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Research Article

Effect of Fuel Injection Pressure on Performance and Emission Characteristics of DI-CI Engine Fueled with Chicken Fat Biodiesel

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Abstract

The depletion of world petroleum reserves and the increased environmental concern have stimulated the search of alternative fuel which is to be environment friendly. Transesterified fat oil (biodiesel) are promising alternative fuel for diesel engines. The objective of this research is to study the performance and emission characteristics of single cylinder diesel engine fueled with chicken fat biodiesel with the influence of fuel injection pressure. Bio diesel was produced from waste chicken fat by transesterification process and used as fuel in diesel engine. The tests were conducted at full load at different injection pressures by means of adjusting injector spring tension. The fuels B20 (20% biodiesel +80% diesel), B40 (40% biodiesel+60% diesel), B100 (100% biodiesel) and B100 PH (100% biodiesel with preheating) were used for the test. The engine performance and emission test results were compared with B0 (diesel). From the test results it was found that 210 bar injection pressure causes better performance and improved emissions characteristics for all fuels.

Key words*: Chicken Fat Biodiesel, Injection Pressure, Diesel Engine, Performance, Emissions*

Introduction

The petroleum fuels play very important role in the development of industrial, transportation, agricultural and many other basic human needs. However these fuels are limited and depleting day by day as consumption is increasing very rapidly. Moreover their use is alarming the environmental problems to the society. Hence researches are searching for alternative fuels. Biodiesel a renewable source of energy seems to be an ideal solution for world energy demand. A lot of research work has been carried out to use vegetable oils and fat oils both in its neat and modified forms. Many studies have revealed that the use of neat vegetable and fat oils is possible but not preferable (Y. V. HanumanthaRao et al, 2009). The high viscosity and low volatility property reduces atomization and spray pattern of fuel leading to carbon deposits, injector choking and incomplete combustion. There are many methods to reduce the viscosity of oils. Among all transesterification is commonly used process to reduce the viscosity and to produce clean bio diesel.

Many researchers (H. M. Dharmadhikari et al, 2012, C.V. Mahesh et al, 2012, MeyyappanVenkatesan, 2013, C.V. Subba Reddy, Bhanodaya Reddy et al, 2007, Yamane K et al, 2001, M L S Deva kumar et al, 2010, and Sanjay Patil et al, 2012) studied influence of injection pressure on engine characteristics with biodiesel. USV Prasad et al, 2012, investigated diesel engine characteristics with different injection pressures and nozzle hole size. Kandasamy Muralidharan et al, 2011 studied the effect of bio fuel blends and injection pressure on emission characteristics. Bio diesel (methyl ester) produced from waste chicken fat oil after transesterification reaction shows similar properties to diesel and can be used as alternate fuel without any modifications in engine design. In the present work, the chicken fat biodiesel (CFBD) obtain from waste chicken fat has been consider as potential fuel for C.I engine. K Srinivasa Rao et al, 2013, investigated DI-CI engine characteristics with chicken fat methyl ester. In this study experiments have been conducted on 4 stroke, single cylinder DI–CI engine to analyze the effect of fuel injection pressure on the performance and emission characteristics. The engine was tested at different injection pressures (190, 200, 210, 220 and 230 bars) with B20 (20% CFBD +80% diesel), B40 (40% CFBD +60% diesel), B100 (100% CFBD) and B100 PH (100% CFBD with 50^{O}c preheating) fuels and results were compared with B0 (diesel). Different fuel injection pressures were maintained by means of adjusting injector spring tension.

Materials and methods

Engine

The experiments were carried out on a 4- stroke, single

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cylinder, naturally aspirated, water cooled, constant speed (1500 rpm) and direct injection compression ignition (DI – CI) engine. Details of engine specifications are shown in Table 1. An eddy current dynamometer was used to apply the load torque on the engine. All the necessary temperatures were measured using thermocouples. The entire test setup is shown in the figures 1a, 1b&1c. The test setup consist of engine, eddy current dynamometer, display panel to display all necessary parameters, injection pressure sensor and exhaust gas analyzer for emission measurement. The technical specification of exhaust gas analyzer is shown in Table 2. "***Lab view***" software supplied by **TECH –ED** Bangalore was used to analyze the engine performance.

