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Effect of Fuel Injection Pressure on Performance and Emission Characteristics of DI- CI Engine with Shea Olein Biodiesel

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Abstract

The use of diesel engines day by day increased because of their low fuel consumption and high efficiencies. Several attempts were made for search of alternative fuels due to increased environmental pollution and exhaustion of conventional fossil fuels and succeeded in the development of Biodiesel as an alternative fuel. An attempt was made on DI- CI engine using shea olein methyl ester blended with diesel in various proportions to study the engine performance and emissions at different injection pressures. The tests were conducted at constant load at different injection pressures (190, 200, 210, 220, 230 bars). In the present work performance characteristics like Brake thermal efficiency, Specific fuel consumption, exhaust gas temperature and emission characteristics like CO, NO_X, HC had been investigated. From the results it is observed that 210 bar injection pressure causes better performance and improved emission characteristics, for all the fuel blends.

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Keywords: Shea olein biodiesel, Diesel engine performance, emission and fuel injection pressure

1.Introduction

It is very much important to find alternative fuels due to depletion of petroleum reserves, increase of automobiles daily and pollution threat to the global environment. Among the various alternative fuels, shea olein methyl ester derived from shea olein oil can also be used as a alternative fuel. Biodiesel can be made from non edible, edible oil and with animal fats. D Sharma et al. [1] studied engine characteristics at different injection pressures and obtained improved performance and emission characteristics with increase in fuel injection pressure. The optimal engine characteristics were observed at 160kgf/cm^2 injection pressure. M. L. S. Deva kumar and K. Vijayakumar Reddy [2] studied the 3.7 kW Kirloskar engine full load characteristics at different injection pressures

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(180, 210 and 240bar) with fossil diesel and producer gas in dual fuel mode. It is observed that the engine performed better at higher injection pressures due to atomization of fuel. KandalsamayMuralidharan and PalanisamyGovindarajan [3] carried out tests on 5 HP kirloskar engine at five different injection pressures (190, 200, 210, 220 and 230 bar) at constant speed of 1500 rpm in standard injection timing 23^{o} CA bTDC for diesel and pongamia biodiesel blends at full load conditions. They obtained improved emission characteristics of Pongamia methyl ester at high fuel injection pressure of 220 bar. C. V. Subba Reddy et al. [4] studied the effect of injection pressure on performance and emission characteristics of DI diesel engine with cotton seed biodiesel blends B0, B10, B20, B30 and B100 at different test pressures of 170, 180, 190, 200, 210 and 220 bar. These experimental investigations revealed higher brake thermal efficiency for B20 fuel blend at 200 bar injection pressure for all loads. Lower emissions are obtained for B20 fuel blend at 200 bar injection pressure. On the whole better performance and emission characteristics among the biodiesel blends are obtained at injection pressure of 200 bar with B20. H. M. Dharmadhikari et al. [5] carried out investigation to analyze the performance and emission characteristics of single cylinder DI diesel engine with Karanja oil methyl ester and Neem oil methyl ester at different injection pressure. They obtained optimal characteristics of the engine at injection pressure of 200 bar in the range of 180-220 bar. K Srinivasa Rao et al. [6] studied 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 fat for biodiesel and blends with diesel fuel. Injection pressure was varied from 190 bar to 230 bar in steps of 10 bar and observed better results at 210 bar. Nagarhalli M. V et al. [7] Investigated effect of fuel injection pressure on C.I engine characteristics with Karanja biodiesel and its blends. Engine performance and emission characteristics are studied at fuel injection pressures of 190, 200 and 210 bar and observed improved performance at 200 bar injection pressure.

