International Journal of
I.C. Engines and Gas Turbines

ISSN: 2582-290X
Volume 9, Issue 2, 2023
DOI (Journal): 10.37628/IJICEGT

http://mechanical.journalspub.info/index.php?journal=JIEGT&page=index

Research IJICEGT

Production of Composite Biodiesel from Pongamia & Simarouba oil and Comparison of Performance of Composite Biodiesel with Diesel

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Abstract

Pongamia oil and simarouba oil are mixed in equal volume to prepare the composite oil. The composite oil is processed through two stage transesterification process to produce composite biodiesel. The composite biodiesel blends are prepared by mixing neat biodiesel with diesel by 5%, 10% and 20% volume respectively. The engine control factors viz., injection pressure, injection timing and fuel preheating temperature are considered for evaluating the performance of composite biodiesel blends on CRDI engine. The experiments are carried out at injection pressure of 600 bar, 21˚bTDC and 40˚C of fuel temperature. On comparison of biodiesel blends, it is observed that BTE is higher and BSFC is lower for composite biodiesel blends than diesel. The emissions such as CO and CO_2 are found to be lower, and NOx is found to be higher for composite biodiesel blends than diesel.

Keywords: Composite biodiesel, Transesterification, Performance, Emissions, Engine

INTRODUCTION

Biofuels are being considered seriously as it could be a solution to many problems such as depletion of fossil fuel resources, environmental issues, energy security issues and rural unemployment. A number of factors, including the irreversible and rapid depletion of fossil fuels, their high price volatility, decreased energy security, supply instability for countries that rely on them, high import costs for fuel, and the negative environmental effects of fossil fuels, are pressing calls for the exploration of non-toxic, renewable alternative energy sources [1]. It has been determined that biodiesel is an affordable energy source that emits less hazardous emissions and is easily accessible for use as an alternative fuel in internal combustion (CI) engines [2,3,4]. As a renewable resource, this fuel has the potential to reduce greenhouse emissions and be considered as a mineral diesel substitute. The primary barrier to the commercialization of biodiesel, however, is its high cost [5]. It is chemically produced by transesterification reaction, in which triacyl glycerides irrespective of its origin react with short chain alcohols (usually methanol/ethanol) to form alkyl esters [6,7,8].

In this research paper, production of biodiesel from composite pongamia and simarouba oil is investigated. The composite biodiesel blends are used as a fuel in diesel engine to explore their viability. The combustion, performance and emissions of composite biodiesel blends are compared with diesel considering injection pressure, injection timing and fuel temperature as engine control variables.

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Received Date: December 06, 2023
Accepted Date: December 20, 2023
Published Date: January 22, 2024

Citation: G.V. Naveen Prakash, Nithyananda B.S., Vinay K.B., S.A. Mohankrishna. Enhancement in Fuel Efficiency with Magnetised Nano Ferro Particles in Internal Combustion Engines. International Journal of I.C. Engines and Gas Turbines. 2023; 9(2): 1–9p.

METHODOLOGY

- *Identification and Selection of Nonedible oil:* In India, non-edible feedstocks, also known as second-generation feedstocks, are a great substitute for first-generation feedstocks. In this study, pongamia and simarouba oil are taken into consideration as possible feedstocks for biodiesel.
- *Production of biodiesel from composite pongamia-simarouba oil:* The simarouba and pongamia oil are mixed in equal proportion to produce composite simarouba - pongamia biodiesel. Then the neat composite biodiesel is blended with diesel by 5%, 10% and 20% by volume.
- *Experimentation on CRDI engine:* The composite biodiesel blends CB5, CB10 and CB20 are tested in CRDI engine to check its suitability as fuel injection pressure of 600bar, injection timing of 21˚bTDC and fuel temperature of 40˚C as engine input variables.
- *Comparison of Performance of Composite Biodiesel Blends with Diesel:* When comparing composite biodiesel blends with diesel, factors like cylinder pressure, net heat release (NHR), performance responses like BTE and BSFC, and emission responses like CO, CO_2 and NO_X are considered.

