Experimental investigation of performance and emission characteristics of CI engine fuelled with pine oil and cotton seed oil

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Abstract. Increase in energy demand, stringent emission norms and depletion of oil resources has led to find alternative fuels that are compatible with internal combustion engines. This paper presents the study of performance and emission characteristics of CI engine fuelled with pine oil and cotton seed oil blended in the blending ratio 70:30, 50:50 and 30:70 respectively. The experiment was carried out in four stroke single cylinder diesel engine by varying the load from 0% to 80%. The result shows the blend of cotton oil and pine oil used as a fuel has increased the brake thermal efficiency with reduction in exhaust gas temperature and specific fuel consumption. By using different blends, it shows the reduction in emission parameters such as CO, CO₂, NOₓ and smoke and yields satisfactory results.

1. Introduction
The most important element which affects the world economy is the sustainability of petroleum resources. The fossil fuels are used as energy resource for many years however the usage is unsustainable and creates environmental issues [1]. The energy demand in world is increasing rapidly because of increase in the usage of petroleum based fuels and also due to limited resources and instabilities of petroleum based fuel supplier countries. Country that depends on fossil fuels for energy requirement faces depletion of fossil fuel stocks, higher price of fossil fuels due to higher demands and further it contributes to greenhouse gases formation [2]. Nowadays, many countries renewable energy system is replacing the conventional energy systems such as solar power, geo thermal, fuel cells, bio fuel, wind power and ocean power [3]. With an increase in environment constrains and price of petrol and diesel leads to search of alternative for the existing fuels. The alternative fuels are not only needs to be sustainable but also friendly with respect to environment and should be economical. The internal combustion engines such as petrol engine and diesel engine emits gases from exhaust which contributes to greenhouse effect and around 22% of global greenhouse gases emission comes from automobile sector [4]. According to the report of International Energy Agency between 1990 and 2020, carbon dioxide emissions will increase up to 92% and will amount to 8.6 billion metric tons of CO₂ will release into the atmosphere [5]. Further it was reported that it will lead to the rise in global temperature to 2 ° C [6]. Bio fuel is one of the options to contribute in renewable energy production and is the solution
of difficulties related to energy faced by countries. This new source of energy has a potential that can help in reducing the dependency on petroleum fuels. Biofuels are generally produced from edible and non edible crops such as cottonseed, palm nut, groundnut, jatropha curcas, animal fats, algae, etc. Import of petroleum based fuels is reduced when biofuel is used and additionally it will provide employment in rural areas where agriculture is the leading activity. Biofuels are directly used in engine to bring the relevant properties closer to petroleum based fuel without any modification in engine design. Gasoline engines have higher emissions of CO and unburned hydrocarbon as compared to IC engines. Dr. Rudolf Diesel is known to be the father of diesel engine and he introduced diesel engine in 1895 and run with variety of oils including vegetable oil. Due to the cost of vegetable oil, it is difficult to commercialize the product. The vegetable oil has 10% lesser calorific value than diesel. The main problem of using vegetable oil is due to its chemical properties like high viscosity and low volatility compared to petroleum and due to these properties it leads to severe injector choking, carbon deposits and piston ring jabbing but if it is blended with other fuels, the outcome is different. In this paper, blends of cotton seed oil and pine oil are made in different proportions and fuelled in CI engine to obtain the desired results.

2. Methods and methodology

The experiment was carried out in four stroke single cylinder diesel engine by varying the load from 0% to 80%, this range of load is kept due to the guarded working capacity of engine. Three blends of pine oil and cotton seed oil were prepared in three different proportions as 70:30, 50:50 and 30:70 respectively. The high viscosity of vegetable oil can be reduced by transesterification, mixing with diesel, micro emulsion, making blends with other fuel. The performance of engine with blended fuel was compared with diesel fuelled engine at different loads. Performance and emission results were obtained and compared with each blend to get better results. The engine specification is shown in given table 1.

