PERFORMANCE AND EMISSION OF CI ENGINE FUELED BY TURPENTINE AND COTTONSEED OIL BLENDS AT VARIOUS INJECTION PRESSURES

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Abstract. In the current study an experimental investigation was carried out with cottonseed oil ester and mineral turpentine oil blend as an alternative fuel in a diesel engine. This study gives the comparative characteristics of performance and emission for the fuel blends and compared with diesel at various injector opening pressures of 190 bar, 210 bar and 230 bar. The experiment was conducted on 5.2 kW single cylinder Compression Ignition engine. Fuel blends in various ratios has been tested. The Turpentine oil was first blended with 20\%, 30\%, 40\% and 50\% of cottonseed oil ester to improve the performance of pure turpentine oil as fuel. It was found that the blend T80 which contains 80 \% turpentine and 20 \% cottonseed oil ester at 210 Bar gives the optimum brake thermal efficiency among all the blends.

1. Introduction

Due to global fuel crisis, we need new fuel to run the engine without any modification, compromising the efficiency and increase in the emissions. By increasing the fossil fuel consumption, environmental issues like air pollution, global warming, waste disposal and reduction of natural resources will recur. Because of these reasons, world is moving to the clean fuels and usage of the biodiesel is one of the most common practice. Especially vegetables oils being more viscous, the esterification process need to be carried out to separate the fatty acids. Simultaneously, the other properties like cetane number may have to be improved.

Karikalan et al.\cite{1} studied the effect of fuel injector opening pressure, state and number of injections, quantity of fuel injected, nozzle spray patterns and design of combustion chamber on the diesel engine and concluded that at very high fuel injection pressures the maximum value of 35\% of BTE is obtained at 200 bar. Authors had examined the impact of fuel injection pressure mixing corn biodiesel, soya bean biodiesel and diesel fuel in diesel engine at various pressures and found that the BTE increases by 15\% over that of diesel\cite{2}. Researchers examined the canola oil biodiesel blends with diesel fuel at four various fuel injection pressures from 180 bar to 240 bars at different loads. They noticed that the increase in fuel injection pressure improved the results for BSFC and BTE compared to the original 200 bar. The BTE increased by 9.80\% and BSFC decreased by 10 \% with increase in injection pressure \cite{3}. The effect of the fuel injection pressure on the diesel engine was studied \cite{4} with equal amount of hone oil and diesel fuel, and reported that increasing the fuel injection pressure would increases BTE from 25\% to 28\% for 200 to 240 bar, also it was noted that the
increase is higher at low and medium load regions. Gopalakrishnan et al. [5] studied the diesel engine fuelled with waste cooking oil and timber chips along with flammable and non-flammable gases. They observed that for the various injection pressures of 160 bar, 210 bar and 260 bar have the liquid fuel consumptions are 1.11, 1.05 and 1.00 Kg/h respectively. Anand et al. [6] estimated the turpentine oil fuel blended with diesel, fuelled in diesel engine. They observed that net heat release rate and brake power was higher due to the addition of 30% Turpentine oil fuel with Diesel. It is also observed that 50% Turpentine oil fuel blend reduces maximum of 9% NOx concentration with exhaust temperature reduced up to 18%. Augustine et al. [7] studied the Preheated cotton seed oil methyl ester in diesel engine and concluded that 10 % reduction in BTE performance, where the CO and HC emissions are low by 34% and 16% respectively and increased NOX emission by 11%.Oztezen et al. [8] used Canola and waste palm oil methyl esters in diesel engine and they found that there is low emission of CO2, CO and HC by 8, 67 and 26% respectively for Waste palm ester and low emission of CO, HC and CO2 by 59, 17 and 5% respectively for canola methyl ester. Godiganur et al. [9] studied mahua methyl ester in diesel engine and observed that for all blends BSFC increased and BTE decreased for biodiesel blends, except B20. At full load for B100, CO and HC emission decreases for all the blends with 12% increase of EGT and 11.6% increase of NOx. Karthikeyan et al. [10] studied the performance of Turpentine fuel with diesel blend, reported that the BSFC is low and the CO and NOx emission is higher whereas HC and smoke intensity is lower. Karikalan et al. [11] examined turpentine oil as a stabilizer for Jatropha biodiesel. They observed that BTE of 20% of mineral turpentine blended with 80% of jatropha biodiesel is found closer to diesel, reaching 27% and for diesel it is 30% at same load (75%).

