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# Experimental Analysis of Performance and Emission Characteristics of Single Cylinder Diesel Engine Using Biodiesel

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**Abstract**—this study shows that the biodiesel blends with fossil diesel at a mixing ratio 20 vol. % can be used in diesel engine without any modification in engine. The various engine performance and emissions parameters with fuel blends of petroleum diesel fuel and biodiesel are discussed in this study. B20 & B30 shows 3% and 4% higher bsfc compared to baseline diesel fuel at all engine loads.The average reduction in CO emission when fueled with B20 is 22.5% for all engine loads correspondingly compared with that of mineral diesel. NOx production is significant for all fuel blends at all load condition; but it decreased with load and for B20 it decreased by 10% at high load condition

**Index Terms**— linseed oil, Biodiesel, performance, emission, NOx, CO, HC, CI Engine.

## 1 Introduction

Fossil fuels are the backbone of our industrial development and transportation system. But fossil fuels are non-renewable in nature and due to their rapidly increasing consumption, they will become obsolete in future. Also, increasing demand of fossil fuel has caused serious challenges to the environment and energy security of the world [1]. These challenges include global warming, air quality deterioration, ozone depletion and acid rain. [2, 3]. The prices of fossil fuels are also increasing day by day. All these factors have focused interests in the search for alternative fuels for internal combustion engine. For these reasons, biodiesel has been subjected to intensive research work all over the world.

## 2 Biodiesel As An Alternative Fuel

Biofuels are renewable, biodegradable, and non-toxic fuel. Biodiesel is a non-toxic, biodegradable and renewable alternative fuel that can be used with no engine modifications. It can be produced from various vegetable oils, waste cooking oils and animal fats [4, 5]. Biodiesel has higher viscosity, density, and cetane number as compared to mineral diesel. The main reason behind the increasing popularity of biodiesel is that its gives considerably lower emissions (PM, CO, HC) as compared to diesel fuel. The main negative point of biodiesel is its lower energy content or net calorific value than that of conventional diesel fuel which is about 10–12% less than that of conventional diesel fuel.

Biodiesel made from linseed oil is used for this work. Since the environmental conditions of India are convenient for the production of linseed crop hence linseed oil can play an important role in the production of biodiesel. Linseed oil is a colourless to yellowish oil which is obtained from the dried, ripened seeds of the flax plant (*Linum usitatissimum*). The pressing machine is used to press the linseeds to obtain the oil from linseeds. Normally there are different kinds of production of oil from their seeds. After this the oil has been filtered to remove the residues.

## 3 Experimental Set Up And Methodology

### 3.1 Experimental Fuels

A total of four test fuels were used for conducting research. The test fuels chosen were (a) 100% neat diesel fuel (D100), (b) 10% linseed biodiesel with 90% diesel fuel (B10), (c) 20% linseed biodiesel with 80% diesel fuel (B20), (d) 30% linseed biodiesel with 70% diesel fuel (B30). The linseed oil biodiesel was purchased from market and the biodiesel of 10%, 20%, 30% (B10, B20, and B30) by volume was blended with base diesel. The experiments were carried out by four test fuels at different engine loads. Table 1 shows the main properties of the blending stocks. The lower calorific value of biodiesel is approximately 7% lower than that of diesel. It can be seen that the density of B30 is the highest.

**Table 1;** Properties of diesel and biodiesel blends.

| FUELS | D100 | B100 | B10 | B20 | B30 |
|---|---|---|---|---|---|
| Diesel, (%) | 100 | 0 | 90 | 80 | 70 |
| Density (kg/m$^3$) | 821.5 | 893.6 | 827.5 | 835.6 | 843.0 |
| Calorific value (MJ/kg) | 44.05 | 40.75 | 43.25 | 42.60 | 42.0 |
| Viscosity (cSt) | 2.64 | 5.8 | 2.66 | 2.71 | 2.80 |

### 3.2 Experimental Set Up and Procedure

Table 2, shows the detailed specifications of the engine used in this work. Fig.3.1 shows the schematic diagram of the test set up. An eddy current dynamometer was used for loading the engine. A piezoelectric strain gauge pressure transducer was mounted on the fuel line for measurement of in-line fuel pressure. A piezoelectric transducer was mounted in the cylinder head for in-cylinder pressure measurement. The crank angle is measured by the crank angle encoder which was mounted on the engine shaft.

