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The Effect of High Fuel Injection Pressure on CRDI Diesel Engine Fueled with Algae Biofuel

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Abstract: ***Experimental investigations were conducted to determine the performance & emission features of a common rail direct injection (CRDI) system using algae biofuel to aid diesel engine. The algae biofuel-diesel blends were taken in two different proportions, B10 & B15 (10% and 15% of algae biofuel is mixed with diesel on a volumetric approach). The tests were conducted on CRDI diesel engine at various injection pressures from 600 to 1050 bar with the difference of 150 bar. From the results it was exposed that at high fuel injection pressure (1050 bar), brake thermal efficiency (BTE) improved and brake specific fuel consumption (BSFC) reduced when related with other injection pressures. CO, HC & smoke density significantly decreases with rise in injection pressures. However, NOx emissions are shown to be increased. At different load conditions, biodiesel algae are associated with higher exhaust gas temperatures.***

Keywords: ***Algae, Combustion, Common rail direct injection, Emissions, Fuel injection pressure.***

I. INTRODUCTION

Biodiesel is currently receiving a lot of attention to reduce greenhouse gas emissions from compression ignition engines. These fuels may be sustainable, renewable and biodegradable. Algae oil is an encouraging source of biodiesel production as the production capacity in quantities. One of the main factors affecting the world economy is petroleum resource sustainability, which is an important source of global energy resource. However, the world's demand for energy is growing more quickly due to excessive use of fuels. These early studies demonstrated vegetable oil's satisfactory performance as a fuel for diesel engines. Despite their comparable performance in diesel engines, when used as fuel, vegetable oils cause engine problems in long run [1]-[3]. Kannan et. al.[4] studied algae biodiesel-diesel blends and found that blends caused higher emissions of NO_x compared to pure diesel.

The main disadvantage of vegetable oils is their high viscosity, which causes, glazing and trumpet formation on the injectors resulting in poor atomization [5]. Transesterification and pyrolysis are potential alternatives to decrease the viscosity of vegetable oils. Biodiesel fuel can be combined easily with mineral diesel and can be used in diesel engines without engine alteration [6-7]. The use of biodiesel has been declared by several engine manufacturers. Biodiesel can be mixed with diesel in small proportions and can be used in unmodified diesel engines effectively. Biodiesel blends are often coded to denote the blend's volume percentage. Most literature studies confirm that the increase in fuel consumption is proportionate to the content of fuel mixtures & the loss of heating value and biodiesel-fuelled engines emit minor emission levels of HC, CO & smoke, except NOx, related to diesel fuel. Raman Piloto et. al. [8] oladapo martins adeniyi et. al. [9] have studied the performance and emissions on diesel engine fuelled with algae biodiesel. We inferred from the findings that biodiesel and its mixtures contribute to a slight decrease in brake power values. Exhaust emission tests revealed that while emission values for CO and HC decrease, NOx emission values increase with the use of biodiesel.

The common rai direct fuel injection system is capable of raising the injection pressure up to 1900 bar and can lead to a cleaner and quieter diesel engine and have a positive impact on the environment [10]. In an immediate mixture diesel engine, the fuel injection structure is designed to achieve a high atomization level for better fuel penetration for order to use the most extreme air calculation and to advance dissipation and to achieve greater ignition output[11].

Based on the study, because of its lower viscosity, higher cetane amounts, algae biodiesel is better than other non-edible biodiesel. In this test, a diesel engine's output and exhaust emissions using the B10 & B15 blends were inspected at various fuel injection pressures to explore the potential for biodiesel use of algae.

II. MATERIALS AND METHODOLOGY

A. Biodiesel Preparation

Algae biodiesel is combined with diesel in two different proportions mixing 10% & 15% of biodiesel with diesel.

B10: Diesel 90% + biodiesel 10%

B15: Diesel 85% + biodiesel 15%

The physical and chemical properties of biodiesel-diesel algae blends have been calculated using standard ASTM methods and are presented in Table 1.