The Turpentine oil was first blended with 20%, 30%,40% ,50% of cottonseed oil ester and noted as T80, T70, T60, T50blends respectively. All the fuel properties are of diesel, turpentine, cottonseed oil ester and fuel blends are determined. In this study fuel blends are tested at varying fuel injector opening pressure of 190,210,230 bars at various loads applied on the engine. The performance and emissions characteristics of the engine are studied.

1.1. Properties of fuels

As the percentage of cottonseed ester increases in the blend the cetane number increases. The cetane number increases from 35 cSt to 46 cSt for T50 blend. As the percentage of cottonseed ester increases, the percentage reduction in calorific value is 5.4 %. However, there is increase in kinematic viscosity from 2.51cSt to 4.16 cSt. Properties of fuel is shown in Table 1.

| Table1. Properties of Fuels. | Cottonseed oil ester | Turpentine oil | Diesel | T50 | T60 | T70 | T80 |
|------------------------------|----------------------|----------------|--------|-----|-----|-----|-----|
| Kinematic viscosity (cSt)    | 5.81                 | 2.51           | 2.5    | 4.16| 3.83| 3.1 | 2.9 |
| Calorific value (MJ/kg)      | 39.64                | 44.4           | 45     | 42  | 42.5| 43  | 43.5|
| Density (kg/m³)              | 910                  | 800            | 840    | 850 | 840 | 830 | 820 |
| Cetane number                | 57                   | 35             | 55     | 46  | 43  | 41  | 39  |
| Fire point (O°C)             | 160                  | 50             | 74     | 120 | 100 | 85  | 70  |

1.2. Experimental setup

The tests were performed on a four-stroke single cylinder, direct injection, water cooled engine which has 5.2 kW as rated power output at constant speed of 1500 rpm. It is coupled with an Eddy current dynamometer for applying brake load. The signals from pressure, load and temperature sensors are
sent to control panel’s board then connected to a personal computer. The AVL 5 gas analyzer was enclosed with the set up to record exhaust the gas emissions for measuring the NOx, CO2, HC, and CO emissions present in the exhaust gas. Schematic diagram of engine setup diagram shown Figure 1. Engine Technical specifications are shown in Table 2. The specifications for the Exhaust gas analyzer have been given in Table 3.

![Figure 1. Schematic diagram.](image)

### Table 2. Engine specifications.

| Feature     | Description                             |
|-------------|-----------------------------------------|
| Model       | TV1, 5.2 kw @ 1500 rpm                 |
| Engine type | single four stroke diesel engine        |
| Cylinders   | Compression ignition, 4S                |
|             | Single                                  |

### Table 3. Exhaust gas analyzer specifications.

| Gas emitted in Exhaust | Range of Measurement | Resolutions               |
|------------------------|----------------------|---------------------------|
| CO                     | 0 to 10% of volume   | 0.01 % of volume          |
| HC                     | 0 to 20000 ppm       | <2000:1 ppm volume        |
| CO2                    | 0 to 20% of vol      | 0.1 % of vol              |
| Nox                    | 0 to 5000 ppm        | 1 ppm vol                 |

2. Performance Characteristics

2.1. Brake thermal efficiency

The brake thermal efficiency variation with load is shown in Figure 2. The brake thermal efficiency is having increasing effect with respect to the increasing load and percentage of cotton seed ester in blend. This is because of the low viscosity and high calorific value of the T80 blend. The maximum brake thermal efficiency recorded was 27% for T80 blend, and the least of 23.98% for T60 blend at 210 bar pressure. The diesel fuel operation had the maximum efficiency of 29.44 % for same pressure at 75% load.
2.2. Brake Specific Fuel Consumption

