Analysis of performance and emission on compression ignition engine fuelled with blends of neem biodiesel

Jayashri N. Nair*, Ajay Kumar Kaviti, Arun Kumar Daram

Department of Mechanical Engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Vignana Jyotith Nagar Bachiupally, Nizampet (S.O), Hyderabad 500090, India

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Abstract As the fossil fuels are depleting and green house gases are increasing usage of biodiesel came into existence. Biodiesel is a renewable, clean-burning diesel which can be produced from vegetable oils. This project deals with study of emission and performance characteristics on diesel engine with blends of Neem oil as biodiesel. Biodiesel is prepared from Neem oil by transesterification process followed by adding 1% v/v H2SO4. The tests were performed with B10, B20, B30 blends on a single cylinder, 4-stroke, diesel engine. The result shows lower emissions and higher performance for B10 than the other blends and diesel. The brake thermal efficiency is higher than the diesel and CO, HC and NO X emissions were 23%, 8.5%, and 22% lesser than that of diesel.

Key words Neem biodiesel; Transesterification; Diesel engine; Performance; Emission; Neem blends

1. Introduction

In the past few decades extensive use of petroleum has led to depletion of fossil fuel. Increasing human population and industrialisation has led to scarcity of petroleum reserves. This has made alternative energy resources more attractive. The alternative energy resources should be renewable, sustainable, efficient and cost effective. Biodiesel is considered as one of the promising alternative resources for diesel engine, especially from non-edible oil feedstock as well as its potential to be a part of a sustainable energy mix in the future. [1] Biodiesel can be produced from non-edible seed oil like Pongamia, Karanja, Neem etc. These oils cannot be directly used in the engine due their high viscosity and density, and low calorific value. The glycerol component should be removed by transesterification reaction. Biodiesels with edible and non-edible oils are widely investigated with respect to their performance, emissions and their impact on environment. Blends of biodiesel can be directly used without much alteration in existing diesel engine. Liaquat et al. [2] investigated performance and emissions of coconut biodiesel with CB5 and CB15 sample against...
neat diesel at 100% load with varying speeds of 1500–2400 rpm at an interval of 100 rpm. The average torque reduction compared to net diesel fuel was found as 0.69% for CB5 and 2.58% for CB15 respectively.

Dawody et al. [3] investigated performance and emissions of soybean biodiesel (20%SME, 40%SME, 100%SME) on diesel engine at various loads and constant speed of 1500 rpm. The brake specific fuel consumption for all the blends was noted less than the No.2 diesel. Mallikappa et al. [4] conducted tests on a double cylinder, direct injection, compression ignition engine with B10, B15, B20, B25. It was observed that brake thermal efficiency increases with higher brake power and emission levels (HC, CO, NO\textsubscript{x}) were nominal up to 20% blends. The Carbon monoxide increases slightly more after 20% blends. Swarup et al. [5] tested biodiesel from neat Mahua oil via base catalysed transesterification and mixed the biodiesel with a suitable additive (dimethyl carbonate) in varying volume proportions (B100, B95, B90, and B85). NO\textsubscript{x} emissions were the highest for pure biodiesel. Mohd Hafizil et al. [6] tests were carried out on Mitsubishi 4D68 4 inline multi cylinder compression ignition (CI) engine with various engine speeds fuelled with diesel and B5 (5% palm methyl ester + 95% diesel) blended fuel. Results showed that at all engine speeds, torque and power outputs for B5 fuel were quite similar to neat petroleum diesel fuel. NO\textsubscript{x} emission reduced significantly for both fuels but the rest emission contents were decreased with engine speed.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Engine type</td>
<td>Kirloskar 4 stroke, single cylinder, constant speed, diesel engine</td>
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<tr>
<td>2.</td>
<td>Power rating</td>
<td>3.50 KW at 1500 rpm</td>
</tr>
<tr>
<td>3.</td>
<td>Stroke</td>
<td>110 mm</td>
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<tr>
<td>4.</td>
<td>Bore</td>
<td>87.5 mm</td>
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<tr>
<td>5.</td>
<td>Capacity</td>
<td>661 cc</td>
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<tr>
<td>6.</td>
<td>Compression ratio</td>
<td>12:1–18:1</td>
</tr>
<tr>
<td>7.</td>
<td>Dynamometer</td>
<td>Eddy current type</td>
</tr>
<tr>
<td>8.</td>
<td>Calorimeter</td>
<td>Type pipe in pipe</td>
</tr>
</tbody>
</table>

