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Impact of Injection Pressure on Emission Characteristics of Diesel Engine Using Rice Bran Oil Methyl Ester

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Abstract

The steep increase of global fuel consumption, the declined fuel reserves, raised import costs of fossil fuel due to monopoly of OPEC nations and great perilous impact on environment due to green gas emissions caused many researchers to focus their search for alternative renewable energy resources. Recently, biodiesels have emerging as potential alternative to diesel fuel because they are non-toxic, environment friendly and abundantly available at all geographic locations irrespective of regions. The present paper is aimed to evaluate the effect of injection pressure on emission characteristics such as smoke density, CO emission, particulate matter and NOx of direct injection compression ignition engine when fuelled with Rice Bran Oil Methyl Ester (RBOME). The experimental results of single cylinder, 4-stroke, water cooled diesel engine fuelled with different blends (BR20, BR40, BR60 and BR100) of RBOME at different injection pressures have revealed that neat biodiesel has lower CO emission, lower smoke density, lower particulate matter and moderately higher NOx emission at all injection pressures and blend percentage is affecting inversely proportional to emission characteristics. At injection pressure of 220 bar, the emission characteristics are optimal and it can be considered as optimum injection pressure with reference to emission parameters.

***Keywords**:* Biodiesel, Rice Bran Oil, Methyl Esters, Emission Characteristics, Injection Pressure.

1. Introduction

The global energy crisis due to disruption of fuel supplies, interruption of crude oil production from fossil fuel rich countries like Venezuela, increase in production cost that rapidly raising the fuel prices are not only threatening the nations economic and energy security, but also vulnerably impacting on environmental pollution. The previous research reviews revealed that the most possible way to meet the increasing demand and reduce the hazardous emissions is by using biodiesels as alternative fuels (Pryde, 1982 & Quick 1980). In general ethanol, methanol, plant oils (vegetable oils) and the methyl esters produced from these oils are commonly referred to as biodiesels (Knothe, 1997). But biodiesel and ethanol are two dominant bio-fuels, which are extensively used in the transportation sector (Poornima, 2013). Many researchers have shown much interest to use vegetable oils as alternative to diesel, because vegetable oils can be directly used as fuel without engine modifications (Çetinkaya, 2005). Biodiesels are usually produced from biological resources such as crude vegetable oils, fats, and tallow. It means biodiesels can be prepared from things that can be reused for some other purpose, re-grown and can be reproduced. So, the plants which are source of the raw material could be produced and increased production quickly within one season to meet the increased requirement. In addition to that biodiesels are more environmental friendly than gasoline and petro-diesels and they have almost similar chemical properties (Panwar, 2010). The production cost of the biodiesels are very less (Sirivella, 2015) and can be prepared domestically that can reduce the dependency on a limited fossil fuel resource and increases the use of renewable resources. Many developing and developed countries recognized that the production and usage of biodiesel can provide energy security, rural development, trade development, and mitigation of adverse impacts of climate change (Dufey et al 2007). At present many countries are using edible oils like soybean, sunflower, rapeseed and palm are used as main biodiesel feed-stocks (Ivanav B. Bankovi´ c-Ili ´cet al., 2012).

