Emission Characteristic Analysis of CI Engine By Varying Injection Pressure Using Diesel-Bio Diesel Blend

[1]C. Dhanasekaran, [2]R. Pugazhenthi, [3]S. Sivaganesan, [4]A. Parthiban

[1,2,3,4] Associate Professor, Department of Mechanical Engineering, Vels Institute of Science, Technology and Advanced Studies, Tamilnadu, India.

Email: dhans.se@velsuniv.ac.in[1], pugal4@gmail.com[2*], sivaganesanme@gmail.com[3], parthibana83@gmail.com[4]

Abstract

Nowadays the automobile has to meet the satisfied environmental constraints and fuel economy standards in addition to meeting the competitiveness of the world market. There are several factors were influence the performance of engines such as compression ratio, atomization of fuel, fuel injection pressure, and quality of fuel, combustion rate, air-fuel ratio, intake temperature, and pressure etc. Among this the fuel injection pressure plays a vital role in better atomization of fuel injection and it allows for a more complete burn and has to reduce the pollution. The objective of this work is to find the variations in engine performance and emission characteristics for the diesel and Jatropha biodiesel blends of B20 and B40 by varying the injection pressures of 180,200 and 220 bar. The tests were carried out to examine the performance and emissions of a direct injection diesel engine for a neat diesel-biodiesel with each injection pressures. Performance parameters such as brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC), emissions such as CO, HC, smoke density and NOx are determined at three injection pressures of 180, 200 and 220 bars.

Keywords: *Fuel injection, Jatropha Biodiesel, BTE, NOx, CO, HC*

1. Introduction

Motor vehicles contribute significantly to the air pollutions problems. Therefore, the use of alternative fuels can help in the promotion of environmental protection. Increased consumption of conventional based fuel gives way for the exploration of several alternative fuels. An important requirement of automotive fuels such as high energy density, safety in usage and handling, conveniences in transportation, storage and cost but not the least environmental acceptability make bio-diesel especially jatropha oil a vegetable oil-derived fuel.

However, some disadvantage of biodiesel obtained by transesterification is limiting the growth of its usage because of its higher viscosity and density when compared to diesel. This can lead to poor atomization and mixture formation with air which results in slower combustion, lower thermal efficiency, and higher emissions. The present design and operating parameters of the engine standardized only for diesel fuel. For all other fuels, the operation parameters of the engine have to be optimized with the view of specific fuel properties. Properties can be improved by preparing esters of jatropha with methanol to form jatropha oil methyl ester (JOME). Fuel injection pressure and fuel injection timing plays a vital role in ignition delay and combustion characteristics of the engine, as the temperature and pressure change significantly close to TDC.

Therefore, modifications of the engine parameters needed to optimize the overall efficiency of the engine due to the difference in chemical composition and combustion characteristics between diesel and biodiesel. Thus, the main objective of the present study is to analyze the effect of varying the injection pressure on performance and emission characteristics of the direct injection diesel engine fuelled with diesel. Further, it aims at determining the effect of varying the injection pressure on performance, emission and combustion characteristics of the direct injection diesel engine fuelled with biodiesel blends of B20, B40.

2. Literature Survey

Sayin Cenk et al [2010] ascertained the application of fuel injection pressure (FIP) and injection timings, which realizes with high efficiency and low emissions. The experiment performed on a single cylinder four stroke DI diesel equipped with the common rail fuel system of maximum injection pressure of 800 bars. The experiments were conducted at the constant speed (2500 rpm) with two FIPs (500 and 1000 bars respectively) and different start of injection (SOI) timings. Cylinder pressure and rate of heat release (ROHR) were found to be higher for lower FIPs however advanced injection timings gave higher ROHR in early combustion stages.

Anand R, et al [2010] investigated the influence of injection pressure on the injection, combustion and performance characteristics of a single cylinder, four strokes, direct injection, naturally aspirated diesel engine. It has been experimentally investigated when using canola oil methyl esters (COME) and its blends with diesel fuel. The tests were conducted for four different injection pressures (18, 20, 22 and 24 MPa) at constant engine speed and different loads. The experimental results showed that the fuels exhibit different injection, combustion and performance characteristics for different engine loads and injection pressure. Investigation of the injection characteristics of the fuels showed that using COME instead of diesel resulted in earlier injection timings.

