The Effect of Super Charging and Rice Bran Oil Biodiesel As an Additive in Diesel- Ethanol Blends For Diesel Engines

R. Vidya Sagar Raju[a], V. Nageswara Reddy[b], G. Narasa Raju[a], Dr. G. Sreenivasa Rao[c]
[a] *B.V.C. Engg. College, Odalarevu, A.P., India.*
[b] *R.G.M. College of Engg. & Tech., Nandyal, A.P., India.*
[c] *R.V.R. & J.C. College of Engg. & Tech., Guntur, A.P., India.*

Abstract

The applications of diesel engines in the present scenario are vast. Generally these engines use conventional petroleum diesel oil as fuel. Probably in this century, it is believed that crude oil and petroleum products will become very scarce and costly to find and produce. The other major problem posed by these petroleum fuels is air-pollution. This situation caused enticement in researchers to find a viable and alternative to conventional fuels and paved a way to alternative fuel technology. Many vegetable oils have similar fuel properties to diesel fuel, except for higher viscosity and lower oxidative stability. If these differences can be overcome, vegetable oil may substitute for petroleum diesel fuel. Before using straight vegetable oil as fuel, their viscosity and surface tensions must be reduced by preheating the oil, otherwise poor atomization, incomplete combustion and carbonization may result. In this investigation, the effect of supercharging is studied on the performance of a diesel engine with the use of straight rice bran oil blends with diesel as fuel, under varying supercharging pressures. The performance of the engine is evaluated in both the cases in terms of various engine performance parameters (Brake power, Brake specific fuel consumption, exhaust gas temperatures, engine emissions etc.). The results are compared with these performance parameters in both Pure Diesel and blended oil operation of the DI Single Cylinder Diesel engine.

Key words: *Diesel engine % Rice bran oil % Biodiesel compressed air% Performance % Emissions*

1. INTRODUCTION

Energy is very important for life quality and social development of people as well as economic growth. Fossil fuels have been an important conventional energy source for years. Energy demand around the world is increasing at a faster rate as a result of ongoing trends in industrialization and modernization. Most of the developing countries import fossil fuels for satisfying their energy demand. Consequently, these countries have to spend their export income to buy petroleum products [1]. The climate changes occurring due to increased Carbon Dioxide (CO_2) emissions and global warming, increasing air pollution and depletion of fossil fuels are the major problems in the present century. The present researchers have been focused on the biofuels as environment friendly energy source to reduce dependence on fossil fuels and to reduce air pollution. The biofuels can play an important role towards the transition to a lower carbon economy and also combine the benefits of low greenhouse emissions with the reduction of oil import. The role biofuels can play within these economies becomes clearer when their relatively developed agricultural sector is taken into account [2].Biodiesel and to a lesser extent pure vegetable oils are recently considered as most promising biofuels. Diesel-rice bran oil blends are a more viable alternative and require little or no change in diesel engines. The use of diesel-rice bran oil blends can significantly reduce the emission of toxic gases and particulate matters when compared to pure diesel. Ozer Can et al; [4] investigated the effects of rice bran addition to Diesel No. 2 on the performance and emissions of a four stroke cycle, four cylinders, turbocharged indirect injection diesel engine with different fuel injection pressures at full load. They showed that the rice bran oil addition reduces Carbon monoxide (CO), soot and Sulphur Dioxide (SO_2) emissions, but increases Oxides of nitrogen (NO_x) emissions. It was also found that increased injection pressure, reduced the CO and smoke emissions with some reduction in power. Andrzej Kowalewicz [5] showed that the injection of compressed air into the inlet port reduced CO_2, NO_x and CO emissions and smoke at higher loads with both diesel fuel and rape oil methyl ester.

Inching Huang et al [6] studied the performance and emissions of a diesel engine using ethanol-diesel blends. They showed that the thermal efficiencies of the engine fuelled by the blends were comparable with that fuelled by diesel, with some increase of fuel consumption. They also found reduced smoke emissions, CO emissions above half loads, and increased HC emissions with the blends comparing with the diesel fuel.