Chemically, biodiesel is a monoalkyl esters of long chain fatty acids derived from vegetable oils or animal fats that meets the ASTM D6751 specifications of DICI engines. Many researches were conducted experiments with edible oils such as soybean, peanut, sunflower, etc., and with non-edible sources such as Jatropha oil, Simarouba oil, Mahua oil, Neem oil, Karanja oil etc., to replace the petro-diesel with a suitable alternative biodiesel. As per reference (Lin et al.,2009) they found that the max and min differences in engine power and torque at full load between petroleum diesel and 8 kinds of vegetable oil methyl ester fuels were only 1.49% and −0.64%, 1.39% and −1.25%, respectively, due to higher viscosity, higher BSFC, higher oxygen content and higher combustion rate of biodiesel. Kenneth et al were conducted performance, emission tests on six-cylinder turbocharged diesel engine using soybean oil as bio-fuel and observed that power loss with reduced combustion efficiency with the fixed fuel system using pure soybean oil. The drop in thermal efficiency was due to high viscosity and the lower heat content of vegetable oil. It was suggested that modification to the combustion chamber of the diesel engine can allow the use of diesel fuel and 100% vegetable oil inter changeability. Long-term endurance tests were also suggested to qualify specific fuels and engines (Kenneth, 1984). Bacon et al. were conducted experiments on usage of several vegetable oils as alternate fuel sources and found that vegetable oils caused carbon build up in the combustion chamber of diesel engine. Bruwer et al., were studied the usage of sunflower seed oil as an alternate fuel in tractors and found that 8% power loss was observed after 1000 hours of operation. Tapir et. Al., have conducted experiments and revealed that sunflower oil has higher viscosity by 14% compared to diesel at 37^0C and the engine performance of sunflower oil was similar to that of diesel fuel, but with a slight decrease in fuel economy. The objective of the present research study is to evaluate the effect of injection pressure on emission characteristics of a single cylinder, 4-stroke water cooled diesel engine using rice bran oil methyl ester (RBOME) and their diesel blends.

2. Materials and Methods

The rice bran oil used in this study was collected from a local vendor at Nellore, AP, India and transesterification was used to reduce the viscosity of the oil and prepared biodiesel.

2.1 Transesterification Process

Biodiesel can be prepared using transesterification, pyrolysis, micro-emulsion technique or can be used by direct blending with diesel. Transesterification process is one of the best processes to reduce the viscosity of the rice bran oil and the same process was used in the present study. The transesterification chemical reaction was depicted in figure 1.

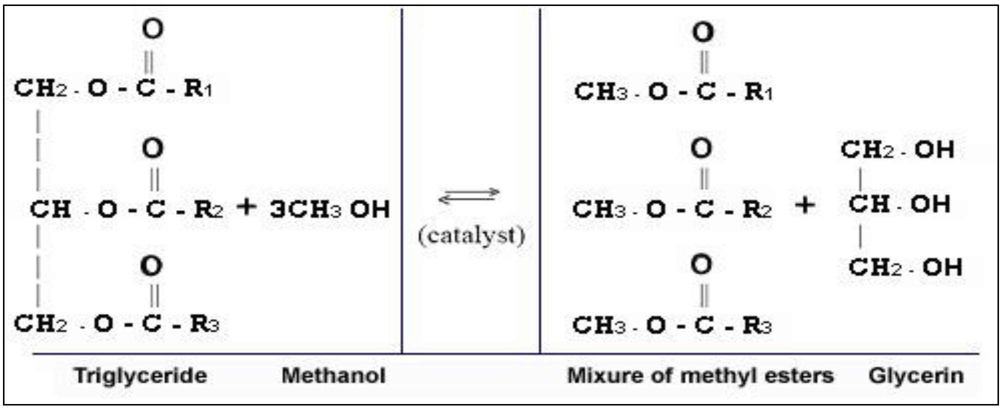

Figure 1: Transesterification Process

These esterified vegetable oils after chemical reactions with alcohol will produce diesel engine friendly fuel. Generally, biodiesels are produced through the reaction of vegetable oils with Methanol in the presence of catalyst to yield glycerine and methyl esters. Methanol in the presence of NaOH as a catalyst was used for transesterification of vegetable oil. The parameter involved in the above processing includes the amount of catalyst, reaction temperature, molar ratio of alcohol to vegetable oil, and reaction time. For the present study, rice bran oil that is available in commercial market, Sodium Hydroxide (NaOH), Methanol and distilled water as used as raw material for transesterification process. The fuel properties of RBOME are shown in table 1.

