Properties and Use of *Jatropha Curcas* Ethyl Ester and Diesel Fuel Blends in Variable Compression Ignition Engine

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There is an increasing interest in India to search for suitable alternative fuels that are environmental friendly. This paper presents the results of investigations carried out in studying the fuel properties of Jatropha ethyl ester and its blend with diesel fuel from 10%, 20%, 30% and 40% blends by volume and compare performance, emission characteristics of ester blends with base line results of diesel fuel at compression ratio of 17.5:1. The performance parameters evaluated were: brake thermal efficiency, brake specific fuel consumption, mechanical efficiency, and volumetric efficiency and exhaust gas temperature. The emission parameters evaluated were: carbon monoxide and oxides of nitrogen. The brake thermal efficiency of Jatropha ethyl ester blends with diesel were higher than diesel fuel. The maximum brake thermal efficiency and brake specific fuel consumption at 75% of rated load for B40 blend was 9.8% and 4.9% higher than that of diesel fuel respectively. Brake specific fuel consumption was found to be higher for all blends. The exhaust gas temperature increased with increase in load and amount of blended ester in the diesel fuel. Mechanical efficiency for all the blends increased with increase in load. However, CO emission was found to be lower for Jatropha ethyl ester blend. NOx emissions on Jatropha ethyl ester blends were higher than Diesel fuel.

**Keywords:** Diesel engine Jatropha ethyl ester, specific fuel consumption, thermal efficiency, mechanical efficiency

**Introduction**

Alternative fuels for diesel engines are becoming increasingly important due to diminishing petroleum reserves and the environmental consequences of exhaust gases from petroleum fuelled engines. Very few non-edible plant oil types have been tried on diesel engine and this leaves a lot of scope for further investigation in this area. But the high viscosity of oils was a main problem. Therefore, reducing the viscosity of plant oil is of the prime importance to make it suitable for diesel engines. Transesterification (alcoholysis) is the chemical reaction between triglycerides and alcohol in the presence of catalyst to produce mono-esters. That is, conversion of triglycerides to diglycerides, followed by the conversion of diglycerides to monoglycerides. Biodiesel has been used in blends with diesel fuels. A test was conducted with a 3 cylinder, 4 stroke, 2500 cc Direct Ignition diesel engine with olive oil methyl ester and reported constant combustion efficiency for methyl ester of olive oil and diesel. The study also reported a slight reduction in Brake Specific Fuel Consumption (BSFC), reduction of 58.9% in CO, 8.9% in CO₂, 37.5% in NO and 32% in NOₓ for olive oil methyl ester. In a separate study karanja methyl ester and its blends in a single cylinder, four-stroke, direct injection (DI) diesel engine and observed slightly higher torque in case of 20% blending (B20) and 40% blending (B40) while lower torque was observed with 60% blending (B60) to pure biodiesel (B100) when compared to diesel. BSFC was lower for B20 and B40 and found to be higher for blends ranging from B60–B100. The BTEs were also higher for B20 and B40. Much research has been done using methanol alcohol as compared to ethanol alcohol. Methanol is toxic in nature, poisonous and is not derived from renewable sources. Whereas, ethanol is non toxic and can be derived from renewable sources. The use of ethanol in biodiesel production has not been studied as extensively as has methanol. Ethyl ester derived from plant oils by using ethanol has greater engine compatibility, lower nitrous oxide levels, less particulate emissions, better biodegradability and lower toxicity than either diesel or methyl ester fuels. Therefore, producing ethyl esters rather than methyl esters is of considerable interest, because, in addition to the entirely agricultural nature of the

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ethanol, the extra carbon atom brought by the ethanol molecule slightly increases the heat content and the cetane number. Ethyl esters have lower cloud and pour points than the methyl esters. This fact improves the cold start of engine \(^8\). The main objectives of the present work were to produce ethyl ester from non-edible Jatropha curcas oil and to find the fuel properties of the ester and its blends with diesel fuel to evaluate the performance of a 3.73 kW diesel engine using different blends of jatropha ethyl ester oil with diesel as fuel.

**Preparation of Jatropha Ethyl ester**

The oil was procured from Udaipur, Rajasthan, India. The oil was filtered and free fatty acid content was determined by standard titrimetry method. The free fatty acid content was reported to be high (7%). This was not suitable for alkali catalyzed transesterification. Thus, the two step acid base catalyzed transesterification process was carried out to produce ethyl ester. The pretreatment process was carried out to reduce the free fatty acid content by (≤ 2%) acid catalyzed esterification. The optimum reaction conditions for esterification were reported to be 5% H\(_2\)SO\(_4\), 20% ethanol and 1 hr reaction time at temperature of 65°C.

The pretreatment process reduced the free fatty acid of oil from 7% to 1.85%. In second process, alkali catalysed transesterification of pretreated oil was carried. The optimum reaction conditions for transesterification were reported to be 3% KOH (w/v of oil) and 30% (v/v) ethanol: oil ratio and reaction time 2 hrs at 65°C. After production of ester, different blends of diesel and jatropha ethyl ester were premixed on a volume basis. Four Jatropha ethyl ester blends were used: 100 % diesel (B0), 90 % diesel with 10 % Jatropha ethyl ester (B10), 80 % diesel with 20 % Jatropha ethyl ester (B20), 70 % diesel with 30 % Jatropha ethyl ester (B30) and 60 % diesel with 40 % Jatropha ethyl ester (B40).

