INFLUENCE OF OXYGEN ENRICHMENT ON COMPRESSION IGNITION ENGINES USING BIODIESEL BLENDS

by

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The influence of oxygen enrichment on performance and emission characteristics of a single cylinder diesel engine operated with biodiesel blends have been investigated in this work. The methyl ester of jatropha biodiesel was selected as biodiesel and four blends (B10, B20, B30, and B40) were selected for experimental investigations. The performance and emission characteristics were obtained for the these blends along with three oxygen enrichment flow rates (1, 3, and 5 L per minute) using an oxygen cylinder at the air intake in the diesel engine. The performance and emission characteristics were studied and compared with the diesel and biodiesel. It was observed that, oxygen enrichment enhances the brake thermal efficiency, HC, CO, and smoke. B10 biodiesel with 5 L per minute oxygen enrichment was found to be the best fuel for biodiesel operation.

Key words: *oxygen enrichment, biodiesel blends, engine performance*

Introduction

The diesel engines are most commonly used in public transport, farming, and power generation applications. However, the fast exhaustion of fossil fuel resources and its poor environmental impacts have created research interests on identifying an alternative option for diesel fuels [1, 2]. During last two decades, many investigations and improvement initiatives have been progressed with biodiesel fuels as alternatives. Biodiesels are regarded as environmentally pleasant fuels comprised completely of renewable resources which have the prospective to reduce fossil diesel dependency and greenhouse gas emissions. Biodiesels are mixtures of fatty acid methyl (or ethyl) esters resulting from vegetable oils, animal fat, algae, or residues of food processing processes by transterification with the aid of methanol (or ethanol) as a solvent to lesser the viscosity and surface tension adequately to allow satisfactory atomization of the sprays in engines [3-7]. Among all biodiesel available, jatropha has the high potential in India because of minimum water requirement, less maintenance, land availability, and government mission. The jatropha biodiesel can be produced effectively by transesterification process [8-10]. However, the use of biodiesel has certain boundaries such as, high viscosity primary to poor atomization and engine gum drop leads to injector chocking in the existing engines. The insufficient oxygen quantity in the engine intake while using biodiesel results in

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raise particulate emissions, CO, and unburned HC. The problems of biodiesel may be reduced by adopting methods like exhaust gas recirculation, water injection, pre-heating, and oxygen enrichment. The oxygen enrichment in the engine intake overcomes the major environmental drawbacks and improves the combustion characteristics, and reduces the emissions. Earlier reported studies confirmed that the engine emissions such as, CO, particulate emissions, unburned HC, more ignition delay were significantly reduced by enriching the oxygen in the engine intake [11-15]. The cited literatures confirmed that many research and development activities have been reported on the performance enhancement of diesel engines using oxygen enrichment. However, there is no specific work reported on oxygen enrichment for the use of jatropha oil. Hence, this research work aims to attempt the oxygen enrichment in a single cylinder diesel engine using jatropha biodiesel for varying proportions of oxygen flow rate and varying biodiesel blends. The objective of this work is to find the performance and emission characteristics of oxygen enriched biodiesel blends in a single cylinder diesel engine.

Production of biodiesel

Jatropha biodiesel is produced by reacting with a methanol in presence of sulfuric acid catalyst. It is obtained by two stage process. The first stage process is called etherification with methanol and acid catalyst (sulfuric acid-98% pure) for one hour reaction at 60 °C. The second stage is called transesterification. Triglyceride of the jatropha oil reacts with methanol with base catalyst potassium hydroxide about 65 °C and form ester and glycerol. The tri glyceride is converted to diglyceride. After transesterification, the two layers were formed. The top cold layer was biodiesel and the bottom layer was glycerin. The raw jatropha biodiesel were separated from the glycerol layer after water washing [16].

Experimental set-up

The experimental set-up is shown in fig. 1. The atmospheric air is supplied into the mixing chamber through the air filter, which filters the air and other impurities. The experimental set-up is equipped with oxygen cylinder, pressure gauge, and flow meter, which enrich the amount of oxygen in the mixing chamber. The atmospheric air and the additional oxygen supplied gets mixed up in the mixing chamber and supplied into engine combustion chamber