Table 1: Fuel Properties

Fuel Property	Unit	ASTM Standard	RBOME
Kinematic Viscosity @ 40^0C	Cst	D445	5.37
Flash Point	^{0}C	D93	165
Density @ 15^0C	Kg/m^3	D1298	880
Calorific Value	KJ/Kg	-	38952
Cetane Number	-	D613	52

3. Experimental Setup

For the present experimental study, a single cylinder, four-stroke, water cooled compression ignition direct injection (CIDI) engine was used. The experiment setup was depicted as a schematic diagram in figure 2. It consists of 3.7 KW (5HP) Kirloskar diesel engine, eddy current dynamometer, smoke meter and exhaust gas analyzer.

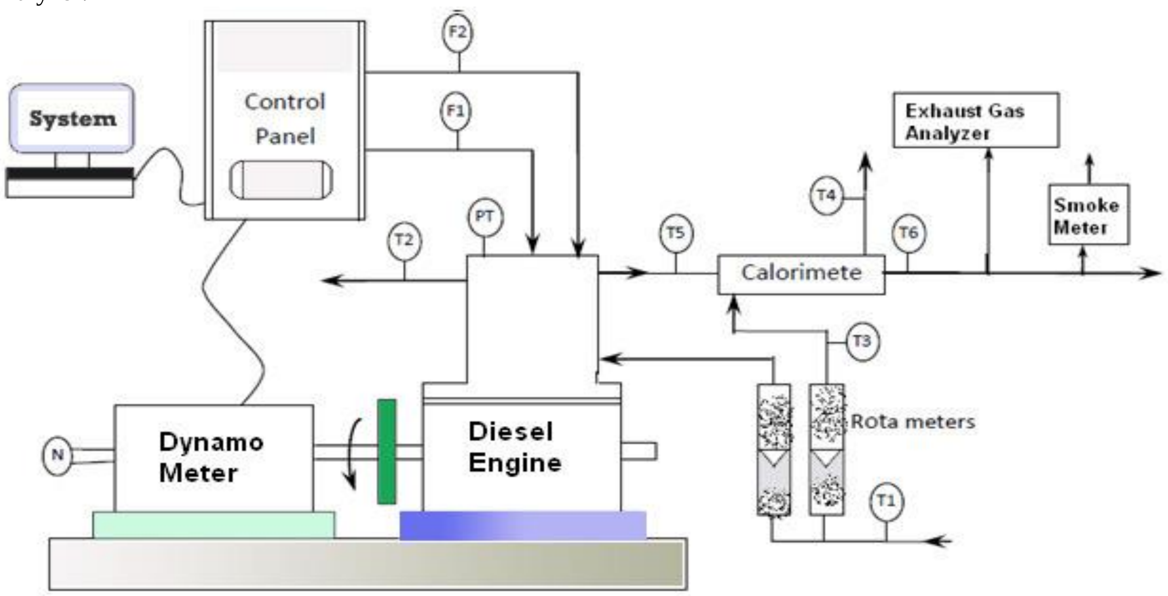

Figure 2: Schematic Diagram of Experimental Setup

T1	Inlet water temparature	PT	Pressure transducer
T2	Outlet engine jacket water temp	F1	Air intake differential pressure unit
T3	Inlet water temparatue	F2	FuelFlow differential pressure unit
T4	Outletcal.water temparature	T6	Exhaust gas temparatue after Cal
T5	Exhaust gas temparatue before Cal		

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The engine specifications are given in Table 2.

Table 2: Engine Specification

Type	Kirloskar Engine
Details	Single cylinder, Direct injection, 4-Stroke, Water cooled engine
Bore & Stroke	80 × 110 mm
Rated Power	3.7 KW (5 HP)
Speed	1500 rpm
Dynamometer	Eddy Current

At the outset the engine was operated with diesel for few minutes and after engine warmup, a series of emission tests were conducted at full load condition with 20% blend of RBOME (BR20) while recording the readings for diffrent injection pressures. Subsequently, the same was repeated using different blends of rice bran oil methyl esters and the readings of each blend for different load conditions were rec-orded. For each operation, speed of the engine was verified and maintained almost constant. Each experiment was repeated with similar operating condition and each reading was recorded as arithmetic mean of two readings for accuracy. The experimental test data was then analyzed using graphs and are given in the subsequent paragraphs. Smoke Desnity, Carbon Monoxide (CO), Particulate Matter (PM) and Oxides of Nitrogen oxide (NO) were considered as emission characteristics of CIDI engine for the present research study.

