biodiesel, methyl ester of mango seed oil, performance, emission, combustion.

I. Introduction.
In IC engine, the thermal energy is released by burning the fuel in the engine cylinder. The combustion of fuel in IC engine is quite fast but the time needed to get a proper air/fuel mixture depends mainly on the nature of fuel and the method of its introduction into the combustion chamber. The combustion process in the cylinder should take as little time as possible with the release of maximum heat energy during the period of operation. Longer operation results in the formation of deposits which in combination with other combustion products may cause excessive wear and corrosion of cylinder, piston and piston rings. The combustion product should not be toxic when exhausted to the atmosphere. These requirements can be satisfied using a number of liquid and gaseous fuels. The biodiesel from non edible sources like Jatropha, Mango, Mahua, Neem etc meets the above engine performance requirement and therefore can offer perfect viable alternative to diesel oil in India. The experiment on the diesel engine are performed and found out that it increase the BSFC using various blends of biodiesel from various resources including diesel. The finding indicates that there is increase in the BSFC when using biodiesel as compared to diesel for the same power output. This is because that heating value of Biodiesel is less as compared to diesel [1]. It is found that there is no significant change in the thermal efficiency while using biodiesel up to B20 but there is a slight decrease in thermal efficiency when B100 was used which is due to the lower energy content of biodiesel [2].

Oil has become increasingly important to the world economy due to its employment to energize the transportation industry. As the world population grows exponentially, so does the demand for oil. Since oil wells have depleted in the United States, it has forced the U.S. to import oil making them dependent on other countries to meet the demand. To solve this problem the U.S. has invested in alternative technologies research like Gasoline Hybrid, Full electric, Hydrogen,
Ethanol, and many others. Another study done by the EIA projects the amount of energy consumed worldwide by fuel type. It is expected that world oil price will remain high, the liquid fuels, are the slowest growing source of energy; liquid consumption increases at an average annual rate of 1.2 percent from 2005 to 2030. A trend is notice as the vehicle ownership increases, also does the change in liquid consumption for transportation energy from 2005 to 2030, especially in North America. India was the fourth largest consumer of oil and petroleum products after the United States, China, and Japan in 2013, and it was also the fourth-largest net importer of crude oil and petroleum products. The gap between India’s oil demand and supply is widening, as demand reached nearly 3.7 million barrels per day (bbl/d) in 2013 compared to less than 1 million bbl/d of total liquids production. EIA projects India’s demands will more than doubleton 8.2 million (bbl/d) by 2040, while domestic production will remain relatively flat; hovering.

II. Characteristics of CI engine fuels.

Mango seed oil is native to a number of countries including India, Malaysia, Indonesia, Taiwan, Bangladesh, Sri Lanka and Myanmar. It has also been naturalized in parts of eastern Africa, northern Australia and Florida. Mango seed oil has a varied habitat distribution and can grow in a wide range of conditions. Mango oil, a.k.a. fraction seed oil Mangifera indica. The oil is semi-solid at room temperatures, but melts on contact with skin, making it appealing for baby creams, sunscreen balms, hair products, and other moisturizing products. The oil is a soft yellow color with a melting point of 32-42 °C. A large green tree, valued mainly for its fruits, both green and ripe. It can grow up to 15–30 metres (49–98 ft) tall. The tree grows best in well-drained sandy loam; it does not grow well in heavy wet soils. The optimal pH of the soil should be between 5.2 and 7.5. mango kernel fat, or, mango butter, is an oil obtained during the processing of mango butter. Mango oil is a extracted from the stone of the fruit.

The following are the important factors, which influence the choice of fuel:

- Viscosity of the fuel
- Density
- Calorific value
- Fire point and flash point
- Water and sediment present
- Ash content of fuel
- Boiling range of fuel
- Ignition quality of fuel
- Fuel viscosity of fuel injection
- Storage facilities
- Materials compatibility issues.

The Properties of Diesel fuel and Mango seed biodiesel.

After tranesterification process the fuel properties like kinematic viscosity, calorific value, density, flash and fire point get improved in case of biodiesel. The calorific value of mango seed biodiesel is lower than that of diesel because of oxygen content. The flash and fire point temperature of biodiesel is higher than the pure diesel fuel this is beneficial by safety considerations which can be stored and transported without any risk.

<table>
<thead>
<tr>
<th>Table 1: Fuel properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Properties</td>
</tr>
<tr>
<td>Fuel density in g/L</td>
</tr>
<tr>
<td>Calorific value (kJ/kg)</td>
</tr>
<tr>
<td>Flash point in °C</td>
</tr>
<tr>
<td>Fire point in °C</td>
</tr>
<tr>
<td>Kinematic viscosity at 40 °C in m²/s</td>
</tr>
</tbody>
</table>

III. Experimentation.
Table 2: Engine Specifications

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Parameters</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Manufacturer</td>
<td>Kirloskar oil engines Ltd. India</td>
</tr>
<tr>
<td>02</td>
<td>Model</td>
<td>TV-SR, naturally aspirated</td>
</tr>
<tr>
<td>03</td>
<td>Engine</td>
<td>Single cylinder, DI</td>
</tr>
<tr>
<td>04</td>
<td>Bore/stroke</td>
<td>87.5mm/110mm</td>
</tr>
<tr>
<td>05</td>
<td>C.R.</td>
<td>16.5:1</td>
</tr>
<tr>
<td>06</td>
<td>Speed</td>
<td>1500 RPM, constant</td>
</tr>
<tr>
<td>07</td>
<td>Rated power</td>
<td>5.2KW</td>
</tr>
<tr>
<td>08</td>
<td>Working cycle</td>
<td>Four stroke</td>
</tr>
<tr>
<td>09</td>
<td>Response time</td>
<td>4 micro seconds</td>
</tr>
<tr>
<td>10</td>
<td>Type of sensor</td>
<td>Piezo electric</td>
</tr>
<tr>
<td>11</td>
<td>Crank angle sensor</td>
<td>1-degree crank angle</td>
</tr>
<tr>
<td>12</td>
<td>Injection pressure</td>
<td>200bar/23 def TDC</td>
</tr>
<tr>
<td>13</td>
<td>Resolution of 1 deg</td>
<td>360 deg with a resolution of</td>
</tr>
</tbody>
</table>