Pugazhenthi, R [2017] examined the performance and emissions of a direct injection diesel engine blended with Jatropha bio-diesel prepared with methanol to get Jatropha oil methyl ester (JOME). Experiments are conducted with JOME single and dual fuel mode with compressed natural gas (CNG) in a single cylinder 4 stroke diesel engine. Performance parameters such as brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC), emissions such as CO, UBHC, smoke density, and NOx are determined at three injection pressures of 180, 200 and 220 bar and two injection timings 27degree BTDC and 31degree BTDC. Parameters are compared with baseline data of diesel fuel. It was found through experiments that CNG - JOME can be used as fuel with better performance at 220 bar pressure and advanced injection timing of 31obtdc. The harmful pollutants such as UBHC, CO and NOx are reduced in Jatropha oil methyl ester with CNG in single and dual fuel mode compared to diesel fuel.

Leung DYC and Guo Y. ,[2006] optimized the biodiesel derived from waste cooking oil through the transesterification process was optimized using Response Surface Methodology. The biodiesel derived under optimum conditions was used for investigating the effect of injection pressure and timing on performance, emission and the combustion characteristics of a single cylinder, four-stroke direct injection diesel engine at a constant speed of 1500 rpm. On varying the injection pressure and timing, it was found that the combined effect of higher injection pressure of 280 bar and an advanced injection timing of 25.5^0 BTDC had significant improvement in the brake thermal efficiency, cylinder gas pressure, and heat release rate. Reduction in nitric oxide (NO) and smoke emission also observed. Biodiesel produced by transesterification process, which involves a chemical reaction between an alcohol and the triglycerides of fatty acids in the presence of a suitable catalyst leading to the formation of fatty acid alkyl esters (biodiesel) and glycerol.

Narayana Reddy J, Ramesh A. [2006] investigates the influence of compression ratio (CR) and injection parameters such injection timing (IT) and injection pressure (IP) on the performance and emissions of a DI diesel engine using biodiesel (%5, 20%, 50%, and 100%) blended-diesel fuel. Tests were carried out using three different CRs (17, 18, and 19/1), ITs (15^0, 20^0, and 25^0 CA BTDC) and IPs (18, 20 and 22 MPa) at 20 Nm engine load and 2200 rpm. The results showed that brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC), and nitrogen oxides (NOx) emissions increased while brake thermal efficiency (BTE), smoke opacity (OP), carbon monoxide (CO) and hydrocarbon (HC) decreased with the increase in the amount of biodiesel in the fuel mixture.

Roy Badal Dev et al [2016] studied Mahua methyl ester (MME), a renewable biodiesel has been considered to be used as an alternate fuel in light of greener emissions compared to diesel. In order to optimize the use of MME in diesel engines, the performance and emissions of B20 blend of MME was investigated using a single cylinder diesel engine at various nozzle opening pressures (NOP) (225, 250, 275 bar) and static injection timings (19^0, 21^0, 23^0, 25^0, 27^0 btdc) in accordance with ISO 8178 D2 cycle, intended for homologation. The performance of B20 Mahua bio-diesel was compared with diesel at manufacturers default NOP of 225 bar and 23^0 BTDC static injection timing, whereas, the emissions were compared with the current regulatory norms for generator engines

3. Preparation of Biodiesel

Biodiesel production begins with the cultivation of Jatropha, a small tree or large shrub that grow to an average height of 3-5 meters and bears fruit containing seeds rich in non-edible oil suitable for conversion to biodiesel. The Oil Extraction made from the Jatropha seeds contains an average of 25-40% oil by mass. The Jatropha curcas seeds were separated from foreign matters weighed and de-hulled using the grinding machine (pulverizer). Oil presses have been used for the purpose of oil extraction as simple mechanical devices - either powered or manually driven. The by-product is used as a fertilizer and pesticides and remaining oil can be directly used in diesel or subjected to transesterification and then used as bio-diesel. Jatropha oil is transesterified to biodiesel and glycerin using methanol as the alcohol and either sodium hydroxide (NaOH) or potassium hydroxide (KOH) as a base catalyst. Glycerin is a marketable co-product.

3.1. Acid-Catalyzed Transesterification Process

The overabundance of free corrosive is responded in the esterification process. The staying corrosive substance in the oil experiences transesterification. Therefore, this system is a compelling one for oils that contains high free unsaturated fat (FFA) content. A large focused sulphuric corrosive utilized for this methodology.