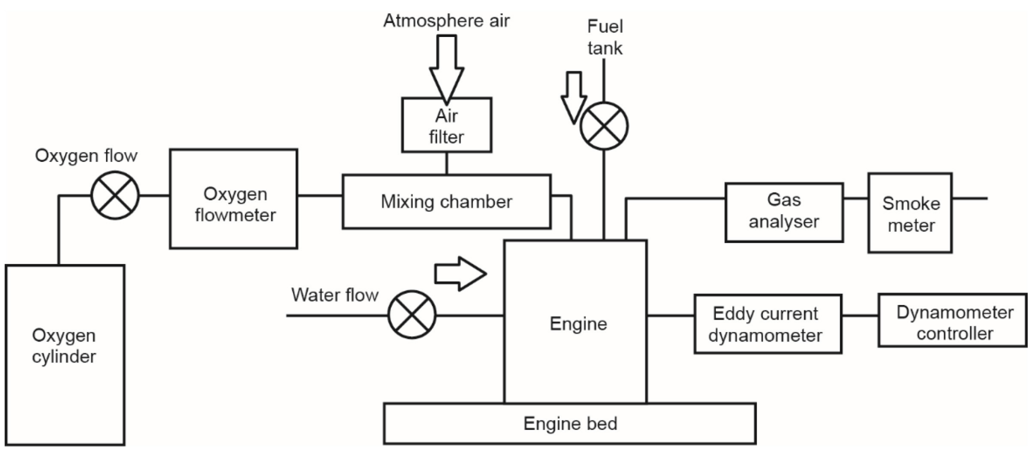

Figure 1. Schematic view of experimental set-up

during the fuel flow. The fuel to red in the tank supplies the required quantity. The fuel flow is controlled by means of a control valve. The engine crank shaft is connected with eddy current dynamometer. The emissions in the exhaust gas passed through the exhaust pipe were measured using gas analyzer (tab 1).

Experimental procedure

The engine working conditions and water availability were checked. Then the engine was started and allowed to run to attain steady-state conditions to avoid the transient errors. The atmospheric air was enriched with oxygen by integrating the mixing chamber with separate oxygen cylinder. The mixing chamber was connected with the inlet manifold. The oxygen flow was measured using the oxygen flow meter and the oxygen pressure can be controlled by a pressure regulator. The oxygen supply was varied at the rate of 1, 3, and 5 L per minute. The oxygen flow measurement was monitored by oxygen flow meter. The biodiesel B10 (90% diesel and 10% jatropha biodiesel), B20 (80% diesel and 20% jatropha biodiesel), B30 (70% diesel and 30% jatropha biodiesel), and B40 (60% diesel and 40% jatropha biodiesel) were prepared separately. The engine performance was tested using each biodiesel fuel blend. The load was varied manually between 0 and 16 kg (five different loads such as, 0, 4, 8, 12, and 16 kg) and it was checked with digital indicator. The fuel flow was controlled by a control valve. The engine speed was maintained at 1500 rpm, which was measured by a digital tachometer. The oxygen supply was measured using oxygen flow meter. The oxygen gets mixed with atmospheric air in the mixing chamber. Initially, the oxygen flow was maintained at 1 L per minute using oxygen control valve. The performance of engine was evaluated for B10, B20, B30, B40, and B50 fuel blends and the experimental observations were made for five different loading conditions (such as 0, 4, 8, 12, and 16 kg). The volume of air intake was monitored using orifice meter-manometer set-up. The fuel consumption was measured using burette. Then the oxygen flow was varied as 3 and 5 L per minute and the experimental procedures were repeated.

Table 1. Specifications of the experimental set-up

Description	Specifications
Make	Kirolosker
Power	5 HP
Number of cylinders/cooling	1/water
Bore and stroke	80 mm and 110 mm
Capacity	661 cm^3
Speed	1500 rpm
Compression ration	12:1-18:1
Load	Eddy current dynamometer
Fuel tank capacity	15 L
Exhaust gas analyzer	AVL 444 gas analyzer

Result and discussions

The performance and emission results of various tests conducted on biodiesel with varying flow rates of oxygen are presented here.

