Experimental investigation of effect of CI-engine fuelled with camphor-oil diesel blend with additive of DTE (Diethyl-Ether)

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Abstract. A Test Rig consisting of Combustion Ignition engine fuelled with camphor oil blended in the ratio B50 with 5% and 10% DTE (Diethyl ether) is guided for varying loads in the range of 0%, 25%, 50%, 75% and 100%. The result illustrates that increase in concentration camphor oil increases the Brake thermal efficiency with lower values of Brake specific fuel consumption. Also better emissions were recorded with notable decrease in parameters such as CO, HC and increase in the CO2. The introduction of DTE in the blended fuel has been tested and obtained comparable results to that of addition of pure camphor oil in varying proportions, with increases in brake thermal efficiency and limiting in specific fuel consumption values, the effect on the emission characteristics by addition of DTE results in a lower CO, HC, NOX and Smoke with an increase in the CO2. The effective mixing of camphor oil and DTE yield satisfactory result on the performance characteristics at lower load as well as in higher loads.

1. Introduction
In the era of Electrical mobility the IC engines find its place in a dark space. The generation transmission and distribution of the electrical energy has always been a problem. The diesel engines comes into the picture again but with the better efficiency and with an approach of alternative fuels. The depleting fossil fuels give a considerable reason for the use of biodiesel and aims to produce less emission. An effort was made by Krzysztof Goeski et al [1] with diesel blended with ETBE in volumetric proportions of 5%,10%, 20%,30% and 40% .Ethyl-tert-butyl ether (ETBE) is obtained from synthesis of isobutene and ethanol. It been reported that the increase in ETBE concentration in the fuel helps in lower smoke emissions with increasing EGR. It has been observed that if the percentage of ETBE is higher leads to misfires at higher EGR rate and higher NOx production is claimed. The results claims that the use of small amount of EBTE with diesel is have reported a significant decrease in emission of particulate matter and smoke emission. The results and properties of EBTE has also reported the decrease in Cetane number as volumetric proportion of the EBTE has increased.

K. Nanthagopala , B. Ashok et al [2] examined with Calophyllum Inophyllum and diethyl ether as additive in the fuel and reported that brake thermal efficiency is reduced by 5.3% as compared to diesel with significant lower emissions . S. Srihari et.al [3] studied Vegetable oil which is always a constant source for fuels, the use of low viscous oil hinder the flow properties and leads to incomplete combustion, Hence the use of less viscous fuel were the major interest of the researchers. The use of
camphor oil leads to such experiments, adding to its chemical behaviour camphor oil is high volatile and burns readily. The researchers have illustrated, a similar progress is made by use of Cashew nutshell oil with camphor oil blend in DI engine. G. Kasiraman et.al [4] proposed that the use of low viscous oil with highly viscous oil leads to complete and faster combustion. It was concluded that 30% blend of camphor oil and Cashew nutshell oil gives the desirable results when compared to diesel in terms of lesser smoke emission of 3.91 Bosch smoke units.

2. Methodology
Four stroke DI diesel engine (kirloskar) engaged with an eddy current dynamometer is availed in the experiment with a preset value of 1500 rpm. The test was conducted for 5 loads 0kg, 4.1kg, 9.1kg and 18.5kg sequentially. Refer table 1 for engine specification. The engine is equipped with various pressure, temperature, crank angle sensors for continuous and sequential operation. To measure the crank angle displacement dynamometer is feed with crank angle sensor (by Kubler-germany) with the range of 360°. Load (by Sensotronics Sanmar Ltd) and speed sensor is attached to the dynamometer with a upper limit of 50 kg and 100Hz respectively.(Refer Table 1). The engine inlet and outlet consist of temperature sensor to give data for exhaust gas temperature, the temperature sensor is the K type thermocouple and assisted with the pressure sensor which is piezo type (by PCB Piezotronics ) with the max pressure of 5000 psi. The Figure 1 shows the engine layout.

Table 1. Engine Specification.

| ENGINE AND SET UP DETAILS | 
|----------------------------|
| Engine power | 5.2 kW @ 12.5 cycles/sec |
| Connecting rod length - Cylinder bore - Stroke length | 234 mm x 87.5 mm x 110 mm |
| Type of Dynamometer | Eddy current |
| Temperature of Exhaust gas (EGT) | Range : 0-1200 °C |
| Transmitter for air flow | Range : (-) 250 – 0 mm WC |
| Transmitter for fuel flow | Range : 0-500 mm WC |

The emission data were computed and analysed with help of an AVL DiGas 444 analyser which gives the emission analysis of five gases namely oxides of carbon and nitrogen , unburnt hydrocarbon. The Accuracy of the AVL DiGas 444 Analyser is Mentioned in Table 2.The engine is initially cranked for 15 Minutes fuelled with the Diesel and then followed by Blends. The Blends so performed are B50, B50+5% and B50+10%. With a Constant reading over the speedometer the engine was tested with different loading conditions i.e. 0kg, 4.5kg, 9.1kg, 13.6kg and 18.1kg.
3. Result and Discussion

3.1 Performance Characteristics

3.1.1 Brake Thermal Efficiency. The plot shows the BTE and load where brake thermal efficiency is in Y axis and load in X axis computing percentage of heat from fuel to mechanical energy [5]. It can be concluded that BTE varies with density and calorific value i.e it decreases with increase in density and calorific value at constant time. So with the introduction of Diethyl Ether density decreases thermal efficiency then B50. As constrain maximum of 10% by vol of DTE can only be used because

