Green fuel utilization for diesel engine, combustion and emission analysis fuelled with CNSO diesel blends with Diethyl ether as additive

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Abstract
The experimental investigation is conducted to evaluate the effects by using Diethyl ether (DEE) as an additive. The Cashew Nut Shell Oil diesel blends (CDB) are tested in a 4-stroke single cylinder DI unmodified diesel engine, rated power is 4.4 kW at a speed of 1500 rpm. The effect of combustion analysis of test fuels on net heat release rate, cylinder pressure, engine power, BSFC, BTE, EGT were observed by the performance tests. The combustion and emission characteristics of a diesel engine with an additive of high cetane number is utilized with CDB and thus investigated. The influence of blends on CO, CO₂, HC, NOx and smoke opacity is investigated by emission tests. Initially, the experiment was conducted with different blends of CDB diesel blends like 10%, 20 %, & 30% by volume basis in a diesel engine. Among this blends B20 shows reasonable result and heat dissipation rate at full load conditions. The BTE of B20 is 27.52% whereas base diesel fuel is 29.73%. Addition of the DEE by 5%, 10% and 15% by volume basis with B20 which is a base fuel has resulted with improved estimates. The result shows that at full load conditions BTE of B20D10 is 28.96% which is close to the base fuel i.e. B20. The emissions like CO₂ shows reducing trends while HC emission rises with increase in CNSO blends. The HC in diesel corresponds to 30ppm and in B20 it is 34ppm, but addition of DEE shows a decreasing trend as in B20D5 has 29ppm and B20D15 has 23ppm respectively. NOx also shows increasing trends with CNSO blend, after addition of DEE it shows declining trend. The NOx for diesel, B20, B30, B20D5, B20D10 and B20D15 emits 1195, 1450, 1511, 1327, 1373 and 1200ppm respectively. The smoke emission is 3.96, 3.38, 3.15 FSN of B20, B20D15 and diesel respectively.

Index Terms— CNSO diesel blends; Diesel Engine; Diethyl ether

NOMENCLATURE

| BTE | Brake thermal efficiency |
| SFC | Specific fuel consumption |
| B20 | 80%Diesel and 20% CNSO |
| BTDC | Before top dead center |
| B20D5 | 95% B20and 5% Diethyl ether (v/v). |
| CNSO | Cashew nut shell oil |
| CI | Compression ignition |
| CDB | CNSO Diesel blends |
| cSt | Centi stoke |
| CO | Carbon monoxide |
| D100 | Neat diesel |
| DI | Direct injection |
| DEE | Diethyl ether |
| EGT | Exhaust gas temperature |
| FSN | Filter smoke number |
| kPa | Kilo Pascal |
| kW | Kilo watt |
| NOx | Oxide of nitrogen |
| ppm | Parts per million (by vol.) |
| rpm | Revolutions per minute |
| UHC | Unburnt hydrocarbon |
| HRR | Heat release rate |

1. INTRODUCTION

The vulnerability of fossil fuels globally has led to create a demand for finding an alternative fuel. The fossil fuels have a crucial role in the human survival. In order to meet the energy demands of the world, CNSO is abundantly available and it one of the low-cost resources [1]. The blend was chosen from a variety of options available from the best alternate sources for minimizing greenhouse effect. So to increase the resource of alternative fuel, the importance of vegetable oil is essential. Vegetable oils are available everywhere in the world, they are easily...
renewable. The plant used for producing the oil seeds are planted with ease, also vegetable oils which are friendly to the environment and contain less sulphur as quoted by Raheman and Phadatare in 2004. Due to the above advantages the vegetable oils are suitable substitute to the diesel fuel [2]. There are various methods to reduce the viscosity like pyrolysis, dilution, trans-esterification and blending. As we know that the vegetable oils have high viscosity and less volatility, this leads in poor combustion and atomization of fuel in diesel engine [3]. The research on a number of oils like Jatropha, sunflower, soybean oil, palm oil, karanja oil, etc. was done for making this paper, the results of the researchers have been compared and summarized CNSO is relatively clean burning alternative fuel, produced from domestic and renewable resources. [4] CNSO contains no petroleum components, but it can be blended in any given amount with diesel to create a biodiesel blend. It can be used in CI engines with little or no modifications [5]. CNSO is biodegradable, nontoxic, and essentially free from sulphur and aromatics. CNSO is most promising alternative solution to protect the world from global warming, gases, emissions, tail pipe particulate matter, HC, CO and other air toxics. Biodiesel improves lubrication and reduces premature wearing of fuel pumps [6]. Fuels are recommended for the better enhancement of saving the fossil fuels and improve the emissions. The oxygenated alternative fuels have gained massive attention recently [7]. The savings on any alternative fuel regarding the economical consumption by one person at the rate of savings of 20% in single refuelling the amount saved is up to 6 litres of diesel per month i.e. if consuming 30 litres per month. Therefore, if this exercise is performed by 1000 people it saves 6000 litres of diesel per month. A comparative study of CBD in diesel engine was made at different loading conditions. The engine combustion parameters are seen as peak pressure, time of occurrence of peak pressure and heat release rate which were found specifically to CNSO [8-11]. Thus, in India alone a great quantity of diesel can be saved as it is the second largest population on earth. The figure 1 explains BS-IV (2017) regulations are subjected to improve upon the same and implement BS-VI directly in 2020. Therefore, CNSO blends can be used in CI engine in rural area for meeting energy requirement in various agricultural operations such as irrigation, harvesting, etc. The objective of this project work is to analyse the effect of DEE as an additional oxygenated fuel in the ratio of 5%, 10% and 15% by volume basis along with B20.