RESULTS AND DISCUSSION

Composite Biodiesel Production from Pongamia-Simarouba oil

The biodiesel production using non-edible oil involves estimation of free fatty acids (FFA) percentage, esterification/transesterification process, biodiesel separation, washing and drying of biodiesel. Oil extracted from the seeds of simarouba and pongamia have higher viscosity due to the presence of FFA. These oils have to be processed further to reduce viscosity and use it as a fuel alternate to diesel. The simarouba oil and pongamia oil is processed in Biofuel park,. The preparation of biodiesel depends on the presence of the FFA percentage. If FFA percentage in oil is more than 4%, then two stage process i.e., esterification and transesterification is carried out. Fig. 1 shows the biodiesel production process.

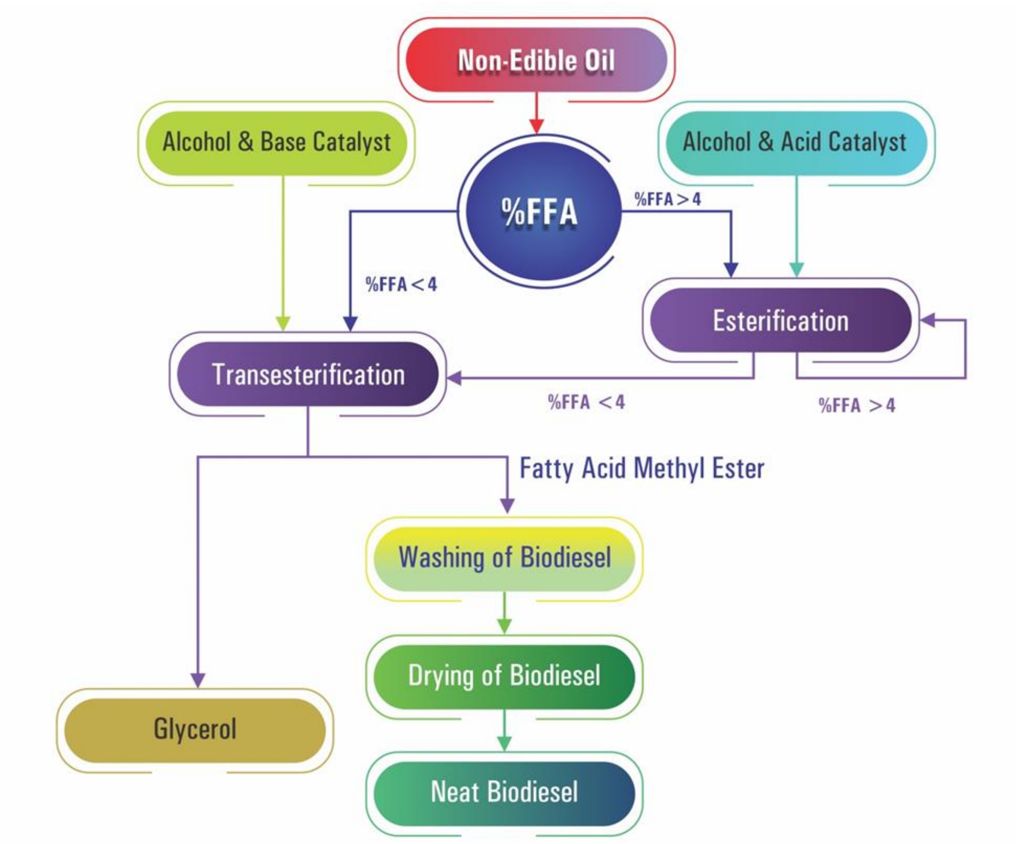

Figure 1. Biodiesel Production Process.