Table.1 Engine Specifications

Engine	
Manufacture	Kirloskar Oil Engine
Engine	Single Cylinder, DI-CI
Admission of air	Naturally aspirated
Bore	80 mm
Stroke	110 mm
Compression ratio	16.5:1
Max power	3.72 kW
Rated speed	1500 rpm
Dynamometer	Eddy Current Dynamometer
Method of cooling	Water cooled
Pressure sensor	PCB, Piezotronic, USA

Fig.1a. Engine Test Rig

Fuel

Chicken fat biodiesel (CFBD) produced from transesterification was used as fuel for test. In comparison to diesel the viscosity of biodiesel is much higher which is reduced by heating and blending with diesel. K SrinivasaRao et al, 2013 and M.Senthil Kumar et al, 2005 studied use of preheated biodiesel in CI engines and obtained improved characteristics. The different blends B20, B40, B100 and B100 PH (Preheated Biodiesel) were considered for the investigating performance and emission characteristics. The various properties of tested fuels are given in Table 3. The variation of viscosity of biodiesel

Fig.1b. Exhaust Gas Analyzer

Fig.1c. Injection Pressure sensor

Table.2 Exhaust Gas Analyzer Specifications

Exhaust Gas Analyser make: INDUS		
	Range	Resolution
NO	0-5000 ppm	1 ppm
HC	0-15000 ppm	1 ppm
CO	0-15.0%	0.01%

with temperature is shown in Fig.2. From this it was observed that viscosity decreases with increase in temperature. Viscosity biodiesel at 50^{O} C is almost equal

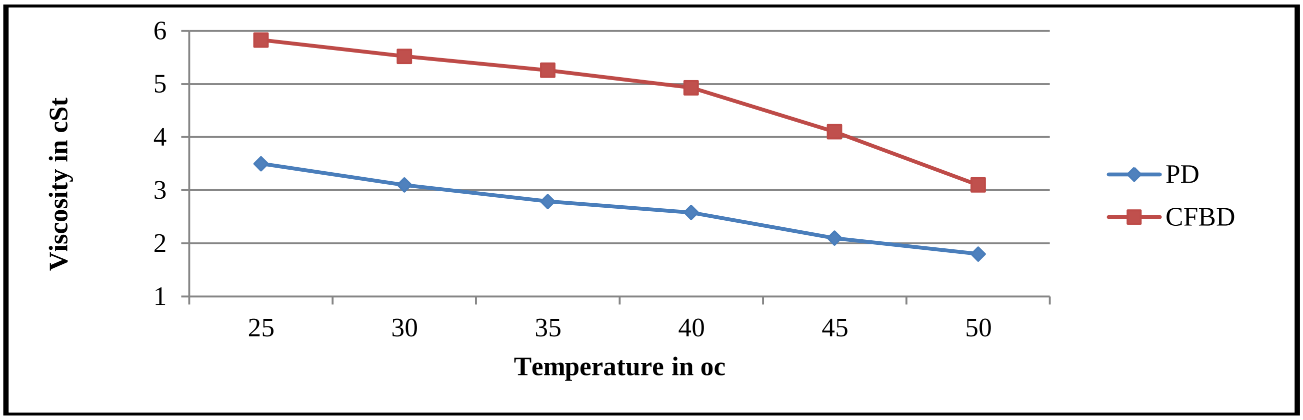

Fig.2 Variation of Viscosity of fuel with Temperature

Table.3 Properties of fuels

Property	Unit	B0 (Diesel)	B20	B40	B100 (CFBD)	ASTM Standards
Density	g/cc	0.831	0.837	0.846	0.862	0.87-0.89
Kinematic Viscosity at 40^{o}c	cSt	2.58	3.11	3.59	4.93	1.9-6.0
Flash Point	^{o}c	50	-	-	160	130 min
Calorific value	kJ/kg	42500	42034	41568	40170	37500

