



Influence of Fuel Injection Pressure on Exhaust Emissions of Compression Ignition Engine Fuelled with Transesterified Rice Bran Oil

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Abstract: Recently the biodiesel fuel became the prominent feasible fuel in diesel engine. The aim of the research work is to evaluate the effect of variation of fuel injection pressure on the emission characteristics such as exhaust gas temperature (EGT), smoke density, particulate matter and NO_x emissions of a direct injection diesel engine when fuelled with transesterified rice bran oil. The outcome from experimental results of a single cylinder, 4-stroke, water cooled diesel engine fuelled with different blends (BR20, BR40, BR60 and BR100) of transesterified rice bran oil at different injection pressures have revealed that B100 biodiesel has shown lower smoke density, particulate matter and BR20 blend of rice bran biodiesel has emitted lower EGT and NO_x emission at all injection pressures and blend percentage is also affecting the emission characteristics. At injection pressure of 220 bar, the EGT and exhaust emissions are optimal and it can be considered as optimum injection pressure with reference to emissions from tested diesel engine.

Keywords: Biodiesel; Rice Bran Oil; Transesterification; Exhaust Emissions; EGT; PM; NO_x

I. Introduction

In the past few decades, the speedy depreciation of fossil fuel reserves, unpredictable petroleum oil prices due to various political and technical issues, and perilous environmental pollution has caused to search for alternative renewable fuels [1]. This is not only to provide energy security to the nations other than OPEC countries, but also to curb the dangerous exhaust emissions. Initially, the researchers have tried neat vegetable oil as fuel in diesel engine without any engine modifications. Even though, it is working fine, but it has given undesirable effects in long period operations such as injector coking, piston ring sticking, and thickening of the lubricating oil in the diesel engine [2-4]. This is due to properties of biodiesel such as high viscosity, density and low volatility. The past research studies revealed that pre-heating the biodiesel, blending oil with diesel and Transesterification are some of the methods used to improve the chemical properties of the biodiesel. The biodiesel, produced through transesterification process with alcohols such as ethanol, methanol solves the most of the problems mentioned above. The biodiesel is a non-toxic, clean burned biodegradable fuel and environmental point view, it is much better fuel than diesel in terms of sulphur content, aromatic content, flash point, and biodegradability [5]. Financial point of view, undoubtedly the use of biodiesel in diesel engine as renewable source of fuel can play a vital role in reducing dependence on diesel imports and can also trigger the rural economic development [6,7].

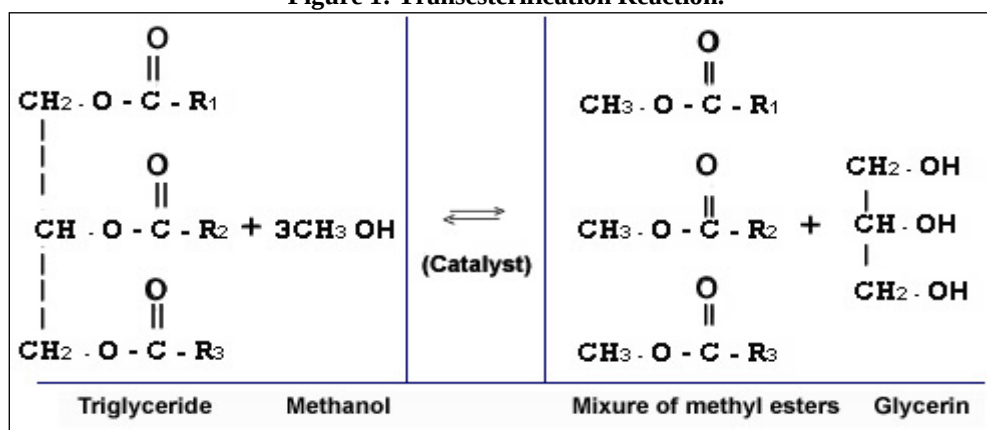
The past research was mostly focused on evaluation of suitability of alternative fuel in terms of engine characteristics in unmodified engine. But engine operational and design parameters such as load, biodiesel blend percentage, compression ratio, injection timings and injection pressure has significant effect individually or groups of parameters on the engine performance and emission properties [8-10]. Sivaganesan et al., injected diesel and biodiesel fuel at 23 °BTDC at various compression ratios using the 20% (B20) concentration of biodiesel that was extracted from mahua oil, mixed with diesel and conducted experiments. It was observed from the results that the higher the compression ratio better the performance and lower the emission. By reducing the compression ratio, the oxide of nitrogen was lower for both diesel and biodiesel compared with higher compression ratio of 17.5 [11]. Naga Raja et al., were investigated the performance of palm oil fuelled engine, which increased with the heating of oil. The exhaust emissions when palm oil used as fuel in diesel engine were a little higher than that of diesel. It was also noticed that carbon deposits, fuel filtering problems, lubricating oil dilution were still evident even after its heating to 80°C [12]. Vallinayagam et al., were studied the combustion performance and emission characteristics using pine oil in a diesel engine and revealed at full load condition, 100% pine oil has very less carbon monoxide, hydrocarbon and smoke emissions. The brake thermal efficiency and maximum heat release rate increase by 5% and 27%, respectively. However, the oxide of nitrogen emission is higher than that of diesel fuel at full load condition. The experimental work reveals that 100% pine oil can be directly used in diesel engine and potential