2. Experimentation

2.1 Engine

Experiments were carried out on stationary water cooled naturally aspirated single cylinder 4- Stroke and direct injection compression ignition kirloskar engine at constant rated speed of 1500 rpm. The bore, stroke and compression ratio are 80mm, 110mm and 16.5 : 1. An Eddy current dynamometer was used to apply the required load. Piezo electric pressure sensor with 1 bar resolution was arranged at fuel injectior to measure injection pressure. The experimental set up of the engine is shown in figure 1. The different injection pressures were set by adjusting the fuel injector spring. Exhaust gas analyser of INDUS make and PEA 205 model is used for studying Exhaust gas analysis purpose which is shown in figure 2. The engine is tested with base line diesel fuel, shea olein methyl ester and its blends at different injection pressures to study performance and emission characteristics. The engine is allowed to get warm up at constant speed of 1500 rpm until all temperatures reaches steady state.

Figure 1 Experimental set up

Figure 2 Exhaust Gas analyser

2.2 Fuel

Shea olein is made by fractionating shea butter, a fat obtained from the fruit of the shea tree. This wild tree from the Sapotaceae family can only be found in its natural state in Africa, in the regions of Sudan and the Sahel north of the Equator. It usually grows in tree-planted savannah, can measure up to twenty meters tall. The tree starts bearing its first fruit when it is 10 years old; full production is attained when the tree is about 20 to 30 years old. It then produces nuts for up to 200 years. The average yield is 15 to 20 kilograms of fresh fruit per tree, with optimum yields up to 45 kilograms. Each kilogram of fruit gives approximately 400 grams of dry seeds. Shea kernels contain 50% solid fat. The Shea tree grows naturally in the wild in the dry savannah belt of West Africa from Senegal in the west to Sudan in the east, and onto the foot hills of the Ethiopian highlands. It occurs in 19 countries across the African continent.

Shea olein biodiesel (SBD) produced from transestification was used as fuel for conducting tests on DI – CI engine. The viscosity of the shea olein biodiesel is much more than the viscosity of diesel so, the viscosity of the shea olein biodiesel is reduced by blending with diesel. The different blends B0 (Pure diesel), B10 (10%SBD + 90% Diesel), B20 (20% SBD + 80% Diesel) , B100 (100% SBD) were considered for investigating the performance and emission characteristics. The properties of the shea olein biodiesel are given in the table1. Diesel and blends were tested at 2.79 kW load condition at constant speed of 1500 rpm. Constant cooling water inlet temperature and flow rate were maintained throughout the test. During each trail the engine is allowed for certain amount of time to attain steady state condition. All necessary parameters are recorded. Emission parameters CO, HC , NOx were noted down by using exhaust gas analyzer. All measurements were recorded at different injection pressures 190, 200, 210, 220 and 230 bars.

Table.1 Properties of fuels

Property	Unit	B0 (Diesel)	B100 (SBD)	ASTM standards
Density	g/cc	0.831	0.877	0.87 – 0.89
Kinematic viscosity	cSt	2.58	4.42	1.9 – 6.0
Flash Point	^{o}C	50	131	130 min
Calorific Value	kJ/kg	42500	46200	37500

3. Results and Discussions

Experimental tests are conducted at different injection pressures (190, 200, 210, 220 and 230 bars) at constant speed of 1500 rpm and at 2.79 kW load condition for diesel and different blends of shea olein methyl ester B0, B10, B20 and B100. The results thus obtained are compared with that of diesel fuel at different injection pressures. Diesel engine performance characteristics like Brake specific fuel consumption (BSFC), Brake specific energy consumption (BSEC), Brake Thermal efficiency (BTE) and Emission characteristics like Carbon monoxide (CO),Hydro carbons (HC), Oxides of Nitrogen (NOx) and exhaust gas temperature are studied based on the output results the discussions are as follows.