However, ethanol and diesel fuel are inherently immiscible because of their difference in chemical structures and characteristics. The addition of ethanol to diesel affects properties such as viscosity, lubricity, Cetane number, energy content and mainly, volatility and stability. Phase separation occurs at relatively low temperatures, which are still used in the blending of anhydrous ethanol. The phase separation can be prevented in two ways. First is the addition of an emulsifier, which acts by lowering the surface tension of two or more substances and the second is the addition of a co-solvent, which acts by modifying the power of solvency for the pure solvent. [7]. Diesel and ethanol fuels can be efficiently emulsified into a heterogeneous mixture of one micro-particle liquid phase dispersed into another liquid phase by mechanical with suitable emulsifiers. The emulsifier would reduce the interfacial tension force and increase the affinity between the two liquid phases, leading to emulsion stability [8]. A suitable emulsifier for ethanol and diesel fuel is suggested to contain both lipophilic part and hydrophilic part, in order to obtain an emulsion of diesel and alcohol. Such chemical structures can be found in biodiesel. [9]. Biodiesels are used because of their similarity to diesel oil, which allows the use of biodiesel-diesel blends in any proportion. The biodiesel allows the addition of more ethanol-blended fuel, keeps the mixture stable and improves the tolerance of the blend to water, so that it can be stored for a long period. The large Cetane number of the biodiesel offsets the reduction of Cetane number from addition of ethanol to diesel, thus improving the engine ignition. The addition of biodiesel increases the oxygen level in the blend. Also biodiesel have lubricating properties that benefit the engine, and are obtained from renewable energy sources such as vegetable oils and animal fats. Similar to ethanol, biodiesel have a great potential for reducing emissions, especially particulate materials [10].The above studies reveal that the diesel-ethanol-biodiesel blends can be used as alternative fuels for diesel engines. Recent research has shown that the use of diesel-ethanol-biodiesel blends can substantially reduce emissions of CO, total hydrocarbons (HC), and particulate matters (PM) [11]. The mixing of biodiesel and bioethanol with diesel significantly reduces the emission of particulate matter because the blended biofuel contains more oxygen [12]. Hadirahimi et al [13] showed that the bioethanol and sunflower methyl ester can improve low temperature flow properties of diesel-ethanol-biodiesel blends due to very low freezing point of bioethanol and low pour point of sunflower methyl ester. The power and torque produced by the engine using diesel-ethanol-biodiesel blends and conventional fuel were found to be very comparable. The CO and HC emission concentration of diesel-ethanol-biodiesel blends decreased compared to the conventional diesel fuel and even diesel– biodiesel blends. Hwanam Kim, Btungchul Choi. [14] Investigated the exhaust gas characteristics and particulate size distribution of PM on a CRDI diesel engine using diesel, biodiesel and ethanol blends. They observed the reduced CO, HC, smoke emissions and total number of particles emitted, but increased NOx emissions. Xiaoping Pang et al [15] reported that the use of biodiesel-ethanol- diesel blend could slightly increase the emissions of carbonyls and NOx but significantly reduce the emissions of PM and THC. Prommes Kwanchareon et al; [16] studied solubility of a diesel-biodiesel- ethanol blend, its properties and its emission characteristics from diesel engine. They found that the blended fuel properties were close to the standard diesel except flash point. It was also found that CO and HC emissions reduced significantly at high engine load, whereas NOx emissions increased compared to those of diesel.

The above studies reveal that the diesel-biodiesel-ethanol blends reduce CO, HC, PM, Smoke emissions and increase NO_x emission's compared with the diesel fuel. There is a little research on the use of rice bran oil biodiesel in diesel-biodiesel-ethanol blends for diesel engines. The performance and emission characteristics of the biodiesel blended up to 20% were close to that of diesel fuel [17, 18]. In the present investigation the performance and emission characteristics of a diesel engine were studied by using 10% rice bran oil biodiesel as an additive in the diesel-biodiesel-ethanol blends and compared with that of the diesel fuel. Rice is the main cultivation in subtropical southern Asia, and it is a staple food for a large part of the world's human population especially in east, south and south-east Asia, making it the most consumed cereal grain. Rice Bran Oil (RBO) is extracted from the germ and inner husk (called bran) of the rice. Rice bran is mostly oily inner layer of rice bran which is heated to produce RBO [19]. RBO is not a common source of edible oil compared to other traditional cereal or seed sources such as corn, cotton, sunflower or soybean. . Until recently, rice bran was used mostly as animal feed and the most of the oil production is used for industrial applications. One of the best ways for the potential utilization of RBO is the production of biodiesel [20].