benefits of pine oil biofuel have been reaped. [13]. Çelikten et.al conducted experimental investigation with rapeseed oil methyl ester and soybean oil methyl esters in a DI diesel engine to evaluate the performance and emissions of engine and compared with diesel fuel. The tests were conducted at different injection pressures such as 200 bar, 300 bar, 350 bar and the test results shown that the performance and emission values of rapeseed oil and soybean oil methyl esters were found to be nearly the same with those of diesel fuels when injection pressure was increased to 300 bar [14]. The present research work is aimed to investigate the influence of fuel injection pressure on emission characteristics in terms of gas temperature (EGT) smoke density, particulate matter and NOx emissions of a single cylinder diesel engine using rice bran oil methyl ester (RBOME) as fuel.

II. Materials and Methods

The raw rice bran oil used in this research study was collected from a local vendor and transesterification process was carried-out to reduce the viscosity of the oil and to prepare the rice bran biodiesel. In the transesterification process, generally the vegetable oil reacts with methanol in the presence of catalyst to yield glycerine and methyl esters as shown in Figure 1. 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.

Figure 1: Transesterification Reaction.



The fuel properties of diesel fuel and RBOME are shown in Table I.

Table I: Diesel Fuel and Rice Bran Biodiesel Properties.

Fuel Property	Unit	ASTM Standards	Diesel	RBOME
Kinematic Viscosity @ 40°C	CST	D445	3.52	5.37
Flash Point	°C	D93	49	165
Density @ 30°C	kg/m ³	D1298	830	880
Calorific Value	kJ/kg	D4868	42850	38952
Cetane Number	--	D613	50	53
Ash	% bymass	D1119	0.01	0.02