Composite oil is prepared by mixing equal volume of pongamia and simarouba oil and then processed to prepare biodiesel by using transesterification process based on FFA percentage. In transesterification process, alkyl esters and glycerol are obtained by the reaction of alcohol with the fatty acids of oil. Since the oil have FFA more than 4 %, acid catalysed esterification is carried out before transesterification process [9, 10, 11]. It is carried out in a three-neck laboratory scale reactor using magnetic stirrer as shown in Figure 2.

Figure 2. Three Neck Laboratory Scale Reactor.

Composite oil is preheated to a temperature of 60-70˚C for about 15 mins in large beaker to remove moisture content. The heated composite oil is poured into three neck laboratory reactor and is maintained at a temperature of 60˚C. A 300 ml methanol and 10 ml concentrated sulphuric acid per litre of oil is added into the reactor. The process is continued for 2 hours with continuous stirring at 60˚C. At the end of process, a dark layer is observed at top layer of oil and esterified oil is transferred into a separating flask. The esterified oil is allowed to settle down for 24 hours and a black coloured acid layer is formed at the top of oil. The bottom layer of oil is collected in a beaker and its FFA is determined using titration process. The FFA percentage of esterified pongamia oil is found to be 3.7 % and hence transesterification process is carried out. If the FFA of esterified pongamia oil is more than 4%, the same procedure is to be carried out till the FFA level is reduced to less than 4%.

The esterified composite oil is taken in three neck laboratory scale reactor and heated to 60˚C temperature. A 300 ml of methanol per litre of oil is taken in a beaker and 10g NaOH catalyst is added to methanol and stirred continuously using a magnetic stirrer to prepare a methoxide mixture. Then methoxide mixture is poured into laboratory reactor with constant stirring at 600 rpm using magnetic stirrer and temperature is maintained around 60˚C for 2 hours. Then, the transesterified oil is transferred into separating flask and kept for 24 hours to settle down. After settling, two layers are formed, with top layer being composite methyl ester (Biodiesel) and the bottom layer of glycerol and impurities . The bottom layer is drained out and composite biodiesel is collected in a beaker.

The obtained composite biodiesel is washed with warm water of 40˚C without any agitation in washing funnel and allowed to settle for 1 hour. A soapy water layer is formed at the bottom of funnel and then soapy water is taken out carefully. This washing process is continued, till the clean water is obtained in bottom layer which indicates that biodiesel is free from soaps, leftover methanol and catalyst. Finally, moisture is removed from obtained composite biodiesel by heating it at 110 ˚C. Then heated composite biodiesel is cooled down to room temperature and stored in a closed container. Thus, neat composite biodiesel is obtained from simarouba and pongamia oil.

Comparison of Performance and Emission of Composite Biodiesel Blends with Diesel:

The B5, B10, and B20 blends of composite biodiesel are used in the experiments, which are conducted on a CRDI engine with an open ECU setup. Fig. 3 shows the technical specification of diesel engine. The responses like cylinder pressure, net heat release, brake thermal efficiency, brake specific fuel consumption, carbon monoxide emission, carbon dioxide emission and nitrogen oxide emission are recorded for biodiesel blends and diesel. The diesel was used in engine at standard operating conditions.

Product	**CRDI VCR Research Engine Test Setup, code 244**
Type	Single Cylinder, Four Stroke, Kirloskar Make Engine
Cooling Type	Water Cooled
Power	3.5 kW
Compression Range	12:1 to 18:1
Standard Injection Timing	23˚ bTDC
Standard Injection Pressure	600 bar
Common Rail	With Pressure Sensor And Pressure Regulating Valve
Dynamometer	Eddy Current, Water Cooled with Loading Unit
ECU	Nira i7r with Solenoid Injector Driver with Programmable ECU
Fuel Injector	Solenoid Driven
Calorimeter	Pipe in Pipe
Data Acquisition Software	"Engine Soft" Engine Performance Analysis Software
Rotameter	Eureka Make, Engine cooling 40-400 lph, Calorimeter 25-250 lph
Air box	MS fabricated with Orifice Meter and Manometer
Propeller shaft	Hindustan Hardy Make with Universal Joints
Fuel tank	15 liters Capacity with Fuel Metering Pipe of Glass

Figure 3. Specifications of CRDI Engine.