2. MATERIALS & METHODS

In the present investigation the fuels used were conventional diesel fuel, rice bran oil biodiesel and compressed air. These fuels were purchased from the local markets. Fuel properties such as density, viscosity, flash point, Cetane number, rice bran oil and biodiesel were determined and shown in the Table 1.

Table 1*:* properties of diesel, rice bran oil biodiesel.

Property parameters	Diesel fuel	Rice bran oil biodiesel
Density at 20^0 C, g/cm3	0.82	0.8742
Viscosity at 40^0C, mm2/s	3.4	4.63
Flash point, 0C	71	165
Auto-ignition temperature, 0C	225	320
Pour point, 0C	1	3
Cetane number	45	56.2
Oxygen content, max wt%	0.4	11.25

The experimental set up consists of a diesel engine, engine test bed, fuel and air consumption metering equipment's The experimental set up consists of a diesel engine, engine test bed, fuel and air consumption metering equipment's, Exhaust gas analyzer and smoke meter. The schematic diagram of the engine test rig is shown in Fig 1.

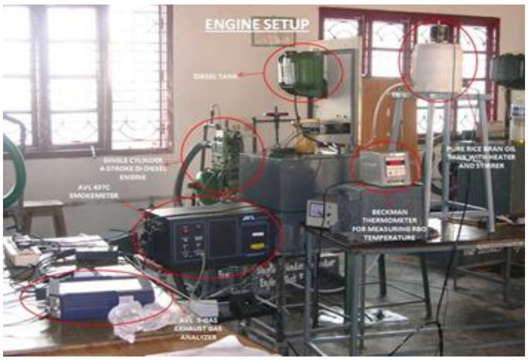

Fig. 1: Engine test rig

The engine was first operated on diesel fuel with no load for few minutes at rated speed of 1500 rpm. The baseline parameters were obtained at 0 kg, 2.5 kg, 5 kg, 7.5 kg, and 12.5 kg of load on the engine with the diesel fuel (DF). The diesel fuel was replaced with the rice bran oil biodiesel B5, B10, B15 and B20. Test was conducted by varying the loads in the same manner and supplying 2.2kg/cm^{2}pressure and 2.9 kg/cm^2. Online blending and dual-fuel systems can more easily adjust the percentage of rice bran oil in the diesel. The directly blended fuel does not require any modifications to diesel engines. Hence direct blending method was used in this test. The tests were conducted with these four blends by varying the load and air pressure on the engine. The brake power was measured by using dynamometer. The mass of the fuel consumption was measured by using a fuel tank fitted with a burette and a stop watch. The performance parameters such as brake thermal efficiency and brake specific fuel consumption were calculated from the observed values. The exhaust gas temperature was measured by using an iron-constantan thermocouple. The exhaust emissions such as carbon monoxide, Carbon Dioxide, Nitrogen Oxides, hydrocarbons and unused Oxygen were measured by AVL Di Gas 444 exhaust analyzer and the smoke opacity by AVL smoke meter 437C for diesel fuel, biodiesel, a blend of diesel and rice bran oil all load conditions. The results from the engine with rice bran oil biodiesel, a blend of diesel and rice bran oil were compared with the baseline parameters obtained during engine fuelled with diesel fuel at rated speed of 1500 rpm.

The specifications of the diesel engine are given in table 2.

Make	Kirloskar model AV1
No. of Strokes per cycle	4
No. of Cylinders	1
Combustion chamber position	vertical
Cooling method	Water cooled
Starting condition	Cold start
Ignition technique	Compression ignition
Bore (D)	80 mm
Stroke (L)	110 mm
Rated speed	1500 rpm
Rated power	5 hp (3.72 kW)
Compression ratio	16.5 : 1

3. RESULTS AND DISCUSSIONS

The results obtained pertaining to the performance and emissions of the engine are demonstrated with the help of graphs. The variation of brake power with load for diesel fuel, biodiesel and blends for different pressures are shown in figures 2&3.