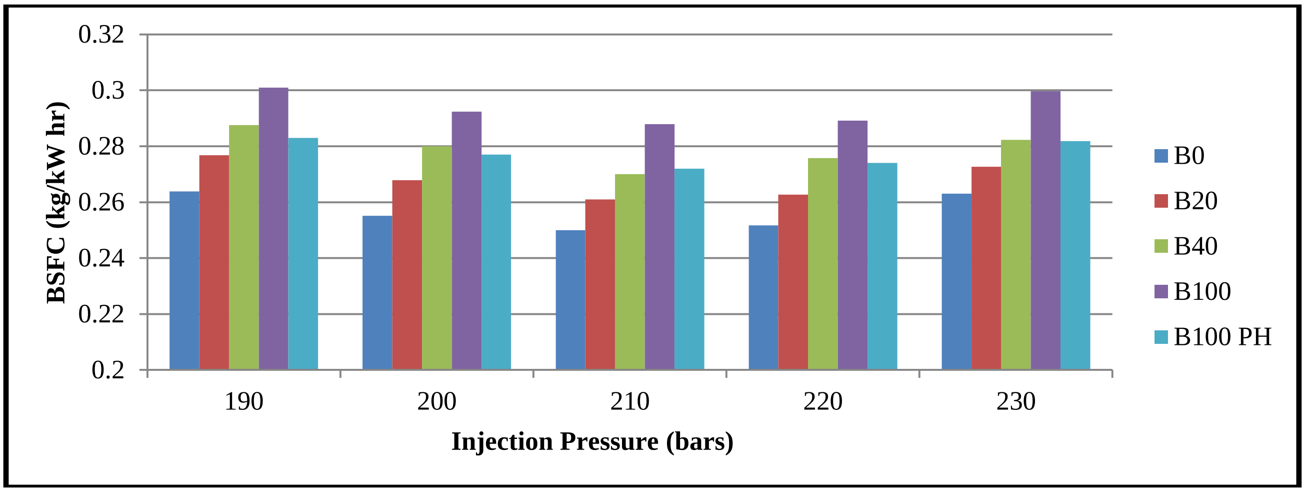

Fig.3 Variation of BSFC with fuel injection pressure at full load

to diesel at 30^{O} C. Hence biodiesel preheated to 50^{O} C (B100 PH) was also used for this study.

Diesel and blends were tested at full load condition and constant rated speed of 1500 rpm. Constant cooling water inlet temperature and flow rate were maintained throughout the test. During each trail engine is allowed for sufficient time and after attain steady state condition, all necessary parameters are measured and recorded. Also the engine emission parameters like CO, HC and NOx were noted from exhaust gas analyzer. All measurements were taken at five different injection pressures (190, 200, 210, 220 and 230 bars) by varying fuel injection spring tension.

Results and discussions

Tests were conducted at five different injection pressures (190, 200, 210, 220 and 230 bars) at constant speed of 1500 rpm and at full load condition (3.72 kW) for diesel, B20, B40, B100 and B100 PH. Engine performance characteristics Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTE), Brake Specific Energy Consumption (BSEC), and emission characteristics Carbon monoxide (CO), Hydro Carbons (HC), Oxides of Nitrogen (NOx) and Exhaust Gas Temperature (EGT) were studied and discussed as fallows.