2. TESTED PROPERTIES OF CNSO

The important chemical and physical properties of CNSO were determined by standard methods as compared with diesel. The analytical data are shown in Table 1, 2 and 3.

### Table 1: Analytical data of Diesel, CNSO and Diethyl Ether

| Properties                        | Diesel  | CNSO | DEE  |
|-----------------------------------|---------|------|------|
| Density (gm/cc) at 40 °C          | 0.843   | 0.930| 0.713|
| Kinematic viscosity (cSt) at 40 °C| 3.12    | 30.24| 0.21 |
| Cetane No.                        | 51      | 38.00| 125  |
| Flash point at °C                 | 53      | 222  | 16   |
| Calorific value MJ/kg             | 43      | 39.94| 33.9 |
### 3. DIETHYL ETHER (DEE)

DEE is also known as ethyl ether or simply ether or ethoxyethane. It is an organic compound with the chemical formula \((\text{C}_2\text{H}_5)\text{O}\). It can be mixed in any proportion in fossil fuel or vegetable oils. DEE is good for cold-start aid for engines. Southwest Research Institute (SWRI) reported that the cetane number of DEE is higher which about 125 is and it is used as a preliminary fluid. When combined with petroleum it distillates for gasoline and diesel engines because of high volatility and low flash point.

### 4. PHOTOGRAPHIC VIEW OF APPARATUS

A photographic view and schematic diagram of the experimental setup of the engine are shown in figure 2 and 3 respectively. Before starting the experimental reading, first run the engine to let it reach the operating temperature. Thus, the peak pressure and heat release rate can be calculated using pressure-crack angle diagram and heat release diagram.

![Photographic View](image1)

![Schematic Diagram of the Experimental Setup](image2)

**Figure 2: Photographic View**

**Figure 3: Schematic Diagram of the Experimental Setup**

1. Engine; 2. Eddy current dynamometer; 3. Fuel injector; 4. Fuel pump; 5. Fuel Filter; 6. Diesel tank 7. B20 tank; 8. AVL gas analyser; 9. AVL smoke meter; 10. Calorimeter; 11. Exhaust silencer; 12. Monitor; 13. Air stabilizing tank; 14. Burette.

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### Table 3: Properties of CNSO blends with DEE

| CNSO-Diesel Blends | Density (kg/m³) | Kinematic Viscosity (Cst) | Calorific value (kJ/kg) | Flash Point (ºC) |
|--------------------|----------------|---------------------------|-------------------------|-----------------|
| B10                | 836.6          | 4.18                      | 42029                   | 83.3            |
| B20                | 845.86         | 5.59                      | 42149                   | 94.6            |
| B30                | 855.12         | 7.01                      | 42269                   | 105.9           |

| DEE with CDB       | Density (kg/m³) | Kinematic Viscosity (Cst) | Calorific value (kJ/kg) | Flash Point (ºC) |
|--------------------|----------------|---------------------------|-------------------------|-----------------|
| B20D5              | 830.27         | 4.04                      | 41583.5                 | 76.8            |
| B20D10             | 839.53         | 5.45                      | 41703.5                 | 88.1            |
| B20D15             | 848.79         | 6.86                      | 41823.5                 | 99.4            |
Table 4 Engine specification