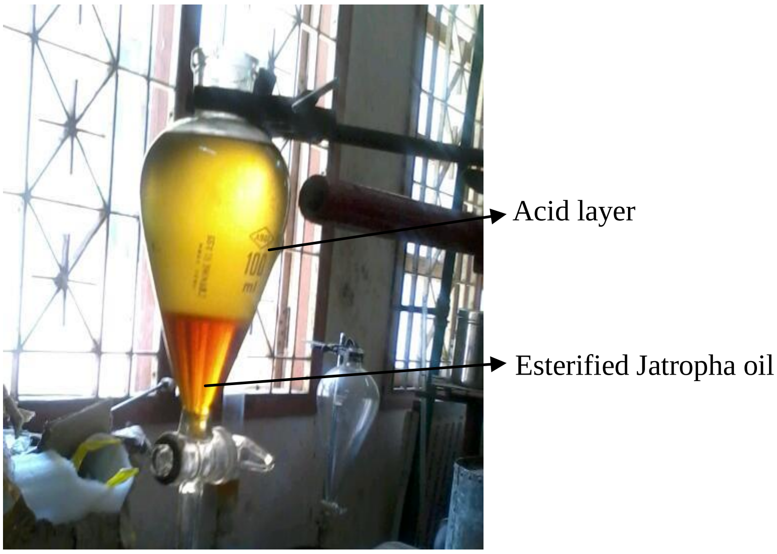


Fig.1 Acid-catalyzed Esterification Process

The principle yearns of esterification response is to evacuate water and to diminish FFA of oil amid preparing. One liter of crude oil taken to vessel with the attractive pellet and change the pace to 200 rpm. The reflux condenser is utilized to keep watercourse ON.

The temperature level is to kept up at 60°C. Take 150ml of methanol and 1.5ml amassed sulphuric corrosive in a 250 ml cone-shaped jar and blend well. Add that mixture to the response vessel which containing crude oil. Upset the mixture in the response vessel at 60°C for 1.5hrs. A dim layer is seen at the top layer of oil. Exchange the mixture to the dividing pipe and settle for less than 2 to 3 hours. The corrosive layer will ascend to the top as a dark layer as demonstrated in figure 1. Channel the base layer to 3-Neck cup. Channel the top corrosive layer and store it independently. Take the specimen of the base layer from the 3-Neck cup and measure the new FFA. Since FFA of esterified Jatropha oil is 1.607 < 2.5. We can go for the transesterification process.

3.2. Heterogeneous base catalyzed transesterfication

The 20 grams of calcium oxide dunked in 200ml of ammonium carbonate arrangement (12% by wt.).Then the mixture mixed for 30 minutes at room temperature. After filtration and drying the hasten at 110°C for around 6 hours, the dried strong was processed and afterward calcined at 900°C for 1.5 hours in a furnace.

Fig. 2 Heterogeneous base catalyzed transesterification process

3.3. Production of jatropha methyl ester (i.e. Biodiesel)

The required conditions for the transesterification process are as follows,

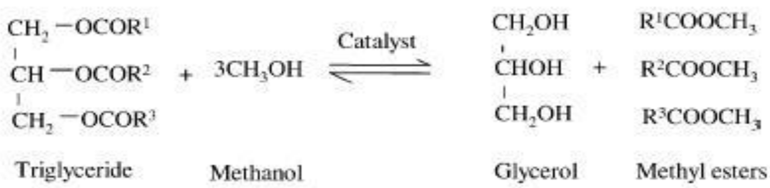
Methanol to oil molar ratio : 10:1

Amount of calcinated CaO catalyst : 1.2% (w/v)

Reaction temperature : 75^{0} c

Reaction time : 2.30 hours

The general equation for transesterification of vegetable oils containing triglycerides is as follows,



Finally, 880ml of Jatropha biodiesel (i.e. 88% yield) and 120ml of glycerin was obtained from 1 liter of Jatropha curcas oil.