Cylinder Pressure

The pressure developed in the cylinder of engine depends on the combustion of fuels. It is well known that combustion in CI engine takes place in four phases namely ignition delay (ID) period, premixed stage/uncontrolled combustion, diffusion stage/controlled combustion and after burning [12, 13]. The biodiesel blends follow a similar cylinder pressure trend as that of diesel as it is evident from the graph. The cylinder pressure of 63.2 bar is obtained for diesel. The higher cylinder pressure is obtained to be 63.72 bar, 65.43 bar and 64.56 bar for CB5, CB10 and CB20 respectively. Composite biodiesel blends undergo combustion a few degrees later than diesel after injection at 21˚ bTDC. This has allowed effective compression of air inside combustion chamber increasing its pressure and temperature. This results in higher peak pressure for biodiesel blends as evident from graph in Figure 4.

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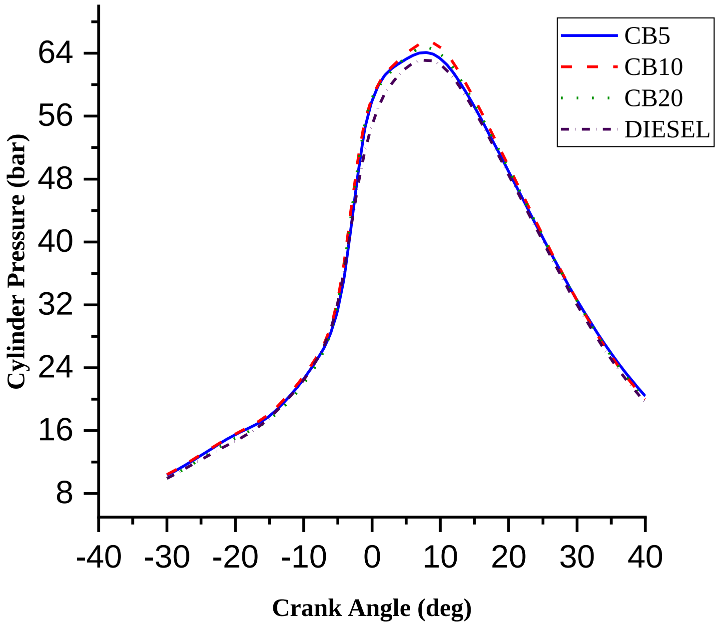

Figure 4. Cylinder Pressure for Composite Biodiesel Blends.

Net Heat Release

Heat release signifies the conversion of chemical energy contained in the fuel into heat energy during the combustion reaction in engine. fig. 5 shows the net heat release for composite biodiesel blends. The peak heat release of composite biodiesel blends CB5, CB10 and CB20 is found to be 60.5 J/°CA, 59.2 J/°CA and 59.6 J/°CA respectively. The higher NHR for biodiesel is a result of proper mixing of blends with air in the combustion chamber and higher oxygen content.