Fig. 3.1  Schematic diagram of experimental setup. T\textsubscript{1}-Engine coolant inlet temperature. T\textsubscript{2}-Engine coolant outlet temperature. T\textsubscript{3}-Calorimeter coolant inlet temperature. T\textsubscript{4}-Calorimeter coolant outlet temperature. T\textsubscript{5}-Engine exhaust gases outlet temperature. T\textsubscript{6}-Exhaust gases outlet temperature from calorimeter.

Fig. 4.1.1  Variation of B.P vs B.S.F.C of biodiesel blends and diesel.

Fig. 4.1.2  Variation of B.T.E vs B.P of biodiesel blends and diesel.
Bhupendra Singh et al. [7] evaluated performance and emissions using Karanja biodiesel with different compositions at 5%, 10%, 20%, 30% and 100% with mineral diesel. Brake thermal efficiency was about 3–5% lower with Karanja biodiesel and its blends with respect to diesel. NO\textsubscript{X} emissions were higher for the blends than neat diesel.

The neem tree \textit{(Azadirachta indica)} is a tropical evergreen with a wide adaptability, native to India and Burma. It has been estimated that Indian neem bears about 3.5 million tons of kernels each year and that, in principle, about 700,000 tons can be recovered. About 34 tons of neem seeds were exported from India in 1990. The neem plant is a fast growing plant with long productive life span of 150–200 years, its ability to survive on drought and poor soils at a very hot temperature of 44\degreeCelsius and a low temperature of up to 4\degreeCelsius, and its high oil content of 39.7–60%. A mature neem tree produces 30–50 kg fruit every year [8]. Prithviraj et al. have studied the biophysicochemical properties of Neem oil for biodiesel production. The comparison of characteristic fuel properties of biodiesel of neem with the BIS standard and diesel indicates that the produced fuels are comparable with diesel and can be treated as another source for the biodiesel feed stock [9].

In this present investigation biodiesel is prepared from Neem oil. The performance and emission characteristics are evaluated on a single cylinder four stroke water cooled engine.

2. Fuel preparation

One litre of Neem crude oil was measured and heated up to 75\degreeCelsius using electric heater. A solution of 300 ml of methanol and NaOH crystals 1% by weight was prepared. When temperature of Neem oil reached 75\degreeCelsius, the mixture of methanol and NaOH was added gradually to it. The mixture was stirred continuously for few minutes and then 1% by volume of H\textsubscript{2}SO\textsubscript{4} was added. The mixture was allowed to settle down for 24 h, so that all the glycerol settles down and biodiesel floats above it [10–15]. After that the following blends were prepared B10, B20 and B30.

3. Experimental set up

A single cylinder, four stroke, constant speed, water cooled, diesel engine was used for the experiment. The technical
specification of the engines is given in Table 1. The schematic diagram of the experimental setup is shown in Fig. 3.1. The engine was operated at a constant speed of 1500 rpm, with constant compression ratio of 18. The load variation was done with the help of eddy current dynamometer. Initially the engine was tested with pure diesel and then with different blends of neem biodiesel (B10, B20, B30). An AVL 444 DI Gas Analyzer was used for measuring CO, HC and NO\textsubscript{X} emissions and smoke density was measured using AVL437 smoke metre. Fuel consumption was measured with the help of a sensor and data acquisition system. The air flow to the engine is dispatched to through the cubical air tank. The air tank regulates the flow of air to the tank. The inlet of the air tank is contributed with an orifice, and the air flow rate is measured using the mass air flow sensor. Different engine performance parameters like brake power, brake thermal efficiency, Specific fuel consumption and emissions like CO, HC, NO\textsubscript{X} were measured and results were plotted with respect to load.