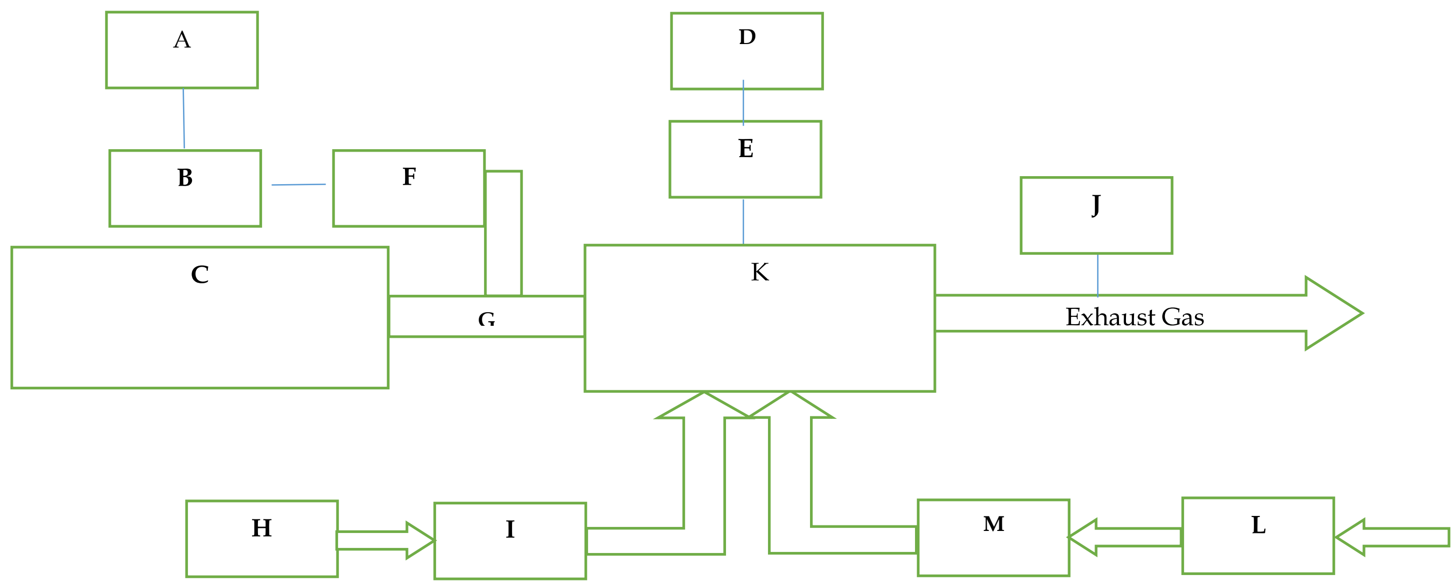


**Fig. 3.1:** Schematic diagram of Engine test set up.

**A:** Computer, **B**: DAQ Card, **C**: Eddy current Dynamometer, **D**: Charge amplifier, **E:** In-cylinder pressure Sensor, **F:** Crank Encoder, **G:** Coupling, **H:** Fuel tank, **I:** Fuel flow meter, **J:** Exhaust Gas Analyzer, **K**: Engine, **L:** Air box, **M:** Air flow meter

The engine speed (1500 rpm) was maintained as constant throughout the tests. The various parameter such as engine speed, power output, fuel consumption, brake specific fuel consumption (BSFC) and brake mean effective pressure (BMEP) for the test fuels were calculated. The exhaust emissions such as CO, CO2 and HC emissions were measured using AVL Di-gas analyser. De-tailed specifications of the exhaust gas analyser are given in Table 3. .

**Table 2;** Technical specifications of the test engine.

| | |
|---|---|
| Made | Kirloskar |
| Type | TV1,Diesel engine |
| No. of cylinders | 1 |
| Bore | 87.50 mm |
| Stroke | 110.00 mm |
| Swept volume | 661.45 cc |
| Compression ratio | 17 |
| Cycle | Four stroke |
| Power | 5.20 kw (7 H.P) |
| Speed | 1500 rpm |
| Orifice diameter | 20 mm |
| Cooling system | Water cooling |
| Loading device | Eddy current dynamometer |
| Inlet valve opens/inlet valve closes | 4.5 BTDC / 35.5 ABDC |
| Fuel injection starts | 23 BTDC |
| Exhaust valve opens/exhaust valve closes | 35.5 BBDC / 4.5 ATDC |