4. Results and Discussion

4.1 Smoke Density

Figure 3 shows the variation of injection pressure with smoke density at constant engine speed of 1500 rpm. As shown in graph, increase of smoke density was observed at 210 bar, 230 bar and 240 bar of injection pressure when compared with rated injection pressure of 200 bar and less value which can be considered as optimum injection pressure was observed at 220 bar.

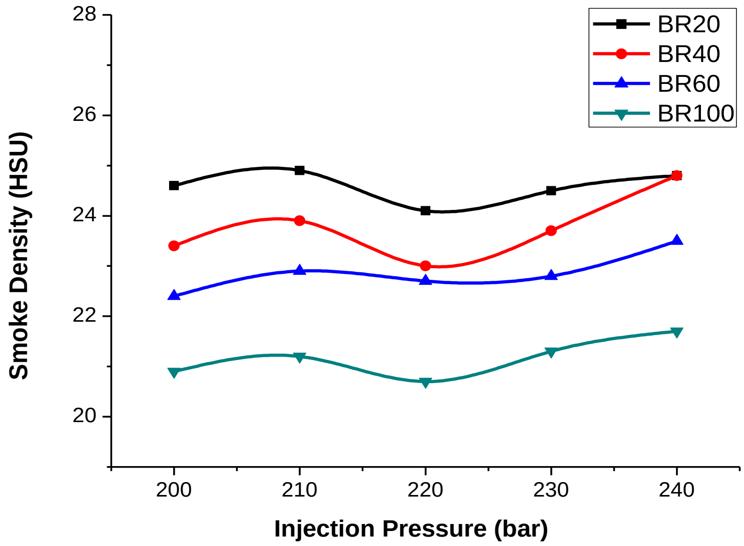

Figure 3: Injection Pressure vs. Smoke Density

Reduction of smoke density revealed with increase of blend percentage of RBOME irrespective of injection pressure as shown in figure 4. The smoke density of neat biodiesel (BR100) is more than 20% less than diesel fuel and increases with the increasing of brake power for all blends and diesel. It is observed that smoke density decreases by 7-8% with the increase of every 20% of blend of RBOME in biodiesel (Sirivella et al., 2015).

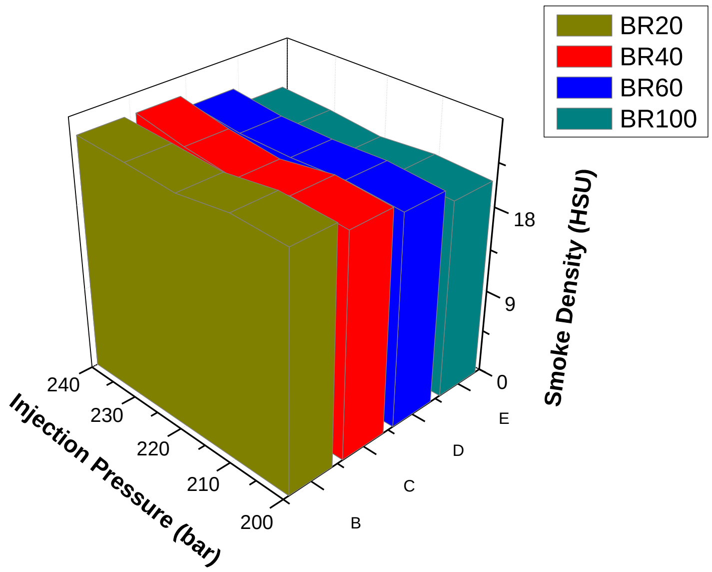

Figure 4: Injection Pressure and Smoke Density

4.2 CO Emission

Figure 5 shows variation of carbon monoxide emission at different injection pressures. The higher CO emission observed at 240 bar. The CO emissions reached to minimum at 220 bar of injection pressure. However the increase of injection pressure from 220 to 240 bar resulted in increase of CO emission as compared to 200 bar of rated injection pressure at full load of the engine.