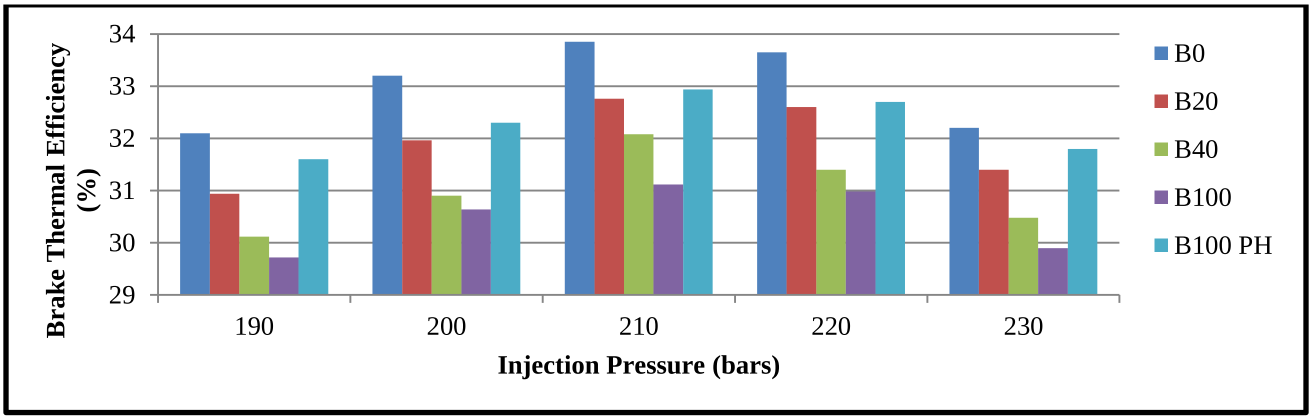

Fig.4 Variation of BTE with fuel injection pressure at full load

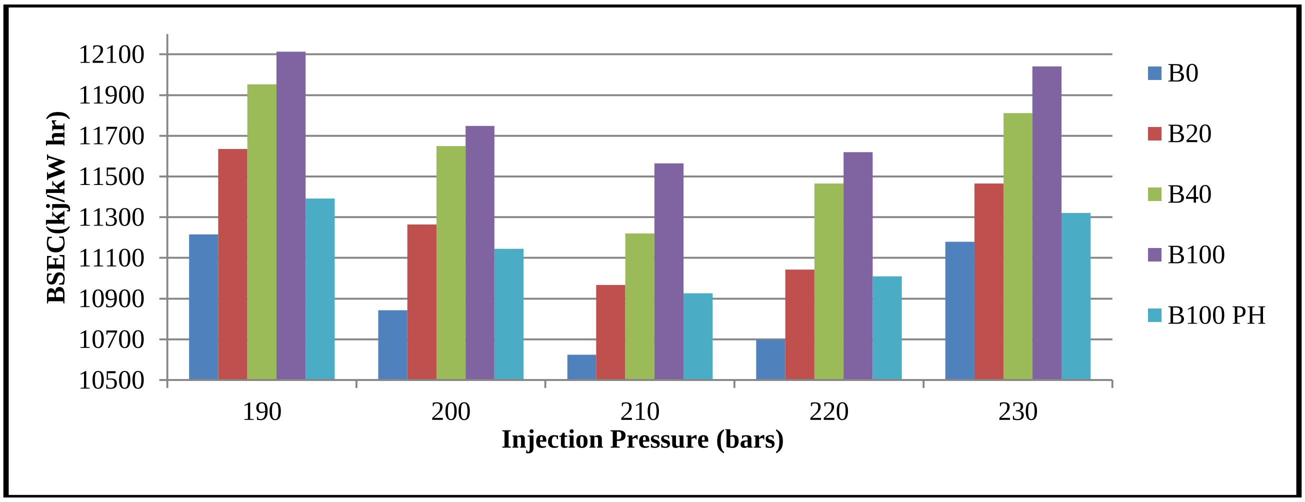

Fig.5 Variation of BSEC with fuel injection pressure at full load

Brake Specific Fuel Consumption (BSFC)

Fig.3 shows the variation of BSFC with fuel injection pressure for all fuels. BSFC decreases with increase of injection pressure up to 210 bar further increase in the injection pressure beyond 210 bar has resulted in higher BSFC. It can be noticed from the figure, the values of BSFC are lower for an injection pressure of 210 bar compared to other injection pressure for all fuels. This could be due to fact that with increase in injection pressure, not only decrease the fuel droplet size but also increase the momentum of fuel droplets. The increase in momentum of fuel droplet could have got impinged on the cylinder inner wall and to develop same power, the fuel consumption should have increased. Among all fuels the diesel has lower BSFC value at 210 bar injection pressure. The BSFC of preheated biodiesel (B100 PH) was lower than neat biodiesel (B100) at all injection pressures.

Brake Thermal Efficiency (BTE)

The variation of BTE of B0, B20, B40, B100 and B100 PH fuels with injection pressure is described in Fig.4. From the figure it can be observed that the BTE decrease with increase of concentration of biodiesel in the blend at all injection pressures. The preheated biodiesel (B100 PH) recorded significantly higher BTE, which are very close to diesel fuel BTE at all injection pressures. For all fuels BTE increases with injection pressure up to 210, further increase in injection pressure beyond 210 bar decrease the BTE. This may be mainly due to increased BSFC and higher momentum of fuel droplets.