3.4. Properties of Jatropha Biodiesel

Table.1 Properties of Biodiesel compared with neat diesel

FUEL PROPERTY	DIESEL	JATROPHA	B40	B20
Density @15 ^{0}C	825	890	846.8	836.5
Kinematic viscosity @40 ^{o}C	3.52	3.97	3.16	2.88
Gross calorific value(MJ/kg)	45000	38650	43119.02	44635.15
Flash point(^{o}C)	48	212	52	58
Fire point(^{o}C)	55	-	62	66

3.5. Fuel Injection

Fuel injection is a system for admitting fuel into an internal combustion engine. It has become the primary fuel delivery system used in automotive engines, having replaced carburetors during the 1980s and 1990s. A variety of injection systems have existed since the earliest usage of the internal combustion engine. The primary difference between carburetors and fuel injection is that fuel injection atomizes the fuel by forcibly pumping it through a small nozzle under high pressure, while a carburetor relies on suction created by intake air accelerated through a venturi tube to draw the fuel into the airstream. Modern fuel injection systems are designed specifically for the type of fuel being used. Some systems are designed for multiple grades of fuel (using sensors to adapt the tuning for the fuel currently used). Most fuel injection systems are for gasoline or diesel applications.

4. Experimental Setup

Engine running tests were conducted on Kirloskar make, single cylinder, 4-stroke-cycle, constant speed (1500 rpm) vertical, water cooled, direct injection, 5hp (3.7 kW), bore 100mm and stroke 110mm, compression ratio 20:1 diesel engine. Tests were conducted at different loads, with diesel oil, and transesterified oil-Diesel for comparative study. The experimental setup of the engine shown in figure 3, in this an eddy current dynamometer is used for load measurement.

The engine speed was sensed and indicated by an inductive pickup sensor facing marks on the flywheel with digital meter output. Chromel-alumel thermocouple was used for exhaust gas temperature measurement and a smoke meter used for smoke measurement. Carbon monoxide (CO), carbon dioxide (CO2), hydrocarbon (HC), nitrous oxide (NOx) was measured by emission monitoring systems. Fuel consumption is measured by a burette with two sensors placed apart two markings to measure 20cc accurately.

Fig. 3 Pictorial view of the engine

Table 2 Specification of the engine

MAKE AND MODEL	Kirloskar oil engine TAF1
Bore and Stroke	87.5 mm X 110 mm
Compression Ratio	17.5 : 1
Rated Speed	1500 rpm
Cubic Capacity	0.661 liters
Injection timing	26 Btdc
Injector opening pressure	200 bar

Table 3 Valve Timing

Inlet valve opening (btdc)	4.5
Inlet valve closing (atdc)	35.5
Exhaust valve opening (btdc)	35.5
Exhaust valve closing (atdc)	4.5

Fig. 4 Exhaust gas analyzer

Table 4 Range of operating parameter tried in the present testing

% Load	20% 40% 60% 80% and 100%
Speed	constant speed (1500 rpm)
Compression ratio	17.5:1
Injection Timing °Btdc	26 °Btdc
Injection Pressure	180bar, 200bar and 220 bar

4.1. Test Procedures

- In the engine test bed, the test was conducted at 26° BDC injection timing and injection pressures of 180bar, 200bar and 220 bar respectively.
- The engine was started on neat diesel and warmed up till cooling water temperature was stabilized (Standard working Condition).
- The Fuel consumption, Exhaust temperature, Exhaust emissions such as UBHC, NOX, CO_2, CO, and Exhaust gas capacity were measured and recorded for all different loads.
- Tests were repeated for 20%, 40%, 60% and 80% same loading conditions.
- The readings were recorded for each load and the average value is taken for calculations.

5. Results & Discussion

The engine performance and emission parameters such as bsfc, bsec, brake thermal efficiency, CO, HC, NO_x, and CO_2 for various injector pressure are presented in figure 5 to 10.