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Table. 1 Properties of Blended Biodiesel Samples

PARAMETERS	(B10)	(B15)	DIESEL
Kinematic viscosity @ 40° C (cst)	6.44	6.44	2.6
Density @15°c	0.8670gm/cc	0.8680gm/cc	0.860gm/cc
Flash point °c	42	42	52
Fire point °c	56	56	57
Lower calorific value in kJ/kg	41600	41700	42100

III. EXPERIMENTAL SETUP

Experiments were carried out on Kirloskar, a four-stroke, single-cylinder & water-cooled diesel engine supported by a common rail direct injection system. To performed experiments on the defined compression ignition engine with fuels to evaluate efficiency, emissions & combustion parameters under different operating conditions, an experimental set-up was created. Set-up consists of dynamometer, fuel and air flow measurement systems, emission measurement instruments and cylinder pressure measurement systems. Table.2 offers descriptions of the engine configuration. The experimental layout schematic diagram is shown in Fig 2.

Table. 2 Engine Specifications

Parameter	Value
Bore	80mm
Stroke	110mm
Compression ratio	17.5:1
Maximum power	3.7 kW
Rated speed	1500 rpm
Loading device	Eddy current dynamometer
Injection pressure	600-1050 bar (variable)
Injection timing	23°C before TDC

In this section the details of experimentations done in various modes of operation are presented. All the experimentations are carried out at a speed of 1500 rpm. All readings were only taken after a balanced operation was reached by the engine. Until beginning the tests, the gas analyzers were turned on to stabilize them until starting the measurements. All the instruments were periodically calibrated. The injection pressures are varied according to the experiments which are carried out. The high-pressure was operated by a model containing of a Kirloskar high-pressure pump powered by an electric motor at a constant speed of 1500 rpm and a single injector. The operation of the high-pressure fuel pump allowable the injection-pressure range as wide as the pump could supply and independent of the engine speed. In production, the pressure of injection is controlled by an inlet metering valve that allows only the required amount of fuel to be pressurized. By actuating the spill valves in the injectors themselves, the pressure would be adjusted using a high-frequency signal. Using AVL software, the pressure traces were obtained from variations in pressure and combustion data such as instantaneous heat release rate and 10, 40 and 90% angles of burned fuel mass fraction. The software "Engine Test Express 2014" was used to monitor the current drive's injection pressure, start and end. However, comparisons have been made to recognize the differences. We have shown that the measurement resulted in a very similar profile match, which was closely linked during the engine cycle to the pressure variation. The emission system consists primarily of a smoke meter and an exhaust gas analyzer, which positions the sampling point from the exhaust manifold to the degree necessary to maintain that the entire flow is representative of the measurement. The smoke meter was AVL 415 Variable Smoke Meter, based on the filtering concept. A transparent photometer is used to test the darkness of the filter paper, which affects HSU (Hatridge Smoke Unit) outputs. For calculating exhaust emissions, an AVL Di-gas analyzer was used. The process used the measuring rule with an accuracy of 2% over a period of 8 hours and linearity of 1% of the signals.

