Experimental investigation of CI engine fuelled with diesel blended neem oil with methanol as additives

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Abstract. To select an alternative fuel suitable for operating an IC diesel engine for real world usage without any major modifications. The need to reduce the use of fossil fuels ignites interest in renewable fuels such as biodiesels. Preventing direct substitution of bio fuels is the higher viscosity of bio fuels. The performance and emission characteristics of CI engine are studied when fuelled with neem oil with diesel blends of ratios B10, B20 and B30 and also with M10% & M20% where methanol is used as the blending agent. The tests were carried out in the 4 stroke, single cylinder diesel engine by varying the load from 25% to 100%.

1. Introduction
Biofuel is produced from various biomass-plant or algae or animal material. One such example is neem oil, which are mono alkyl esters. Neem seeds are preferred for extraction process since they contain about 30-40% oil. The quality of neem oil depends on their extraction process-Mechanical pressing, Steam pressure extraction and solvent extraction. Crushing seed kernels in a temperature-controlled environment is a cold extraction process.

Thamarai Kannan M.et al, analysed combustion and emission characteristics experimentally of a CI engine powered by 5% methanol and 10% methanol blend. When the methanol composition is increased beyond 10%, which brings about the phase separation in the fuel blend, resulting in cavitation in fuel injector nozzle, observable by unstable engine operation and heavier exhaust smoke. When methanol is blended with diesel, BSFC of the conventional diesel engine is reduced while increasing the brake thermal efficiency. The NOx emissions are decreasing in nature but results in increased HC and CO emissions which can be avoided by optimising the ratio of the blend.

Injecting neem methanol blend with decelerating injection timing and a superior injection rate improved the performance of diesel engine significantly. Furthermore, the emission levels observed were found to be even better than petrodiesel. But Reddy et al. [2] concluded that brake thermal efficiency of the neem-methanol biofuel blend was lower than that of petrodiesel.

S. Bajpai et al. [3] conducted study on Neem Methanol blended with petrodiesel on a single-cylinder constant speed (1500 rpm) diesel engine having compression ratio of 17.5. It concluded that petrodiesel
blended with 10% neat neem-methanol mix can be used as an alternative fuel for the conventional CI engines without major hardware modifications. This blend showed improved BTE and reduced BSEC and exhaust emissions. They also conducted fuel characterization of pre-heated fuel mix whose viscosity was similar to that of petrodiesel. It was found that the engine performance mainly depends on self-lubricity and oxygen content of neem-methanol mix.

Devan et al. [4] conducted tests using neem oil and methanol blended in various composition with petrodiesel on a diesel engine. The specifications of the engine are single-cylinder, 4-stroke and air cooled. At full load, 32% decrease in NOx emission was observed for neem-methanol blend and for 20% blend the emission got reduced by 4%. Observation of CO emissions showed increase in emission except for neat 20% blend.

Ziesjewski et al. [5] concluded that with the dilution of methanol concentrations, the viscosity of the blend lowers which addresses problems such as injector choking and carbon deposits. The experiment used the fuel blend of 25% sunflower methanol along with 75% petrodiesel.

For neem oil with methanol biodiesels, appropriate blend ratios are required to optimize the performance characteristics like low emission, best combustion characteristics as suggested by Sahoo and Das [6]. The ignition delays are shorter than petrodiesel and the difference increases with the load by varying the neem oil and methanol blend percentage, shows good improvement in NOX and HC emission.

2. Methods and methodology
The experiment was carried out in a 4-stroke, naturally aspirated, direct injection diesel engine attached to eddy current type dynamometer with load range of 0 - 18kg (advised to load only till 16kg). The Kirloskar engine has a constant speed of 1500 RPM where temperature, pressure etc. are measured using various sensors paired with a Kubler-Germany make for crank angle sensing. The PCB Piezotronics with a range of 5000 psi is used as the pressure sensor. A Load sensing range of 50kg is achieved by the usage of Sensotronics SanMar Ltd. A k-type thermocouple is used as the temperature sensor.

A passive mix of diesel with neem oil and methanol (both miscible in diesel) is used for our study. The blends possess good mixing properties which is validated by the observation of no separation of layers after stagnation for a period of time for each blend. The blends are B10M10, B10M20, B20M10, B20M20, B30M10, B30M20 based on the volume ratio with neem oil during preparation.

![Figure 1. Test rig setup.](image1)

![Figure 2. Test rig schematics.](image2)
2.1. Methodology

Table 1. Apparatus Specifications.

| Specification                  | Details                        |
|--------------------------------|-------------------------------|
| Engine power                   | 5.2 Kilo Watt                 |
| Engine maximum speed           | 1500 RPM                      |
| Cylinder bore Diameter         | 87.5 millimetres              |
| Stroke length                  | 110 millimetres               |
| Connecting rod length          | 234 millimetres               |
| Compression Ratio              | 17.5                          |
| Compression type               | Fixed                         |
| Stroke type                    | Four                          |
| No. of cylinder                | One                           |
| Speed type                     | Constant                      |
| Cooling type                   | Water                         |
| Dynamometer type               | Eddy current                  |

2.2. Fuel ratios used

- Diesel
- B10 (10% Of Neem oil + 90% of Diesel)
- B20 (20% Of Neem oil + 80% of Diesel)
- B30 (30% Of Neem oil + 70% of Diesel)
- B10M10 (10% volume of methanol with 90% of B10)
- B20M10 (10% volume of methanol with 90% of B10)
- B30M10 (10% volume of methanol with 90% of B10)
- B10M20 (20% volume of methanol with 80% of B10)
- B20M20 (20% volume of methanol with 80% of B10)
- B30M20 (20% volume of methanol with 80% of B10)