The brake power increased with load for all fuel modes. The brake power of rice bran oil biodiesel (B5) was higher than that of the conventional diesel fuel over the entire range of the load. The reason may be a larger amount of fuel

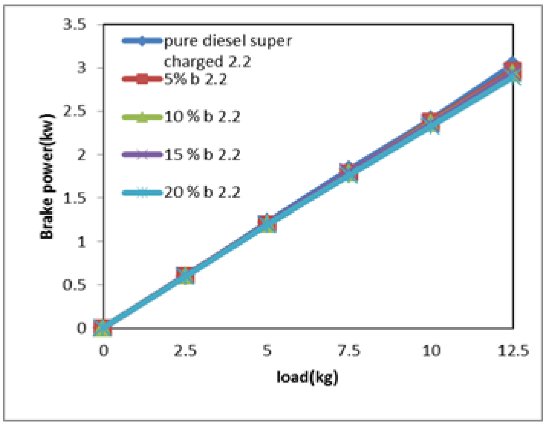

Fig.2: variation of Brake Power against load at a pressure of 2.2 bar

burned in the premixed mode of the blends. The brake thermal efficiency was increased by 1.5%, 2.2% and 2.91% the extended ignition delay and the leaner combustion of biodiesel. The maximum brake power was observed with B5, 2.2 bar at all the loading conditions of the diesel engine.

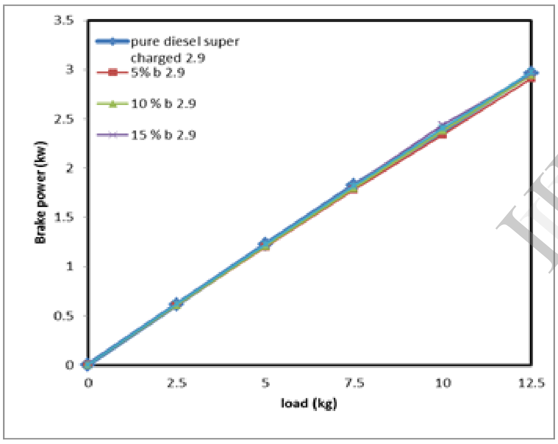

Fig.3: variation of Brake Power against load at a pressure of 2.9bar

The brake power increased with load for all fuel modes. The brake power of rice bran oil biodiesel (B20), was higher than that of the conventional diesel fuel over the entire range of the load. The reason may be a larger amount of fuel burned in the premixed mode of the blends. The brake thermal efficiency was increased by 1.5%, 2.2% and 2.91% the extended ignition delay and the leaner combustion of biodiesel. The maximum brake power was observed with B20, 2.9 bar at all the loading conditions of the diesel engine.

The variation mechanical efficiency with load for different fuels and different pressures are shown in figures 4&5.

The mechanical efficiency increased with load for all fuel modes. The mechanical efficiency of rice bran oil biodiesel (B15& 2.2abs), was higher than that of the conventional diesel fuel over the entire range of the load. The reason may be a larger amount of fuel burned in the premixed mode of the blends. The mechanical efficiency was increased by 5% compared with other blends. The maximum mechanical efficiency was observed with B15&2.2abs at all the loading conditions of the diesel engine.