The variations of brake thermal efficiency with load for B10, B20, B30, and B40 biodiesel blends under the influence of 1, 3, and 5 L per minute oxygen enrichment are compared in fig. 2. It is observed that, brake thermal efficiency (BTE) is decreased with biodiesel blend and is increased with increase in oxygen concentration at the engine intake. The decreases in BTE are 2, 4, 6, and 8% for B10, B20, B30, and B40 blends, respectively, when compared with diesel. The average increases in BTE are 1.5, 3, and 4.5% for 1, 3, and 5 L per

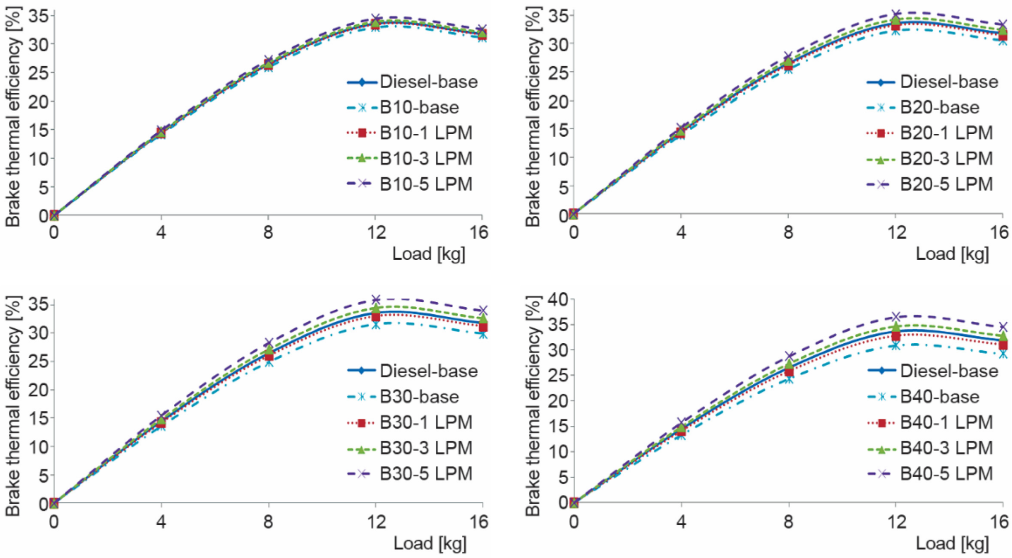

Figure 2. Variations of load *vs.* brake thermal efficiency for various blends and oxygen enrichment

minute, respectively, in B10 blend. The average increases in BTE are 3, 6, and 9% for 1, 3, and 5 L per minute, respectively, in B20 blend. The average increases in BTE are 4.5, 9, and 13.5% for 1, 3, and 5 L per minute, respectively, in B30 blend. The average increases in BTE are 6, 12, and 18% for 1, 3, and 5 L per minute, respectively, in B40 blend. These results show that oxygen flow rate of oxygen produces more efficiency because of complete combustion in the engine.

The variations of hydrocarbon (HC) with load for B10, B20, B30, and B40 biodiesel blends under the influence of 1, 3, and 5 L per minute oxygen enrichment are compared in fig. 3. It is observed that, HC is decreased with biodiesel blend and is further decreased with increase in oxygen concentration at the engine intake. The decreases in BTE are 6, 9, 12, and 16% for B10, B20, B30, and B40 blends, respectively, when compared with diesel. The average decreases in HC are 25.4, 58.3, and 82% for 1, 3, and 5 L per minute, respectively, for all biodiesel blends when compared with base biodiesel blend. The decrease in HC for biodiesel blend is due to complete combustion because of oxygenated blends. The further decrease in HC in oxygen enrichment is due to excess oxygen present in the system.

The variations of carbon monoxide with load for B10, B20, B30, and B40 biodiesel blends under the influence of 1, 3, and 5 L per minute oxygen enrichment are compared in fig. 4. It is observed that, carbon monoxide (CO) is increased with biodiesel blend and is decreased with increase in oxygen concentration at the engine intake. The decreases in CO are 1, 2, 3, and 4% for B10, B20, B30, and B40 blends when compared with diesel. The average decreases in HC are 38.4, 53.8, and 77% for 1, 3, and 5 L per minute, respectively, for all biodiesel blends when compared with base biodiesel blends. The increase in HC for biodiesel blend is due to incomplete combustion because of poor oxygen in the system. The decrease in HC in oxygen enrichment is due to oxygen present in the system which produces complete combustion.

