

EXPERIMENTAL STUDY ON THE UTILIZATION OF OXYGENATED ADDITIVE DIETHYL ETHER ON THE PERFORMANCE AND EMISSIONS CHARACTERISTICS OF C.I. ENGINE

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Abstract- Due to increased environmental pollutions and depletion of fossil fuel resources it is necessary to search for an alternative fuel for diesel engines. Biodiesel is an alternative fuel which can be used in the diesel engines without major modifications. Biodiesel has become more attractive recently because of its environmental benefits. Biodiesel fuel can be made from new or used vegetable oils and animal fats which are non-toxic, biodegradable and renewable resources. Methyl ester of Rice Bran oil is derived through transesterification process. The present research investigates in detail the performance and emissions characteristics of blended biodiesel with oxygenated additive diethyl ether. Diethyl ether (DEE) is selected due to its high oxygen content and secondly its cetane number which is nearer to diesel.

In this study, experimental investigations have been carried out to examine the performance and emissions characteristics of different blends D80-B10-DEE10 and D60-B20-DEE20 used in the C.I. Engine. Results indicate that at full load conditions, the blend D80-B10-DEE10 and blend D60-B20-DEE20 has the better performance characteristics as compared to the diesel. The Brake Power & Brake thermal efficiency of blend D80-B10-DEE10 is 4.90% and 6.9% more than diesel respectively and the Brake Power & Brake thermal efficiency of blend D60-B20-DEE20 is 8.1% and 7.4% more than diesel respectively. Results also shows that the HC and CO emissions of the blend D80-B10-DEE10 are 3.4% and 10.5% less than the diesel fuel respectively and HC and CO emissions of the blend D60-B20-DEE20 are 10.5% and 19.4% less than the diesel fuel respectively. So the oxygenated additive has significant effect on the performance and emissions of C.I. engine.

Keywords: Diethyl Ether, Transesterification, Oxygenated Additive, Carbon Monoxide, Compression Ignition

1. INTRODUCTION

Energy crisis is a serious problem in several countries due to increase in the population and due to depletion of the conventional fossil fuels. The large increase in number of automobiles in recent years has resulted in great demand for petroleum products. With crude oil reserves estimated to last for few decades, there has been an active search for alternate fuels. The depletion of crude oil would cause a major impact on the transportation sector [1]. In the recent years, the price of conventional fuels is higher due to depletion of conventional fuels. Since the higher price of fuel, the alternative fuels from renewable resources that are cheaper and environmentally eco friendly are challenge [2].

Straight vegetable oils can be used as the alternative fuels in the unmodified engines; however this leads to several operational problems in the engines on long-term usage. Three major drawbacks of vegetable oils adversely affect the performance of the engine. These are high viscosity, poor volatility and polyunsaturated character of vegetable oils [3-6]. High viscosity of

Vegetable oils leads to inefficient pumping and spray formation with large droplets. Therefore air and fuel are not optimally mixed and combustion remains incomplete in the engine. Low volatility of vegetable oils and their ability to polymerize (due to unsaturation) leads to formation of undesirable carbon deposits in the combustion chamber, injector coking and piston ring sticking issues. To eliminate these issues, different processes were developed to make these oils adapt modern engines. These processes (such as direct use by blending, micro-emulsion, pyrolysis, transesterification etc.) allow the vegetable oils to attain properties very similar to mineral diesel [7].

Transesterification (alcoholysis) is a chemical reaction between triglycerides present in the vegetable oils and primary alcohols in the presence of a catalyst to produce mono-esters (biodiesel) and glycerol [8]. Nevertheless, transesterification is not always possible. Oils, which have high free fatty acid (FFA) content can't be transesterified by this reaction. The process rather leads to saponification i.e. formation of soap. Formation of soap makes it very difficult to separate the layers of biodiesel and

glycerol [9]. Many different thresholds of FFA contents are proposed in literature, but commonly, it is accepted that above 5% FFA level in the vegetable oils, it becomes very difficult to produce biodiesel by transesterification process [10-12].

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The FFA content of the oil influences the yield of biodiesel from this oil. Lower FFA results into easier production and higher yield of biodiesel. In particular, biodiesel has received wide attention as a replacement for diesel fuel because it is biodegradable, nontoxic and can significantly reduce exhaust emissions and overall life cycle emission of carbon oxides (CO₂) from the engine when burned as a fuel. Many investigations have shown that using biodiesel in diesel engines can reduce hydrocarbon (HC), carbon monoxide (CO) and particulate matter (PM) emissions, but nitrogen oxide (NO_x) emission may increase [12-15].