IV. Results and discussions

A. Introduction.

This chapter consists of two types of experimental analysis at 200 bar injection pressure, first one is performance characteristics like brake thermal efficiency, specific fuel consumption, exhaust gas temperature, against brake power, second one is emission characteristics like carbon monoxide (CO), unburned hydrocarbon (HC), carbon dioxide (CO2), NOx against brake power.

B. Performance characteristics of diesel, blends of Mango seed biodiesel on diesel engine with 200 bar injection pressure

1. Brake Thermal Efficiency:

The variation of brake thermal efficiency with brake power for diesel and blends of Mango seed biodiesel are shown in fig.3. As the load on the engine increases, brake thermal efficiency increases because brake thermal efficiency is the function of brake power and brake power increases as the load on the engine increases. The maximum value of brake thermal efficiency for biodiesel blend B20 is 28% against 32% for pure diesel. The brake thermal efficiency of all the blends are lower than that of diesel, this is attributed to more amount of fuel consumption for blends as compare to diesel. At full load conditions, the brake thermal efficiency of diesel is more than all blends. Brake thermal efficiency of B20 blend is very close to diesel for entire range of operation.

2. Specific fuel consumption:

The power developed increases the specific fuel consumption decreases for all the tested fuels. The specific fuel consumption of mango seed biodiesel blends are higher than diesel because of lower calorific value and high density of biodiesel. From the graph it is clear that the specific fuel consumption is more for initial loads and further it is almost constant for remaining loads.

3. Exhaust Gas Temperature:
The variation of exhaust gas temperature for different blends with respect to the brake power is indicated in Figure 5. The exhaust gas temperature for all the fuels tested increases with increase in the brake power. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber. At all loads, diesel was found to have the highest temperature and the temperatures for the different blends showed a downward trend with increasing concentration of mango seed biodiesel in the blends.

C. Emission characteristics

1. Carbon monoxide:

2. Hydrocarbon:

3. Carbon Dioxide:

Fig.5: Variation of exhaust gas temperature with brake power.

Fig.6: Variation of carbon monoxide with brake power.

Fig.7: Variation of hydrocarbon with brake power.

Fig.8: Variation of carbon dioxide with brake power.

The variation of carbon dioxide with brake power for diesel and blends of mango seed biodiesel are shown in figure 8. CO₂ emission increased with increase in load for all blends. The lower percentage of blends emits less amount of CO₂ in comparison with diesel at higher loads. Blends B40 emit very low emissions. This is due to the fact that biodiesel in general is a low carbon fuel and has a lower elemental carbon to hydrogen ratio than diesel fuel. In general biodiesels...
themselves are considered carbon neutral because, all the CO2 released during combustion had been sequestered from the atmosphere for the growth of the vegetable oil crops.

4. NOx:

Fig. 9 shows the variation of nitrogen oxides emission with brake power output. Three factors that affect the formation of NOx in the cylinder are oxygen content, combustion flame temperature and reaction time. NOx emissions of biodiesel and its blends are slightly higher than those of diesel fuel. The higher temperature of combustion and the presence of oxygen with biodiesel cause higher NOx emissions, especially at high engine loads. NOx emissions were found to increase due to the presence of extra oxygen in the molecules of biodiesel blends. From the figure, it is clear that at full load, NOx emission for B100 is higher than that of biodiesel blends and diesel, diesel emitting least NOx emissions.

V. Conclusions.

Experimental investigations are carried out on a single cylinder diesel engine to examine the suitability of mango seed biodiesel as an alternative fuel. The performance, emission and combustion characteristics of blends are evaluated and compared with diesel and optimum blend is determined. From the above investigations, the following conclusions are drawn.

• The fuel properties of neat mango seed biodiesel and its blends, density, viscosity, flash point and fire point were found to be higher than that of diesel and calorific value is lower than that of diesel.

• A study of performance of the engine with the Mango seed biodiesel and its blends at higher temperature can be carried out. Higher temperature results in lower viscosity of the fuel; hence an improvement in the performance of the engine can be expected.

• At full load, the emission of CO for B25, B50 and B75 are lower, whereas for B100 it is higher than diesel.

• It is observed that there is a significant reduction of HC for biodiesel and its blends at all engine loads.

• The CO emission of mango seed biodiesel is higher in comparison with diesel. Blends B40 and B20 emit low emission compared to all other blends and diesel at full load..

• The emission of NOx is higher than diesel for biodiesel and its blends.

• The engine performance characteristics with mango seed biodiesel blends such as, brake thermal efficiency is lower than diesel, break specific fuel consumption is higher than diesel, and the exhaust gas temperature is higher for diesel.

The above comparative study clearly reveals the possibility of using mango seed biodiesel in a diesel engine. We observed that the mango seed blend B20 gives optimum performance, combustion and emission characteristics than diesel. Thus, B20 is found to be an optimum blend.

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