3.1Brake Specific Fuel Consumption

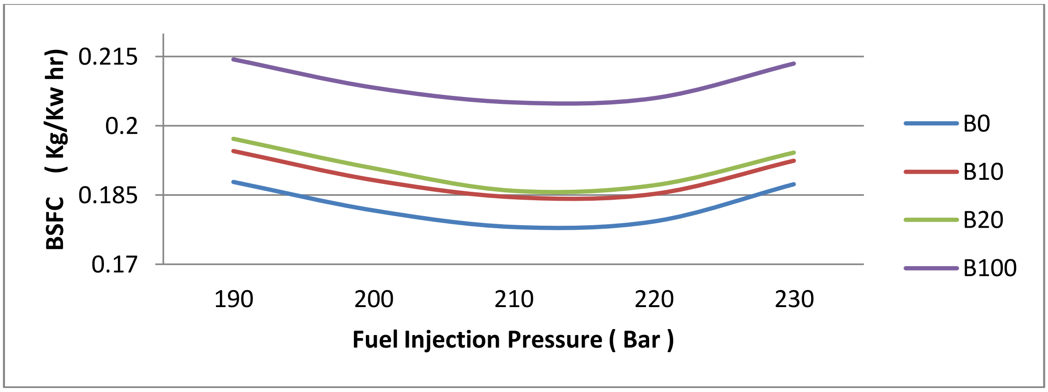

Figure 3 Variation of BSFC with fuel injection pressure

The variation of Brake Specific Fuel Consumption with injection pressure is shown in figure 3. Increasing fuel injection pressure decreases the BSFC for all fuel blends up to 210 bar. Increasing the injection pressure increases the atomization of fuel leading to formation of homogenous mixture results complete combustion and decreases the BSFC. Engine when operated at injection pressure above 210 bar shows the trend in increasing bsfc for all blends. This may be mainly due to fine atomization of fuel at higher injection pressure reduces the fuel droplets size and increased momentum leads to escaping from combustion space results to waste of fuel . This trend was increased further at very high injection pressures.

3.2 Brake Specific Energy Consumption

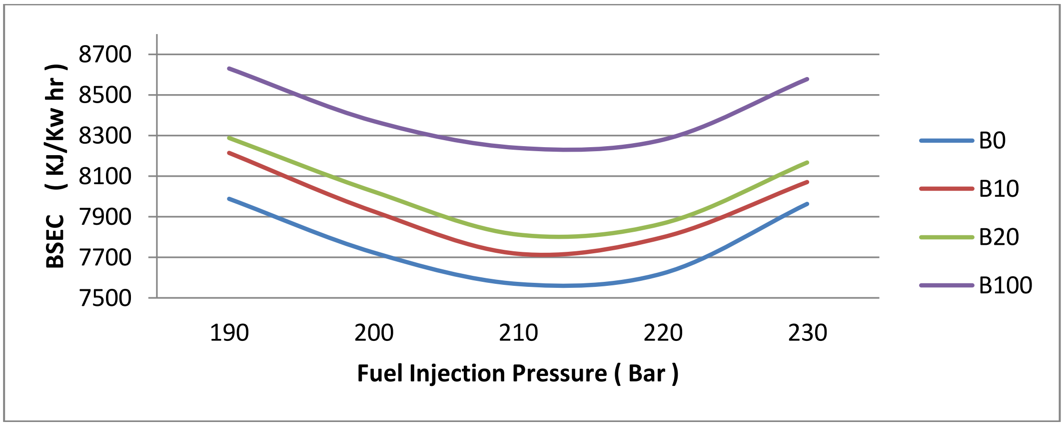

Figure 4 Variation of BSEC with fuel injection pressure

Figure 4 shows variation of Brake Specific Energy Consumption. BSEC is defined as the equivalent fuel energy required producing unit brake power for all fuel BSEC decreases with injection pressure initially and increases thereafter. AS BSEC directly depends an BSFC the same trend of BSEC was observed as BSFC. Decreasing BSFC is the main reason for decrease of BSEC up to 210 bar, beyond increased BSEC due to increased fuel consumption with loss of fuel because of fine atomization of fuel at higher injection pressure.