Fig. 1 Photograph of Experimental Set-Up

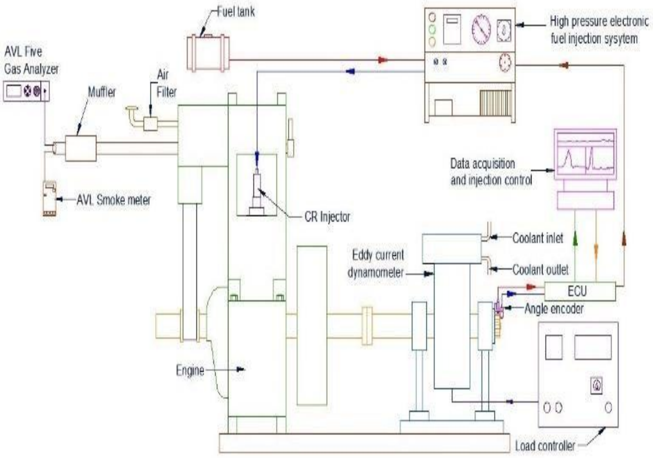


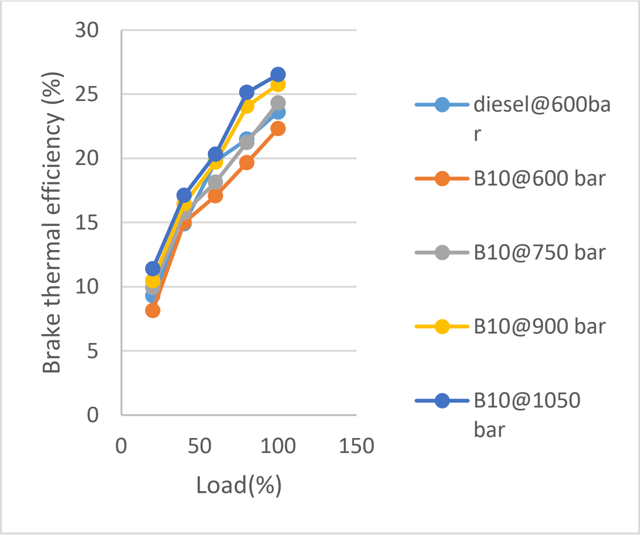
Fig. 2 Schematic Diagram of Experimental Set-Up

IV. RESULTS AND DISCUSSION

A. Performance Characteristics

a. Brake Thermal Efficiency

Fig 3 shows variation of brake thermal efficiency with load for all the fuels used. An increase in fuel injection pressure decreases the fuel consumption and enhances the mixing of fuel with air. It was found that the BTE amplified with the increase in fuel injection pressure. This increase is happened because of the increase in injection pressure helps in proper atomization of fuel leading to a better combustion & there is a rise in temperature, air-fuel mixture is efficient, which increases combustion efficiency and thermal efficiency. The brake thermal efficiency increases with a rise in injection pressure for all the fuel samples. The reduction in BTE was discovered in B10 compared to diesel fuel by about 1.28% at 600 bar pressure and in B15 there is an increase in BTE by about 1.4% compared to diesel fuel at 600 bar pressure. BTE of B15 at 600, 750, 900, 1050 bar pressures were 25.04, 26.47, 27.25, 28.24 respectively.



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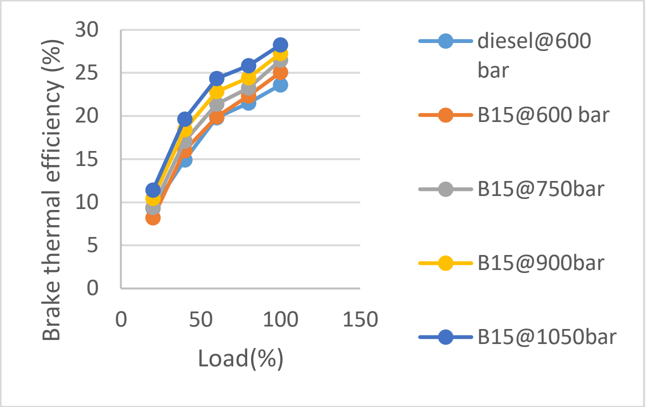