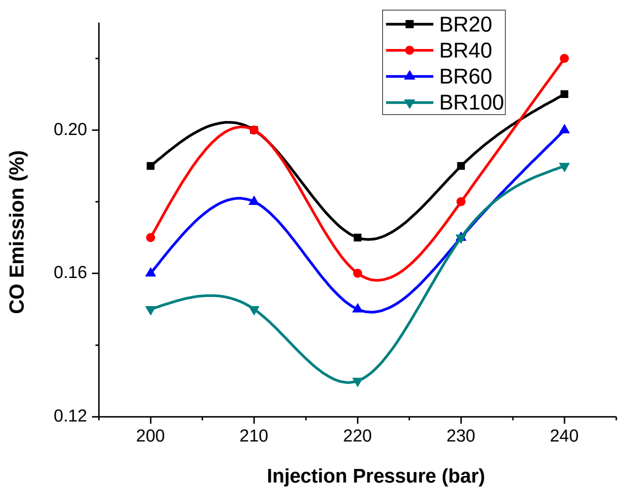

Figure 5: Injection Pressure vs. CO Emission

Figure 6 is clearly indicating that BR100 has lower emission values when compare with all other blend percentage of RBOME at all injection pressures. The CO emission is found to increase with the increase in load and decrease with increase in percentage of methyl ester of rice bran oil (RBOME) in biodiesel blend. It was also observed that the percentage of carbon monoxide in all the blends was found to be low at all load conditions when compared with diesel. (Sirivella et al., 2015).

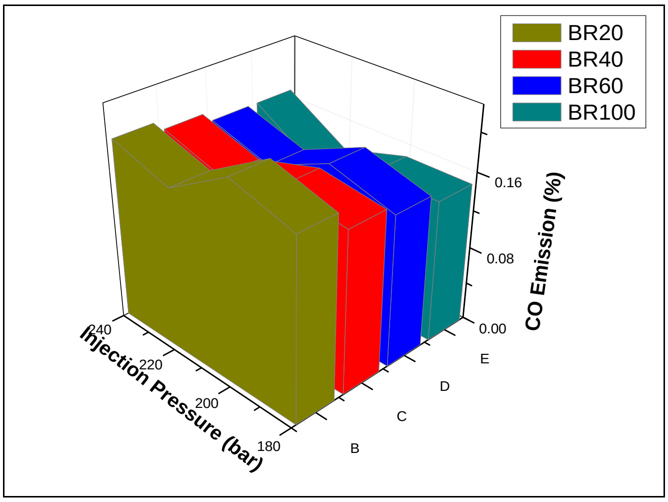

Figure 6: Injection Pressure vs. CO Emission

4.3 Particulate Matter (PM)

Particulate matter is the most complex of diesel emissions and mostly comprises of both solids, as well as liquid material. Breathing particulate matter has been found to be dangerous for human health, especially in terms of respiratory system problem. The variations of particulate matter with different injection pressures are depicted in figure 7 and the graph is clearly revealing that the particulate matter is lowest at 220 bar for all blend percentages of RBOME at full load condition. Particulate matter emission increases with increase of injection pressure except at 220 bar due to incomplete combustion.