| Parameters                               | Description                                      |
|------------------------------------------|--------------------------------------------------|
| Engine type and make & number of cylinder| 4- stroke water cooled single cylinder CI engine, Kirloskar TAF-1 |
| Bore Diameter                            | 87.5 mm                                          |
| Stroke length                            | 110 mm                                           |
| Maximum power                            | 4.4 kW                                           |
| Compression ratio                        | 17.5:1                                           |
| Speed                                    | 1500 rpm                                         |
| Displacement volume                      | 553 cm³                                          |

5. ENGINE TEST RESULTS AND DISCUSSION
The experiments were conducted with CDB with 5%, 10% and 15% DEE blends at different loads. The measured values were analysed and compared with those of diesel fuel.

A. HEAT RELEASE RATE
The duality of HRR (heat release rate) in accordance to crank angle at full load conditions for CBD is shown in Fig. 4 (a) and 4 (b). The cooling effect of the fuel vaporising as it is injected into the cylinder, the HRR is slightly negative during the injection period after the combustion is started, and this becomes positive. The initial phase of combustion is called the premixed combustion which is very rapid because of the combustion of a fuel that has mixed with it during ignition delay. This phase is known as mixed-combustion phase. It is observed that peak HRR of neat diesel is higher than the any blends of diesel. From the result it is observed that HRR during the ignition delay period in B20, B20D10 and diesel is 66.335, 70.615 and 70.732 KJ/m³deg at full load condition. Thus increases in HRR 6.22% with respect to diesel and B20. Also it is observed that HRR B20D10 is much closed to the diesel. This may be due to the DEE which acts as an ignition improver for CDB and hence it increases the premixed combustion rates, thus resulting in increased HRR.

B. PRESSURE CRANK ANGLE
The variations in peak cylinder pressure with crank angle for all test fuels are shown in Figure 5(a) and 5(b). The peak pressure mainly depends upon the combustion rate in the initial stages, which is influenced by the fuel taking part in uncontrolled heat release phase. A similar kind of result was obtained by the addition of DEE with CDB. The peak pressure increases with the addition of DEE with neat diesel. It has been seen that the peak cylinder pressure for B20D10 is considerably increased as compared to B20 under full load conditions. Indicating an improved combustion process thus, resulting due to DEE combustion. Especially when the engine is operating at low load condition fuel to air equivalence ratio is low. The addition of DEE can promote the formation of combustible mixture for a better combustion. However, with further increase in the blend ratio, the volatility effect of DEE is traded off by the significant reduction in calorific value. As a result, the peak cylinder pressure reduces reliably. This may be due to the higher cetane number and high flammability of DEE which increases the premixed combustion phase resulting in higher peak pressure. The peak pressure for CNSO with adding 10% and 15% DEE is 68.922 and 68.360 bars, respectively at full load. While for diesel and B20 the values are 69.479 and 67.879 bars at full load condition. The peak pressure reduces at high power output with the introduction of DEE along with CNSO due to reduction in ignition delay as compared with diesel fuel.
C. BRAKE THERMAL EFFICIENCY (BTE)

The BTE with respect to load for diesel and various blends of CNSO and DEE are shown in Figure 6(a) and 6(b). In all cases, BTE has increased with increase in load. This is due to reduction in heat losses and increase in brake power with increase in load. The BTE increase slightly for lower blends of DEE but with the increasing concentration of DEE blends its reducing trends. This is due to little more amount of oxygen present in the blends, which gives enhanced combustion as compared to pure diesel. The variation of BTE at full load operation is 28.37, 27.52, and 29.73% for B20D15, B20 and diesel respectively. It is observed that BTE B20D10 is closed to the diesel fuel. BTE of B20D10 is increased by 5.3% with respect to B20 at full load conditions. Table 5(a) and 5(b) shows the relative differences of the engine BTE between diesel fuel and that of CNSO blends.

