Performance and emission characteristics of CI engine fuelled with turpentine oil-diesel blend with diethyl ether as additives

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Abstract. The ingestion of fossil fuels such as diesel has augmented immeasurably with transformation and increase in the use of automobiles [1]. Biodiesel derived from renewable resources such as non-edible vegetable oil is used as a substitute for the conventional diesel fuel. Amplified demand for energy, abridged emission standards and diminution of resources which cannot be renewed claimed in discovering of alternative and non-conventional fuels for IC engines [2]. In the subsequent paper, the performance, radiation and characteristics of emission in CI engines powered with turpentine oil. The DEE inclusion has tolerable chattels on the performance characteristics of the fuel, augmented brake thermal efficiency is conquered by the intensification in the extent of DEE and thus consuming the divergent effect on the specific fuel ingesting. The experiment was supported in a 4-stroke, diesel engine of single cylinder by fluctuating the load. Adding Turpentine Oil in diesel raises the aggregate of density, viscosity and level of oxygen content present in it, but diminishes its calorific value [2]. Liberation arches depict the same physiognomies as tallying of Turpentine oil which reduces the amount of CO, CO₂, NOₓ and O₂ upsurge to quantity of these HC.

1. Introduction
One of the major reasons for global warming is air pollution caused by vehicles [3]. Combustion of fossil fuels such as diesels emit carbon dioxide (CO₂), nitrogen dioxide (NO₂), and carbon monoxide (CO) contribute to the increase in the amount of greenhouse gases produced. Heat is trapped in the atmosphere due to the presence of these greenhouse gases and this leads to the increase in global temperature. The only way to reduce these pollutants is to reduce the toxic exhaust emissions [4]. Moreover, there is a high depletion rate in fossil fuels, therefore there should be an alternate fuel source. These can be bio-fuels which can be taken from vegetable oil or animal fat [4]. Crude oil is not available in every country, so instead of consuming crude oil which has to imported, it is effective to use bio-fuels which are readily available in most countries. This could also secure our economy. Therefore there is a need for alternate fuels which are renewable, cleaner and pollution free. Using bio-fuels reduce the emission on unburnt hydrocarbons (HC), carbon dioxide (CO₂), nitrogen dioxide (NO₂), carbon monoxide (CO) [5].Turpentine Oil has characteristics similar to that of Diesel. The chemical formula for turpentine oil is C₁₀H₁₆ [5]. Turpentine oil is derived from the resins present in pine trees. There are various methods to collect these resins, some of the most common methods are Borehole Method and
Bark Chipping Method. Turpentine oil is colourless, odourless, water-immiscible and flammable. Calorific value of turpentine oil is 44.4 MJ/Kg whereas for Diesel it is 42.5 MJ/Kg [6].

The kinematic viscosity of turpentine oil is 2.4 cST which is less compared to the other bio-fuels. So it could be used as alternative for Diesel. The resources from which turpentine oil is derived are from the resins which are tapped from the pine trees. Pine trees are present in Jammu and Kashmir, Punjab, Himachal Pradesh, Margalla Hills and Sikkim. As all these resources are present within India, there is no need to import expensive fuel and depend on certain countries [7]. DEE stands for di-ethyl-ether, whose chemical formula is C₄H₁₀O and its calorific value is 33900 MJ/Kg. The molecular weight of diethyl-ether is 76. It has a kinematic viscosity of 0.23 (less viscous compared to turpentine oil). It can be used as an additive in fuel mixture in order to increase certain parameters present in the exhaust emission and performance. It has properties similar to that of Ethanol and it can be used in compression ignition engines as additives. Various compositions of the fuel mixture has been taken and then experimented in order to check for the efficiency, performance and exhaust emission of the diesel engine and their respective performance and emission graphs have been plotted according to the observed readings. By performing this experiment we can have a knowledge on the composition of the fuel mixtures for efficient combustion, more efficiency, specific fuel consumption and the overall performance of the diesel engine [8].

2. Methodology
The experiment was carried out in a single cylinder 4 stroke Diesel Engine with a power of 5.2 KW at 1500rpm that is coupled to eddy current and a dynamometer as in figure 1. Load sensor, Crank angle sensor, in-cylinder pressure and temperature sensors were used. These signal values were interfaced and computed.

| Description     | Diesel | Turpentine Oil | DEE  |
|-----------------|--------|----------------|------|
| Density (kg/m³) | 830    | 900            | 713  |
| Calorific value (MJ/kg) | 42.5 | 44.4          | 33,900 |
| Kinematic Viscosity (cST at 40°C) | 4.59 | 2.4           | 0.23  |
| Chemical Formula | C₁₂H₂₄ | C₁₂H₂₀O₇       | C₄H₁₀O |
| Molecular weight | 168    | 276            | 76   |
| Air fuel ratio  | 14.9   | -              | 11.2 |
| C (% by wt)     | 86     | 52             | 63%  |
| H (% by wt)     | 14     | 7              | 13   |
| O (% by wt)     | 0      | 40             | 21.6 |
| C/H ratio       | 0.52   | 0.6            | 0.4  |
| Cetane Number   | 48     | 38             | >125 |
| Heat of evaporation (kJ/kg) | 230 | 285          | 355  |
The engine is first run with diesel for 10-15 minutes and then the engine is run with the blends mentioned below. The engine was run at a constant speed of 1500rpm to measure parameters such as IMEP, BMEP, BTE, SFC. Exhaust gas analyser and smoke meter were used to measure exhaust emission parameters. The following are the composition and blends of fuels used in this experiment:

a) Diesel
b) Turpentine oil
c) B10 - 90% Diesel (900ml) + 10% Turpentine oil (100 ml)
d) B20 - 80% Diesel (800ml) + 20% Turpentine oil (200 ml)
e) B30 - 70% Diesel (700ml) + 30% Turpentine oil (300 ml)
f) B40 - 60% Diesel (600ml) + 40% Turpentine oil (400 ml)
g) B10+5DEE - (850ml Diesel + 100ml Turpentine oil) + 50ml + 50ml DEE (1 litre)
h) B20+5DEE - (750ml Diesel + 200ml Turpentine oil) - 50ml + 50ml DEE (1 litre)
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i) B30+5DEE - (650ml Diesel + 300ml Turpentine oil) – 50ml + 50ml DEE (1 litre)
j) B40+5DEE - (550ml Diesel + 400ml Turpentine oil) – 50ml + 50ml DEE (1 litre)

3. Results and discussion
The probability of consuming an alternate fuel for CI engines has been established and demonstrated by means of the blend of turpentine oil and DEE as additives and essences. The experiment result and outcome demonstrated that the Turpentine oil, along with DEE can be used as stabilizer and the blend of turpentine oil and DEE achieved well.

3.1. Brake Thermal efficiency

![Figure 4. BTE Vs BP.](image)

![Figure 5. BSFC Vs BP.](image)

The graph depicts the variation of the BTE and Brake Power (BP) in kW for a constant speed. Brake thermal efficiency was a function of brake power and the fuel energy supplied (heat input) to the engine. As per the BTE formula, the efficiency is inversely proportional to the CV. Figure shows that the value BTE increases as BP increases. BTE of Turpentine oil blends show higher values than diesel and it further increases with the increment in the amount of DEE. B40 5%DEE yields greater Brake Thermal Efficiency than diesel.

The BSFC was mainly dependent on the BTE, density of the fuel and calorific value of the fuel. Increasing the BSFC leads to poor performance of the Diesel engine. Increasing the DEE in the blend reduces the BSFC because of the lower calorific value and low density of the fuel DEE. The higher calorific value of the turpentine oil leads to lower BSFC for blended fuel. Addition of the DEE to turpentine blended fuel reduces the viscosity and density of the blended fuel and act as the justification for the lower BSFC for the blended fuel.
3.2. Carbon Dioxide

Figure 6. CO$_2$ Vs Load.

The graph demonstrates the deviation of the carbon dioxide regarding load acting upon the engine. The annexation of the turpentine fuel leads to dropping the carbon dioxide in the engine, addition of the DEE in the blended fuel intensification of the carbon dioxide in the engine exhaust because of the minor density and viscosity of the DEE. The CO$_2$ values for fewer loads are less as the due to higher values of A/F and the fuel as an outcome of a smaller amount CO$_2$ and at advanced loads the A/F is lower thus as the A/F are nearer to the ratio of stoichiometry have formation of extra soot[9]. Thus the effects on the basis of average values can be determined and it displays that the reduction in the extent of CO$_2$ upsurges the quantity of Turpentine oil in the blend and it is also reciprocated in the addition of DEE, consequently by diminishing the amount of CO$_2$ in the exhaust.

3.3. Carbon Monoxide

Figure 7. CO Vs Load.

The Graph depicts the estimates of the emission of CO in % volume in y-axis with the load in x-axis with constant rpm. At lower loads, the combustion process is incomplete because of the very lean content of the mixture and thus at greater values of CO and A/F ratio is less at higher loads, so this forms soot[9]. CO number in exhaust gas are comparatively satisfactory in 10% & 20% blends of turpentine oil when analysed with diesel fuel.
3.4. Hydro Carbon

The overhead epitomized figure illustrates the HC diagram in standings of ppm hex contrived in contradiction of the consignment. The graphic representations here are random and haphazard and an explicit trend is not rendered with reverence to the DEE accumulation. As it could be seen from the chart that DEE blends of B40+5% have standards which are more advanced than that of HC when it is associated with the remaining blends whereas diesel among the assortment of B10 blends. By adding TURPENTINE oil we can see that the values of HC are increasing which is a feature to the sophisticated extent of viscosities leading to atomization to be compacted hence consequential in HC values to be outsized for the B30 blends. Primary cause for greater values of HC is the high viscosity of these blends which precludes fraternisation of air and the fuel which takes prolonged period and quenching using flame transpires as viscosity is elevated means that the atomization is meagre and these are residue of the unburnt.

3.5. Nitrogen oxide

The graph represented depicts the features of the curve of NOx that increases with the increase in load and hence the temperature in the cylinder upsurges this yields more NOx. But the value of NOx reduces at higher loads. [10]. As inclusion of DEE increases, the oxygen content for combustion
increases. The viscosity of the fuel is increased as well. This leads to increase in cylinder temperature and pressure and thus this increases the emission of NOx.

4. Conclusion

From the above elucidated experiment arrangement and operation it can be determined that the addition of turpentine oil plus the DEE additives have given away an enormous incredible improvement in the reduction of unburnt HC, CO, CO2. This would brand the fuel to be considerably cleaner. It is also eminent that the BSFC drops with the upsurge in concentration of turpentine oil and 5% DEE and the Brake Thermal Efficiency is augmented as the blend of turpentine and DEE additives concentration intensify. Overall this experiment has been recognized to be more effective and successful.

5. References

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