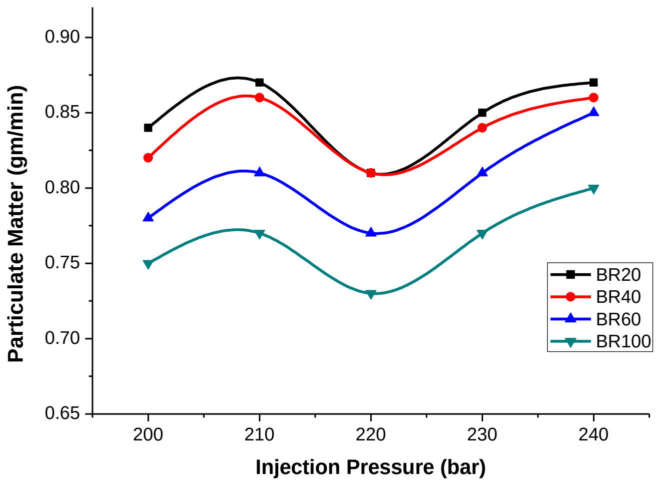

Figure 7: Injection Pressure vs. Particulate Matter

Figure 8 is visibly showing that BR100 has lower particulate emission values when compare with all other blend percentage of RBOME at all injection pressures. The particulate matter increases with the increase of load for diesel and all blends of RBOME but reduction was observed with the increase in percentage of RBOME in biodiesel (Sirivella et al., 2015).

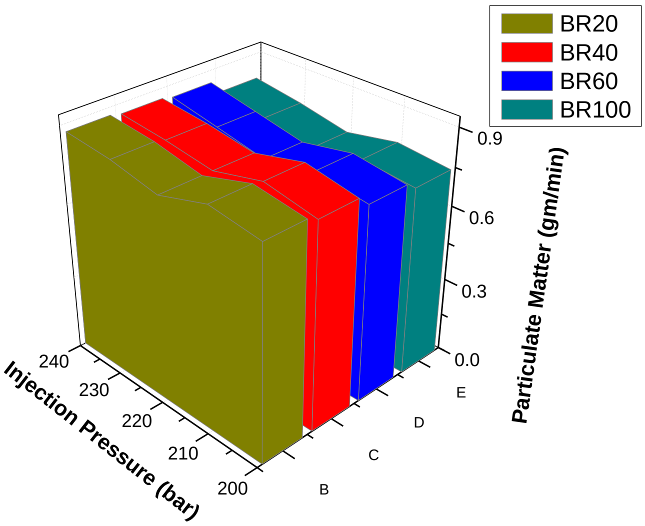

Figure 8: Injection Pressure and Particulate Matter

4.4 NOx Emission

A NOx emission from diesel engine is mainly due to availability of oxygen and the peak combustion temperature during premixed combustion. The variation of NOx emission with injection pressure is shown in figure 9. The graph is clearly illustrating that NOx emission at 220 bar is lowest due to poor combustion of biodiesel. NOx emission increases with increase in injection pressure except at 220 bar of injection pressure due to improved combustion. The NOx emissions at full load, increased when injection pressure increased from 200 to 210 bar, 230 bar and 240 bar respectively.

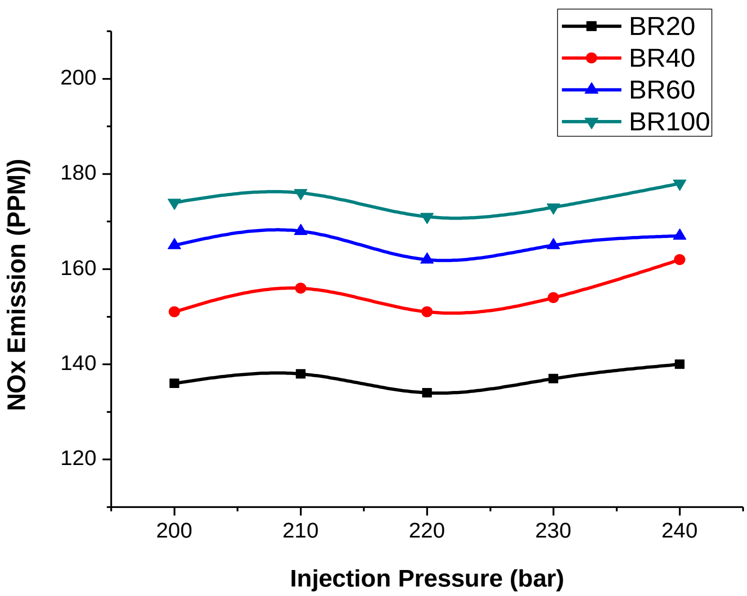

Figure 9: Injection Pressure vs. NOx Emission

Figure 10 is clearly revealing that neat biodiesel has lower particulate emission values when compare with all other blend percentage of RBOME at all injection pressures.