On the other hand, biodiesel has some disadvantages, such as higher viscosity and pour point, and lower volatility compared with diesel. The poor cold flow property of biodiesel is a barrier to the use of biodiesel-diesel blends in cold weather [16]. Diethyl ether (DEE) and ethanol might be expected to improve low temperature flow properties. Previous studies have suggested that the weight percent of oxygen content in the fuel is the most important factor for PM reduction, and it is more important than other properties such as volatility [17, 18]. Including diethyl ether and ethanol in biodiesel and diesel blends can increase the oxygen contents, which may further improve the PM emissions.

1.1 Diethyl Ether - A Review

DEE has favorable properties for application in diesel engines, such as higher cetane number (>125), moderate energy density (for bulk storage applications), higher O₂ content in its structure, lower auto-ignition temperature, prolonged flammability and improved miscibility with diesel.

T.K. Kannan et al. [19] studied an oxygenated additive diethyl ether (DEE) was blended with bio diesel in the ratios of 5%, 10%, 15% and 20% and tested their performance. Reduction of 14.63% of smoke opacity and 15% of NO_x emission was observed for 20% DEE blends at full load which was the highest reduction among the blends. BTE 29.9% which was 5% higher than biodiesel. M. Pugazhivadivu et al. [20] studied the effect of adding DEE to biodiesel-diesel blends (B25, B50 and B75) and biodiesel (B100). DEE was added in 10%, 15% and 20% (v/v) to the biodiesel fuels.

This revealed addition of diethyl ether to biodiesel blends reduced the both NO_x and smoke emission further. Babu et al. [21] analyzed the effect of DEE in mahua oil methyl ester (MOME) and revealed that, carbon monoxide and smoke were reduced greater than 50% with DEE addition. Sivalakshmi and Balusamy [22] performed experiments in a single cylinder diesel engine fuelled with biodiesel and various percentage of DEE addition (5%, 10%, 15%) and concluded that, 5% DEE addition lowered the CO and smoke emissions with increased HC and NO_x formation. Subramanian and Ramesh [23] evaluated the performance, combustion and emission characteristics of diesel with DEE blends (5–15% by wt) on a single cylinder DE diesel engine. They interpreted that, 10% DEE addition improved the BTE, lowered the smoke and CO emissions without affecting NO_x. Mohanan et al. [24] conducted series of experiments with diesel-DEE blends at DEE ratio of 5–25% with increments of 5% (by vol). They reported that, 5% DEE addition resulted in higher BTE with lowered CO and smoke emissions compared to diesel. At sharp contrast, with higher percentages of DEE (20% and 25%), deteriorated BTE, with increase in CO and smoke as compared to diesel.

Even though various literatures focused on using oxygenated additives to improve a base fuel and developing a ternary fuel blend, there were merely negligible works in context of improving the ternary blends with an oxygenated additive. With this prime objective, the current study is focused on improving the performance of the ternary blends (alcohol-biodiesel-diesel) with the use of diethyl ether (DEE).

2. MATERIALS AND METHODS

2.1 Materials

Following materials were used:

1. Refined Rice Bran oil
2. Methanol (Methyl alcohol)
3. Sodium hydroxide (NaOH)/ Potassium hydroxide (KOH) as catalyst
4. Di-Ethyl Ether (Oxygenated Additive).

Refined rice bran was purchased from local general store. Methanol & Sodium hydroxide (NaOH) or Potassium hydroxide (KOH) was available in the Project Laboratory. The diesel fuel & Di-Ethyl Ether were purchased commercially. Transesterification was carried out to convert the rice bran oil into rice bran oil methyl ester (RBOME) through the biodiesel reactor also known as biodiesel stirrer. Biodiesel production and its properties tests were done in DST- SERB Sponsored Fast Track Project Laboratory (Govt. of India) at Adesh Institute of Engineering and Technology, Faridkot (Punjab). Performance and Emission experiments were also performed at Adesh Institute of Engineering and Technology, Faridkot. The biodiesel obtained was then blended with a reference diesel and with the additive Di-Ethyl Ether.