Brake Specific Energy Consumption (BSEC)

BSEC plays very important role in evaluation of engine performance and describes the requirement fuel energy to produce unit broke power. Fig.5 indicates the variation of BSEC with injection pressure for all fuels. For all fuels BSEC decreases with increase in injection pressure up 210 bars, further increase in injection pressure above 210 bar increases the BSEC. Neat diesel (B0) recordsvery low BSEC at all injection pressures compared to other fuels. BSEC increases with increase of concentration of biodiesel in the blend. Preheated biodiesel (B100 PH) BSEC is lower compared to other blends and the values are closer to diesel at all injection pressures. For all fuels better BSEC was recorded at 210 bar injection pressure.

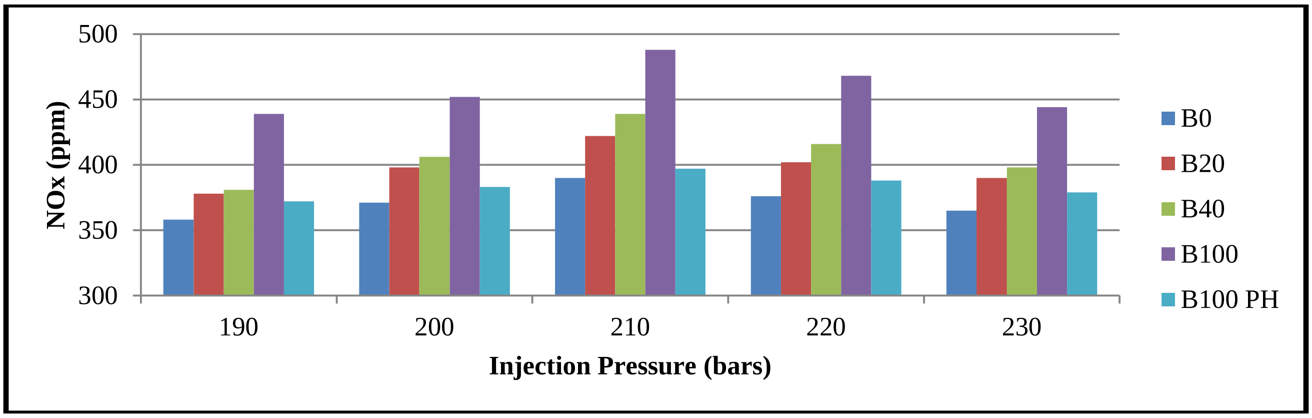

Fig.6 Variation of NO_X Emission with fuel injection pressure at full load

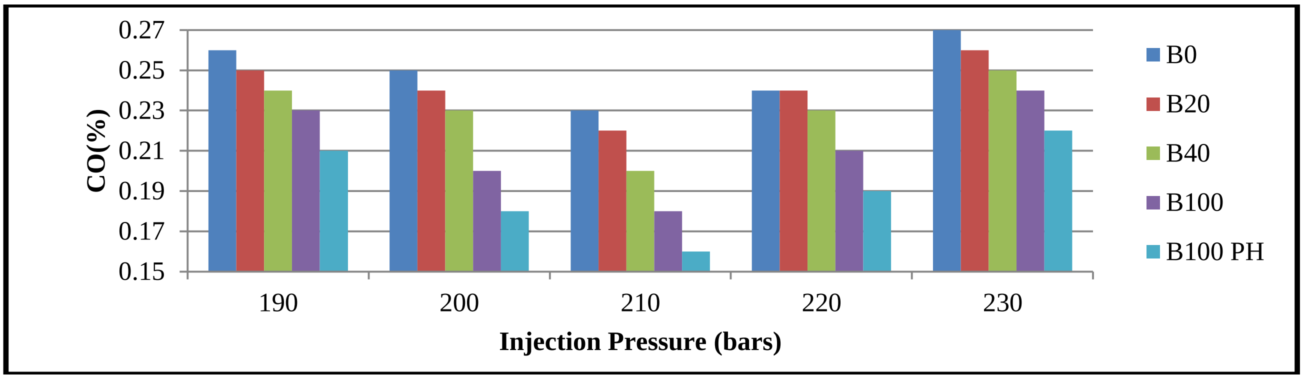

Fig.7 Variation of CO Emission with fuel injection pressure at full load

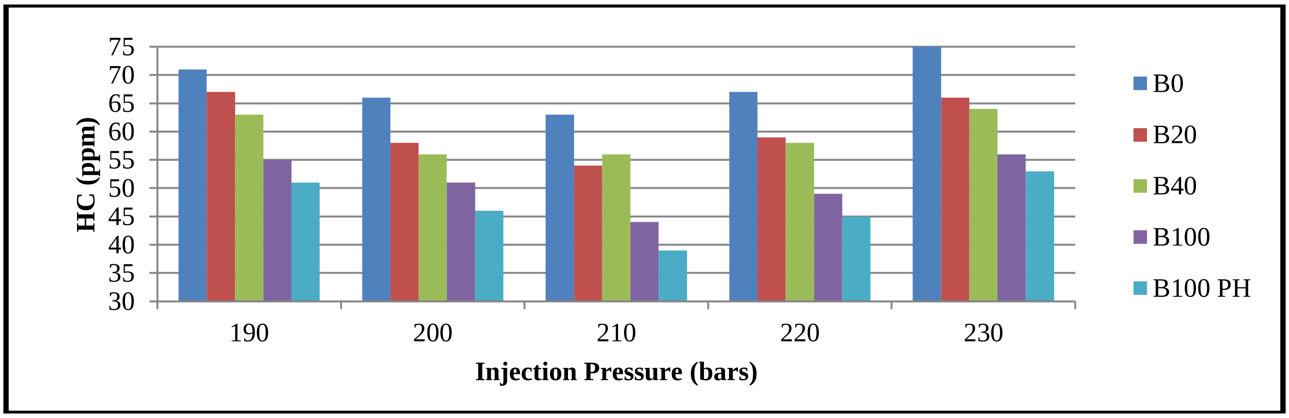

Fig.8 Variation of HC Emission with fuel injection pressure at full load

Oxides of Nitrogen (NOx)

The formation of NO_X is mainly dependent upon the availability of oxygen during combustion and cylinder gas temperature. Fig.6 indicates the variation of NO_X emission of all fuels with injection pressure. It was clear from the figure that by increasing the injection pressure NO_X emission shows an increasing trend up to 210 bar for all fuels. Further increase of injection pressure beyond 210 bar decrease NO_X emission slightly, which may be due to lower peak pressure arises due to lesser heat release rate during combustion leads to lesser spray penetration inside the combustion chamber. The increase of biodiesel blend concentration in diesel tends to increase the NO_X levels at all injection pressures, this may be due the presence of oxygen content in the biodiesel which enhances combustion process. The lesser values of $NO_X$was observed for diesel fuel compared to other. Preheated biodiesel (B100 PH) also records comparatively lesser NO_X values than biodiesel without preheating (B100) at all injection pressures.