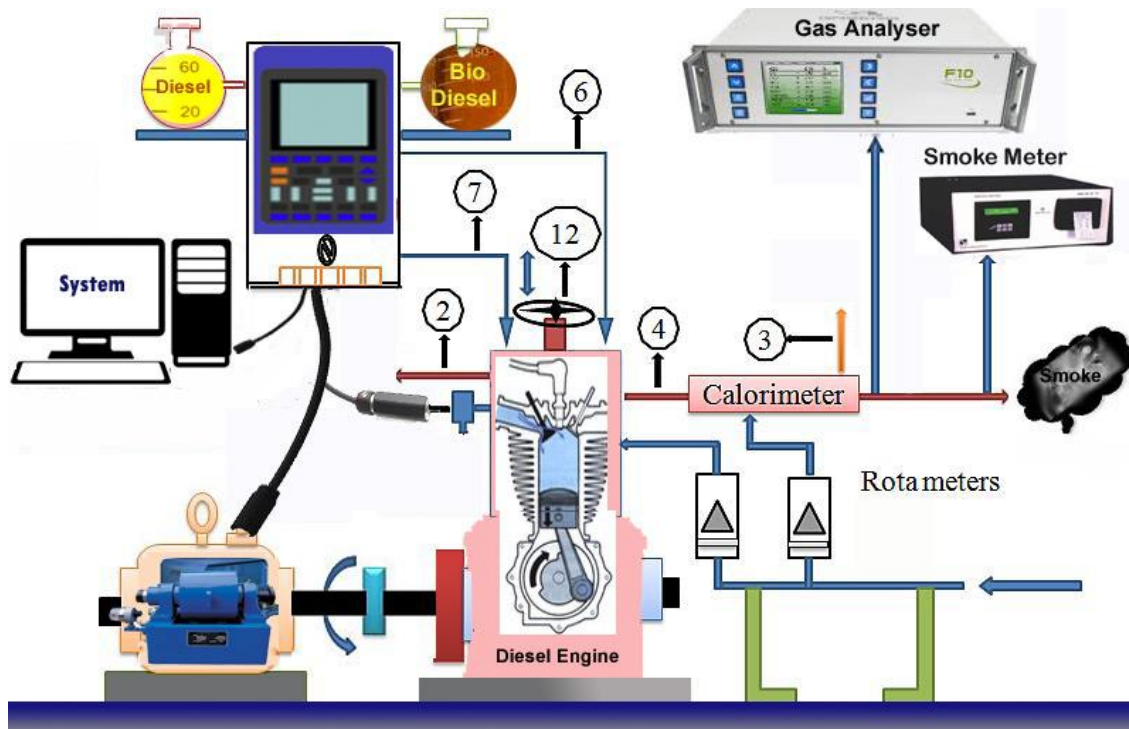
III. Experimental Setup

The experimental set-up which was utilized to conduct experiments consist of a single cylinder, 4-stroke, water cooled DI diesel engine of 5 HP power as shown in Figure 2. An eddy current dynamometer that was attached to test engine was used as loading unit. The instrumentation attached to the test rig is able to measure the air consumption, fuel consumption, in cylinder pressure, crank angle, cooling water flow rate, exhaust gas temperature. A separate gas analyser was used which was coupled to the computerized test rig to measure the emissions. The lubricating oil, fuel and ambient temperatures are measured by thermocouples. The computed values are recorded by considering the error analysis of the respective devices. The specifications of the engine are given below in Table II.

Table II: Engine Specifications

Type	Kirloskar, AV1
Details	Single cylinder, Direct injection, 4-Stroke, Water cooled engine
Bore & Stroke	80 × 110 mm
Rated Power	3.7 KW at 1500 rpm
Compression Ratio	16.5 :1
Fuel Injection Pressure	200 bars

Figure 2: Experimental Setup.



Nomenclature:

2: Outlet engine Jacket Water Temperature ($^{\circ}\text{C}$); 3: Inlet water temperature ($^{\circ}\text{C}$);
4&6: Exhaust Gas Temperature before and after Calorimeter ($^{\circ}\text{C}$); 12: Pressure Transducer

IV. Results and Analysis

A. Exhaust gas temperature (EGT)

Figure 3 shows the variation of exhaust gas temperature (EGT) with injection pressure for different blends of rice bran biodiesel at constant engine speed of 1500 rpm. The exhaust gas temperature (EGT) reflects the fuel energy used by the engine, which in turn represents the engine's thermal efficiency. The graph shows that B20 blend has lowest and rice bran biodiesel in its neat form has highest EGT when compared with all tested blends. EGT initially decreased from 200 bar to 220 bar and then increased, but 220 bar has lowest exhaust temperature. The lowest exhaust gas temperature was noticed with BR20 blend of rice bran biodiesel. As biodiesel percentage in the blend increases, the exhaust gas temperature has also increased. At injection pressure of 220 bar, the engine has exhibited lowest exhaust gas temperature for all tested fuels.