Following fuel blends were prepared which were to be used in the C.I. engine for performance and emission analysis:

1. D80-B10-DEE10 (Diesel 80% + Biodiesel 10% + Di-Ethyl Ether 10%)
2. D60-B20-DEE20 (Diesel 60% + Biodiesel 20% + Di-Ethyl Ether 20%)

These fuels blends were to be used in the C.I. engine and performance and emissions characteristics were compared with diesel.

2.2 Transesterification Process

Rice bran oil was converted into its methyl ester (RBOME) by transesterification process. This involves making the triglycerides of the Rice bran oil to react with methanol in the presence of a potassium hydroxide (KOH) catalyst to produce glycerol and fatty acid ester. For transesterification process, the known amount of (1000 ml) rice bran oil, 270 ml. of methanol and 5 gm potassium hydroxide were taken in a round bottom flask. The contents were stirred till ester formation began. The mixture was heated to 70°C and held at that temperature without stirring for an hour, and then it was allowed to cool for 24 hours without stirring. Two layers were formed. The bottom layer consisted of glycerol and the top layer was the ester. The bottom layer was removed and ester was collected [25]. Purification of biodiesel was done with the water washing method. In water washing the water was heated up to 70°C and then added to biodiesel in gravity separator. The crude biodiesel and water mixture was shaken thoroughly for 1 min and placed on stand in separating funnel to allow separation of biodiesel and water layers. 24 hour time was given between next washing [26].

Water washing of the biodiesel thus produced is essential for removal of the impurities and the residual catalyst, which may be harmful for combustion engines. It was purified by washing with distilled water to remove all the residual by-products. Water washing was done for 3-4 times to remove the glycerol from biodiesel. Biodiesel was heated above 100°C for the removal of water contents and methanol after washing process. The water contents present in the biodiesel may affect the performance of the engine, so it is necessary to remove these water contents [27].

2.3 Experimental Setup and Procedure

A four stroke, single cylinder diesel engine was employed for the present study. The experimental setup used for experimentation is shown in the Fig.1. AVL Gas analyzer was used to measure the concentration of gaseous emissions such as unburned hydrocarbons (HC), carbon monoxide (CO) and carbon dioxide (CO₂). The performance and emission tests were carried out on the C.I. engine using various blends of diesel-biodiesel-DEE blends as fuels. First, the experimentation was performed with diesel (for getting the base line data of the engine) and then two blends of D80-B10-DEE10 and D60-B20-DEE20 were carried out. The performance of the engine is evaluated in terms of, brake power, brake specific fuel consumption and brake thermal efficiency and emissions of the engine (HC, CO & CO₂) were analyzed. The fuel consumption of the engine was measured by determining the time required for consumption of given volume of fuel using a glass burette. The mass of fuel was calculated by multiplying volumetric fuel consumption to its density.



Fig. 1: Photograph of Experimental Setup

Keywords: 1. Engine. 2. Dynamo. 3. Resistive Load Bank. 4. Electric Control Panel. 5. Air Surge Tank. 6. Biogas Flow Meter. 7. Digital Tachometer. 8. Exhaust Gas Temp Thermocouple. 9. AVL Exhaust Gas Analyzer. 10. Probe. 11. Fuel Measuring Burette. 12. U-Tube Manometer

2.3.1 Load Bank

A load bank is a device which develops an electrical load, applies the load to an electrical power source and converts or dissipates the resultant power output of the source. The purpose of a load bank is to accurately mimic the operational or “real” load that a power source will see in actual application. The 5 KW load bank was used in setup.

The 5 KW load was applied on the engine into 5 steps. There are 10 switches on the load bank. Each switch has capacity of 0.5KW load. These switches have applied load one by one. First of all, engine was run on no load condition, then 0.5 KW load is applied on the engine and this process continued till the 5 KW load was applied on the engine.

The specifications of the engine used for experimentation are shown in the Table 1.

Table 1: Specifications of the Engine

Parameters	Specifications
Engine Make	Fc Dod
Stroke Length	110 mm
No of Strokes	4
Cylinder Diameter	102 mm
No of Cylinders	1
Cooling Media	Air Cooled
Rated Capacity	6 KW
Fuel	Diesel

3. RESULTS AND DISCUSSIONS

3.1 Performance Analysis

The performance of an engine is evaluated on the basis of the brake horse power (BHP), brake thermal efficiency (BTE) & brake specific fuel consumption (BSFC).

The readings from the experimentation are tabulated in the form of line charts/graphs.

