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# Experimental Investigations on a Diesel Engine Fueled with Biodiesel Blends and Diethyl Ether as an Additive

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***ABSTRACT***
*Blends of bio-diesel (or diesel) are fueled for engines (diesel) though direct injection by a single cylinder at various (or multiple) propagations. The determination of the emissive power and the performance of the engine is done. The emission of the NOx is considerably high when compared to the diesel fuel operation (considering all the blends). Blends are added with the diethyl-ether at various proportions. Reduction of NOx emission at the low and medium loads is observed due to the addition of diethyl-ether with the blends. But at higher loads it cannot be altered, and NOx is high in comparison with the fuel and is observed to be low when comparison is done with the bio-diesel blends. Further reduction of NOx along with the emission of smoke is observed when diethyl-ether is added to the blends of bio-diesel.*

**Keywords :** bio-diesel, diethyl-ether, emission, $NO_x$

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## INTRODUCTION

The research in the alternative resources and renewable resources is put forth due to the thought of decreasing of the environmental pollution and also the steady increase in the consumption of energy in our day to day life. Opting for the alternative fuel resources according to their region and availability is done in developing various new materials that are useful and methods to implement is carried out by many countries of the world. In this research, we implement the outcome of di-ethyl-ether addition to the blends of bio-diesel. De-hydration of bio-ethanol, a renewable fuel produces di-ethyl-ether.

## MATERIALS AND TECHNIQUES

A Kirloskar engine with single cylinder and direct injection diesel engine is used for the experimental setup for the analysis of the performance of the engine and the emission of the engine. The specifications that are needed for the engine are as follows. [1-4]

For the operations to be carried out at various loads the engine used will be coupled with a dynamometer (electrical) and a resistance. Storing of the bio-diesel blends with diesel is done by a separate tank of 5L capacity. By using a timer and a burette the measurement of the volumetric flow of fuel rate as well as the fuel fed into the injector pump at normal gravity. The measurement of temperature of exhaust gas is done using thermocouple which is connected to an indicator of temperature. The measurement of the emission of $NO_x$ and emission of smoke determine the exhaust emissions as shown in Table 1.

  

***Table 1.*** *Engine specs.*

| S.no | Type | 4-Stroke direct injection diesel engine |
|---|---|---|
| 1 | Engine | Kirloskar-AV 1 |
| 2 | Type of cooling | Water cooling |
| 3 | Bore | 80 mm |
| 4 | Stroke | 110 mm |
| 5 | Displacement Volume | 553 cc |
| 6 | Piston (Standard) | Hemispherical |
| 7 | Compression ratio | 1:16.5 |
| 8 | Rated power | 4.4 kW at 1500 rpm |
| 9 | Nozzle opening pressure | 250 bars |
| 10 | Injection timing | 23$^{o}$ before TDC (static) |
| 11 | Fuel oil | Commercial high-speed diesel |
| 12 | Type of governor | Mechanical centrifugal type |
| 13 | Lubrication system | Forced feed |

## EFFECTS AND DISCUSSION

At optimum injection timing and pressure of injection use the pre-heated bio-diesel (sun-flower) for the experiments conducted with 5%, 10%, 15% di-ethyl-ether blend at various loads as an additive for fuel. The optimum blend for the emission reduction and combustion properties enhancement is the 10% di-ethyl-ether. [5]

### Pressure Crank Angle Diagram

The variations in the cylinder pressures are depicted in Figure 1 with crank angle for pre-heated sun-flower bio-diesel at optimum timing and pressure of injection (21°C AbTDC and 230 bar) with the di-ethyl-ether 10% blend at full load. 72 bar and 68.1 bar are the peak pressures for diesel and blends of B25. By the addition of the di-ethyl-ether the enhancement of pressure takes place to 68.1 bar and 70.4 bar. The additive di-ethyl-ether acts as enhancer of ignition for the bio-diesel fuel which results in the increase of cylinder pressure for the B25 with di-ethyl-ether.