5.1. Effect of Injection Pressure on Brake Energy Specific Energy Consumption

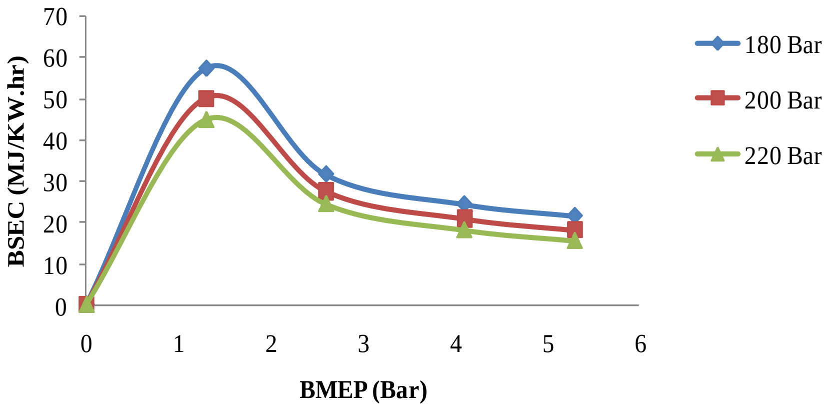


Fig. 5 Pressure on Brake Energy Specific Energy Consumption

The variation in brake specific energy consumption with respect to bmep of diesel. The injector pressure of 220 bar shows the result in increasing bsec with respect to bmep. The variation in brake specific energy consumption with respect to bmep of biodiesel for the injection pressure of 180, 200, 220 bar. The injector pressure of 220 bar shows the result in increasing bsec with respect to bmep. Break specific energy consumption is low while compared with diesel.

5.2. Effect of Injection Pressure on Brake Specific Fuel Consumption

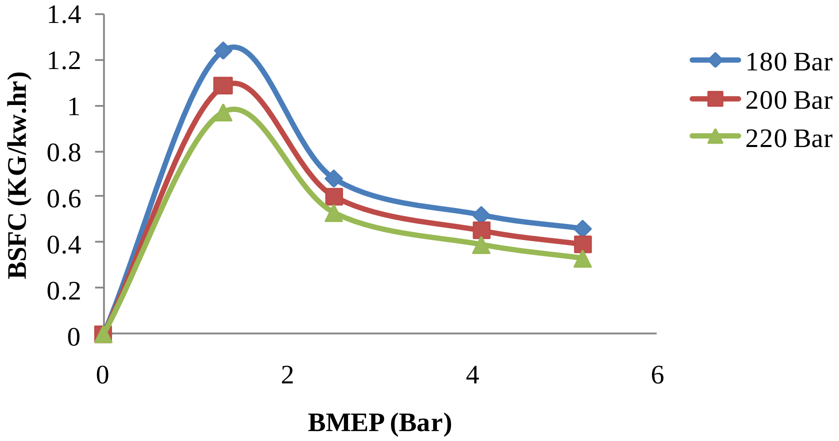


Fig. 6. Effect of Injection Pressure on Brake Specific Fuel Consumption

Figure 6 clearly shows that, Brake Specific Fuel Consumption of diesel with Brake Mean Effective pressure and the Brake Specific Fuel Consumption of biodiesel with Brake Mean Effective pressure. BSFC diminishes with increment in motor burden for both diesel and biodiesel mixed fuel by varying injection pressure, slight variations attained for two different fuels.

5.3. Effect of Injection Pressure on Thermal Efficiency

For all the injection pressures, the brake thermal efficiency of a diesel rises with increasing load condition. The increase in brake thermal efficiency of biodiesel is due to better combustion because of proper atomization resulted from increasing injection pressure. It is found that at the combination of injection pressure 180 bar, the engine delivers.

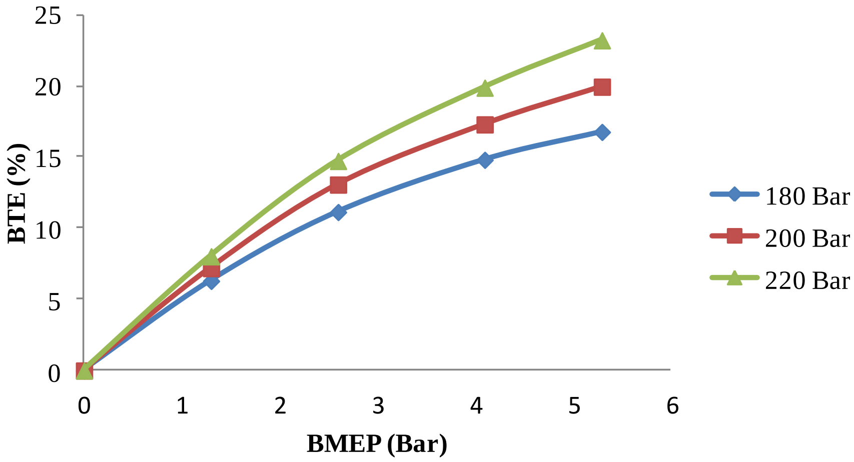


Fig. 7 Effect of Injection Pressure on Thermal Efficiency

The Figure 7 shows that Brake Thermal efficiency of biodiesel with Brake Mean Effective pressure and the results obtained are higher to that of diesel. The combined effect of 220 bars, B40 gives more efficiency compared to that of 180 bar and 200 bar injection pressure.