**Table 3;** Technical specifications of the exhaust gas analyser.

| Instrument | | Measuring Range | Resolution |
|---|---|---|---|
| AVL Digas analyser 444 | HC/ppm | 0-20000 | 1 |
| | CO/% | 0-10 | 0.01 |
| | CO2/% | 0-20 | 0.1 |
| | NOX/ppm | 0-4000 | 1 |

## 4 Results And Discussions

The engine parameters such as brake power indicated mean effective pressure (IMEP) brake thermal efficiency (BTHE), oxides of nitrogen (NOx), carbon monoxide (CO), hydrocarbon (HC) and carbon-di-oxide (CO2) are discussed below.

### 4.1 Performance Characteristics

In Fig. 4.1 shows that the brake power for different biodiesel blends is almost similar to mineral diesel. However a slightly increase in brake power is obtained for mineral diesel at a load of 12 kg. It can be predicted that at higher loads there will be loss in engine power because of lower calorific value and energy content of biodiesel.

It can be seen from Fig. 4.2 that IMEP for different biodiesel blends is almost similar; however increase in IMEP is obtained with the increase in the amount of biodiesel in biodiesel-diesel blends. Higher IMEP is obtained for mineral diesel at higher loads because of higher calorific value and energy content of mineral diesel.

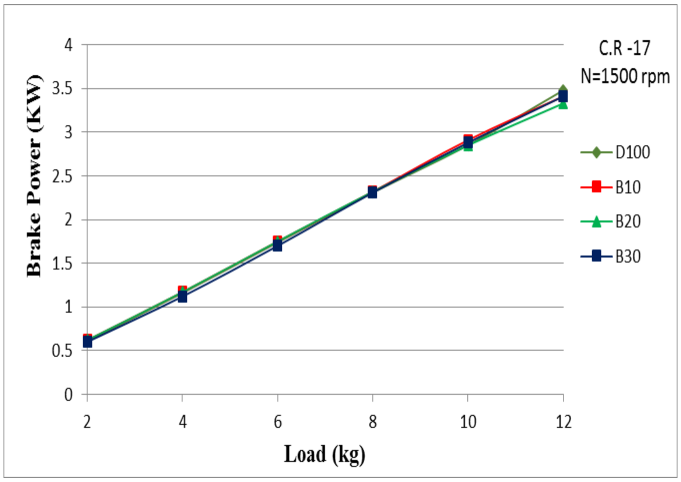


**Fig. 4.1:** Brake Power at different biodiesel concentration

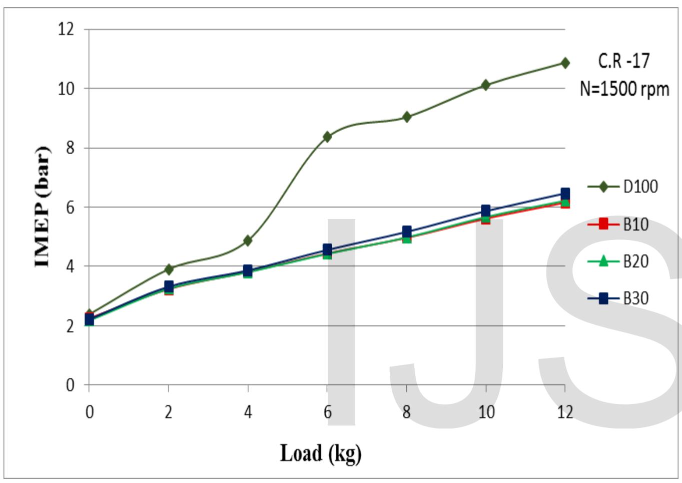


**Fig. 4.2:** IMEP of different biodiesel concentration.

It can be seen from Fig. 4.3 that ITHE increases with the increase in the amount of biodiesel in biodiesel-diesel blends and decreases as the load increases for a particular biodiesel-diesel blend because of lower calorific value and energy content of biodiesel. At a load of 4 kg the efficiency of B10 and B30 is approximately 47% and 52% respectively. Similarly at a load of 12 kg the efficiency of B10 and B30 is approximately 44% and 46% respectively.

It can be seen from the Fig. 4.4 that at a load of 4 kg the bsfc for B10, B20 and B30 are higher when compared to mineral diesel. When operating with fuels that have a lower heating value such as biodiesel, more fuel needs to be injected to obtain a comparable power output to that of mineral diesel.