3.1.1 Brake Power

It is defined as the power output produced by engine. Brake Power is obtained on the crankshaft of the engine. Brake power is one of the most important parameter in the engine experiment. It is always less than indicated power. It is expressed in terms of KW.

Fig. 2 shows the engine power output (Brake Horse Power) under the changing load operating conditions. It is clear from the figure that the power of engine increases with the amount of oxygen in the fuel blend. As the amount of DEE increases in the blend, the brake power increases.

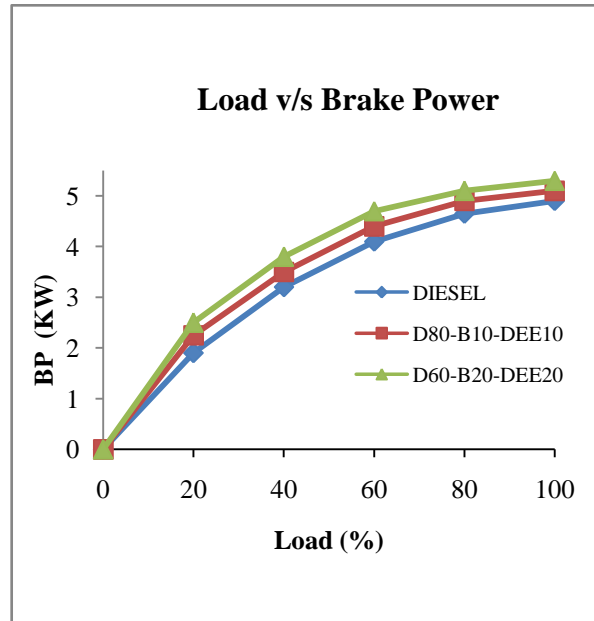


Fig. 2: Variation of Brake Power with different load conditions

Figure shows that the BP increase marginally with increase in % of DEE and at DEE20 it is maximum.

3.1.2 Brake Specific Fuel Consumption

It is defined as the fuel flow rate per unit power output. It is a measure of the efficiency of the engine in using the fuel supplied to produce work. It is desirable to obtain a lower value of BSFC meaning that the engine used less fuel to produce the same amount of work. This is one of the most important parameters to compare when testing various fuels. It is expressed in Kg/KWh.

The variation of BSFC with load for different blends and loads are presented in Fig. 3.

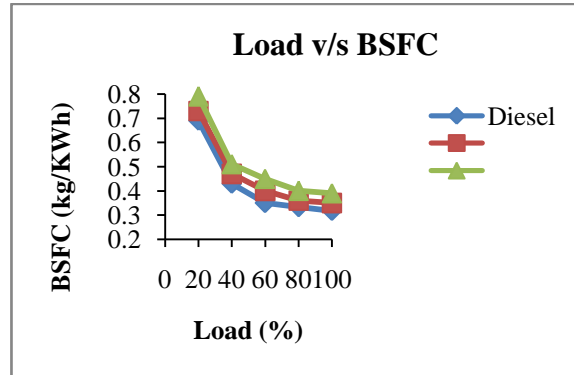


Fig. 3: Variation of Brake Specific Energy Consumption with different load conditions

It is observed from the chart that the BSFC for all the fuel blends tested decreases with increases in load. This is due to higher percentage increase in Break power with load as compared to increase in the fuel consumption. For blends with Oxygen fuel greater than 10%, the BSFC was observed to be greater than that of diesel.

3.1.3 Brake Thermal Efficiency

It is the ratio of the thermal power available in the fuel to the power of the engine delivers to the crankshaft. This greatly depends on the manner in which the energy is converted since the efficiency is normalized with fuel heating value.

Fig. 4 shows the brake thermal efficiency (BTE) variation with respect to varying load for Diesel and DEE blends. The brake thermal efficiency increases with increase in DEE percentage. At full load conditions, the blend D80-B10-DEE10 and D60-B20-DEE20 produce 4.3 % & 7.6 % higher brake thermal efficiency than sole Diesel respectively. The improvement is due to increase in constant volume combustion and the larger increase of molecules by fuel injection, which leads to better combustion efficiency especially at higher loads.