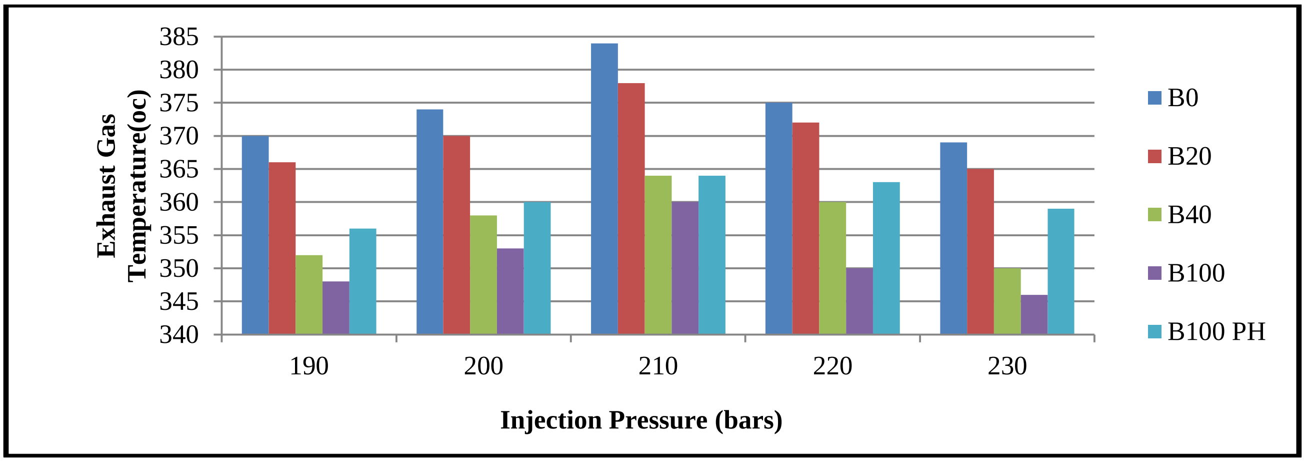

Fig.9 Variation of EGT with fuel injection pressure at full load

Carbon monoxide (CO)

The effect of fuel injection pressure variation over CO emissions for diesel and different blends at full load is shown in Fig.7. From this figure it was observed that CO emission decreases with the increase of injection pressure up to 210 bar, while CO emission increases with further increase of injection pressure beyond 210 bar for all fuels. At lower injection pressure, the higher CO emissions are due poor atomization of fuel resulting in complete combustion. Increase of injection pressure up to 210 bar ensure better mixing of fuel with air leads to improved combustion reducing CO emission. Further increase of injection pressure beyond 210 bar results higher fuel droplet momentum due to improved atomization causing impingement of fuel droplets to combustion chamber walls. Preheated biodiesel (B100 PH) has very low CO emission at 210 bar injection pressure.

Hydro Carbons (HC)

The variation of HC emission with injection pressure at full load for all fuels is shown in Fig.8. From the figure it was observed that the un burnt HC emission tend to decrease with the increase of injection pressure up to 210 bar, further increase of injection pressure beyond 210 bar increase the un burnt HC emission. Increase of concentration of biodiesel in blend decreases HC emission at all injection pressures. The reason may be due to availability of more oxygen present in biodiesel causes complete combustion. The lower HC emissions are observed for all fuels at 210 bar injection pressure. The lower HC emissions are observed with preheated biodiesel (B100 PH) at all injection pressure compared to neat biodiesel without preheating (B100).

Exhaust Gas Temperature (EGT)

Fig.9 indicates the variation of EGT of all fuels with injection pressure at full load condition. It was observed from this figure that for all fuels EGT slightly increase with increase of injection pressure up to 210 bar, this may due to effective atomization and improved combustion of fuel. Further increase in injection pressure beyond 210 bar decreases the EGT, due to the reason that, at very higher injection pressure the momentum of fuel droplet increases rapidly and impinged on cylinder inner walls leading to comparatively poor combustion. For all fuels the lower EGT was observed at 210 bar injection pressure.

Conclusions

In this study the effect of fuel injection pressure on the engine performance and emission of DI-CI diesel engine has been experimentally investigated at full load condition using chicken for biodiesel and blends with diesel fuel. Injection pressure was varied from 190 bar to 230 bar in steps of 10 bar. The observations drawn from this study were summarized as follows.

- BSFC was found to be higher for all fuels at very higher injection pressure; the BSFC was minimum at 210 bar injection pressure.
- Preheated biodiesel (B100 PH) records higher BTE (close to diesel) compared to other blends at all injection pressure.
- The lower BSEC was obtained for diesel compared to other fuels at 210 bar injection pressure. The preheated biodiesel (B 100 PH) has lower BSEC compared to other fuels other than diesel.
- When compared to other injection pressure, at 210 bar injection pressure the engine CO emission are very low for all fuels. The lowest CO emission 0.16% was observed with preheated biodiesel (B 100 PH) at 210 bar injection pressure.
- At full load the engine exhibits very good performance and emission characteristics for all the fuels at injection pressure of 210 bars.
- The highest NO_X emission was attained with chicken fat biodiesel (B 100) at 210 bar injection pressure. The preheated biodiesel (B 100 PH) recorded lower NO_X emission which is very close to diesel at 210 bar injection pressure.

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