3.3 Brake Thermal Efficiency

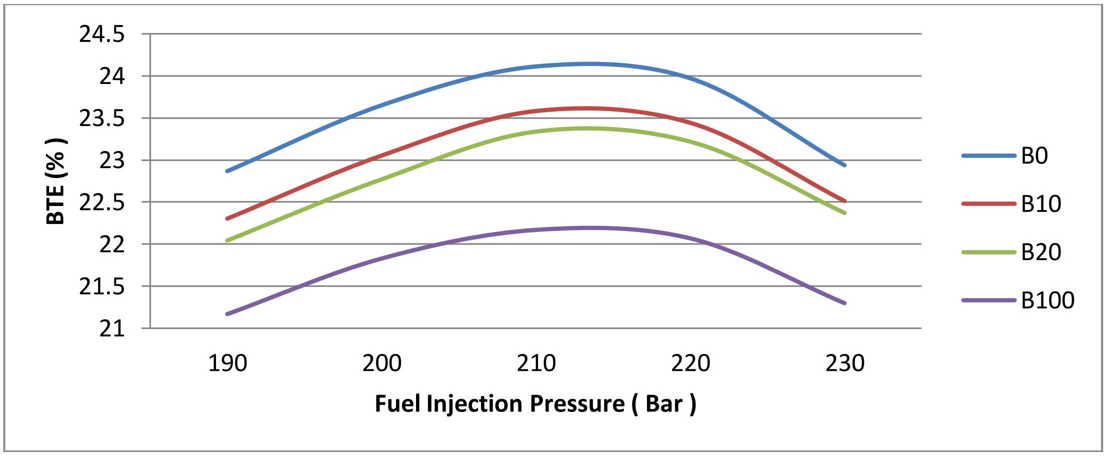

Figure 5 Variation of BTE with fuel injection pressure

The effect of injection pressure on Brake thermal Efficiency is described in figure 5. From the figure it is observed that BTE increases with injection pressure up to 210 bar and there after further increase in injection pressure decreases the BTE. Increase of injection pressure beyond 210 bar decreases the fuel droplet size thereby increases the momentum got impinging on cylinder walls leading to loss of heat through cylinder walls. The maximum BTE was observed at injection pressure of 210 bar for all fuels. The BTE of B0, B10, B20 and B100 fuels were measured as 24.11, 23.58, 23.34 and 22.17 respectively. From the graph it is also observed that the increase of blend ratio decreases the BTE at constant injection pressure. This is mainly due to higher viscosity value of SBD fuel compared to diesel.

3.4 Exhaust Gas Temperature

The exhaust gas temperature variation of all fuel blends with injection pressure is shown in figure 6. For all fuel blends it was observed that lower EGT were recorded at lower injection pressure because of lower injection pressure and improper atomization forms non homogenous mixture due to higher fuel droplet size this leads to in complete combustion releasing less heat energy. Similarly at very higher injection pressure fine atomization was carried and attains higher momentum while entering in to engine cylinder and impinging on cylinder walls. The loss of heat energy through cylinder wall during combustion reduces the exhaust gas temperature at high injection pressure. The effective and complete combustion was observed at 210 bar injection pressure produces high temperature exhaust gases. Among all blends B100 releases lower EGT because of lower heating of B100 fuel compared to other.

