Performance and Emission Characteristics of C.I Engine using Jatropha and Pongamia Mixed Biodiesel

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Abstract. In the present study, experiments were conducted on compression ignition engine and the performance and emission characteristics of a diesel engine using jatropha and pongamia mixed biodiesel were observed. The mixed biodiesel was mixed with diesel in different combination of MB25 (25% mixed biodiesel and 75% diesel), MB50 (50% mixed biodiesel and 50% diesel), MB75 (75% mixed biodiesel and 25% diesel), and MB100 (100% mixed biodiesel) and the results were compared with diesel. From the results, it was found that the brake thermal efficiency is increased when increasing diesel amount to mixed biodiesel and it was lower for MB100. The reduction in brake specific fuel consumption has been found for MB25, MB50, MB75 when compared to MB100. The reduction of HC (hydrocarbon), CO (carbon monoxide), smoke emissions, and increase of NOx (nitrogen oxides) for different loads were observed and compared with diesel.

1. Introduction

Owing to the enormous increase in the number of automobiles and the increasing electricity demand has resulted in greater demand for petroleum products. The increasing demand for petroleum products has led to the oil crisis in recent times. Therefore, there is an urge for finding out a replacement and attention has been focused on developing renewable or alternative fuels to replace petroleum based fuels for vehicle usage. Senthil Kumar et al. [1] conducted experiments with jatropha oil and methanol on a dual-fuel engine. He reported that dual fuel engines can use a wide range of fuels and yet operate with low smoke emissions and high thermal efficiency. HC and CO emissions were reported to be higher in the dual fuel mode. Pramanik [2] showed that 50% pure Jatropha curcas oil can be substituted for diesel to use in an IC engine without any major operational difficulties with acceptable BTE and BSEC.

The performance of jatropha oil blends in a diesel engine was investigated by Forson et al. [3]. The test showed that jatropha oil could be conveniently used as a diesel substitute in a diesel engine. The test further showed increases in BTE, brake power, and reduction of BSFC for jatropha oil and its blends with diesel. Biodiesel from Jatropha curcas and Pongamia pinnata were used as fuel in a direct injection diesel engine by Kumar et al. [4] and reported that 20% blend gives comparable performance and less emission. Hebbal et al. [5] carried out experimental investigations on a single-cylinder DI diesel engine to examine the suitability of deccan hemp oil as alternative diesel fuel. The BSFC was reported to be higher and the BTE was lower slightly than that of diesel. From the emission analysis, it was observed that the smoke, CO and HC emissions at full load for neat deccan hemp oil are higher than that of diesel.
The authors also validated the performance of deccan hemp oil, as the results are in good comparison with the results of jatropha and pongamia oils. The experiments were conducted to examine properties, performance, and emission characteristics of different blends (B10, B20, and B40) of pongamia, jatropha and neem in comparison to diesel. They reported that B20 had a closer performance to diesel with less emission of HC, CO and smoke. Venkateswara Rao et al. [6] concluded that the pongamia methyl ester gives an improved performance compared to jatropha and neem methyl esters. It is attempted single cylinder four stroke diesel engine on the performance, combustion, and emission characteristics of different methyl ester of biofuels including thevetia peruviana seed oil, jatropha oil, pongamia oil, mahua oil and neem oil. It is concluded that methyl ester of thevetia peruviana seed oil (METPSO) has comparable engine performance with a lesser amount of emission compared to other blends. Brake thermal efficiency increases with increasing brake power for all fuels. This is due to a decrease in heat loss and raise in power developed with an increase in load. It is observed that with the brake thermal efficiency curves of five blends of biodiesel closely follow that of diesel and the maximum deviation is found to be 9.39% for neem oil at the maximum load. It is only 2% for METPSO. This is due to the higher energy content and lower density of the METPSO blend compared to other bio-diesel blends. The experiment was conducted by Balusamy et al. [7].