As shown in Figure 3, the performance characteristics of specific fuel consumption has more decreasing trends at 75% load conditions. It is due to high calorific value of the blend, the specific fuel consumption, recorded its lowest value of 0.32 Kg/KWhr for T80 and T50 blends and 0.33 Kg/KWhr, 0.36 Kg/KWhr for T70 and T60 blends respectively, at 210 bar at same load conditions. The brake specific fuel consumption of diesel operation consumes a minimum of 0.3 Kg/KWhr at 210 bar injector opening pressure.

3. Emission characteristics

3.1. Hydrocarbon Emission

Figure 4 shows the distinction of hydrocarbon emission for various blends with different load. The blend showing the maximum HC emission is T50 blend at 190 bar of injection pressure suggesting that it is undergoing the maximum amount of incomplete combustion. The lowest emission of HC at full load is seen in the T50 blend at 230 bar injection pressure where there is less amount of complete combustion followed by T60 blend at 190 bar injection pressure. Generally, hydrocarbon emissions increase with increase in incomplete combustion of the fuel. However, at injection pressure 230 bar the hydrocarbon emission is lower than other pressures. This is because of the better atomization of fuel droplets.
3.2. Carbon monoxide Emission

Thus, the Figure 5 shows an increasing trend after the 75% load of the total load. The highest emission of carbon monoxide occurs at 100% load for T60 blend at 210 bar followed by the blend T80 at 210 bar. The lowest carbon monoxide emission was observed for the T50 blend at 190 bar injector opening pressure. Generally, at peak load conditions because of less amount of oxygen is available for combustion, incomplete combustion result in high carbon monoxide emission.

3.3. Carbon Dioxide Emission

The variation of carbon dioxide emissions with respect to load for various blends and injector opening pressures is shown in Figure 6. The carbon dioxide emission at peak load reduced, when compared to 75% of load for blends and injector opening pressures. This is due to lower air fuel ratio at peak load. T60 blend at 210 bar gives the lowest carbon dioxide value when compared with all blends at full load.
3.4. NOx Emission.

The variation of NOx emission with load for all blends and injection opening pressures is shown in Figure 7. At peak load due to reduction in combustion the in-cylinder temperature should be lower [6]. Hence the NOx emission is reduced when compared to 75 % of load. This can be correlated to lower brake thermal efficiency at full load. The NOx emissions for all the blends at all injector opening pressures are lower than diesel fuel operation emissions. The minimum NOx emissions for diesel fuel operations 776 ppm at 230 bar injector opening pressure. Maximum NOx emission among the blends is 667 ppm for T50 at 190 bar.

3.5. SMOKE

The smoke emissions for all blends and injector opening pressures are highest at full load operation. As the fuel injected peaks at full load operation, the smoke emission reaches the highest value. The highest emission of smoke87.5% opacity occurs at 100% load for T60 blend at 230 bar. The highest smoke emission for diesel fuel operation 58.4 % opacity at 100% load at 230 bar injector opening pressure.
4. Conclusions
In the current work the cotton seed ester is mixed in various volumes with turpentine oil and 4 blends are made. The engine is operated with three fuel injection opening pressures. The characteristics of performance and emission are studied with the diesel fuel operations and is compared at same pressures. The following inferences are obtained.
- For T80 blend with 210 bar at 75% of the total load condition, the maximum brake thermal efficiency was recorded as 27% and the lowest value of specific fuel consumption was recorded as 0.32Kg/KWh next highest value compared with diesel.
- Emission of Nox and carbon dioxide value for 667 ppm for T50 at 190 bar injector opening pressure and T60 blend at 210 bar gives the lowest carbon dioxide value when compared with all blends at full load.
- T80 blend at 210 bar injection pressure is found to be most suitable blend among all blends tested. However, CO, HC emissions are higher than diesel. The long-term engine tests are required to assess the engine deposits that may arise due to the high viscous biofuels.

5. References
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