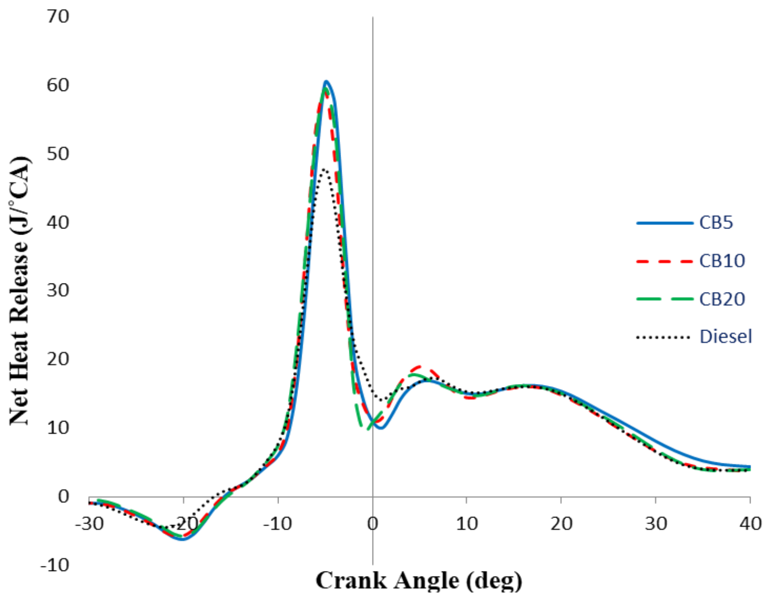

Figure 5. Net Heat Release for Composite Biodiesel Blends.

Brake Thermal Efficiency

Brake Thermal Efficiency is defined as brake power of engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy.

Figure 6 that the BTE of composite biodiesel blends is found to be higher than the diesel at IP of 600 bar, retarded IT of 21˚ bTDC and FPT of 40˚C. It is seen that the BTE for composite biodiesel blends increases by more than 5 % on an average than diesel. The graph shows the improved BTE for blends of biodiesel due to the availability of more oxygen in it than diesel, which enhances the combustion reactions.

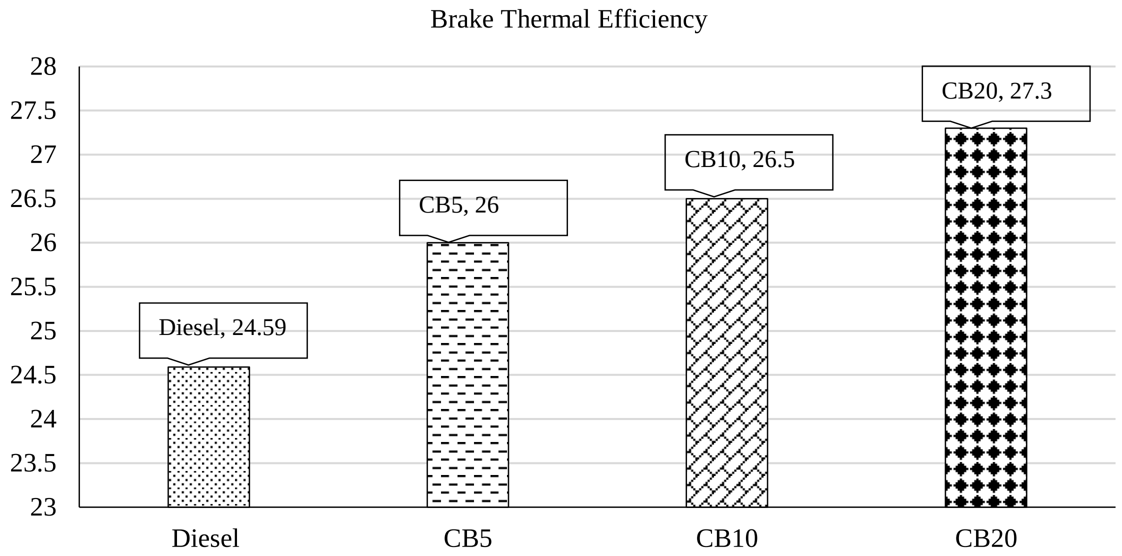

Figure 6. BTE for Composite Biodiesel Blends.