**Table 2. Properties of Fuel.**

| Blend         | Calorific value (MJ/kg) | Density (kg/m³) | Viscosity (centistoke) |
|---------------|--------------------------|-----------------|------------------------|
| DIESEL       | 42.50                    | 840             | 4.59                   |
| B50          | 40.35                    | 872             | 4.68                   |
| B50 DTE 5%   | 40.02                    | 864.14          | 6.99                   |
| B50 DTE 10%  | 39.70                    | 856.10          | 7.83                   |
| Camphor Oil  | 38.20                    | 894.14          | 1.9                    |

**Figure 1.** Engine Layout.
of less viscosity. Further Blends with camphor oil showed more BTE values than Diesel because of oxygenated molecules which results in complete combustion (Refer Figure 2).

![Figure 2](image.png)

**Figure 2**: BTE Vs Load.

### 3.1.2. Brake Specific Fuel consumption

![Figure 3](image.png)

**Figure 3**: BSFC Vs Load.

The plot shows variations of load against BSFC. BSFC is inversely proportional to BTE and directly proportional to the calorific value. Further due to addition of Oxygenates the calorific value decreases hence leads to higher BSFC [6]. Hence highest BSFC is recorded with B50 10% DTE, which has a significant value than diesel at lower loading conditions. The graph has the higher BSFC for diesel at higher load and the least value of BSFC is for blend B50 10% at high load.
3.2 Emission Characteristics

3.2.1. Carbon dioxide. The plot shows the trends in emission of CO₂ and concluded that B50+5% at higher loads tops the curve which signifies proper combustion of fuel [7]. The graph gives a least value of Carbon di oxide at lower loads due to the less fuel to burnt in the air because of higher oxygen content and less fuel injection. Further improper combustion take place properly at low loads due to low temperature of cylinder. The blends show more CO₂ formation than diesel because of oxygen content which reacts with carbon to form CO₂

![Figure 4: CO₂ Vs Load.](image)

3.2.2. Carbon Monoxide (CO). The figure 5 shows the variation of the carbon mono oxides with respect to load. Diesel has the higher carbon mono oxides at high load because of the lower oxygen content induced for combustions [8]. Addition of the DTE to the camphor diesel blend leads to complex chemical combination results in higher Carbon mono oxide emissions.

![Figure 5: CO Vs Load.](image)
3.2.3. Hydrocarbon (HC) Emissions. The graph shows the load v/s HC emission (in %vol) which gives a notable decrease in HC for all the camphor and DTE blends with respect to the pure diesel. It’s been noted from the graph that B50+5% blend has higher values of HC among the camphor oil blends. The main cause for the unburnt hydrocarbon Emissions is the high viscosity leads to obstruct the mixing process i.e uniform air fuel mixture is not obtained leads to flame quenching and poor atomization. Higher HC emission can also be a characteristic feature for lower cetane number as lower value of cetane number results in spun-out ignition delay which leads to formation of unburnt carbon particles. (Refer Figure 6)

![Figure 6. HC Vs Load.](image)

3.2.4. Oxides of Nitrogen (NOx). The figure 7 gives the perfect typical characteristics of NOx emissions. The formation of NO happens when the temperature is high enough to break the nitrogen in air to free radicals which are very reactive and form NOx with oxygen present in air, further graph shows B50 has the highest NOx emission and diesel has lowest at higher loads. At higher loads the NOx value increases as a result of higher cylinder temperatures. Addition of DTE at 10% increases the oxides of Nitrogen because of the enhancement of oxygen quantity.

![Figure 7. NOx Vs Load.](image)

3.2.5. Smoke Emissions. The plot is the measures of opacity of the smoke V/s load(kg). As we can see that on increasing the load the smoke value increases for all the blends. Soot emission from diesel engine are shown by smoke emission. All the factors affecting soot formation and oxidation results in smoke formation. Smoke formation increases due to higher fuel air ratio equivalence and less oxygen
concentration. B50+5% shows the lowest value and B50 shows the highest value of smoke (Refer Figure 8).

![Figure 8. Smoke vs Load.](image)

4. Conclusion
B50, B50+5% and B50+10% Volume based composition is made of camphor oil, Diesel and Diethyl ether (DTE) as additive were tested and following observation were made:

1. A shoot in BTE of the fuel is observed on increasing the concentration of camphor Oil and DTE, further BSFC is spotted to be lower as DTE have lower Calorific Value.
2. A weighty reduction in HC and CO is observed because of more content of oxygen and lower air Fuel mixture at higher loading condition. Further decrease in CO and HC emission is reported with increase concentration of DTE as additive. Comparing with the blends it clearly shows that the addition of DTE to the blend reduces the NOX considerably also.
3. The blends showed more CO\textsubscript{2} formation than diesel because of oxygen content which reacts with carbon to form CO\textsubscript{2}.
4. Smoke formation increases on increasing the load due to higher fuel air ratio equivalence and less oxygen concentration. B50+5% shows the lowest value and B50 shows the highest value of smoke.

It has been observed, out of the multiple blend proportions tried, the optimum result achieved on B50+10% considering performance and emission point of view.

5. References
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