B. Smoke Density (SD)

The variation of injection pressure with smoke density for different blends of transesterified rice bran oil is presented in Figure 4. 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. It was also noticed the engine has exhausted lowest exhaust gas temperature (EGT) at 220 bar of fuel injection pressure when blends of rice bran biodiesel used as fuels in a DI diesel engine. The lowest smoke density was observed with BR100 blend of rice bran oil methyl ester (RBOME).

Figure 3: Variation of EGT with Fuel Injection Pressure for Different Biodiesel Blends

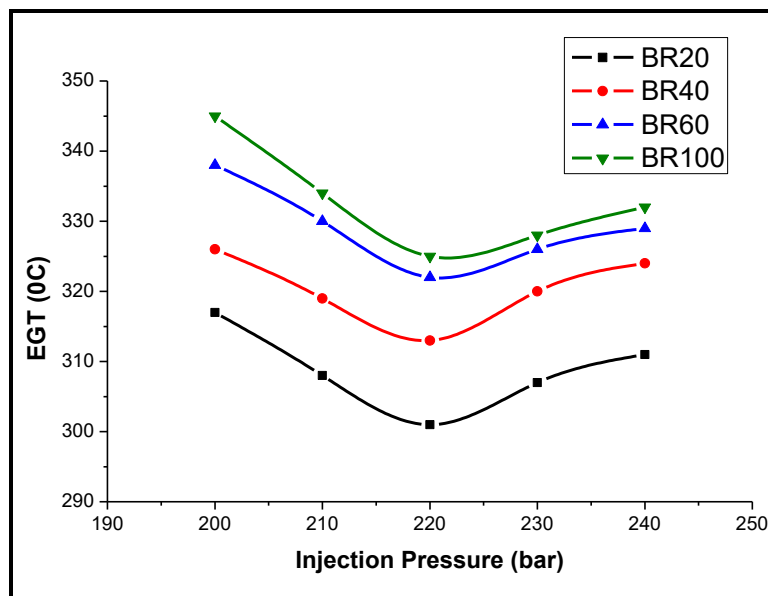
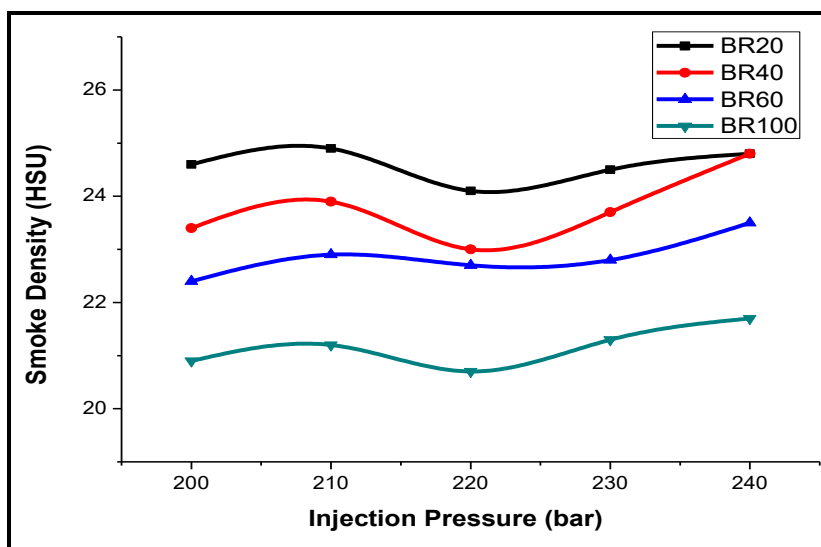


Figure 4: Variation of Smoke Density with Fuel Injection Pressure for Different Biodiesel Blends



C. Particulate Matter (PM)

The 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 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

D. NO_x Emission

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

bar and 240 bar respectively. 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.