Brake Specific Fuel Consumption

Brake specific fuel consumption is the fuel rate per unit power output. It measures how efficiently an engine is using the fuel supplied to produce work. The BSFC for composite biodiesel blends is as shown in Figure 7. The decrease in BSFC for CB5, CB10 and CB20 biodiesel blends, when compared with diesel are found to be 3.13%, 3.13% and 6.45%, respectively. All the biodiesel blends are injected into the combustion chamber at 21˚ bTDC at higher IP of 600 bar and temperature of 40˚ C resulting in enhanced atomization of fuel and proper fuel and compressed air mixing.

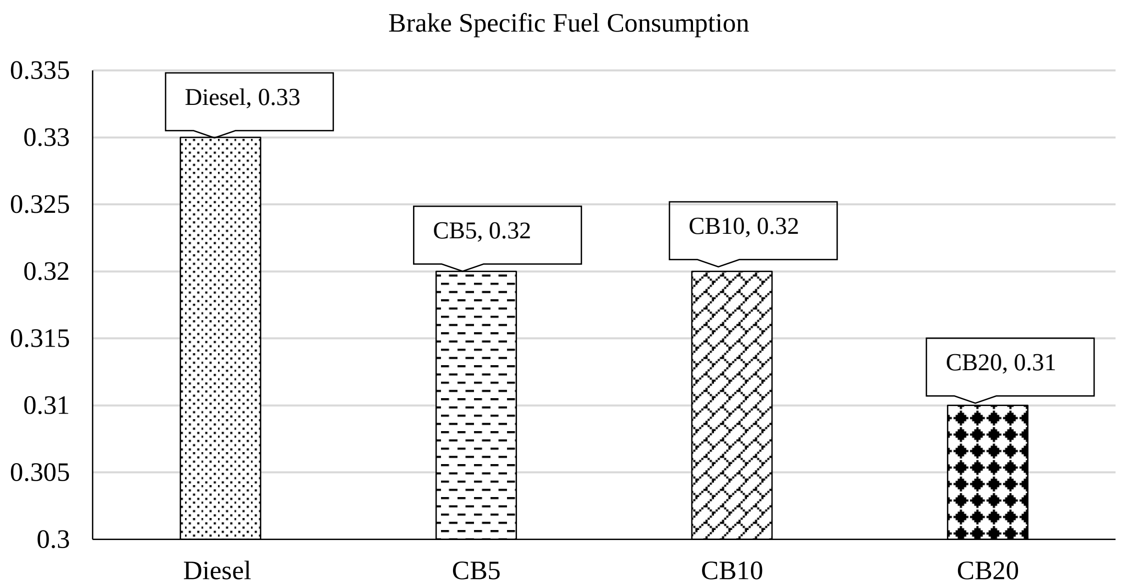

Figure 7. BSFC for Composite Biodiesel Blends.

Carbon Monoxide (CO) Emissions

The CO emission of CRDI engine for various blends of composite biodiesel and diesel are as given in Figure 8. The composite biodiesel blends i.e., CB5, CB10 and CB20 shows 101.67%, 73.48% and 130.48% of reduction in CO emissions respectively. It is evident from graph that the CO emissions of biodiesel blends are lower than diesel, resulting by the presence of more oxygen molecules in biodiesel. It may results in improved combustion and reduced CO emissions of engine.