Bhupesh Sahu et al. [8] conducted an experiment in CI engine using Jatropha oil and evaluated the performance and emission characteristics of a diesel engine using different blends of methyl ester of Jatropha with mineral diesel. From the results, it is concluded that the decrease in brake thermal efficiency and an increase in brake specific fuel consumption was achieved. There was a reduction of CO, HC, NOx, Smoke opacity, and an increase of CO₂ and NOx emission. Suryawanshi et al. [9] conducted experiments on various blends using pongamia oil methyl ester with diesel on CI engine. There is significant progress in engine performance with a reduction in HC, CO and Smoke emissions. NOx emissions are found to be slightly high. Abed et al. [10] conducted experiments on a single cylinder diesel engine using Jatropha, palm, algae, and waste cooking oils. Emissions are measured and compared with diesel. CO, HC, CO₂ and smoke emissions are lower for biodiesel mixtures B10 and B20 (Jatropha, algae, and palm) compared to diesel fuel. NOx emissions from all biodiesel mixtures B10 and B20 increases than diesel fuel for all biodiesel blend B10 and B20. Arunprasad et al. [11] made an attempt to study the influence of injection pressure (IP) and injection timing (IT) on the performance and emission characteristics of diesel engines by using mixed biodiesel (Thevetia peruviana, Jatropha, Pongamia, and Azadirachta indica). The injection pressure is varied from 200 to 230 bar and the injection timing is varied from 23 to 29° bTDC at an increment of 10 bar and 2° bTDC, respectively, and the results were compared with diesel. From this study, the results showed that the brake thermal efficiency (BTE) was increased by 2.4% with an increase in injection pressure and 1.5% with an increase in the injection timing for the maximum load, but lesser than diesel. Furthermore, a reduction of 5.08% of brake specific fuel consumption (BSFC) has been noticed for the rise in IP and IT with loads but higher than diesel. The reduction was 34.17%, 53.85%, and 29.7% and 29.17%, 53.85%, and 21.95% of hydrocarbons (HC), carbon monoxide (CO), and smoke emissions, respectively, at 230 bar injection pressure and 27° bTDC injection timing. Also, a significant increase in nitrogen oxides (NOx) and carbon dioxide (CO₂) emissions at the maximum load was observed by increasing the injection pressure and injection timing. Arunprasad et al. [12] experimented with neem oil biodiesel blends and diesel value was compared with these results and presented. The result clearly shows that blend B60, compression ratio 18:1, and 6 Kg load was the optimum parameters.
2. Experimental Test Setup

A 3.5 kW, 1500 rpm, Kirloskar diesel engine [13] is used in this investigation as shown in Figure 1. The detailed specification is given in Table 1. Two separate fuel tanks with a fuel switching system are used, one for diesel (D100) and the other for biodiesel (MB100). Fuel consumption is measured using an optical sensor. A differential pressure transducer is used to measure the air flow rate. The engine is coupled with an eddy current dynamometer to control engine torque through a computer. Engine speed and load are controlled by varying excitation current to eddy current dynamometer using a dynamometer controller. A piezoelectric pressure transducer is installed in the engine cylinder head to measure combustion pressure. A high precision crank angle encoder is used to give signals for the top dead center and crank angle. An AVL exhaust gas analyzer and AVL smoke meter are used to measure emission parameters and smoke intensity respectively. Thermocouples (chrommel alumel) are used to measure exhaust temperature, coolant temperature, and inlet air temperature. The properties of fuel are shown in Table 2.

Table 1: Engine Specifications

| Engine Specifications          | Values                      |
|-------------------------------|----------------------------|
| Make                          | Kirloskar –TV1             |
| Power and Speed               | 3.5 kW and 1500 rpm        |
| Type of engine                | Single cylinder, DI and 4 Stroke |
| Compression ratio             | 16.5:1                     |
| Bore and Stroke               | 80 mm and 110 mm           |
| Method of loading             | Eddy current dynamometer   |
| Method of starting            | Manual cranking            |
| Method of cooling             | Water                      |
| Type of ignition              | Compression ignition       |
| Inlet valve opening           | 4.5° before TDC            |
| Inlet valve closing           | 35.5° after BDC            |
| Exhaust valve opening         | 35.5° before BDC           |
| Exhaust valve closing         | 4.5° after TDC             |
| Fuel injection timing         | 23° before TDC             |
| Nozzle opening pressure       | 210 bar                    |
| Lube oil                      | SAE40                      |
### Table 2 Properties of fuel

| Property                  | Diesel  | Mixed Vegetable oil | Mixed Biodiesel (MB100) | ASTM code |
|---------------------------|---------|---------------------|-------------------------|-----------|
| Calorific value, kJ/kg    | 43200   | 39854               | 38720                   | D4809     |
| Specific gravity          | 0.823   | 0.892               | 0.831                   | D445      |
| Kinematic viscosity       | 2.5     | 38                  | 4.16                    | D2217     |
| (at 40°C) cSt             |         |                     |                         |           |
| Cetane number             | 50      | 48                  | 52                      | D4737     |
| Fire point, °C            | 64      | 158                 | 96                      | D92       |
| Cloud point, °C           | -8      | 8                   | 10                      | D97       |
| Pour point, °C            | -20     | 6                   | 9                       | D97       |
| Ash content, %            | 0.001   | 0.003               | 0.003                   | D976      |
| Kinematic viscosity       | 2.5     | 38                  | 4.16                    | D2217     |
| (at 40°C) cSt             |         |                     |                         |           |
| Cetane number             | 50      | 48                  | 52                      | D4737     |
| Flash point, °C           | 56      | 148                 | 88                      | D92       |