The variations of CO_2 with load for B10, B20, B30, and B40 biodiesel blends under the influence of 1, 3, and 5 L per minute oxygen enrichment are compared in fig. 5. It is

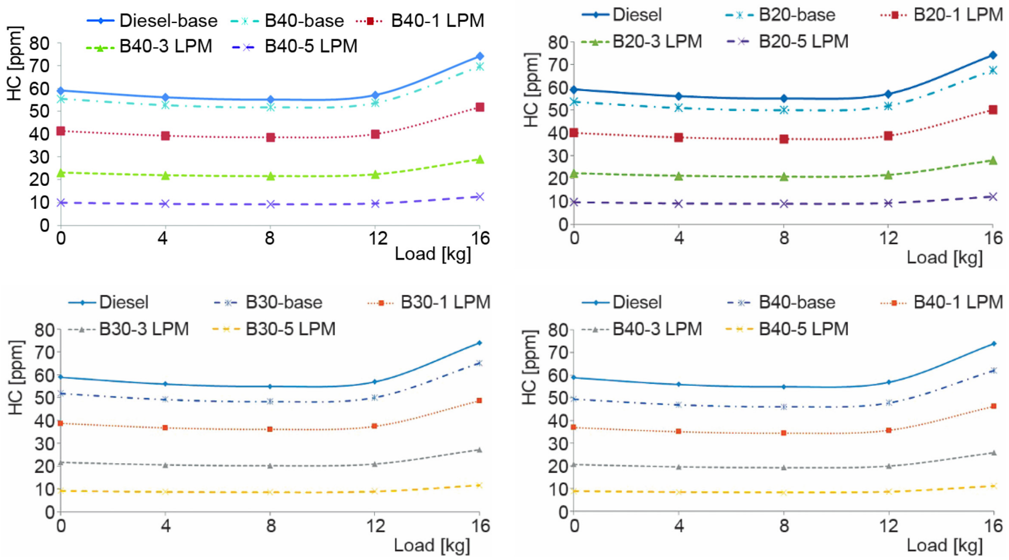

Figure 3. Variations of load *vs.* HC for various blends and oxygen enrichment

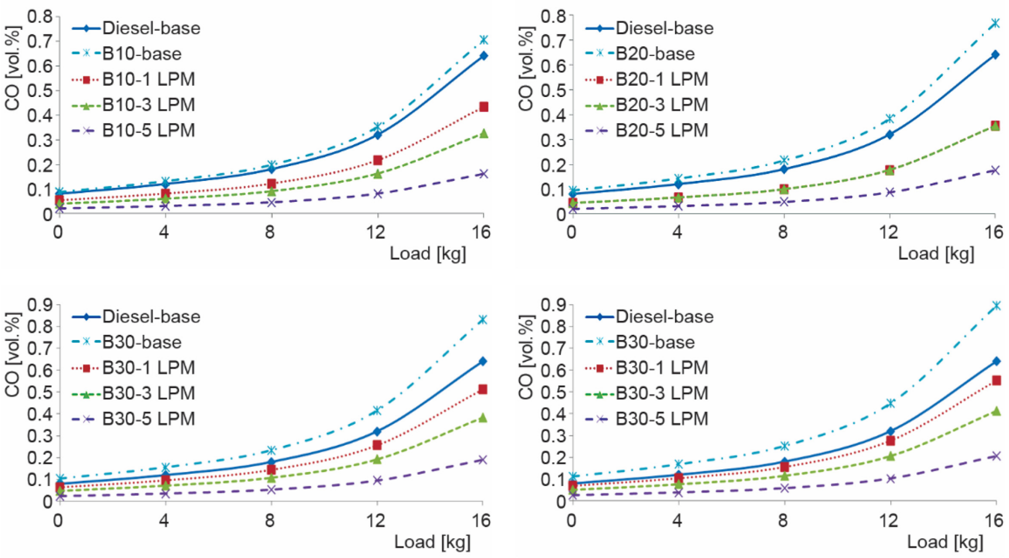

Figure 4. Variations of load *vs.* CO for various blends and oxygen enrichment

observed that, CO_2 is decreased with biodiesel blend and is increased with increase in oxygen concentration at the engine intake. The decreases in CO_2 are 2, 4, 6, and 8% for B10, B20, B30, and B40 blends when compared with diesel. The average increases in HC are 15.6, 31.25, and 41.6% for 1, 3, and 5 L per minute, respectively, for all biodiesel blends when compared with base biodiesel blends. The decrease in CO_2 for biodiesel blend is due to incomplete combustion because of poor oxygen in the system. The increase in CO_2 in oxygen enrichment is due to oxygen present in the system which produces complete combustion.