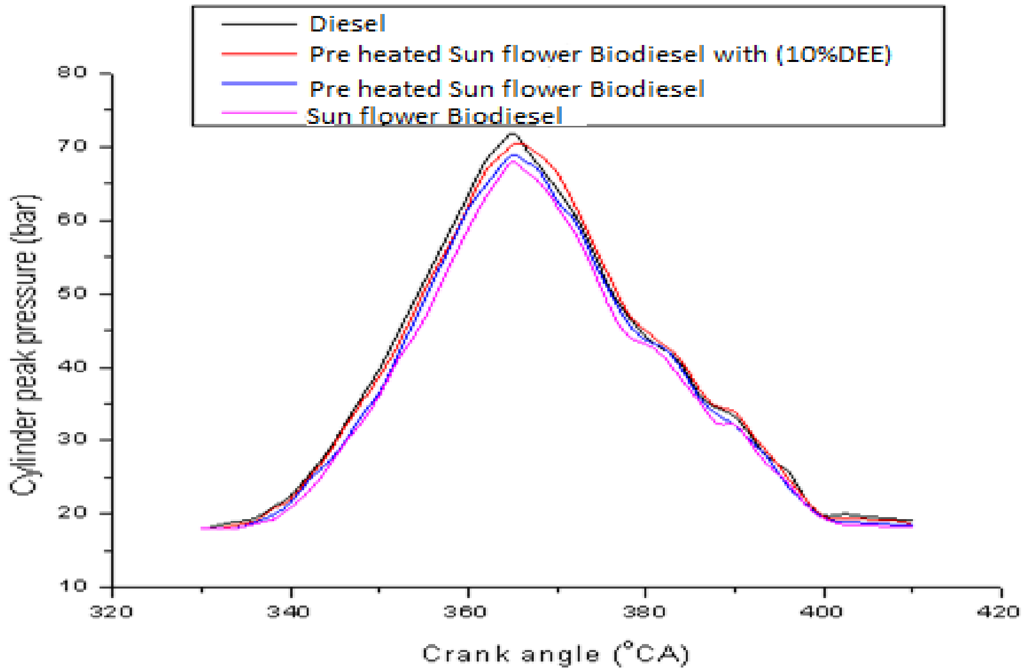


***Fig. 1.*** *Variation of cylinder stress with CA at complete load.*

  

### Peak Cylinder Pressure

Figure 2 depicts the variations in the cylinder peak pressure in 10% pre-heated sun-flower bio-diesel with brake power. 55.8 bar to 73.1 bar and 53.1 bar to 69.1 bar are the obtained peak pressures for the diesel. This is due to the high oxygen content in the di-ethyl-ether and blends of bio-diesel resulting in a better combustionand increases the peak pressure.

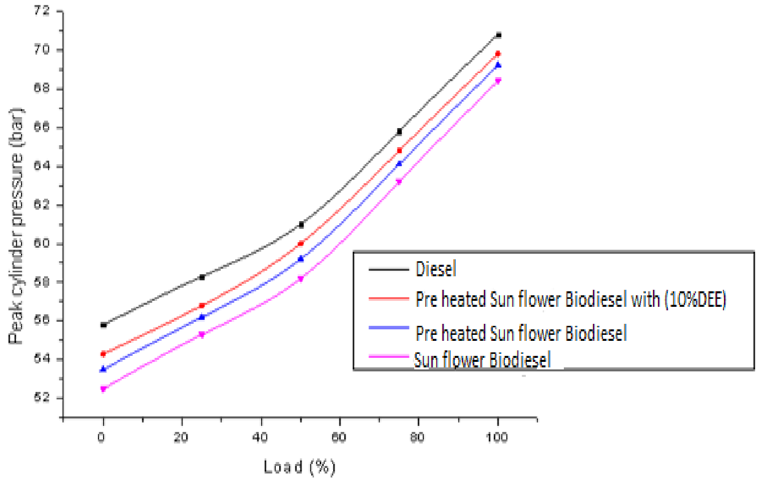


***Fig. 2.*** *Variant of peak stress with load.*

### Heat Release Rate

The changes in the release rate with the crank angle for diesel, B25 and B25 with di-ethyl-ether fuels is illustrated by Figure 3. At 66J/$^{o}$CA and 57J/$^{o}$CA are the values of maximum rate of rise in pressure obtained foe the diesel and B25, respectively. By the addition of the di-ethyl-ether by making it a homogeneous mixture, which causes combustion in a better way. The di-ethyl-ether acts as ignition enhancer by creating multiple ignition centers inside a combustion chamber, the resultant will be an increase in the release rate of heat.