### 3. Results and Discussion

#### 3.1 Performance Characteristics

The variation of brake thermal efficiency with brake power for various blends of mixed biodiesel is shown in Figure 2. The BTE increases with all loads for all blends of biodiesel [14]. It is noticed from the graph that B25 has given maximum BTE when compared to other blends and minimum for MB100. The BTE values for MB25, MB50, MB75 and MB100 are 29.2%, 28.0%, 27.8% and 27.6% respectively, whereas 30.2% for diesel at full load. This is due to the lower calorific value and low viscosity of the fuel blends.
Figure 2 BTE Vs Brake Power

The variation of brake specific fuel consumption with brake power for various blends biodiesel is shown in Figure 3. The BSFC of mixed biodiesel is higher than the value when compared to diesel. For all blends, the BSFC decreases with an increase in brake power. At the higher load, the BSFC for MB25 and MB100 is found to be higher by 3.33 % and 13.33 % respectively when compared to diesel. It is noticed that BSFC values for blends such as MB25, MB50, MB75, and MB100 are 0.31 kg/kWh, 0.32 kg/kWh, 0.32 kg/kWh and 0.34 kg/kWh respectively, whereas 0.3 kg/kWh for diesel. This is due to more viscosity and specific gravity and lower heating value of MB25 compared to diesel.

Figure 3 BSFC Vs Brake Power

It is concluded that the exhaust gas temperature increases gradually for various blends of mixed biodiesel as the load increases. It is shown in figure 4. In comparison with diesel, MB100 has the extreme EGT at the higher load. The maximum deviation for MB100 is 17.72 % and MB25 is 6.33 % compared to diesel fuel at the higher load condition. It is due to the mitigation of friction power at higher load conditions.
3.2 Emission Characteristics

The CO emissions for various blends with brake power is shown in figure 5. It is noted from the figure that the CO emissions are decreased with an increase in load. The growth of CO emission is mainly due to the shortfall of oxygen in the fuel-rich mixture during halfway stages of combustion, which leads to incomplete combustion of the fuel. CO emissions are lower for all mixed biodiesel blends for all loads compared to diesel. The maximum variation is for MB100 (33.33%) at higher load and for MB25 it is only 8.33%. This is due to the higher combustion temperature in the engine cylinder accelerates the oxidation rate. The HC emissions for different blends with load is shown in the figure. It is shown in Figure 6. HC emission decreases when the load increases for different blends of mixed biodiesel. In MB100, HC emission is lesser than diesel by 13.48% at higher load and for MB25 the variation is 4.35% when compared to diesel. This is due to the higher content of oxygen which leads to more complete burning than diesel fuel.

The variation of NOx emission with brake power for various blends of mixed biodiesel is shown in figure 7. It is noted that NOx contents are more for all blends of mixed biodiesel than that of diesel. Due to lesser combustion chamber temperature NOx value is lower at low load and increases when the load increases. The NOx emission variation for MB100 and MB25 are 20% and 6.36% respectively when compared to diesel. The NOx emissions for all the blends are noticed as 620 ppm and 625 ppm for MB50 and MB75 respectively while 550 ppm in the case of diesel. It is due to the higher adiabatic flame temperature during combustion and also due to an increase in the local temperature and the concentration of oxygen within the fuel spray envelope.

The variation of smoke emissions with brake power is shown in figure 8. The smoke emissions of mixed biodiesel for all blends are lower than that of diesel. At full load, the smoke emission of MB100 is found to be lesser by 9.75% compared to that of diesel due to oxygen present in the mixed biodiesel and for MB25, the smoke emission is lower by 4.88% when compared to diesel. The various values of smoke emissions recorded for the different blends such as MB50 and MB75 are 7.32%, 8.54%. It is due to the presence of oxygen in the mixed biodiesel and its blends that contributes to improved combustion at maximum load conditions.
Figure 5 CO Vs Brake Power

Figure 6 HC Vs Brake Power

Figure 7 NOx Vs Brake Power
4 Conclusions

Experiments were conducted with different blends of mixed biodiesel in CI engine for various loads and the results as follows

- Mixed of biodiesel MB25 has given higher BSFC than diesel by 3.33 % and lower BTE than that of diesel at maximum load.
- The EGT of mixed biodiesel blends is comparable with diesel. It is found that 6.33% and 17.72 % is higher for MB25 and MB100 than that of diesel.
- The presence of HC, CO in the exhaust gas of MB25 is lower than diesel by 4.35 %, 8.33 % at maximum load.
- NOx content is higher for MB100 by 20 % and MB25 by 6.36 % when compared to diesel.
- The smoke emission is reduced by 9.75 % at full load compared to that of diesel

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