**Fuel properties**

The properties of diesel fuel, Jatropha ethyl ester and its blend 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 ethyl ester is approximately 5.16% higher than that of diesel fuel. The heating value is approximately 16.62% lower than that of diesel fuel. Fuels with flash point above 52°C are regarded as safe. Thus biodiesel and its blends with high flash point is an extremely safe fuel to handle and storage. Even B10 blend has a 61.7°C flash point much above that of diesel fuel, making biodiesel a preferable choice as far as safety is concerned. The fuel-borne oxygen in biodiesel is 11-12%, which improves combustion processes effectively.

**Experimental set up**

The performance test was conducted in a single cylinder, water cooled, 3.73 kW variable compression ratio engine. For running the engine, the compression ratio of the engine was changed to the desired ratio. Engine was started manually. Loading and unloading was done through computer. Various sensors are mounted on the engine to measure different parameters. The stored data were analyzed using the engine software. Brief specifications of the VCR engine are given in Table 2. A constant level of engine cooling water flow was maintained at > 60 ml/sec by means of a rota-meter with stainless steel float. The standard fuel injection timing for the test engine was 23°C BTDC.

**Evaluation procedure**

The engine was evaluated for performance using different fuel blends (10% to 40% in steps of 10%) at loads of 0 (no load), 25, 50 and 75 % of rated load at a compression ratio of 17.5:1. The substitution of Jatropha ethyl ester with diesel beyond 40 % was not done because it was observed during trial run that at 50% blending of Jatropha ethyl ester the engine performance was not smooth and engine sound was

| Table 1—Comparison of fuel properties of different fuels |
|-----------------|--------|-----------------|-----------------|--------|--------|--------|--------|
| S No. | Fuel properties | Diesel | Crude Jatropha oil | Jatropha Ethyl Ester | Jatropha Ethyl Ester Blends |
|-------|-----------------|--------|-----------------|-----------------|--------|--------|--------|
| 1     | Viscosity at 37°C, cS | 4.38   | 38.33           | 7.33            | 5.16   | 5.66   | 5.83   | 6.00   |
| 2     | Density at 37°C, g/cc | 0.832  | 0.931           | 0.875           | 0.843  | 0.850  | 0.856  | 0.861  |
| 3     | Calorific value, MJ/kg | 42.90  | 32.62           | 35.77           | 41.47  | 40.39  | 39.52  | 39.08  |
| 4     | Cloud Point, °C | 0.5    | 8               | 1.7             | 0.7    | 0.8    | 1.3    | 1.5    |
| 5     | Pour point, °C | -7.8   | 4               | -2.8            | -7.2   | -6.8   | -6.3   | -5.3   |
| 6     | Flash Point, °C | 58.3   | 287.7           | 111.7           | 61.7   | 68.7   | 76.3   | 83.67  |
abnormal. The engine is first run with neat diesel at loading conditions such as no load, 25%, 50% and 75% of rated load. At each loading condition, performance parameters namely, brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, mechanical efficiency, volumetric efficiency and emission characteristics i.e. carbon monoxide (CO) and nitric oxide (NOx) concentration in exhaust gas were measured and recorded. The experiments are repeated thrice for various combinations of diesel and Jatropha biodiesel blends. Brake Specific fuel consumption is defined as the amount of fuel consumed for each unit of brake power developed per hour. It is an indication of the efficiency with which the engine develops power from fuel. Brake Thermal efficiency of an engine is defined as the ratio of the output to that of the chemical energy input in the form of fuel supply. It is the true indication of the efficiency with which the chemical energy of fuel (input) is converted into mechanical work. Volumetric efficiency of an engine is an indication of the measure of the degree to which the engine fills its swept volume. It is defined as the ratio of the mass of air inducted into the engine cylinder during the suction stroke to the mass of the air corresponding to the swept volume of the engine at atmospheric pressure and temperature.

**Results and Discussion**

**Engine performance characteristics**

**Brake specific fuel consumption**

The variation of BSFC with respect to load for Jatropha ethyl ester blend and diesel fuel is shown in Figure 1. For all fuels tested, brake specific fuel consumption decreased with increase in load. Among the fuels tested the lowest BSFC values are obtained with diesel fuel due to low fuel consumption rate and high brake power. The specific fuel consumption was found to increase with increasing proportion of ester in the test fuels under all loading conditions. This is due to lower calorific value, higher viscosity and density of ester in comparison with diesel fuel. As the density of ester was higher than that of diesel fuel, which means the same fuel consumption on volume basis resulted in higher specific fuel consumption in case of ester (biodiesel). The results indicated that specific fuel consumption for all blends were higher than that of diesel fuel.