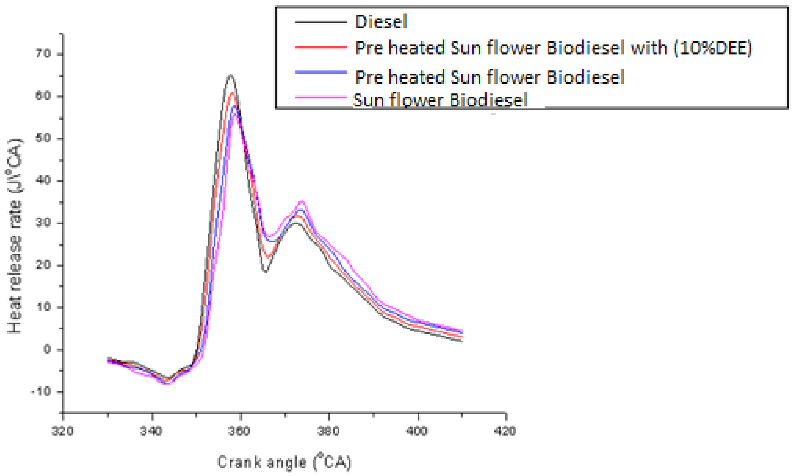


***Fig. 3.*** *Version of the heat launch price with CA at full load.*

**Maximum Rate of Pressure Rise**

The changes in the maximum rate of pressure rise for diesel, B25 and B25 with di-ethyl-ether fuels is illustrated by Figure 4. At 5.5 bar/$^o$CA and 4.8 bar/$^o$CA are the values of maximum rate of rise in pressure obtained foe the diesel and B25, respectively, when the addition of di-ethyl-ether is done its corresponding value at full load its equivalent is 5.25 bar/$^o$CA. This is due to the high premixed combustion, which results in the maximum rate of rise in pressure to increase.

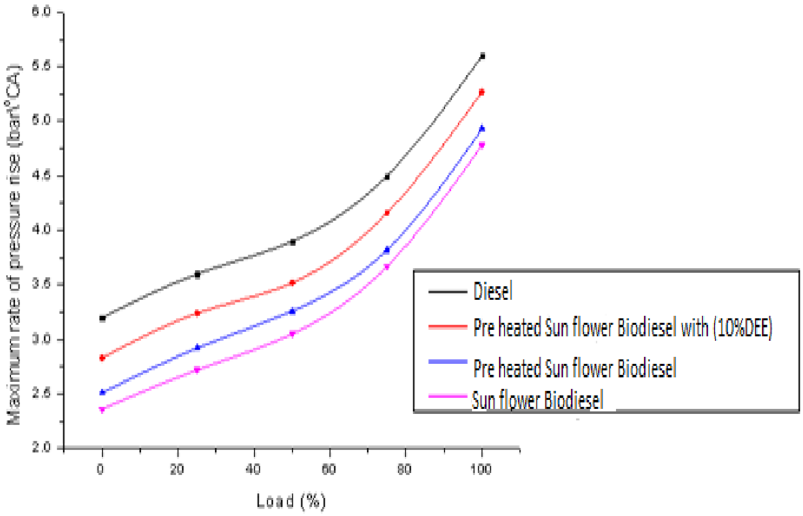


***Fig. 4.*** *Variation of max rate of pressure rise with load.*

**Maximum Heat Release Rate**

The changes in the maximum heat release rate for diesel, B25 and B25 with di-ethyl-ether fuels is illustrated by Figure 5. 52 J/°CA to 67 J/°CA and 50 J/°CA to 64 J/°CA are the values of heath release rates obtained foe the diesel and B25 respectively, when the addition of di-ethyl-ether is done its corresponding value at full load its equivalent is 51J/°CA to 66 J/°CA. This is due to the high combustion temperature and may also be the di-ethyl-ether evaporation phenomenon at the full load, which results in ignition in a better way and higher premixed combustion.