5.4 Effect of Injection Pressure on CO

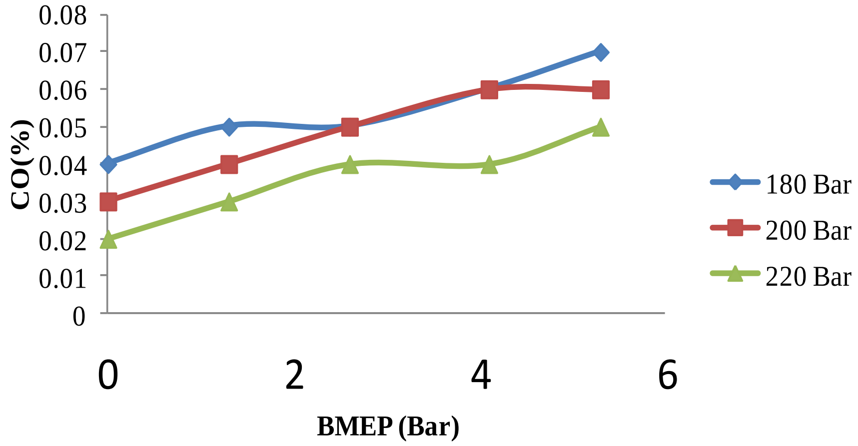


Fig. 8 Effect of Injection Pressure on CO

The figure 8 shows the effect of injection pressure on CO emission of biodiesel shows variation by using biodiesel CO emission is low in optimal load condition.

5.5. Effect of Injection Pressure on the HC Emission of Diesel

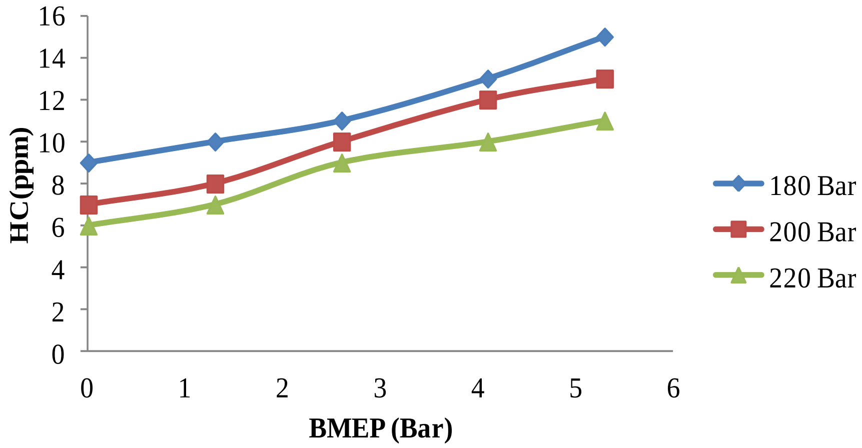


Fig. 9 Effect of Injection Pressure on the HC Emission of Diesel

The figure 9 shows the comparison of hydrocarbons (HC) emission for different injection pressure of the diesel fuel and comparison of the hydrocarbons (HC) emission for different injection pressure of the biodiesel fuel. In a diesel, the HC emission is reduced at 220 bar, whereas in biodiesel the HC emission is low in 200 bar itself.

5.6. Effect of Injection Pressure on NO_x Emission

The figure 10 shows the comparison of nitric oxide (NO) emission for different injection pressure of the diesel and comparison of the nitric oxide (NO) emission for different injection pressure of the biodiesel. The NO emission level increases with increasing injection pressure. This is because of faster combustion and higher cylinder gas temperature due to peak pressure, which occurs at an earlier crank angle.

