Experimental investigation of performance and emissions of CI engine fuelled with neem oil blended turpentine fuel

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Abstract. Developing countries like India spending huge money in the energy sector and reliable on the other countries which act as the barrier for its own improvement. The developing countries has the constraint in either economic and environment impact because of the higher pollutant released the energy sector like Automobiles. This paper deals with fuel of neem oil and turpentine oil blend in the Proportional of N30T70 (30% of Neem oil and 70% of Turpentine oil) N50T50 (50% of Neem oil and 50% of Turpentine oil) and N70T30 (70% of Neem oil and 30% of Turpentine oil). Experiment was conducted in four stroke diesel engine by varying load from 0% to 100%. The results shows that increasing the turpentine oil in the blend reduces the viscosity, density and increase the Calorific value blended fuel supports for better combustion. Increase the turpentine oil in blended fuel increase the efficiency, decrease CO and increase the Nox emissions.

1. Introduction

With the increase in the development of mankind, industrialisation also increases rapidly. And for a better efficiency, industries are using fossil fuels as their source of power. Fossil fuels being a non-renewable resource are getting depleted at a high rate. To prevent this, researchers are investigating on biofuels as an alternative source of power. Many oils are used in the preparation of biofuels, for example, cottonseed, kapok, neem, jatropha, turpentine, olive etc. These oils can either be mixed with other oils to form a biofuel or mixed with diesel to form biodiesel. These biodiesels are easy to manufacture and have other good properties like cetane number, viscosity, calorific value, density, performance, combustion and emission of harmful gases like (HC), (CO), (NOx), (CO2). The combustion and emission of the fuel depends upon the Cetane number of the blend. Exhaust emissions are affected indirectly by Cetane number by increasing or decreasing the ignition period. Fuels with more cetane number perform better on a diesel engine as they increase the quality of combustion and decrease the delay in ignition. Whereas fuels with lower cetane number decrease in ignition time and the combustion does not occur properly. In this paper, neem oil and turpentine oil are used as a biodiesel to investigate the performance, emission and combustion characteristics in a single cylindered CRDI diesel engine with varying pressure to find the best
blend which may further increase the efficiency with low fuel consumption and required emission characteristics.

Biodiesel are made from alcohol or animal fats and vegetable oil. With the help of biodiesel we can reduce HC, CO, and increase NOx than diesel-fueled engine. It is an eco-friendly fuel derived from neem oil. Biodiesel is environment friendly fuel[1,2]. Biofuel possesses several distinct advantages over petro-diesel in aspects like bio-degradability, etc [3]. The evergreen tree is large tree with a circumference of up to 180 to 240 centimeters. Neem oil is generally brown in colour, bitter in taste and has strong odor that is said to combine the odors of peanut and garlic [4,5]. Neem oil is synthesized from solvent extraction of its seed. The left over neem oil in the seed is generally extracted by the help of hexane [6]. India and Burma are native places for neem tree [7,8] and 90% of the neem tree can be used for various purposes like medicine, organic fertilizer, pesticide. Neem tree is grown in soils that are very rocky, shallow, dry. Neem tree have ability to tolerate some extreme temperature conditions of 45C and rainfall less than 13.77 inch per year [9].

Turpentine oil has an inferior cetane number. Turpentine oil is utilized in direct injection diesel engines[10]. By using turpentine as a fuel some research has been done to investigate the performance, combustion and emission characteristics of diesel engines. It has been [10] experimentally examined that the performance and emission characteristics of turpentine oil in diesel engines have the performance improvement at 3.8kW load condition, upto 40–45% smoke reduction, with the help of minor engine modifications turpentine oil can replace diesel. All the physical and chemical properties of diesel, turpentine, cottonseed oil ester and fuel blends have been given in below table 1.

| Table 1. Physical and Chemical properties of fuels. |
|---------------------------------------------------|
| **Fuel** | Neem oil | Turpentine oil | Diesel | T50N50 | T30N70 | T70N30 |
| Formula | C10H16 | C10H20 | - | - | - | - |
| Kinematic viscosity (cst) | 5.81 | 2.51 | 2.5 | 4.16 | 4.82 | 3.5 |
| CV (MJ/Kg) | 39.5 | 44.4 | 45 | 41.95 | 40.97 | 42.93 |
| Density (kg/m³) | 0.91 | 0.8 | 0.855 | 0.855 | 0.877 | 0.833 |
| Cetane number | 31 | 35 | 55 | 33 | 32.2 | 33.8 |
| Fire point (C) | 222 | 50 | 74 | 136 | 170.4 | 101.6 |

2. Experimental Setup
The experiment was done on a four-stroke single cylinder, water cooled, direct injection engine has rated capacity of 5.2 kW at constant speed 1500 RPM. It has coupled with Eddy current dynamometer for applying brake load. The output signals from sensors are sent to control panel’s board then connected to a personal computer. To record exhaust gas emissions AVL 5 gas analyzer was attached to the set up for measuring the NOx, CO, CO2 and HC emissions present in the exhaust gas. Engine Technical specifications are shown in Table 2.
Table 2. Engine specifications.

| Feature               | Description                                      |
|-----------------------|--------------------------------------------------|
| Model                 | Research Engine Test Setup 240 PE                |
|                       | Apex Innovations Private ltd.                   |
| Engine type           | Multi-fuel                                      |
| Cylinders             | Four Stroke Single cylinder                     |
| Cooling Medium        | Water cooled                                    |
| Capacity              | 5.2 kW @ 1500 rpm                               |
| Cylinder Dia.         | 87.5 mm                                          |
| Length of stroke      | 110 mm                                           |
| Range of Compression ratio | 17.5:1                                       |

Figure 1. Engine Setup.