Fig. 4.5 presents that B10 and B20 gives almost similar results as obtained by mineral diesel (D100). The value of torque decreased as the amount of biodiesel in biodiesel-diesel blends increased. Loss in engine torque is predictable at higher loads because of lower calorific value and energy content of biodiesel.

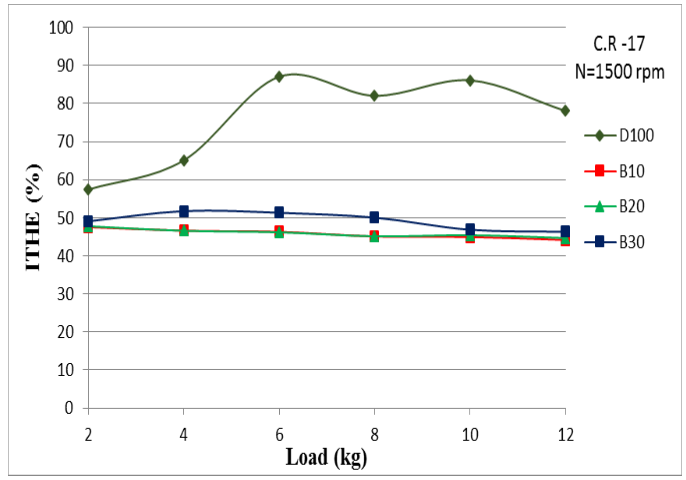


**Fig. 4.3**: ITHE (%) at different biodiesel concentration.

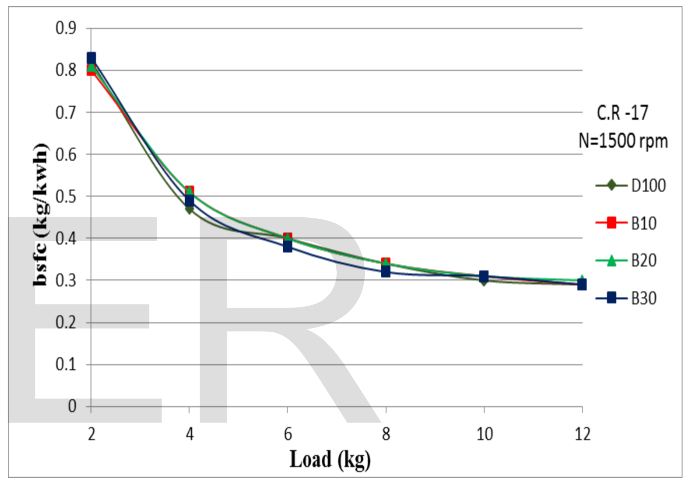


**Fig. 4.4:** bsfc for different tested fuels at different loads.

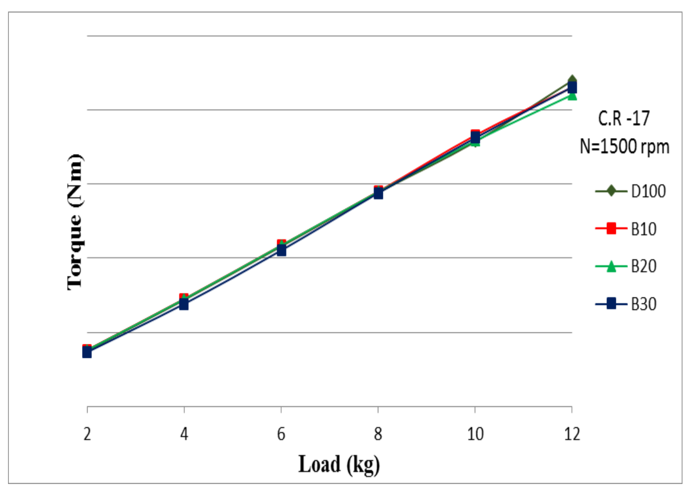


**Fig. 4.5:** Torque against the engine load for various fuels.

Fig. 4.6 shows that mineral diesel has lower brake thermal efficiency as compared to B30 due to its lower combustion efficiency. It is due to the higher oxygen content of biodiesel which in turns improve the combustion of the engine and increase the BTHE significantly. Also, due to larger ignition delay of biodiesel, a larger amount of fuel gets burned in the premixed mode which increases BTHE.