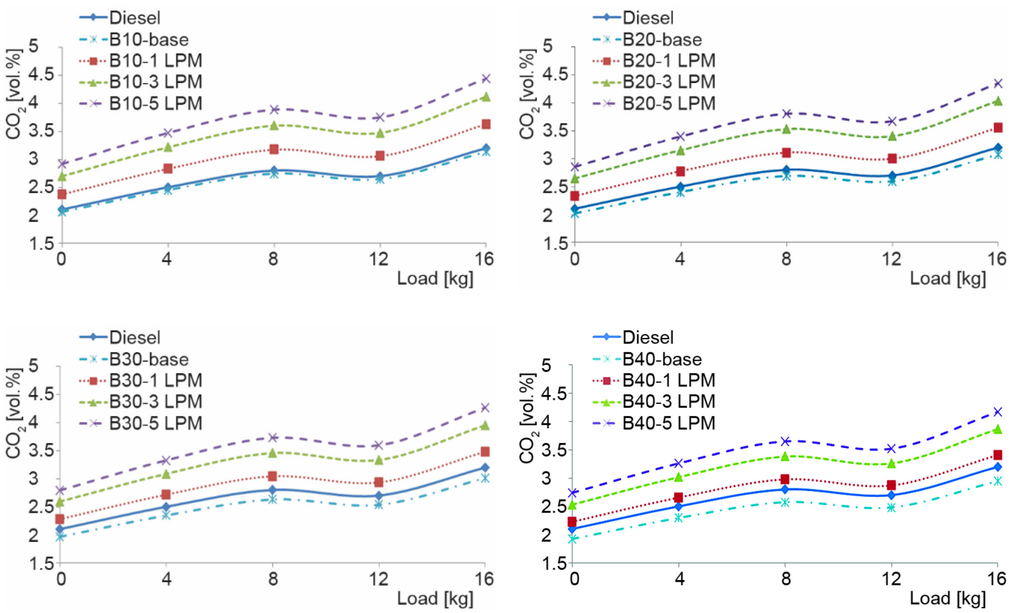

Figure 5. Variations of load *vs.* CO_2 for various blends and oxygen enrichment

The variations of NO_x with load for B10, B20, B30, and B40 biodiesel blends under the influence of 1, 3, and 5 L per minute oxygen enrichment are compared in fig. 6. It is observed that, oxides of nitrogen (NO_x) is increased with biodiesel blend and is further increased with increase in oxygen concentration at the engine intake. The increases in NO_x are 3, 6, 9, and 12% for B10, B20, B30, and B40 blends, respectively, when compared with diesel. The average further increases in NO_x are 5.7, 14.28, and 20.7% for 1, 3, and 5 L per minute, respectively, for all biodiesel blends when compared with base biodiesel blends. The increase in

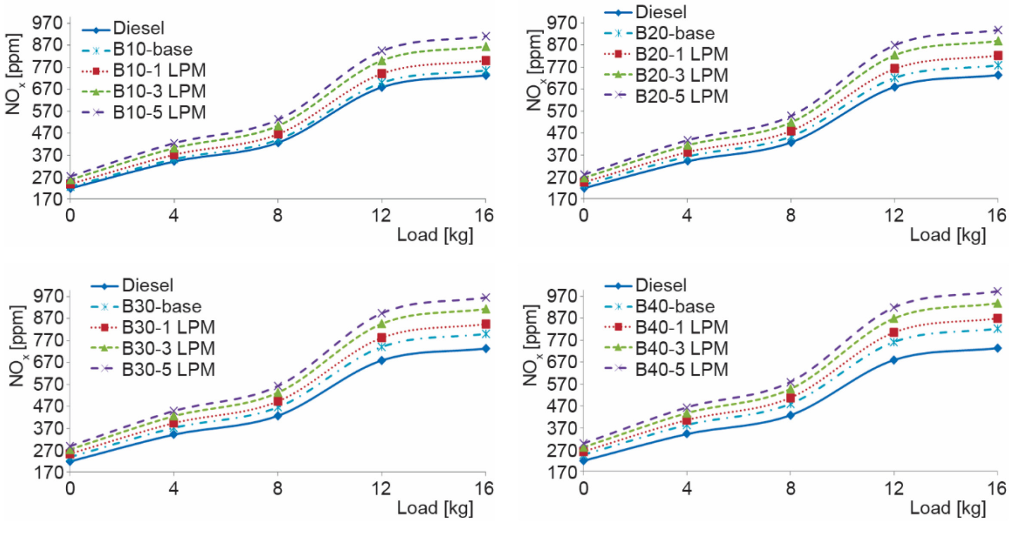

Figure 6. Variations of load *vs.* NO_x for various blends and oxygen enrichment

NO_x for biodiesel blend is due to complete combustion because of oxygenated fuel in the system. The further increase in NO_x in oxygen enrichment is due to excess oxygen present in the system.