Table 5(a) and 5(b): Relative differences of BTE at different loading conditions for different fuel blends (%)

| Engine load (%) | Diesel | B10 | B20 | B30 |
|-----------------|--------|-----|-----|-----|
| 0               | -      | -   | -   | -   |
| 25              | -      | -4.1| -8.1| -17.4|
| 50              | -      | -0.12| -4.1| -9.4 |
| 75              | -      | -2.6| -4.8| -8.8 |
| 100             | -      | -3.7| -7.4| -12.7|

D. BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

It shows variation in BSFC with respect to load for CNSO in figure 7 (a) and 7(b). If load increases BSFC decreases, mainly due to lower calorific value and high viscosity of CNSO. BSFC of CNSO is higher than that of diesel at all loading conditions. BSFC for diesel is 0.202 kg/Kw-hr and for various blends such as B10; B20 and B30 are 0.216, 0.237, and 0.248 kg/Kw-hr respectively. In next stage, B20 is considered as a base fuel and blended with DEE as 5%, 10%, and 15% by volume. It shows that for various blending of DEE, BSFC shows reducing trend for B20D10 and B20D15 blends which is, 0.226 and 0.231 kg/Kw-hr respectively. The results show BSFC for B20D10 is closed to the B20. Table 6(a) and 6(b) shows the relative BSFC differences.

Table 6(a) and 6(b): Relative differences of BSFC at different loading conditions for different fuel blends (%)

| Engine load (%) | Diesel | B10 | B20 | B30 |
|-----------------|--------|-----|-----|-----|
| 0               | -      | -   | -   | -   |
| 25              | -      | 8.7 | 12.1| 20.2|
| 50              | -      | -1.2| 1.3 | 9.3 |
| 75              | -      | -4.7| 0.47| 5.7 |
| 100             | -      | 6.9 | 17.3| 22.7|

| Engine load (%) | Diesel | B20 | B20D5 | B20D10 | B20D15 |
|-----------------|--------|-----|-------|--------|--------|
| 0               | -      | -   | -     | -      | -      |
| 25              | -      | 12.1| 7.3   | 4.9    | 7.1    |
| 50              | -      | 1.3 | 11.8  | 7.9    | 10.6   |
| 75              | -      | 0.47| 7.1   | 2.4    | 3.3    |
| 100             | -      | 17.3| 13.7  | 10.6   | 12.5   |
E. EXHAUST GAS TEMPERATURE (EGT)

The EGT is high with neat CNSO due to low HRR and poor combustion, so a part of the combustion extends into the exhaust stroke, thereby increasing the combustion duration. Higher ignition delays result in a delayed combustion and higher exhaust temperature. The maximum EGT is 409°C for B30 blends and 378°C for diesel at full load conditions. Result shows that the EGT is relatively low at initial load and then high at full load of B30 as compared to diesel and CBD, which shown in Fig.8 (a) and 8(b). Using DEE with B20 blends gives 398°C. Table 7(a) and 7(b) shows the relative differences of the engine EGT.

Table 7(a) and 7(b): Relative differences of EGT at different loading condition for different fuel blends (%)

| Engine load (%) | Diesel | B10 | B20 | B30 |
|-----------------|--------|-----|-----|-----|
| 0               | -      | 3.5 | 6.7 | 8.7 |
| 25              | -      | 4.4 | 7.5 | 9.3 |
| 50              | -      | 4.5 | 8.3 | 10.6|
| 75              | -      | 5.6 | 8.9 | 10.5|
| 100             | -      | 3.4 | 5.3 | 8.2 |

6. EMISSION CHARACTERISTICS

The emissions prevailing from the exhaust gas analyser are processed using data processing and calculations which were conducted by the analyser system to determine the various emissions.

A. CARBON MONOOXIDE (CO)

The tested CO emissions with varying loading conditions are shown in Figure 9(a) and 9(b). CO emission of CI engine is low due to lean mixture operations. It depends on the air fuel ratio. The CO emission is higher for neat CNSO than its blends and diesel, due to poor atomization of CNSO. From the result it is observed that CO percentage decreases in B20 with respect to B20D15 which is 11.11%. Also in diesel and B20 it increases by 23.8% by volume. Presence of DEE in the blends enhances the combustion process, which is reflected in the reduction of CO emissions. Table 8(a) and 8(b) shows the relative differences of the engine CO emissions between diesel fuel and that of CNSO blends.