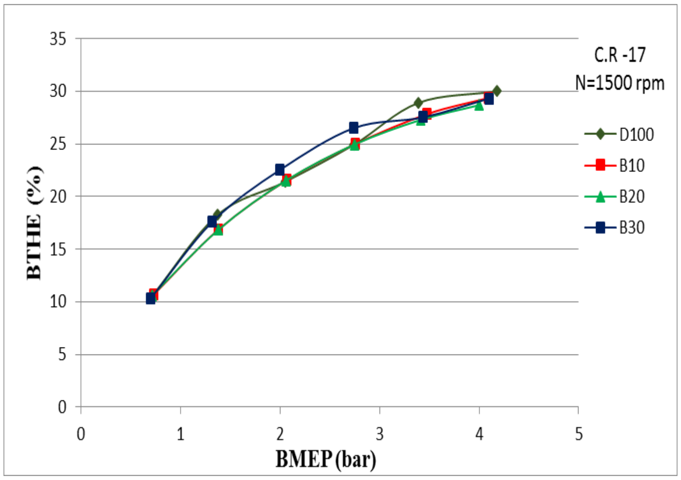


**Fig. 4.6:** BTHE relative to BMEP for various fuels

## 4.2 Emission Characteristics

Fig. 4.7 shows the emission of carbon monoxide (CO) at different load condition decreased along with the increase in the amount of biodiesel up to B20 in biodiesel-diesel blends. Highest reduction in CO emission was observed for B20 for all engine loads. The average decrease of CO emissions when fueled with B20 is 22.5% for all engine loads correspondingly compared with that of mineral diesel this may be due to the additional oxygen content of biodiesels than diesel fuel which ensures complete combustion.

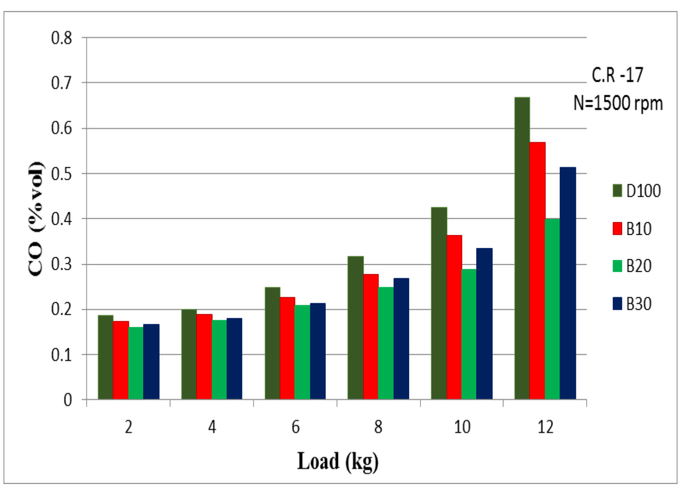


**Fig. 4.7:** CO against engine load for various fuels.

Fig. 4.8 shows that all the biodiesel-diesel blends gave the higher CO2 emission as compared to with that of mineral diesel. B10 gave the highest amount of CO2 emission. Although CO2 is considered as a pollutant, from the engine performance point of view, it indicates that the engine can perform well as it can achieve complete combustion.

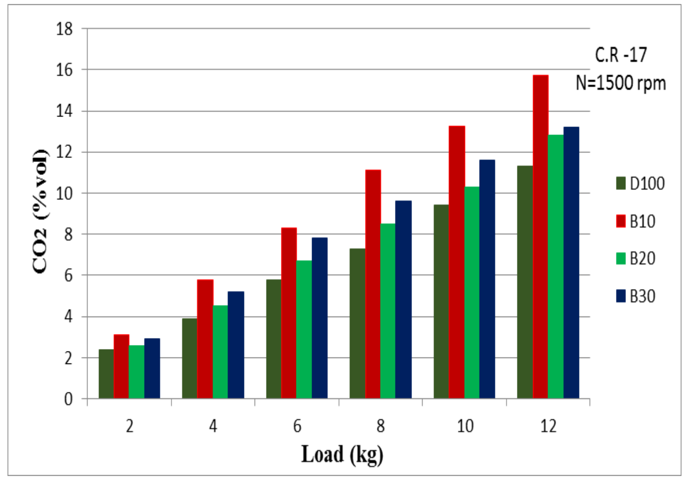


**Fig. 4.8:** Carbon dioxide against engine load for various fuels.

It can be seen from the Fig.4.9 that amount of unburned hydrocarbons (HC) decreased with the increase in the amount of biodiesel in the biodiesel-diesel blends. B20 gives the minimum emission of HC for almost all load conditions. The average decrease of UHC emissions when fueled with B20 is 20% for all engine loads correspondingly compared with that of mineral diesel. High oxygen content of biodiesel also aids to complete combustion, hence reduce HC emission.