Table 3. Exhaust gas analyzer specifications.

| Gas emitted in Exhaust | Range of Measurement | Resolutions | Precision                                      |
|------------------------|----------------------|-------------|------------------------------------------------|
| CO                     | 0 to 10% of volume   | 0.01 % of volume | <0.6% ± 0.03% vol ≥0.6% ± 5% vol of ind val |
|                        | <2000:1 ppm volume  | ≥2000 ppm of vol ± 10 ppm of ind val |
|                        | >2000:10 ppm volume | ≥2000 ppm of vol ± 5% of individual val |
| HC                     | 0 to 20000 ppm      | <2000 ppm of vol ± 10 ppm of individual val |
| CO2                    | 0 to 20% of vol     | 0.1 % of vol | <10 % vol ±0.5% ≥ 10% vol ± 5% of ind val |
| NOx                    | 0 to 5000 ppm       | 1 ppm vol | <500 ppm of vol ± 50 ppm ≥500 ppm vol ± 10% of individual val |
3. Result and Discussion

3.1. Performance Characteristics

3.1.1. Brake thermal Efficiency. The brake thermal efficiency of the blends namely T50N50, T30N70, T70N30 and diesel were compared for different loads with the help of the following graph. The maximum BTE was observed for the T70N30 blend at 50% of load and T30N70 blend gives maximum at 75 % load. At maximum load, T30N70 blend shows the best BTE characteristics. Up to 50 % of load BTE is high for T70N30 because of turpentine fuel have high calorific value and high cetane number.

![BP vs BTE](image)

**Figure 2.** Brake Power vs BTE.

3.1.2. Total Fuel Consumption. Total fuel consumption at maximum load was lowest for diesel then followed by T30N70, T50N50 and T70N30 respectively. The TFC of all the blends is increasing with increasing load as well as increasing brake power. Neem fuel have low calorific value and low cetane number so fuel consumption more while increase the neem oil in the blend fuel consumption is high.

![BP VS TFC](image)

**Figure 3.** Brake Power vs Total Fuel Consumption.
3.2. Emission Characteristics

3.2.1. Carbon monoxide Emission. Carbon monoxide emission is minimal until 75% of loads used. There is a spike in CO emissions after 75% load percentage mainly due to partial combustion taking place at higher load; this may be due to decrease in oxygen content available at higher load specifications. All the blends have a greater CO emission characteristic when juxtaposed with diesel. The blend with the lowest CO emission is T30N70 followed by T50N50 and T70N30 blends. Turpentine fuel has less oxygen content hence more incomplete combustion.

![Figure 4. Brake power vs Carbon monoxide.](image)

3.2.2. Carbon Dioxide Emission. Carbon dioxide is the result of complete combustion of fuel and is showing an increasing trend with increase in load and brake power. All the blends have higher CO₂ emission than diesel except for the T30N70 blend at 3.85kW and 5.19kW brake power. The T70N30 blend has the highest emission and is followed by T50N50 blend at all brake powers.

![Figure 5. Brake power vs Carbon dioxide.](image)
3.2.3. Hydrocarbon Emission. The hydrocarbon emission is highest for the blends and diesel at high load percentages; the main reason being the partial combustion of the fuel at high loads. The lowest HC emission is for the T30N70 blend then T50N50, T70N30 and diesel. The given graph shows an increasing trend of HC emission with respect to brake power.

![Figure 6. Brake power vs Hydrocarbon.](image)

3.2.4. NOx Emission. The NOx emissions have an increase till 3/4th of the total load and then a decreasing trend is followed till the highest load. T50N50 blend shows the highest emissions of NOx showing good combustion rate followed by T30N70, diesel and T70N30.

![Figure 7. Brake power vs NOx.](image)

3.2.5. Smoke. The smoke emission for the blends and diesel were found out and compared against each other while load was also kept as a parameter. At the highest load or brake power of 5.19kW, it was found that the blend T70N30 had the highest emission of smoke then came the T30N70 blend along with T50N50 and diesel respectively. Smoke emission was also showing an increasing trend with increase in BP.
4. Conclusion
By the emission and performance characteristics of the fuel blend T30N70 has given less emission and high efficiency at all loads. The emission is nearer to the diesel values and high at 75%. As from the emission results it can be seen that the NOx emissions are higher due to increase in exhaust gas temperature at 75% of load.
Up to half of the full load, the blend T70N30 shows high BTE due to the fact that turpentine has high calorific value along with a high cetane number.
Since, the cetane number as well as the calorific value of neem is low, the blend T70N30 was showing the lowest values for total fuel consumption.
All the blends have a greater CO emission characteristic when compared to diesel. The blend with the lowest CO emission is T30N70 followed by T50N50 and T70N30 blends. Turpentine fuel has less oxygen content hence more incomplete combustion. The HC emission also follow the same trend as that of CO emission.
The T70N30 blend has the highest emissions of CO$_2$, thus showing high combustion properties at high loads.
The NOx emission is the highest for the T50N50 blend followed by T30N70 and T70N30 blends.
At the highest load or brake power of 5.19kW, it was found that the blend T70N30 had the highest emission of smoke then came the T30N70 blend along with T50N50 and diesel respectively.

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