| Table 1. Engine configuration data. |
|-----------------------------------|
| Manufacturer                       | Kirloskar            |
| Number of cylinders                | 1                    |
| Number of strokes                  | 4                    |
| Rated Power                        | 7HP (5.2kW) @ 1500 rpm |
| Type of Dynamometer                | Eddy current dynamometer |
| Dynamometer arm length             | 185 mm               |
| Cylinder diameter                  | 87.5 mm              |
| Stroke length                      | 110 mm               |
| Compression ratio                  | 17.5 : 1             |
| Orifice diameter                   | 20 mm                |
| Coefficient of discharge           | 0.6                  |
| Manometer liquid                   | water                |

3. Properties

Property tests have been done for all three blends and for pure oil as well. All the parameters are then compared with diesel.
3.1. Density

**Table 2.** Density of oil at different temperature.

| Oil          | At 30 °C | At 40 °C | At 50 °C |
|--------------|----------|----------|----------|
| Pine oil     | 0.846    | 0.840    | 0.834    |
| Cotton oil   | 0.898    | 0.892    | 0.886    |
| Blend 1      | 0.789    | 0.783    | 0.778    |
| Blend 2      | 0.779    | 0.774    | 0.769    |
| Blend 3      | 0.816    | 0.811    | 0.805    |

From the above table 2, it is found that in pure pine oil was less dense than pure cotton oil and due to the highly dense nature of cotton oil it makes the blend denser in which it is present in higher proportion that is blend 3. Among all three blends, blend 2 is least dense followed by blend 1 and blend 3 respectively.

3.2. Viscosity

**Table 3.** Viscosity of oils at different temperature.

| Oil          | At 30 °C | At 40 °C | At 50 °C | Viscosity        |
|--------------|----------|----------|----------|------------------|
| Pine oil     | 1.47     | 0.97     | 0.81     | Kinematic ( centistokes) |
|              | 1.24     | 0.81     | 0.80     | Dynamic (centipoise) |
| Cotton oil   | 38.83    | 37.54    | 26.86    | Kinematic (centistokes) |
|              | 34.86    | 33.4     | 23.79    | Dynamic (centipoise) |
| Blend 1      | 8.4      | 6.63     | 4.74     | Kinematic (centistokes) |
|              | 6.56     | 5.13     | 3.64     | Dynamic (centipoise) |
| Blend 2      | 8.43     | 6.81     | 5.91     | Kinematic (centistokes) |
|              | 6.70     | 6.69     | 4.46     | Dynamic (centipoise) |
| Blend 3      | 20.8     | 13.16    | 10.95    | Kinematic (centistokes) |
|              | 16.97    | 10.67    | 8.81     | Dynamic (centipoise) |

From the above table 3 it is concluded that cotton seed oil is highly viscous in nature than pine oil. Due to this reason, the viscosity of blend in which the proportion of cotton seed oil is higher is highly viscous. Among all three blends, blend 1 is least viscous due to high proportion of pine oil present in it.
3.3. Flash point and fire point

Table 4. Flash point and fire point of oils.

| Oil            | Flash point °C | Fire point °C |
|----------------|----------------|--------------|
| Pine oil       | 49             | 54           |
| Cotton seed oil| 220            | 340          |
| Blend 1        | 56             | 60           |
| Blend 2        | 56             | 68           |
| Blend 3        | 95             | 73           |

The above table shows the flash point and fire point of pure oils and different blends. It is concluded that due to higher density of cotton seed oil, the blends in which it has higher proportion shows large values of flash point and fire point. Blend got least values because of low density of pine oil as it has higher proportion in blend 1.

4. Results and analysis

The performance test and emission test of three blends is conducted in a single cylinder diesel engine and the results are compared with performance of diesel. The engine performance is often characterized by the engine operating behavior in load speed domain like, mechanical loading, thermal loading, noise, specific fuel consumption and emissions. Graphical result shows the deviation in performance and emission test of different blends compared to diesel.

Figure 1. Indicated power vs. load.