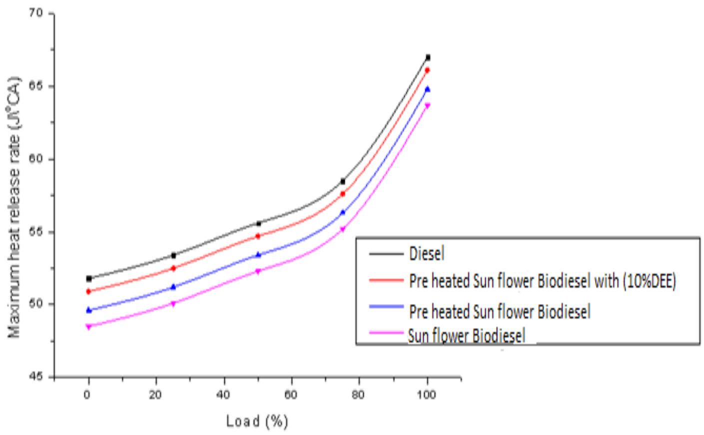


***Fig. 5.*** *Variant of max warmth launch rate with load.*

## Ignition Delay

The changes in the ignition delay for diesel, B25 and B25 with di-ethyl-ether fuels is illustrated by Figure 6. At 6.7 and 7.2°C are the values of combustion obtained foe the diesel and B25 respectively, when the addition of di-ethyl-ether is done its corresponding value at full load its equivalent is 7.6°C. This is due to the high oxygen and may also be the di-ethyl-ether evaporation phenomenon at the full load, which results in ignition in a better way by lowering the temperature of ignition and minimizes the delay of ignition. Also, cetane number of di-ethyl-ether is high which reduces the delay of ignition. [6]

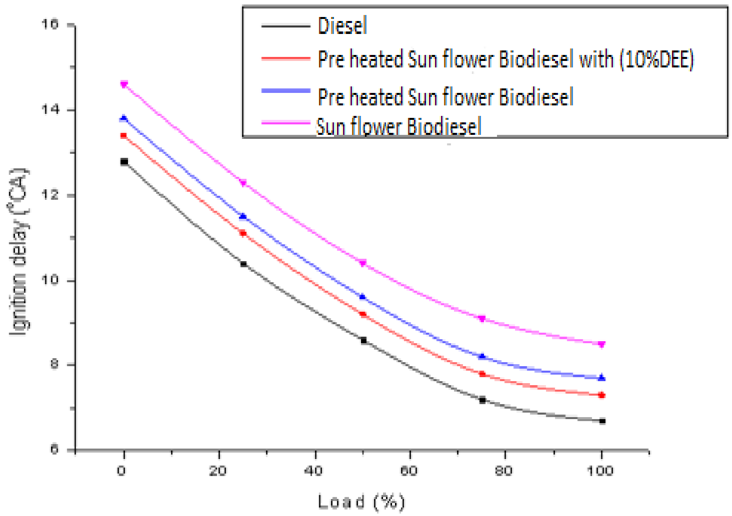


***Fig. 6.*** *Version of ignition put off with load.*

## Combustion Period

The changes in the combustion duration for diesel, B25 and B25 with di-ethyl-ether fuels is illustrated by Figure 7. At 47° C and 48° C are the values of combustion obtained foe the diesel and B25 respectively, when the addition of di-ethyl-ether is done its corresponding value at full load its equivalent is 46° C. This is due to the low charge temperature and may also be the di-ethyl-ether evaporation phenomenon at the full load, which results in ignition in a better way and minimizes the duration of combustion.