4. Results and discussions

4.1. Performance graphs

4.1.1. Specific fuel consumption (kg/kwhr)

Fig. 4.1.1 shows the brake specific fuel consumption of neem biodiesel blends as well as diesel as function of brake power. From the graph it is observed that the B.S.F.C for diesel as well as B10 blend is less than B20 & B30 at all loads. As the concentration of neem biodiesel increases in the blends, it is found that B.S.F.C also increases. This can be attributed to the lower calorific values of B30 and B20 as for the same energy output more mass of fuel is consumed.

4.1.2. Brake thermal efficiency (%)

Fig. 4.1.2 shows the comparison of brake thermal efficiency for neem biodiesel blends with diesel. From the graph it is clear that brake thermal efficiency of neem biodiesel blends are higher than that of diesel at all loads. It is also observed that at lower loads all the three blends are falling on the same curve. The reason that the blends are showing higher brake thermal efficiency can attributed to the higher oxygen content of the blends neem which ultimately improves the combustion efficiency. An average increase in brake thermal efficiency of B10 and B20 for all loads was noted to be 34% against diesel [15].

4.2. Emission graphs

4.2.1. Co emissions

Fig. 4.2.1 shows the variation of CO emissions of Neem seed blends and diesel against brake power. The main reason for CO emissions is incomplete combustion where the oxidation process does not occur completely. Since biodiesel contain extra oxygen content CO is converted into CO\textsubscript{2}. The CO emissions were reduced for Neem blends compared to pure diesel. From Fig. 4.2.1 it is clear that CO emissions of Neem B10 and Neem B20 are very less compared to Neem B30 and Diesel. Average reduction in CO emissions for B10, B20, B30 was 26%, 22%, 5% respectively.

4.2.2. HC emissions

Fig. 4.2.2 shows the variation of HC emissions against load variations. Hydrocarbon emissions are composed of unburned fuels as a result of insufficient temperature which occurs near the cylinder wall. In lean mixtures, flame speeds may be too low to complete the combustion process.
low for combustion to be completed during the power stroke, or combustion may not occur, and these conditions cause high hydrocarbon emissions. On an average HC emissions are reduced compared to that of diesel by 17%, 10% and 9% for B10, B20, B30 respectively.

4.2.3. NOX emissions

Fig. 4.2.3 shows the variation of NOX emissions of biodiesel blends and diesel against brake power. Generally nitrogen does not react with oxygen in the combustion chamber. However, high temperatures in the cylinders cause the nitrogen to react with oxygen and generate NOX emissions. It is noted that the blends of Neem oil are emitting less NOX as compared to diesel. It may be attributed to lower heat release rate of blends which leads to lower combustion temperatures. Lower heat release rate may be because of poor mixing of blends and air [16]. On an average NOX emissions are reduced compared to those of diesel by 21.875%, 8.375% and 18.875% for B10, B20, B30 respectively.

4.2.4. Smoke emissions

Fig. 4.2.4 shows the variation of smoke emissions of Neem blends and diesel against brake power. The smoke emission increases for all the test fuels. It can be observed that smoke emission is higher with the blends than diesel. As the viscosity of the neem blends is higher the atomisation is not proper which results in slow combustion. It is observed that at higher loads smoke is equal in all the cases i.e. 100%. On an average smoke emission is increased compared to that of diesel by 12% for B10 and 21% for B20 and B30.

5. Conclusions

From the experimental investigation on performance and emission test on diesel engine with blends of neem biodiesel, we can conclude that:

1. Neem biodiesel blends are showing higher brake thermal efficiency than diesel.
2. In terms of brake power, neem biodiesel can replace diesel in the form of blends as there is no significant drop in engine performance.
3. CO, HC, CO2, and NOX emissions of neem biodiesel are decreasing than diesel.
4. O2 emissions of neem biodiesel are increasing than diesel.
5. Without any modifications, neem biodiesel can be directly used in the diesel engine or it can also be used as blends.
6. B10 shows higher performance and lower emissions than other blends and diesel.

References


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