**Brake thermal efficiency**

The variation of brake thermal efficiency with load for different fuels at different load is represented in Figure 2. It increases with an increase in load in case of all the blended fuel tested. This can be attributed to reduction in heat loss and increase in power with increase in load. The thermal efficiency of the engine is improved by increasing concentration of the ester in the blends. tested a 4750 cc engine under different steady modes using 5%, 10%, 20%, 35% blends with diesel and pure rapeseed-oil biodiesel. They obtained higher BTEs with 5-10% blends compared to the others. The possible reason for this is the additional lubricity provided by ester and percent of oxygen presence in the ester, that gives the extra oxygen leads to causes better combustion inside the combustion chamber. Break thermal efficiency was observed to be varied from 16.45 to 31.72%, 16.6 to 31.92 %, 16.65 to 33.00% and 17.98 to 33.91% and was higher than that of diesel fuel (16.42 to 30.87%) at 25 to 75 percent of rated load for B10, B20, B30 and B40 fuel, respectively.

**Mechanical Efficiency**

It has been observed that there is a steady increase in mechanical efficiency for all the blends as the load increases.
increases. Blended fuels exhibited better mechanical efficiency compared to the neat diesel fuel. This is due to better lubricity properties of blended fuels compared to diesel. Mechanical efficiency was observed to be 64.09%, 65.99%, 67.39% and 68.34 at 75% of rated load for B10, B20, B30 and B40 fuel respectively which was 62.14% more than diesel fuel.

**Volumetric efficiency**

The volumetric efficiency of ester blends is lower than diesel fuel. A higher exhaust temperature leads to a lower volumetric efficiency. This is because the temperature of the retained exhaust gases will be higher when the exhaust gas temperature rises. A high-retained exhaust gas temperature will heat the incoming fresh air and lower the volumetric efficiency. Volumetric efficiency was observed to be varied from 87.43% to 83.42%, 86.19 % to 81.11%, 84.55 % to 80.85% and 84.12% to 79.99 %, at no load to 75% of rated load for B10, B20, B30 and B40 fuel respectively which was lower than that of diesel fuel (89.84 % to 85.89%).

**Exhaust gas temperature**

The exhaust gas temperature increased with increase in load and amount of blended ester in the diesel fuel. The poor volatility and high viscosity of the blended fuels lead to a more dominant diffusion combustion phase than diesel, which is responsible for increase in exhaust gas temperature. Exhaust gas temperature increased for all fuel types because of pressure rise in combustion chamber and an increase in fuel injection rate with increase in brake load. Biodiesel that has a slightly lower cetane rating results in longer ignition delay and slower burning rate. This means late combustion in the expansion stroke, resulting in higher exhaust and lubrication oil temperatures. In addition, a biodiesel may contain some constituents having higher boiling points that are not sufficiently evaporated during the main combustion phase and continue to burn in the late combustion phase. This causes higher exhaust temperature. Higher ignition delay results in a delayed combustion and higher exhausts gas temperatures.

**Exhaust emission characteristics**

**Carbon monoxide emission (CO) and NOx emission**

The emissions of CO increases with increasing load. It can also be observed that carbon monoxide emission decreased with increase in percentage of esters in the fuel. Reduced CO emissions were due to the oxygen inherently present in the biodiesel, which makes it easier to be burnt at higher temperature in the cylinder. Similar results were found in other studies. Increase in NOx emissions with increase in load and with increase in percentage of esters in the fuel was observed because NOx emission in exhaust gases was very much dependent on combustion chamber temperature. This is due to higher viscosity of blended fuels and increase in heat release rate when compared with diesel fuel.

**Conclusions**

The main objective of the present investigation was to evaluate suitability of biodiesel production from Jatropha curcas oil as a fuel for Diesel engine, to evaluate the performance and emission characteristics of the engine. The experimental results show that the engine performance with Jatropha ethyl ester blends was comparable to the performance with diesel fuel. The conclusions are summarized as follows:

- Brake thermal efficiency of the blends increases with increase in applied load. The maximum brake thermal efficiency at 75% of rated load is 33.91% for B40, which is 9.8% higher than that of diesel. BSFC of the engine gradually decreases with increase in load. The Specific fuel consumption of the blends B10, B20, B30 and B40 at 75% of rated load is 0.267kg/kWh, 0.276 kg/kWh, 0.273 kg/kWh and 0.278 kg/kWh respectively, whereas for diesel it is 0.265 kg/kWh.
- The exhaust gas temperature increased with increase in load and also increased with increase in proportion of ester in blends.
- The mechanical efficiency for all the blends increases as the load increases. The maximum
mechanical efficiency obtained from blend B40 at 75% of rated load is 68.34%.

- The oxides of nitrogen concentration from Jatropha ester blends during the whole range of experiment were higher than diesel fuel. While emissions of CO was reduced as compared to diesel. These reductions of emission could be due to better combustion of fuel.

The results from the experiments suggest that ester derived from non edible oil like Jatropha could be a good substitute fuel for diesel engine in the near future as far as decentralized energy production is concerned. Hence it can be concluded that the blends of ethyl ester with diesel up to 40% by volume could replace diesel for running the diesel engine.

References