Table 2. Various fuels and their properties.

| FUEL PROPERTIES | DENSITY (kg/m³) | CALORIFIC VALUE (kJ/kg) | FIRE POINT(°C) |
|-----------------|-----------------|-------------------------|----------------|
| DIESEL          | 840             | 42500                   | 75             |
| NEEM OIL        | 920             | 39648                   | 185            |
| METHANOL        | 830             | 42500                   | 67             |
| B10 M10         | 846             | 42575                   | 86             |
| B20 M10         | 840             | 42979                   | 84             |
| B30 M10         | 856             | 42049                   | 82             |
3. RESULT AND DISCUSSION

3.1. Brake Thermal Efficiency

Dependence of the Brake thermal efficiency against load is depicted in the figure 3 which shows BTE is in direct proportionality with load. Diesel fuel has highest brake thermal efficiency compared to blended fuel at all loading condition. B10M20 has the highest BTE in comparison with other blended fuels.

3.2. Specific fuel consumption

SFC is generally used as the engine performance parameter and it is dependent inversely to the thermal efficiency of the engine.

| Fuel Consumption (g/kwhr) |
|---------------------------|
| Load (kg)                 |
| 25% LOAD                  |
| 50% LOAD                  |
| 75% LOAD                  |
| 100% LOAD                 |
| Diesel                   |
| B10 M10                  |
| B20 M10                  |
| B30 M10                  |
| B10 M20                  |
| B20 M20                  |
| B30 M20                  |

Figure 3. BTE v/s Load.

Figure 4. SFC v/s Load.
Variation of the Specific fuel consumption against load was shown in the figure 4. With increase in engine load, the specific fuel consumption also increases in nature. Diesel fuel has good specific fuel consumption compared to blended fuel at all loading condition. B10M10 is a better blended fuel in all parameters except diesel. Specific fuel consumption is directly proportional to the increasing quantity of methanol and neem oil mix.

3.3. Carbon Di-Oxide
Carbon diode is a by-product of complete combustion in an engine. Therefore, increasing carbon diode is a measure of more complete combustion of the fuel. Therefore, it can be considered as a keystone parameter in measuring engine performance.

![Figure 5. CO$_2$ v/s Load.](image)

Variation of the carbon dioxide against load was shown in the figure 5. With increase in load, the carbon quantity is also increasing. B30M20 has higher carbon dioxide compared with other blended fuels except diesel. Diesel has the highest brake carbon percentage compared to other blended fuel. B30M20 is effective when it comes to complete combustion parameter.

3.4. Carbon Mono-Oxide

![Figure 6. CO v/s Load.](image)

CO is a by-product of incomplete combustion due to insufficient oxygen or temperature or both. Carbon Mono-oxide is an emission gas and is major air pollutant causing respiratory problems. Carbon Mono-oxide is a formed majorly due to cold start inability or due to insufficient combustion temperature.
Variation of the Carbon monoxide against load was shown in the figure 6. Carbon monoxide was increasing with decrease in load due to low combustion temperature. Diesel Fuel has the least carbon monoxide formation when compared to blended fuels. With the variation of blend mixture there was not found to be any change in the carbon mono-oxide emissions.

3.5. Hydro Carbon

![Hydro Carbon](image)

**Figure 7. HC v/s Load.**

Variation of the Hydro Carbon against load was shown in the figure 7. Hydro Carbon was increasing with increase in load. Blended fuel has highest Hydro carbons compare to diesel fuel at all loading condition Hydro carbon is more or less very similar to other blended ratios except diesel.

3.6. Oxygen

![Oxygen](image)

**Figure 8. Oxygen v/s Load.**

Variation of the Oxygen percentage against load was shown in the figure 8. The lowest value of O₂ in the graph tells us that the maximum percentage of oxygen is used in the combustion process. In addition of Neem oil and methanol cases in reduces the Oxygen gas volume and improves the oxidation process for better combustion.
3.7. Nitrogen Oxide
Variation of the Oxides of Nitrogen against load was shown in the figure 9. NO\textsubscript{x} was increasing with increase in load due to increase in combustion temperature. But at the same time in high load NO\textsubscript{x} was decreasing because of internal circulation of exhaust gas which will lead to reduction in the inside combustion temperature. Diesel fuel has high oxides of nitrogen compare to blended fuel at all loading condition. With increase in methanol with blended diesel is decreasing NO\textsubscript{x} emissions in full load condition and also not much variation in low load condition except diesel.

![Figure 9. NO\textsubscript{x} v/s Load.](image)

4. Conclusion
The various tests were carried out with the engine at 1500 RPM under different load conditions for the blends formed using Diesel with Neem Oil and Methanol on volume basis namely B10M10, B10M20, B20M10, B20M20, B30M10 and B30M20. The changes in performance is analyzed for each blend to determine the best blend fuel.

The NO\textsubscript{x}, HC and CO emissions decreases as the percentage of Neem oil in the blend is increased and also addition of methanol is improving the brake thermal efficiency. At the same time Fuel consumption was affected as the values for the SFC increased with the addition of the neem oil in the blend due to high self-ignition temperature of blended diesel.

B10M20 had the highest BTE among the blends and hence has the best performance characteristics. The lowest SFC was observed in the blend B20M10 which is used to achieve better mileage.

Higher CO\textsubscript{2} is most desirable as it represents better combustion which is observed in B30M20. Lower CO level represents complete combustion of fuel and is observed in B20M10. B30M20 had the lowest HC level which is most desirable.

Lower O\textsubscript{2} level in emission is most desirable and is observed in B30M20. Higher NO\textsubscript{x} value lowers the combustion temperature and B20M20 had the best NO\textsubscript{x} characteristics.

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