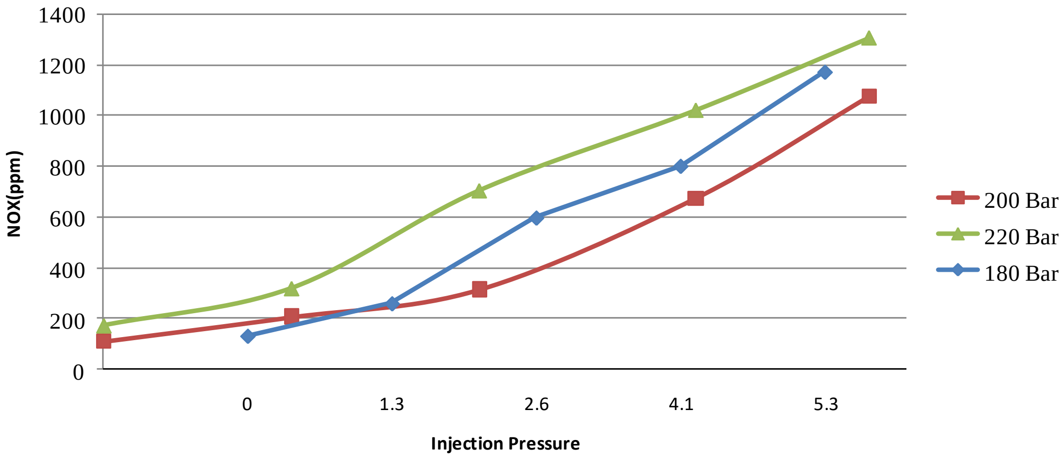


Fig. 10 Effect of Injection Pressure on NO_x Emission

6. Conclusion

In this work, the engine performance and emission characteristics for the diesel and Jatropha biodiesel blends of B20 and B40 by varying the injection pressures of 180,200 and 220 bar. It is found that maximum brake thermal efficiency attained at the injector pressure of 220 bar. The best specific fuel consumption is attained at the injector pressure of 200 bar. In the volume constraint at a pressure of 200 bar lower HC emission is obtained and NOx also lesser in this pressure. By increasing fuel injection pressure, pollution levels are reduced due to complete combustion of fuel. Through the results by varying the injector pressure very much useful in the reduction of pollution and increase the performance of the engine.

References

[1]. Sayin Cenk, Gumus Metin, and Canakci Mustafa. “Effect of fuel injection timing on the emissions of a direct-injection (DI) diesel engine fueled with canola oil methyl ester-diesel fuel blends”. Energy Fuel 2010; 24:2675-82.

[2]. Pugazhenthi, R., Chandrasekaran, M., Muthuraman, R. K., Vivek, P., & Parthiban, A. (2017, March). A Comparative Characteristic Study of Jatropha and Cardanol Biodiesel Blends. In IOP Conference Series: Materials Science and Engineering (Vol. 183, No. 1, p. 012038). IOP Publishing.

[3]. Dhanasekaran C and Mohankumar G 2016 Dual fuel mode DI diesel engine combustion with hydrogen gas and DEE as ignition source International journal of hydrogen energy 41 713-721.

[4]. Anand R, Kannan GR, Nagarajan S, Velamathi S. Performance mission and combustion characteristics of a diesel engine fueled with biodiesel produced from waste cooking oil. SAE Paper No: 2010-01-0478 2010.

[5]. Leung DYC, Guo Y. Transesterification of neat and used frying oil: optimization for biodiesel production. Fuel Process Technol 2006; 87:88`3e90.

[6]. Narayana Reddy J, Ramesh A. Parametric studies for improving the performance of a Jatropha oil-fueled compression ignition engine. Renew Energy 2006;31: 1994-2016.

[7]. Salar-García M.J et al 2016 Analysis of optimal conditions for biodiesel production from Jatropha oil in supercritical methanol: Quantification of thermal decomposition degree and analysis of FAMEs The Journal of Supercritical Fluids 112 1-6.

[8]. Roy Badal Dev et al 2016 Experimental investigation of turbocharger mapped by datalogger in I.C. engine ARPN Journal of Engineering and Applied Sciences 11 4587-4595.

[9]. Ruban, M., Ramasubramanian, S., & Pugazhenthi, R. (2017, March). Investigation of Performance Analysis and Emission Characteristics of Waste Plastic Fuel. In IOP Conference Series: Materials Science and Engineering (Vol. 183, No. 1, p. 012037). IOP Publishing.

[10]. Mani M, Nagarajan G. Influence of injection timing on performance, emission and combustion characteristics of a DI diesel engine running on waste plastic oil. Energy 2009; 34:1617-23.