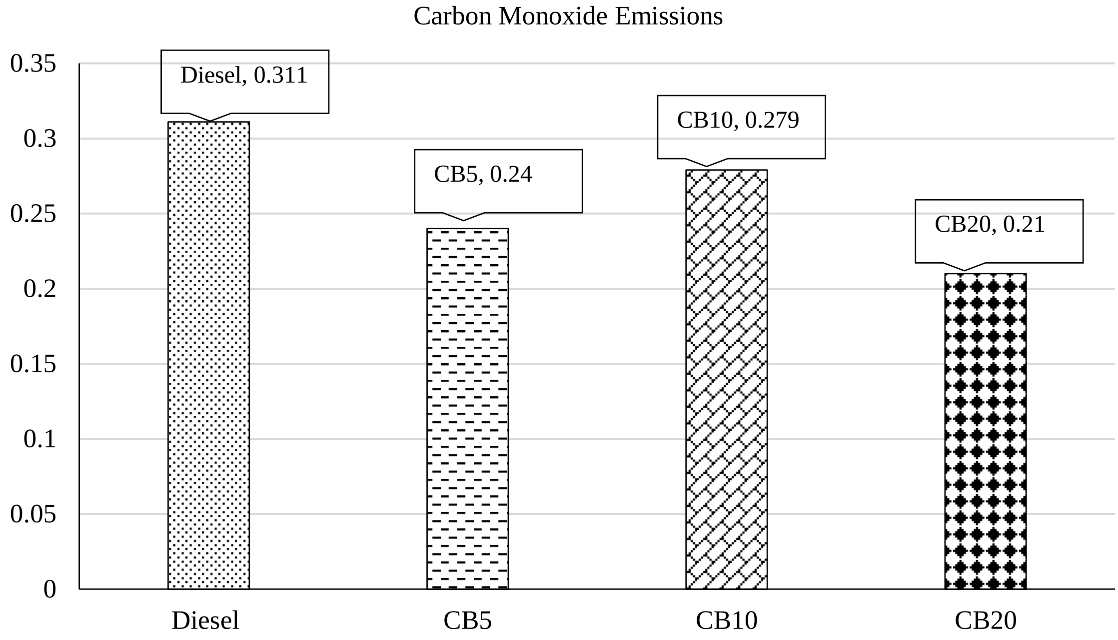

Figure 8. CO Emission for Composite Biodiesel Blends.

Carbondioxide (CO_2) Emissions

Figure 9 shows the CO_2 emission of CRDI engine running using composite biodiesel blends. It is noticed from the graph that the running an engine using biodiesel blends has resulted in decreased CO_2 emissions compared to diesel.

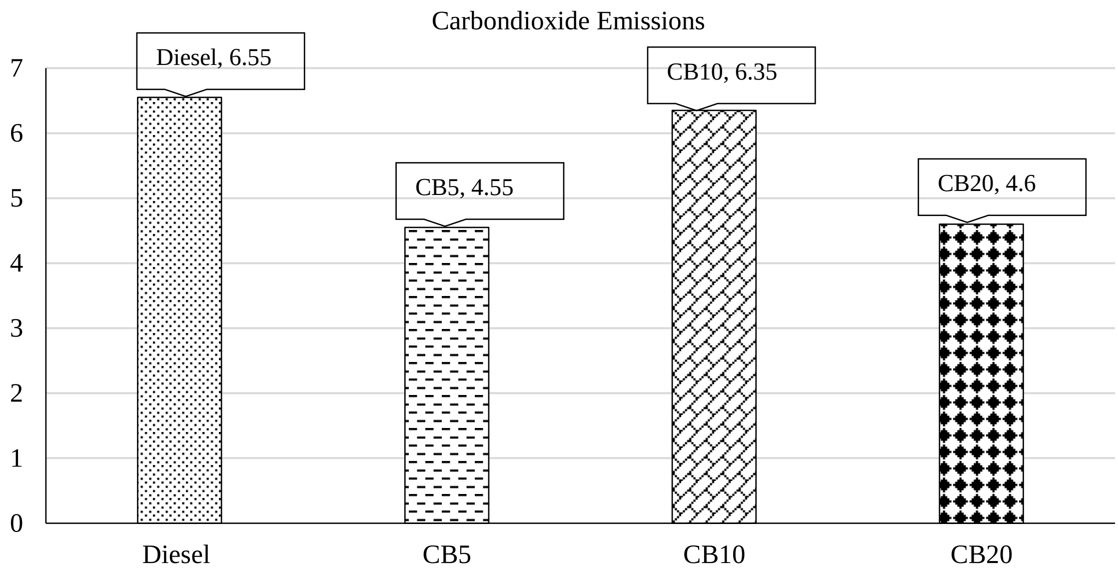

Figure 9. CO_2 Emission for Composite Biodiesel Blends.