Table 8(a) and 8(b): Relative differences of CO at different loading conditions for different fuel blends (%)

| Engine load (%) | Diesel | B20 | B20D5 | B20D10 | B20D15 |
|-----------------|--------|-----|-------|--------|--------|
| 0               | -      | -16.7| 16.7  | 33.3   | 50     |
| 25              | -      | -14.3| 14.3  | 28.6   | 57.2   |
| 50              | -      | -27.3| 9.1   | 27.3   | 18.2   |
| 75              | -      | -6.7 | 20    |        |        |
| 100             | -      | -23.8| 4.8   | 19.1   | -14.3  |

B. CARBON DIOXIDE (CO2)

The result of CO2 emissions with different loading conditions is shown in figure 10(a) and 10(b). It is inferred the percentage of CO2 by volume of diesel, B10, B20 and B30 blends are 7.1, 6.5, 5.9 and 5.6% respectively, which is a reducing trend than neat diesel fuel at various load conditions. But adding DEE the result for B20D5, B20D10 and B20D15 blends are 6.2, 6.4 and 6.8% respectively. We observed that percentage decrease of CO2 with respect to diesel and B20 is 16.9% and 9.81% viz. with respect to diesel and B20D10 blends by volume basis. Table 9(a) and 9(b) shows the relative differences of the volume basis engine CO2 emission between diesel fuel and that of CNSO blends.

Table 9(a) and 9(b): Relative differences of CO2 at different loading conditions for different blends (%)

| Engine load (%) | Diesel | B20 | B20D5 | B20D10 | B20D15 |
|-----------------|--------|-----|-------|--------|--------|
| 0               | -      | -16.7| 16.7  | 33.3   | 50     |
| 25              | -      | -14.3| 14.3  | 28.6   | 57.2   |
| 50              | -      | -27.3| 9.1   | 27.3   | 18.2   |
| 75              | -      | -6.7 | 20    |        |        |
| 100             | -      | -23.8| 4.8   | 19.1   | -14.3  |
shows the relative differences of the Smoke emission between diesel and CDB. Result shows at full loading condition smoke level of B20 is 3.96 FSN whereas for diesel its level increases it may be due to poor atomization of the CNSO. It is observed that the smoke opacity of CNSO blend is 3.15 FSN. This is because improved viscosity resulting improve combustion rate of the fuel blends. Table 11(a) and 11(b) is 3.38 FSN. After addition of DEE with B20 it is reduced. It has been found that Smoke level of B20D15 is 3.87 FSN.

The tested results of NOx emissions at different loading conditions are shown in Figure 12(a) and 12(b). NOx emissions of CDB are higher than that of diesel fuel as there is reduction in HRR and combustion temperature. This is because improved viscosity resulting improve combustion rate of the fuel blends. Table 10(a) and 10(b) shows the relative differences of the NOx. It means that the addition of DEE in B20 blends reduces the NOx emission. Table10 (a) and 10(b) shows the relative differences of the NOx.

Table 10(a) and 10(b): Relative differences of NOx at different loading conditions for different fuel blends (%).

| Engine load (%) | Diesel | B10  | B20  | B30  |
|-----------------|--------|------|------|------|
| 0               | -      | 2.4  | 6.8  | 7.97 |
| 25              | -      | -3   | 7.9  | 18.3 |
| 50              | -      | 11.7 | 19.7 | 25   |
| 75              | -      | 10.4 | 19.3 | 24.63|
| 100             | -      | 10.13| 21.4 | 26.44|

C. HYDRO CARBON (HC)

The tested results of HC emissions at different loading conditions are shown in Fig.11 (a) and 11(b). Result shows that the HC emission is increased for neat CDB and it is decreased with adding DEE in the CDB at all load conditions. The percentage increases of HC with respect to B20 and B20D15 is 32.35% by volume. This decrease in HC emission for DEE blends due to improved combustion.

D. OXIDE OF NITROGEN (NOx)

The tested results of smoke level at different loading conditions are shown in Figure 13(a) and 13(b). CNSO has prolonged aromatic chain-like structure and it has poor combustion. Thus it results in more amounts of smoke level. The next stage after addition of DEE, NOx for B20 is 1450 ppm which is higher than that of B20D5 (1327ppm). It means that the addition of DEE in B20 blends reduces the NOx emission. Table10 (a) and 10(b) shows the relative differences of the NOx.