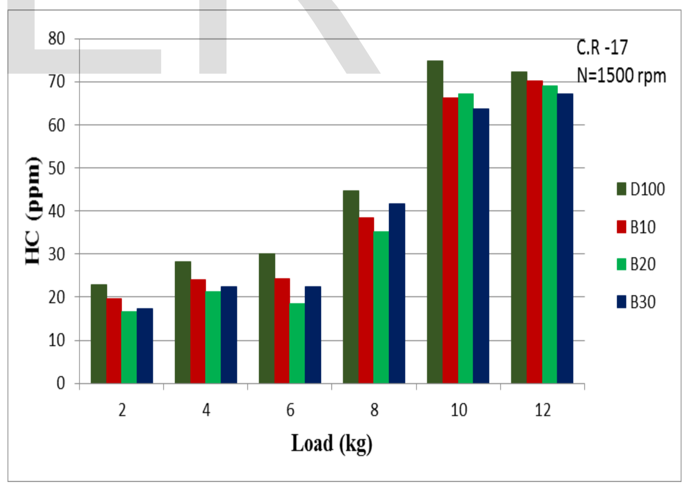


**Fig. 4.9:** HC emission against engine load for various fuels.

It can be seen from the Fig. 4.10 that NOx emissions increased with the increase in the amount of biodiesel in biodiesel-diesel blends. Average NOx emission of D100 was found 13% lower than B20. NOx production is significant for all fuel blends at all load condition; but it decreased with load and for B20 it decreased by 10% at high load condition. The main reason behind that is the higher oxygen content of biodiesel, which results more complete combustion and higher peak temperature that results more NOx.

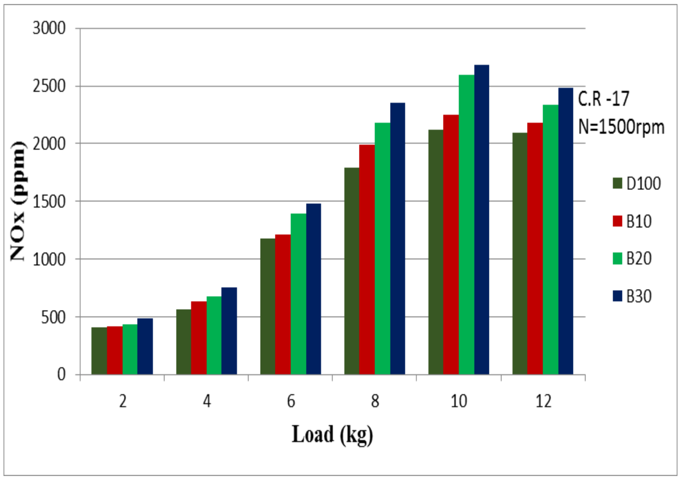


**Fig. 4.10:** NOx emission against engine load for various fuels.

## 5 CONCLUSIONS

An experimental investigation has been conducted in this work to explore the performance and emissions of different biodiesel blends on a single cylinder diesel engine. Test result analysis has shown that

- B20 & B30 shows 3% and 4% higher bsfc compared to baseline diesel fuel at all engine loads. The 20% biodiesel blend (B20) was found to be optimum concentration which improved the thermal efficiency of the engine. The highest improvement is around 1.5% with respect to diesel fuel.
- Highest reduction in CO emission was observed with B20. The average reduction in CO emission when fueled with B20 is 22.5% for all engine loads correspondingly compared with that of mineral diesel.
- Highest reduction in HC emission was observed when fueled with B20. Compared with the mineral diesel.
- NOx emissions for biodiesel blend fuels are higher. Average NOx emission of D100 was found 13% lower than B20. NOx production is significant for all fuel blends at all load condition; but it decreased with load and for B20 it decreased by 10% at high load condition.

Based on the above study it is found that the blends containing up to 20% (by volume) biodiesel can be used directly as alternative fuel and do not require any major modification in the engine.

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