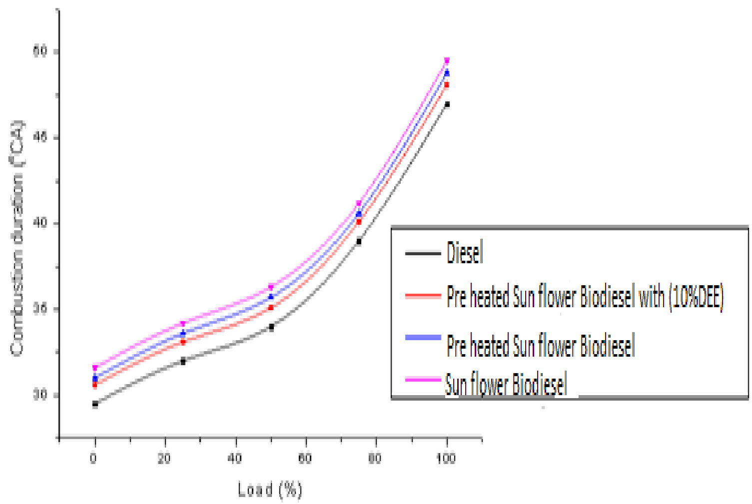


***Fig. 7.*** *Version of combustion length with BP.*

**Brake Thermal Efficiency**
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Figure 7 depicts the variations in brake thermal efficiency for diesel with break power, B25 and B25 added with di-ethyl-ether fuels. For B25 and diesel fuels the thermal efficiency obtained are 28.6% and 29.3% at full load for any base engine, respectively. The decrease in the emission of carbon monoxide is caused by the evaporation of the di-ethyl-ether as it is a homogeneous mixture mixes with air, which causes combustion in a better way, which causes combustion in a slow way. The resultant will be the complete combustion with increased thermal efficiency.

**Brake Specific Fuel Consumption**

Figure 8 depicts the variations in brake thermal efficiency for diesel with break power, B25 and B25 added with di-ethyl-ether fuels. For B25 and diesel fuels the specific fuel consumption for brakes are 0.22 and 0.30 kg/kWh at full load for any base engine, respectively. The increase in the specific fuel consumption of brake is caused by the addition of the di-ethyl-ether by making it highly dense and viscous, which causes combustion in a slow way. The resultant will be the complete combustion with reduced specific fuel consumption for brakes.

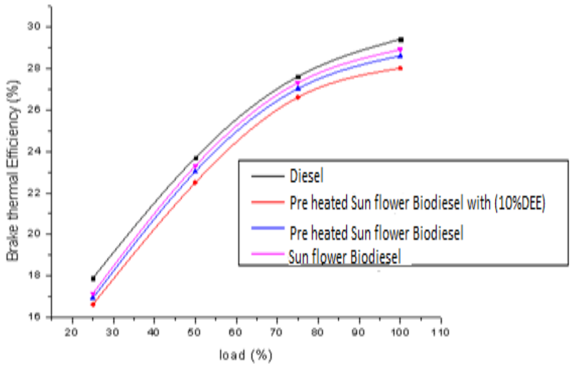


***Fig. 8.*** *Version of Brake thermal efficiency with load*.

**Exhaust Gasoline Temperature**

Figure 9 depicts the emission variations in exhaust gas for diesel with break power, B25 and B25 added with di-ethyl-ether fuels. For B25 and diesel fuels the exhaust gas temperatures are 358 and 330$^{o}$ C at full load for any base engine respectively. The decrease in the emission of hydrocarbons is caused by the high latent evaporation of the di-ethyl-ether by making it a homogeneous mixture, which causes combustion in a better way, the resultant will be the complete combustion temperature of the emission will be reduced which will reduce the exhaust gas temperature also shown in Figure 10.