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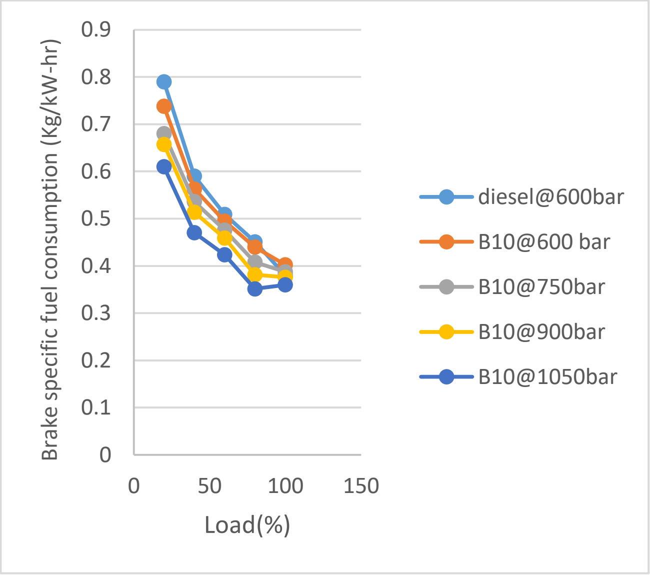
Fig 3. Variation of BTE with Load

b. Brake Thermal Efficiency

Fig 4 shows variations of brake specific fuel consumption with load for all the fuels used. The brake specific fuel consumption was improved with increase in load for all the fuel samples. From the figure, it is also clear that with an increase in injection pressure leads to a significant reduction in the specific fuel consumption. This is because of an increase in injection pressure reduces the size of the fuel droplet and this atomization creates better combustion. The BSFC of blends B10 & B15 shows a considerable reduction at the pressure 1050bar compared to other injection pressures. The BSFC of fuel blends at 600bar fuel injection pressure shows a considerable decrease of about 9.5%iin comparison with the diesel at 600bar fuel injection pressure. For B15 fuel blend BSFC was 0.3926kg/kW-hr at 600bar and it decreased with the increase in pressure up to 0.2886kg/kW-hr at 1050bar, it is clear that the fuel consumption in all injection pressures has been decreased.



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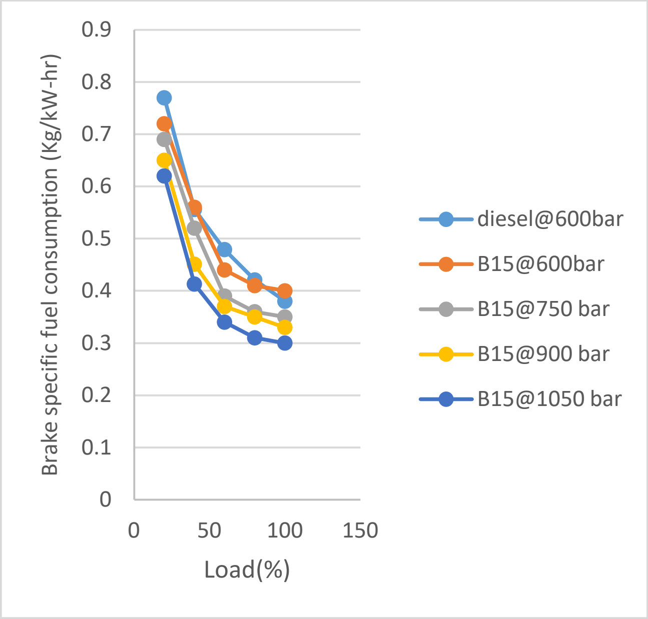

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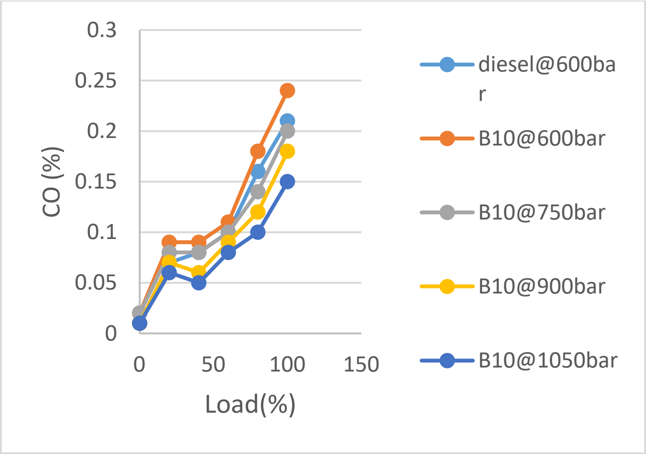
Fig 4. Variation of BSFC with load