The variations of smoke with load for B10, B20, B30, and B40 biodiesel blends under the influence of 1, 3, and 5 L per minute oxygen enrichment are compared in fig. 7. It is observed that smoke decreases with biodiesel blend and is further decreased with increase in oxygen concentration at the engine intake. The decreases in smoke are 3, 6, 9, and 12% for B10, B20, B30, and B40 blends, respectively, when compared with diesel. The average further increases in smoke are 33, 50, and 67% for 1, 3, and 5 L per minute, respectively, for all biodiesel blends when compared with base biodiesel blends. The decrease in smoke for biodiesel blend is due to complete combustion because of oxygenated fuel in the system. The further decrease in smoke in oxygen enrichment is due to excess oxygen which completed burning completely.

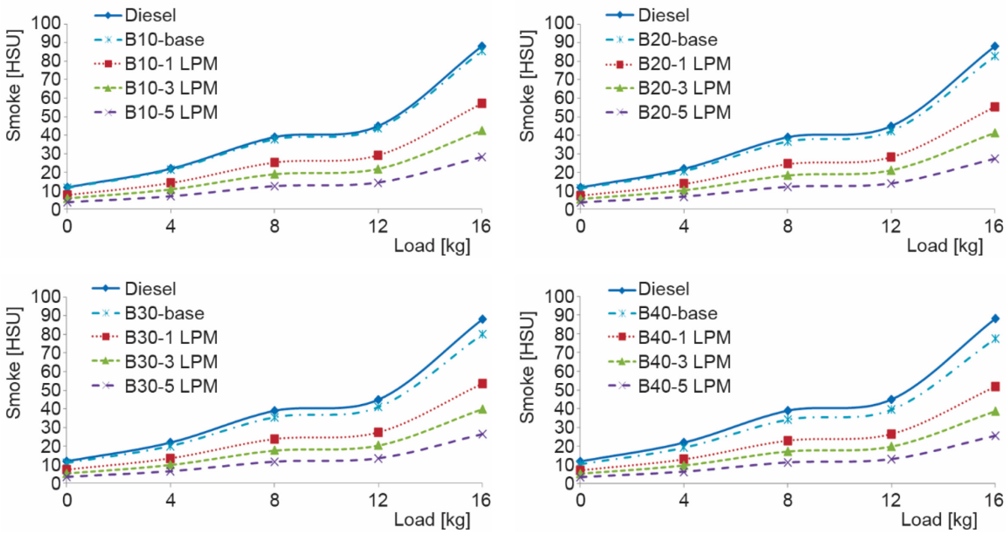

Figure 7. Variations of load *vs.* smoke for various blends and oxygen enrichment

Conclusions

The performance and emission characteristics of a single cylinder diesel using four jatropha biodiesel blends (B10, B20, B30, and B40) under the influence of three oxygen enrichment (1, 3, and 5 L per minute) have been investigated and the following major conclusions are drawn.

- In biodiesel blends, the decreases in brake thermal efficiency, HC, and smoke were obtained. And also increases in CO, CO_2, and NO_x were obtained for biodiesel blends. These problems of biodiesel were attempted by using oxygen enrichment in this work.
- The thermal efficiency was improved for oxygen enrichment in biodiesel and it was highest as 34.54% for B40 blend with 5 L per minute oxygen enrichment.
- The HC emission was decreased for oxygen enrichment in biodiesel and it was lowest as 11.18 PPM for B40 blend with 5 L per minute oxygen enrichment.
- The CO emission was decreased for oxygen enrichment in biodiesel and it was lowest as 0.19 % volume for B10 blend with 5 L per minute oxygen enrichment.

- The CO_2 was increased for oxygen enrichment in biodiesel and it was highest as 4.44% volume for B10 blend with 5 L per minute oxygen enrichment.
- The NO_x emissions were increased for oxygen enrichment in biodiesel and it was highest as 992 PPM for B40 blend with 5 L per minute oxygen enrichment.
- The smoke emission was decreased for oxygen enrichment in biodiesel and it was lowest as 25 HSU for B40 blend with 5 L per minute oxygen enrichment.
- The B10 blend along with 5 L per minute oxygen enrichment will be the best option as it gives increases increased brake thermal efficiency and reduced HC, CO, CO_2, NO_x, and smoke emissions.

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