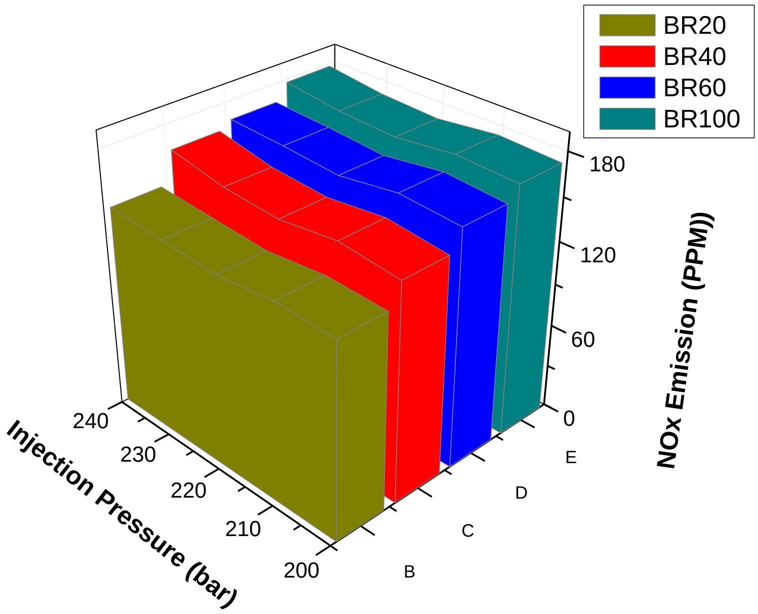

Figure 10: Injection Pressure vs. NOx Emission

5. Conclusion

Injection pressure is one of the important engine parameters that influences on performance and emission characteristics of diesel engine. Higher injection pressures generate faster combustion rates, resulting in high cylinder gas temperatures and fuel atomization characteristics improve with higher injection pressure so that higher surface area is exposed to the surrounding air. The experimental results of single cylinder, 4-stroke, water cooled diesel engine fuelled with different blends (BR20, BR40, BR60 and BR100) of RBOME at injection pressures of 200 bar, 210 bar, 220 bar, 230 bar and 240 bar at full load condition revealed that BR100 has lower CO emission, lower smoke density, lower particulate matter and moderately higher NOx emission at all injection pressures and optimum emission values were observed at 220 bar. The results have also revealed the following:

- smoke density is decreasing with the increase of blend percentage of RBOME and the smoke density at 220 bar is 2% lesser than rated injection pressure of 200 bar
- CO emission from diesel engine was low at 220 bar of injection pressure for all blend percentage of RBOME. The lowest CO emission at 220 bar of injection pressure is 1.5% lower than the CO emission at rated injection pressure.
- particulate matter is lowest at 220 bar for all blend percentages of RBOME at full load condition and is less than 3.5 % when compared with rated injection pressure
- NOx emission at 220 bar of injection pressure is lowest for all blend percentages of biodiesel. It increases with increase in injection pressure except at 220 bar of injection pressure and 220 bar can be considered as optimum injection pressure when 5 HP diesel engine was fuelled with biodiesel.

The diesel engine with different blends of RBOME exhibits very good emission characteristics at injection pressure of 220 bar at full load condition. This can be considered as rated injection pressure when single cylinder, 4 –stroke water cooled direct injection compression ignition engine at full load condition.

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A Brief Author Biography

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