B. Emission Characteristics

a. CO Emissions

Fig 5 shows the variations of carbon monoxide with load for different fuels at various injection pressures. Compared to diesel, both the blends B10 & B15 show lower CO-emissions. The emission of carbon monoxide depends on the fuel's oxygen content and cetane number. Biodiesel has more oxygen content than diesel fuel. Biodiesel blends are therefore involved in the complete combustion. From the Fig, it is found that the use of biodiesel resulted in 20.27% average reduction of CO at the standard fuel injection pressure of 600 as compared to that of neat diesel. Carbon monoxide is mostly a by-product of incomplete combustion, developed via the partial oxidation of carbon-containing compounds and formed when there is not enough oxygen to obtain CO_2. This state is attributed to a rich fuel condition. Because CO emissions are caused by a rich mixture and the rise in the pressure of fuel injection contributes to leaner mixtures. When the fuel injection pressure is increased from 600 bar to 1050 bar, the CO emissions decrease by 27.24%.



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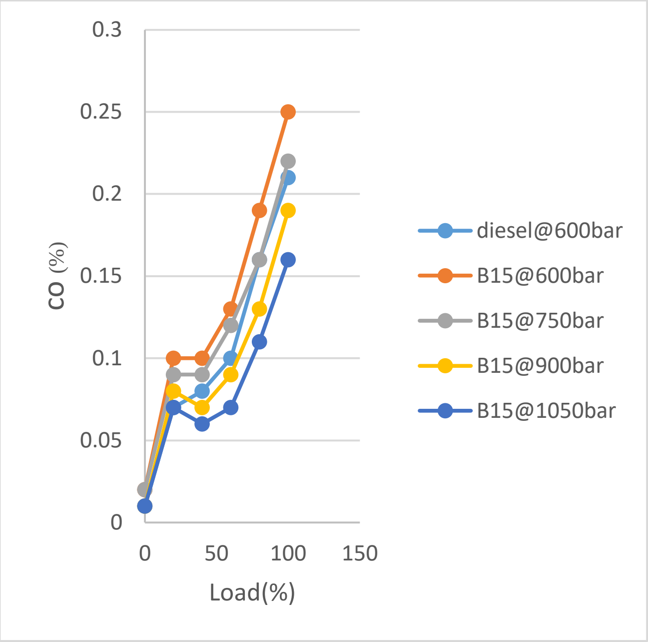

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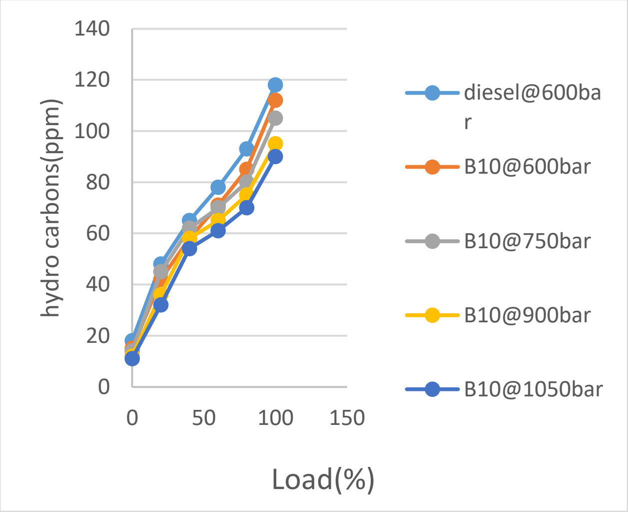
Fig 5. Variation of CO Emissions with Load