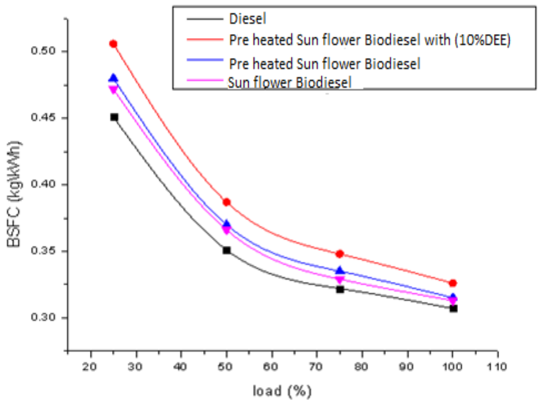


***Fig. 9.*** *Version of BSFC with load.*

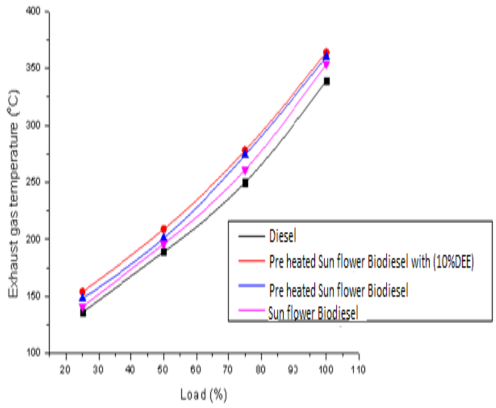


***Fig. 10.*** *Variation of exhaust gasoline temperature with load.*

**Carbon Monoxide Emission (CO)**

Figure 11 depicts the emission variations in carbon monoxide for diesel with break power, B25 and B25 added with di-ethyl-ether fuels. For B25 and diesel fuels the emission of carbon monoxide are 0.10% vol and 0.11% vol at full load for any base engine, respectively. The decrease in the emission of carbon monoxide is caused by the evaporation of the di-ethyl-ether as it is a homogeneous mixture mixes with air, which causes combustion in a better way, the resultant will be the complete combustion of the emission of carbon monoxide is minimized.

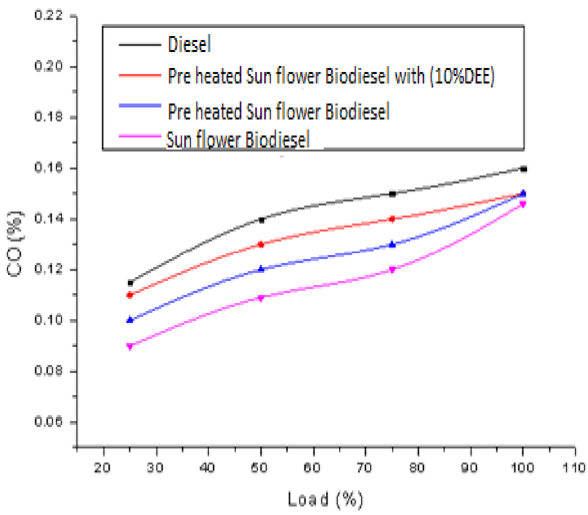


***Fig. 11.*** *Carbon monoxide emission variations with load.*

**Hydrocarbon Emission (HC)**

Figure 12 depicts the emission variations in hydrocarbon for diesel with break power, B25 and B25 added with di-ethyl-ether fuels. For B25 and diesel fuels the emission of hydrocarbon are 140 ppm and 144 ppm at full load for any base engine respectively. The decrease in the emission of hydrocarbons is caused by the addition of the di-ethyl-ether by making it a homogeneous mixture, which causes combustion in a better way. The di-ethyl-ether acts as ignition enhancer by creating multiple ignition centers inside a combustion chamber, the resultant will be the complete combustion of the emission of hydrocarbons 138ppm.

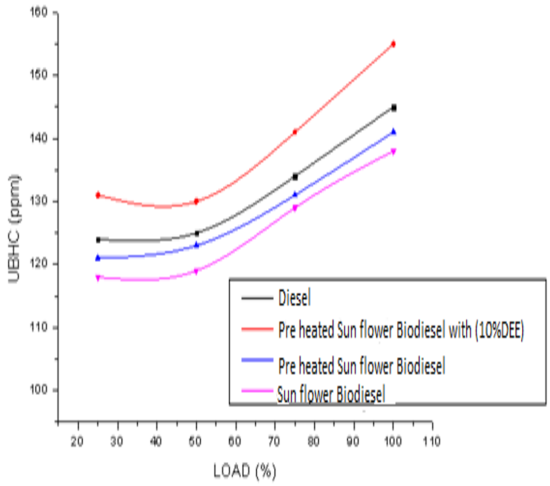


***Fig. 12.*** *HC emission variations with load*.

**NO Emission**

The changes in the break power in regards with the NO emission for diesel, B25 and B25 with di-ethyl-ether fuels is illustrated by Figure 13. 462 ppm and 500 ppm are the values of NO emission obtained foe the diesel and B25 respectively, when the addition of di-ethyl-ether is done its corresponding value at full load its equivalent is 1BSU. The reason for the reduced levels of NO is due to the low charge temperature and may also be the di-ethyl-ether evaporation phenomenon at the full load.