From the above figure, it is shown that the relation between indicated power and load is linear, on increasing the load indicated power increases. It is concluded that diesel has got much higher indicated power as compared to all blends. Among three blends, blend 2 has got higher IP value.
than blend 1 and blend 3 respectively. Hence, blend 2 leads to higher power developed by combustion of fuel in combustion chamber.

Figure 2. Brake power vs. Load.

Given figure shows the linear relationship between brake power and load. On increasing the load, brake power increases. Diesel has got highest BP value among all blends. Blend 2 has got higher BP value when compared to other blends. There is very small difference in brake power value among all blends due to the properties of oil and blends. But Diesel has got higher brake power followed by blend 2, blend 3 and blend 1 respectively.

Figure 3. mechanical efficiency vs. load.
Given figure shows the relation between mechanical efficiency and load. As seen in above figures, here the relation between load and mechanical efficiency is not linear. Blend 3 has got higher followed by diesel, blend 1 and blend 2 respectively. For other blends and diesel on increasing the load, mechanical efficiency is increasing but for blend 3, it attains a maximum value on increasing the load and then gets constant. Hence higher proportion of cotton seed oil leads to have better mechanical efficiency.

![Carbon monoxide Vs Load](image)

**Figure 4.** Carbon monoxide vs. load.

Given figure shows the relation between load and carbon monoxide expelled in exhaust of an engine. The geometry of curves obtained is non linear. On increasing the load, the CO value first decreases up to specific load value then it starts to increase. Blend 3 has lower CO emission at higher loads followed by diesel, blend 1 and blend 2 respectively. Higher proportion of cotton seed oil present in blend 3 shows better CO emission than diesel.

![Carbon dioxide Vs Load](image)

**Figure 5.** Carbon dioxide vs. load.
Given figure shows, variation in carbon dioxide emission in exhaust on increasing the load. The curve shows little up and down in carbon dioxide value on increasing load. Blend 1 has got lowest carbon dioxide emission value compared to diesel, blend 2 and blend 3 respectively. It can be concluded that higher proportion of pine oil in a blend will have lower carbon dioxide emission.

Figure 6. Nitrogen oxides vs. load.

Figure shows relation between load and nitrogen oxides. On increasing load, NO$_x$ emission increases. Diesel has got lowest NO$_x$ emission while increasing the load and among all three blends, blend 3 shows lower NO$_x$ emission value followed by blend 1 and blend 2 respectively. It can be concluded that higher proportion of cotton seed oil in a blend leads to lower NO$_x$ emission at higher load.

Figure 7. smoke vs. load.
Given figure shows relation between smoke and load. On increasing the load, smoke increases. For blends, the curve is not linear but for diesel, it shows linearity in smoke and load. Diesel has got highest value of smoke at same loads as of blends. Blend 3 has got lower value of smoke emission at higher loads followed by blend 1, blend 2 and diesel. Hence it can be concluded that the blend having higher proportion of cotton seed oil has lower smoke emission at higher load.

5. Conclusion

1. In this paper, the performance test and emission test of three different blends of pine oil and cotton seed oil is compared against diesel under same conditions.
2. In property tests, clear differences were observed based on the nature of oils. 2. Cotton seed oil due to highly dense and viscous nature got higher viscosity, density flash point and fire point compared to pine oil.
3. Nearly same results are obtained in blends, blend 3 having higher proportion of cotton seed oil shows high value of flash point and fire point, density and viscosity. Blend 2 had a balanced proportion of pine oil and cotton seed oil and has shown a better result.
4. In terms of performance, diesel has shown best results among all but among three blends, blend 2 has shown better results that means balanced proportion of pine oil and cotton seed oil has better performance results followed by blend 1 and blend 3 respectively.
5. In emission test, blend 3 has outperformed diesel under similar conditions. At higher loads, blend 3 has lower carbon monoxide emission, smoke emission and nitrogen oxides emission. Over all in emission test blend 3 has shown better results followed by diesel, blend 2 and blend1. This blend has shown good results as compared to diesel without making any modifications in engine design.
6. The results can be made better by making more number of blends and introducing additives to yield good overall performance.

6. Reference

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