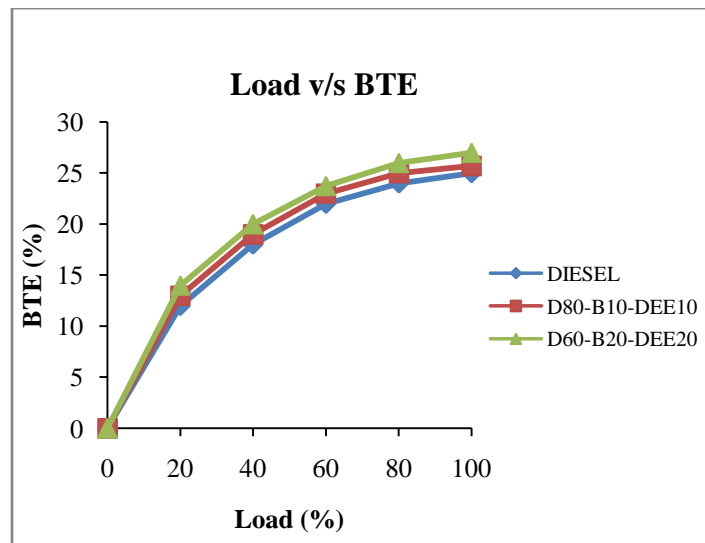


Fig. 4: Variation of Brake Thermal Efficiency with different load conditions

3.2 Emissions Analysis

The exhaust emissions of the engine are checked by finding the CO, HC and CO₂ from the engine and then those readings are tabulated in the form of charts.

3.2.1 CO Emissions

Fig. 5 shows the variation in CO emissions under various load conditions. CO emissions decrease as the wt. % oxygen is increased. For each load condition, for the 10 wt. % and 20 wt. % oxygen by DEE in diesel-biodiesel blends the change is not much but with increase in DEE %, the decrease in CO emissions is significant.

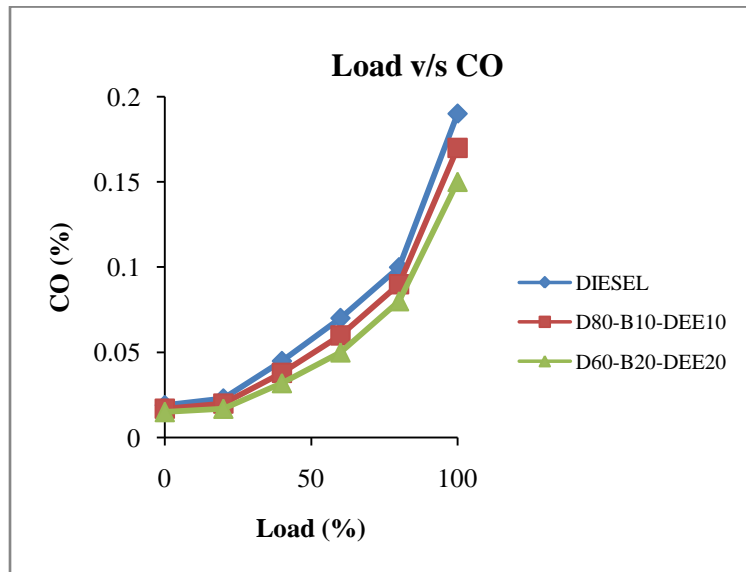


Fig. 5: Variation of Carbon Monoxide Emissions with different load conditons

3.2.2 HC Emissions

The variation of HC emission for different blends at various loads is indicated in Fig. 6. From the figure, it is clear that the addition of DEE results in the reduction of hydrocarbon emissions. As the proportion of oxygen is increased, the reduction in HCs increases. Due to the DEE increase within the blend, it exhibits a shorter delay period and results in better combustion leading to low HC emissions.