b. HC Emissions

Fig.6 shows the variation in load-bearing hydrocarbon emissions for neat diesel fuel & algae fuel with different injection pressures. It is noticed from the graph that all other parameters indicate reduced hydrocarbons emissions compared to the standard injection pressure of neat diesel fuel. The highest reduction in hydrocarbon emissions is shown in particular by B15 with standard injection pressure, Hydrocarbon emission for was 112ppm for diesel at 600bar pressure, and for B10 & B15 it was 118ppm and 120ppm at 600bar of fuel injection pressure. It could be indirect that when the fuel injection pressure increases hydrocarbon emission was further decreased. HC emission for B10 & B15 decreased to 90ppm and 72 ppm when the fuel injection pressure was increased from 600-1050bar.



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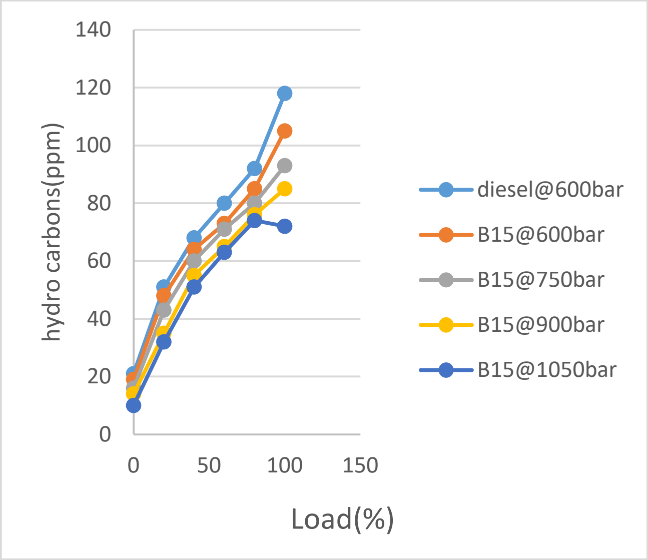

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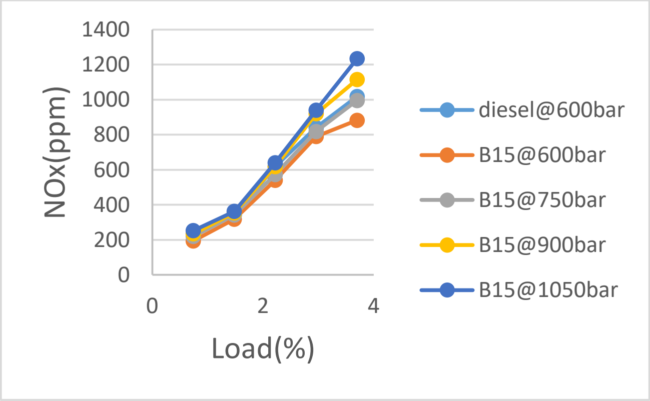
Fig 6. Variation of HC Emissions with Load

c. NOx Emissions

In the diesel engine, nitrogen oxides emission depends primarily on both the flame temperature and oxygen content in the fuel. Fig. 7 Shows NOx emissions variations with load for diesel and diesel-biodiesel blends at various injection pressures. With the algae blends, the start of combustion was advanced, resulting an increase in the mean temperature. As shown in Figure 8, NOx emissions enlarged by constant rpm compared to neat diesel with injection pressure. From the fig.7, it can be seen that, compared to neat diesel fuel, NO emissions for biodiesel blends are the highest. NOx emissions were enhanced with increased injection pressure in the case of injection pressures. It is because the fuel injection pressure increases the rapid atomization and shortens the ignition delay; this will result in improved combustion of fuel. Because of better combustion, N2 will react with oxygen at high temperatures & yield more NOx emissions. The NOx emissions increased by 6.8% for the blends B10 & B15 with the fuel injection pressure.