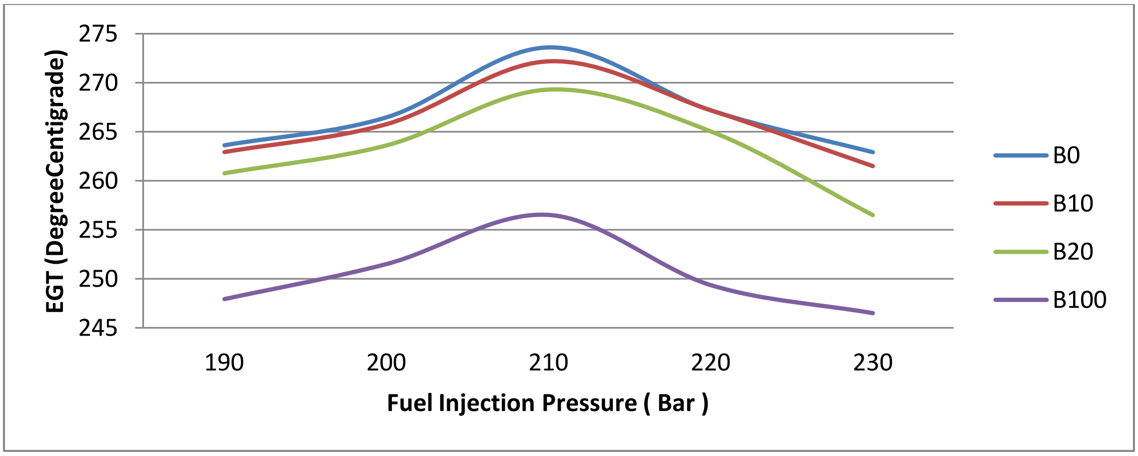

Figure 6 Variation of EGT with fuel injection pressure

3.5 NOx Emission

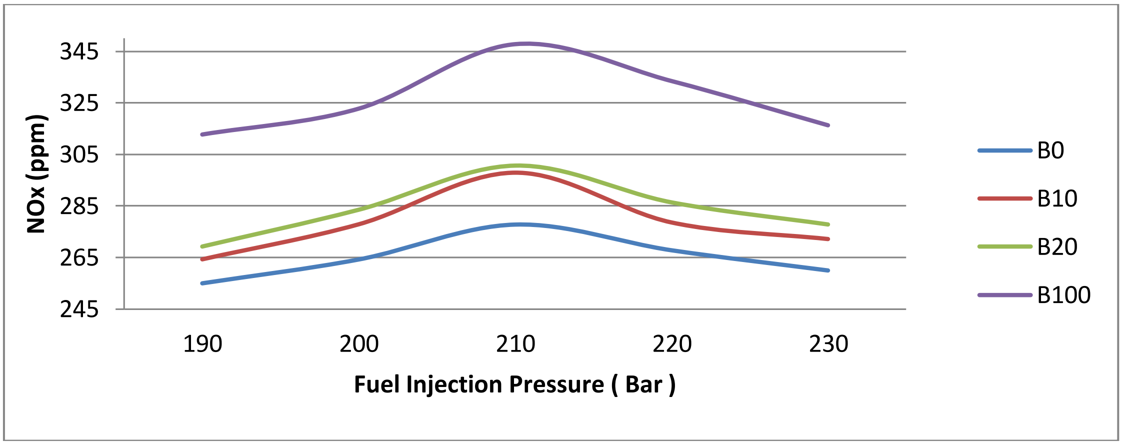

Figure 7 Variation of NOx Emission with fuel injection pressure

In general biodiesels contain 10-12% higher oxygen compared to diesel fuel. Shea olein biodiesel also contain more oxygen than diesel which is evident for more NOx emission in the exhaust as shown in figure 7. NOx emissions of SBD and its blends promote reaction of nitrogen present in the admitted air with oxygen in the biodiesel produce more NOx emissions. NOx emissions increases for all fuels with injection pressure up to 210 bar, beyond 210 bar further increase in injection pressure decreases the NOx emission. This is because of non homogenous mixture formation due to less atomization of fuel results incomplete combustion of fuel at lower injection pressures and even at higher injection pressures also waste of fuel due to higher momentum reduce the oxygen availability for combustion resulted lower NOx emission.

3.6 HC Emission

The HC emission variation with fuel injection pressure is shown in figure 8. From the graph it was investigated that HC emission in the exhaust decreases with injection pressure from 190 bar to 210 bar and above 210 bar increasing injection pressure increases HC emission. The lowest HC emission were observed for all blends at 210 bar. This is mainly due to more effective combustion at 210 bar. But at all pressures biodiesel and it blends produce less HC compared to diesel because the oxygenated biodiesel promotes complete combustion.