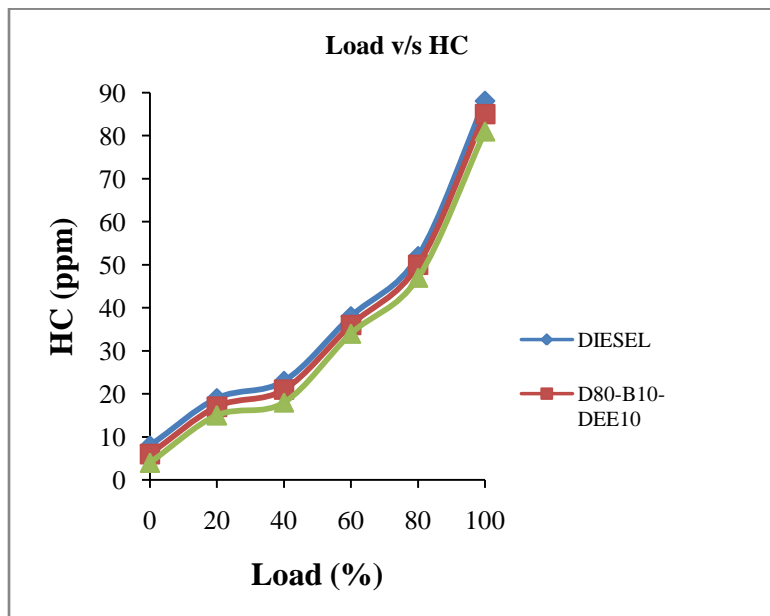


Fig. 6: Variation of HydroCarbon Emissions with different load conditons

3.2.3 CO₂ Emissions

The variations of CO₂ emissions with respect to load for different blends are shown in Fig. 7. The oxygenated fuel has oxygen content within it. These oxygen particles help in complete combustion process which releases more amount of CO₂ during combustion. As amount of oxygenated fuel increases, more CO₂ released.

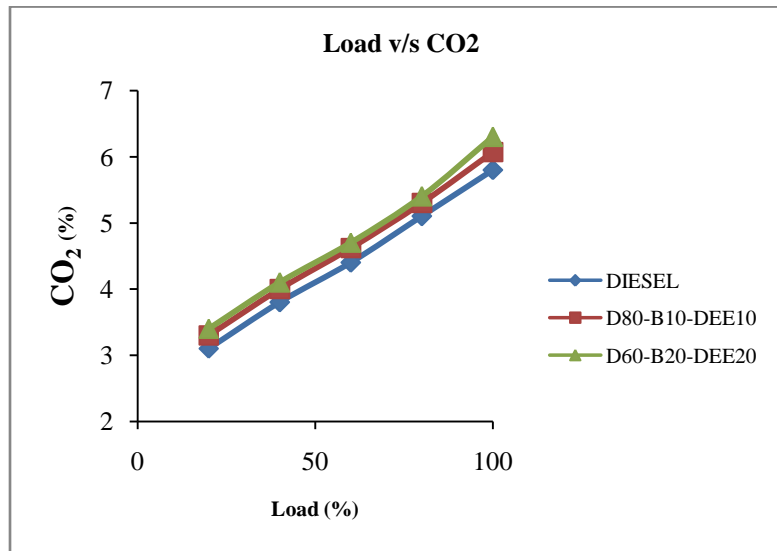


Fig. 7: Variation of Carbon Dioxide Exhaust with different load conditions

4. CONCLUSIONS

The main objective of the present study is to investigate the effect of oxygenated additive DEE on the performance and emissions characteristics of the C.I. engine. In this study, the DEE is used in the different blends of RBOME- diesel. It can also be directly use in the diesel blends. Two blends were prepared using diesel, Rice bran oil methyl ester (biodiesel) and DEE i.e. D80-B10-DEE10 and D60-B20-DEE20.

The results from this research lead to the following conclusions:

- (1) DEE- biodiesel-diesel blends can be used as a fuel in compression ignition engine, using an easily modified fuel system. The engine operates in a similar manner with the DEE-biodiesel-diesel blend as with the diesel fuel. No requirement of the modification of the engine when used DEE in the diesel blends.
- (2) The results show that both the blends D80-B10-DEE10 and D60-B20-DEE20 have better performance characteristics than the diesel fuel. Brake power and brake thermal efficiency of the both blends are more than the diesel fuel. BP and BTE of blend D80-B10-DEE10 is 4.90% and 6.9% more than diesel respectively. BP and BTE of blend D60-B20-DEE20 is 8.1% and 7.4% more than diesel respectively. So, the blend D60-B20-DEE20 is the optimum blend in the manner of performance of engine.
- (3) The results show that both the blends D80-B10-DEE10 and D60-B20-DEE20 have better emissions characteristics than the diesel fuel. HC and CO emissions of both blends are less than the diesel fuel, but the CO₂ contents are more in both blends due to the complete combustion of the fuel because of the presence of DEE. HC and CO emissions of the blend D80-B10-DEE10 are 3.4% and 10.5% less than the diesel fuel respectively. Similarly, HC and CO emissions of the blend D60-B20-DEE20 are 10.5% and 19.4% less than the diesel fuel respectively. So, the blend D60-B20-DEE20 is the optimum blend in the manner of emissions of the engine.
- (4) The blend D60-B20-DEE20 has great impact on performance and emissions of the engine. So it is the optimum blend.

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