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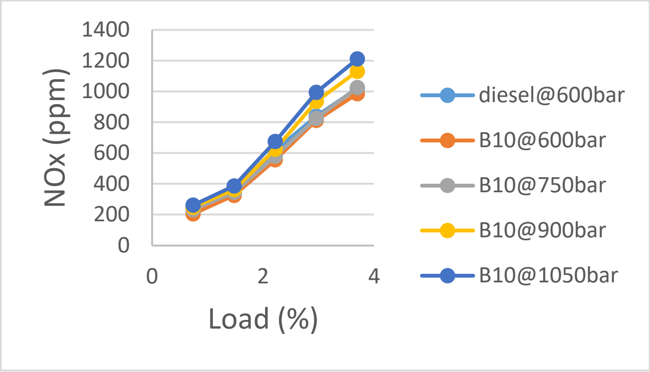

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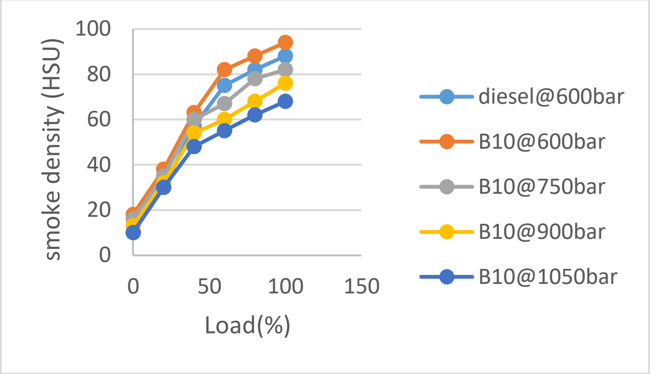
Fig 7. Variation of NO_x Emissions with Load

d. Smoke Density

Fig 8 shows smoke density variations with load for diesel & diesel-biodiesel mixtures at altered injection pressures. From the Fig. 8 it is found that all other parameters show reduced smoke density related to the standard injection pressure of neat diesel fuel. The maximum reduction in smoke density is shown in particular by B15 with standard injection pressure. Smoke emission at constant rpm dropped to 9.21% for both blends B10 & B15 with relative to neat diesel fuel. The smoke emissions for B10 & B15 are 94 and 96 HSU at 600 bar pressure and at 1050bar it is 68 and 68 HSU.



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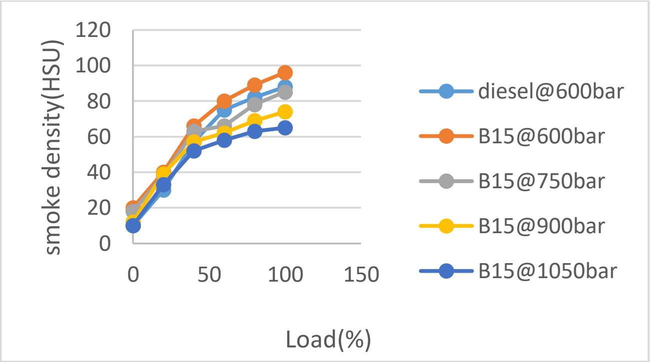

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Fig 8. Variation of Smoke Density with Load

V. CONCLUSION

These are the conclusions which are drawn on the basis of investigational examinations conducted on the equipment with neat diesel fuel and the blends B10 & B15 algae fuel with varying injection pressures 600 bar, 750 bar, 900 bar & 1050 bar respectively.

- For blend B15 at 1050 bar brake thermal efficiency indicates an enhancement with relative to diesel fuel and all other parameters.
- Injection pressure at 1050 bar blends B10 & B15 shows lower smoke density compared to all other parameters.
- For B10 & B15 blends, carbon monoxide shows the maximum reduction relative to diesel fuel.
- The utmost reduction in hydrocarbon emissions is shown at the injection pressure 1050bar with B15 blend.

The algae oil (B15) mixture in the diesel engine can be used as an alternative fuel. At 1050 bar injection pressure indicates a change in performance & emission characteristics.

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