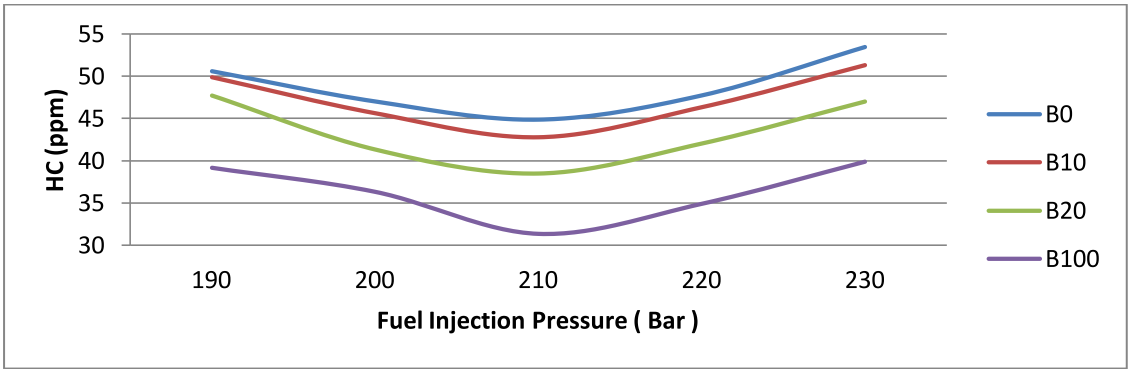

Figure 8 Variation of HC Emission with fuel injection pressure

3.7 CO Emission

Figure 9 describes the variation of CO emission with fuel injection pressure. From the figure the decreased CO emission are observed up to 210 bar injection pressure. Beyond 210 bar increasing injection pressure increases CO emission for all fuels mainly formation of CO emission depends on the combustion process. Always the complete combustion resulted lower CO emission. At 210 bar injection pressure the CO emission are observed minimum for all the fuel blends due to complete combustion. CO emission for biodiesel and its blends are observed lower than pure diesel. This is also because of more oxygen content of biodiesel leads to effective combustion and resulting lower CO emission.

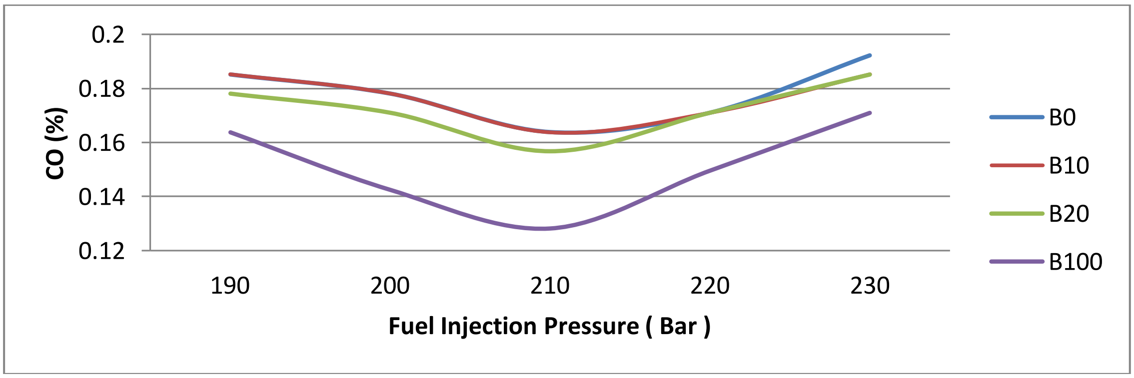

Figure 9 Variation of CO Emission with fuel injection pressure

4. Conclusions

Engine was made to run with all different blends at different injection pressures successfully and the following conclusions are drawn from experimental investigation

- Brake Specific fuel consumption is low at 210 bar and with increase of injection pressure BSFC increases. At higher injection pressures BSFC is increased because of higher momentum of fuel got impinges on cylinder walls leads to wastage of fuel and improper combustion
- BSEC is low at 210 bar injection pressure.
- BTE of B0, B10, B20 and B100 fuels measured as 24.11, 23.58, 23.34 and 22.17 at 210 bar injection pressure which are higher compared to other injection pressures. This was mainly due to complete combustion of entire fuel which was admitted without any wastage with higher momentum
- It was observed that lower EGT were recorded at lower injection pressures.
- NOx emissions increases for all fuels with increase of injection pressure up to 210 bar.
- The lowest HC and CO emissions were observed at 210 bar compared to other pressures.

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