Table 10(a) and 10(b): Relative differences of NOx at different loading conditions for different fuel blends (%).

| Engine load (%) | Diesel | B20 | B20D5 | B20D10 | B20D15 |
|-----------------|--------|-----|-------|--------|--------|
| 0               | -      | 6.8 | 9.96  | 9.2    | 2      |
| 25              | -      | 7.9 | 5.94  | 6.2    | 3.82   |
| 50              | -      | 19.7| 14.97 | 3.2    | 1.6    |
| 75              | -      | 19.3| 8.7   | 7.3    | 1.4    |
| 100             | -      | 21.4| 11.1  | 6.53   | 0.42   |

E. SMOKE OPACITY

The tested results of smoke level at different loading conditions are shown in Figure 13(a) and 13(b). CNSO has prolonged aromatic chain-like structure and it has poor combustion. Thus it results in more amounts of smoke level increases it may be due to poor atomization of the CNSO. It is observed that the smoke opacity of CNSO blend is higher than diesel. Result shows at full loading condition smoke level of B20 is 3.96 FSN whereas for diesel its level is 3.15 FSN. After addition of DEE with B20 it is reduced. It has been found that Smoke level of B20D15 is 3.38 FSN. This is because improved viscosity resulting improve combustion rate of the fuel blends. Table 11(a) and 11(b) shows the relative differences of the Smoke emission between diesel and CDB.

Table 11(a) and 11(b): Relative differences of Smoke level at different loading condition for different fuel blends %.

| Engine load (%) | Diesel | B10 | B20 | B30 |
|-----------------|--------|-----|-----|-----|
| 0               | -      | 166.7| 133.3| 158.3|
| 25              | -      | 90.9 | 72.73| 86.4 |
| 50              | -      | 97.4 | 55.3 | 79   |
| 75              | -      | 28.5 | 15.2 | 27.3 |
| 100             | -      | 11.11| 25.7 | 33.33|

| Engine load (%) | Diesel | B20 | B20D5 | B20D10 | B20D15 |
|-----------------|--------|-----|-------|--------|--------|
| 0               | -      | 133.3| 125  | 100    | 41.7   |
| 25              | -      | 72.73| 63.64 | 50    | 27.3   |
| 50              | -      | 55.3 | 34.2  | 21    | 5.3    |
| 75              | -      | 15.2 | 3     | -1.82 | -12.1  |
| 100             | -      | 25.7 | 18.4  | 13.65 | 7.3    |
Figure 6(a) and 6(b): Evaluation of BTE of engine at various loads and blends

Figure 7(a) and 7(b): Comparison of BSFC of engine with various loads for various blends

Figure 8(a) and 8(b): Comparison of EGT of engine with various loads for various blends

Figure 9(a) and 9(b): Comparison of carbon monoxide of engine with various loads for various blends
Figure 10(a) and 10(b): Comparison of CO₂ emissions of engine with various loads for various blends

Figure 11(a) and 11(b): Evaluation of HC emission with various loads and blends

Figure 12(a) and 12(b): Comparison of NOx emission of engine with various loads for various blends

Figure 13(a) and 13(b)
CONCLUSION

An extensive experimental study is conducted to evaluate and compare the use of DEE as an additive to the CBD in a diesel engine. The CNSO is cheaper than other kinds of vegetable oils, which is an important advantage for biodiesel production. In addition, DEE has high oxygen content and cetane number (125) it decreases the density and the viscosity of the blends. The BTE increases of blends B20D5, B20D10 and B20D15 which are slightly higher than B20. The B20D5, B20D10 and B20D15 have higher oxygen content than B20. The EGT increases for all the blends with increase in the applied load. It is inferred that the CO emissions for pure CNSO are infeasible as being higher than the blend of CNSO and Diesel. The NOX emission increases with increased proportion of blends and also with higher EGT. This result is achieved as the presence of oxygen in CNSO, leads to improved oxidation at higher temperature and it is responsible for more NOX emission. The NOx of B20 is increased by 21.34% with respect to diesel at full load conditions and with respect to diesel and B20D5 it is 9.94%. Prediction for CO2 emission decreases when we use DEE as an additive in B20, but HC emissions will be higher in comparison with diesel. Smoke opacity increases in B20 especially at high engine load using DEE with B20 it shows a decline. DEE has good solubility in the diesel fuel and this blend can be effectively used in diesel engines without any further modifications in the engine.

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