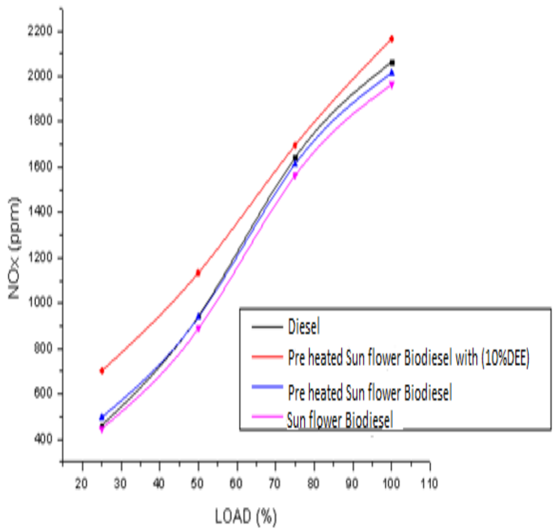


***Fig. 13.*** *NO emission variations with load*.

**Smoke Emission**

The changes in the break power in regards with the smoke density for diesel, B25 and B25 with di-ethyl-ether fuels is illustrated by Figure 14. 2.3 BSU and 2.29 BSU are the values of smoke emission obtained foe the diesel and B25 respectively, when the addition of di-ethyl-ether is done its corresponding value is 2 BSU and when at full load its equivalent is 1BSU. The reason for the reduced levels of smoke is due to the bio-diesel having more oxygen as content causes better combustion in comparison with the reduction of levels of smoke in the B25 and di-ethyl-ether combination.

  

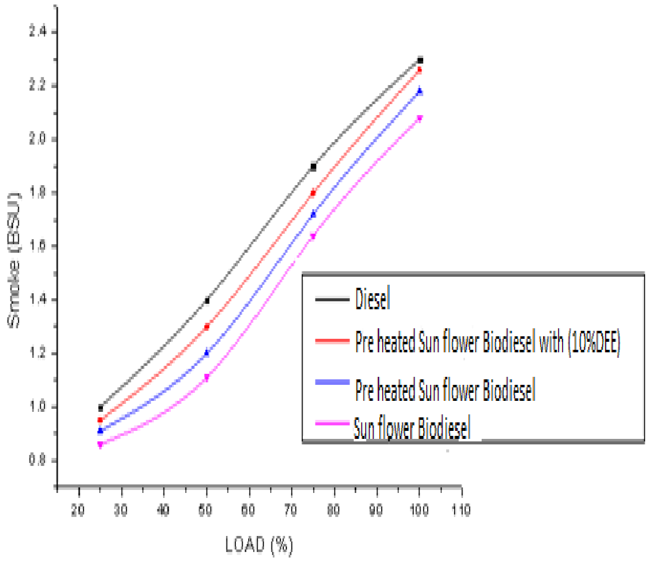


***Fig. 14.*** *Smoke emission variations with load.*

## CONCLUSION

The emission of $NO_x$ by all the blends of bio-diesel is high in comparison with the diesel. Reduction of $NO_x$ is done by the B25 blend by the diethyl-ether addition for any load given. But at higher loads it cannot be altered, and $NO_x$ is high in comparison with the fuel and is observed to be low when comparison is done with the bio-diesel blends. In comparison with 15%-20% diethyl-ether 10% diethyl-ether addition is more promising for the $NO_x$ reduction. Reduction of the emission of smoke is significant by the use of bio-diesel blends which is shown in the tests. The di-ethyl-ether addition shows further enhancement in the reduction of the emission of smoke. Thermal efficiency has a marginal deterioration due to the addition of 10% di-ethyl-ether for the reducing of the $NO_x$ along with the emission of smoke for the blends of bio-diesel.

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