Nitrogen Oxide (NO_x) Emissions

Figure 10 shows NO_x emissions released by the CRDI engine running with composite biodiesel blends and diesel. It is noticed in the graph that there is an increase in the emission of NOx for an engine fuelled by biodiesel blends. Biodiesel blends such as CB5, CB10 and CB20 shows increased NO_x emission by 2.03%, 18.84% and 8.87%, respectively.

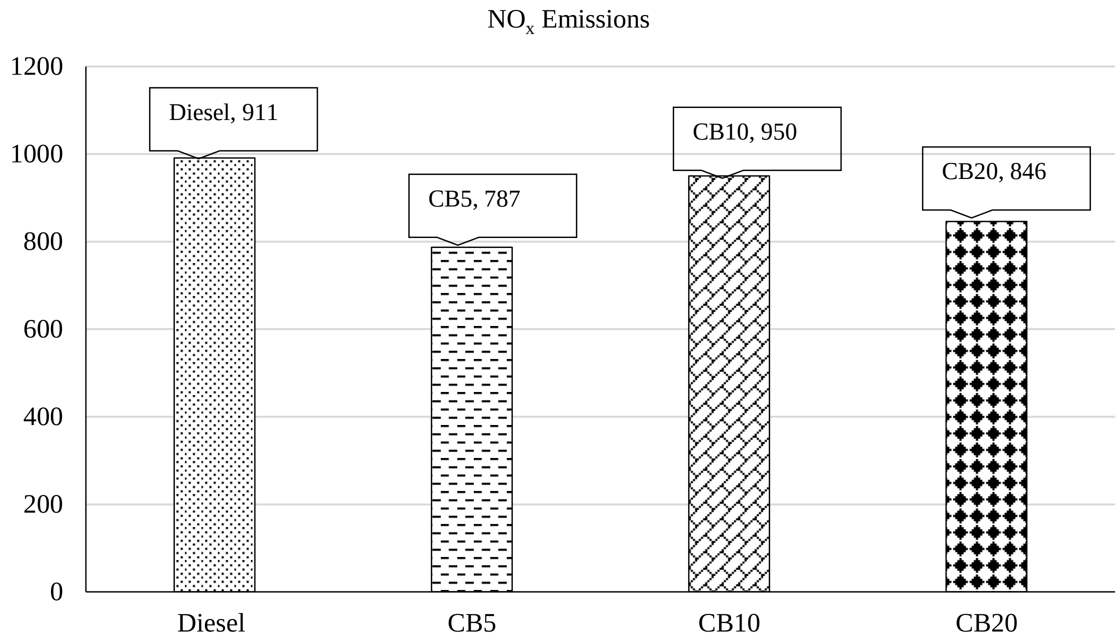

Figure 10. NOx Emission for Composite Biodiesel Blends.

CONCLUSION

Running biodiesel blends in a CRDI engine designed for diesel may not be appropriate due to its operating circumstances. The combustion, performance and emission of CRDI engine for composite biodiesel blends at injection pressure (IP) of 600 bar, injection timing (IT) of 21˚ bTDC and fuel preheating temperature (FPT) of 40˚C is compared with diesel under standard operating conditions. The results of the combustion investigation show that the cylinder pressure of blends of biodiesel is marginally greater than that of diesel. When compared to diesel, the biodiesel mixes exhibit a larger net heat release (NHR). The emissions viz., CO, and CO_2 for biodiesel blends of CRDI engine are found to be lower than diesel. The decrease can be attributed to increased oxygen concentration, improved atomization, faster vaporization, and adequate mixing of biodiesel as a result of elevated IP, delayed IT, and elevated fuel temperature. It is discovered that engines running on biodiesel emit more NOX than those running on diesel. This is explained by the biodiesel's increased oxygen concentration and combustion temperature.

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