Figure5: Variation of PM with Fuel Injection Pressure for Different Biodiesel Blends

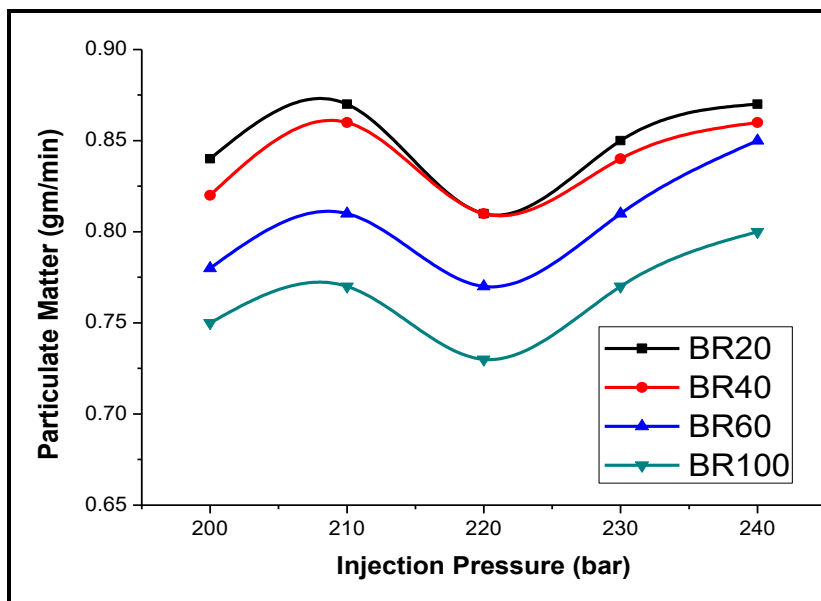
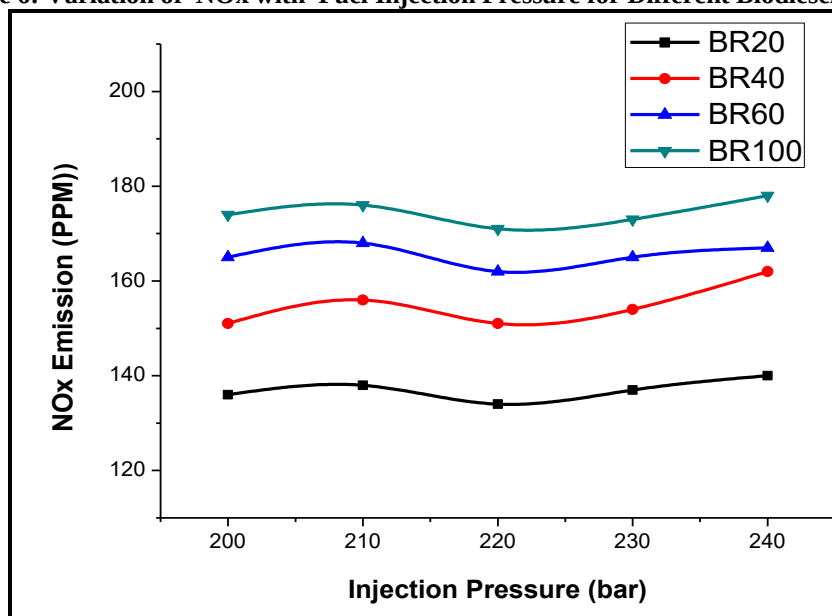


Figure 6: Variation of NOx with Fuel Injection Pressure for Different Biodiesel Blends



V. Conclusions

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 smoke density, particulate matter and B20 blend has emitted lower EGT and NOx emissions. All blends have lowest emissions at 220 bar of fuel injection pressure. The results have also revealed the EGT and NOx emissions have increased with increase of biodiesel percentage in blend, but smoke density and PM has decreased with the increase of blend percentage of RBOME.

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