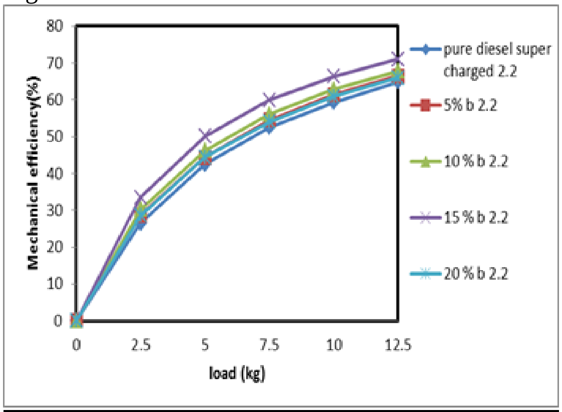

Fig.4: variation of Mechanical efficiency against load at a pressure of 2.2 bar

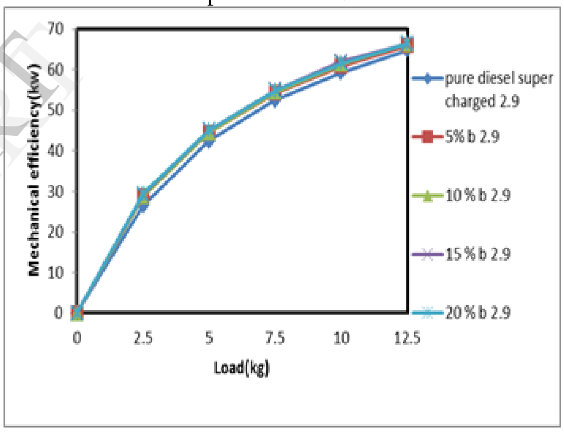

Fig.5: variation of Mechanical efficiency against load at a pressure of 2.9bar.

The variation brake thermal efficiency with load for different fuels and different pressures are shown in Fig. 6 & 7.

The brake thermal efficiency increased with load for all fuel modes. The brake thermal efficiency of rice bran oil blend of B5, biodiesel and all diesel-biodiesel-ethanol b2.2 abs and B5, 2.9 abs lends was higher than that of the conventional diesel fuel over the entire range of the load. The reason may be the extended ignition delay and the leaner combustion of biodiesel, resulting in a larger amount of fuel burned in the premixed mode of the ethanol blends. The brake thermal efficiency was increased by 1.5%, 2% and 2.91% respectively with B5 and 2.2 abs of rice bran oil blend compared with the remaining blends.

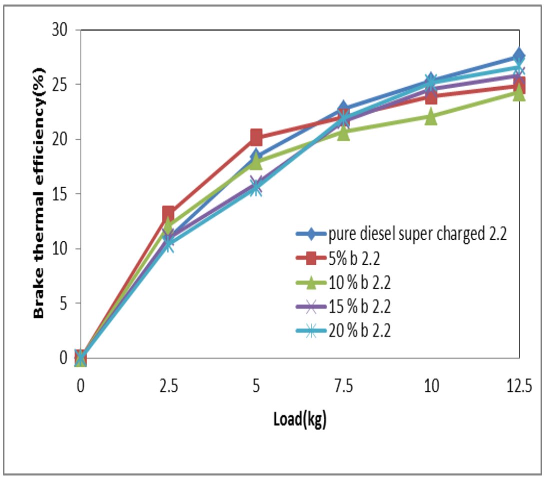

Fig.6: variation of Brake thermal efficiency against load at a pressure of 2.2 bar

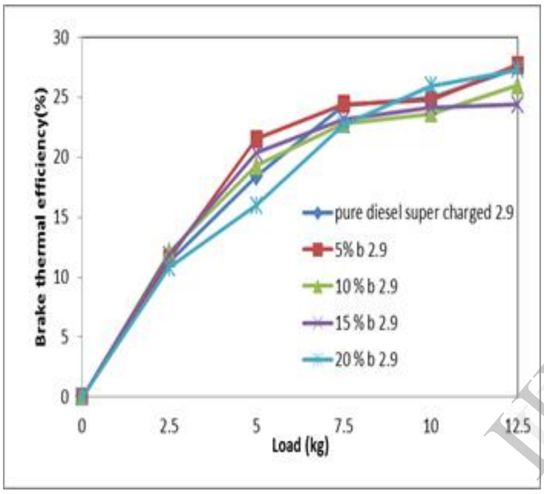

Fig.7: variation of Brake thermal efficiency against load at a pressure of 2.9 bar

The variation of brake specific fuel consumption (BSFC) with load for different fuels is shown in figures 8&9.

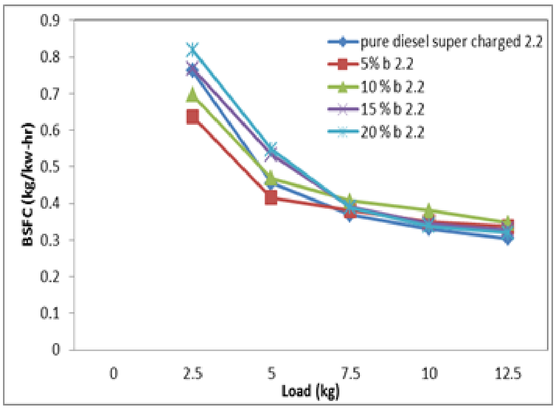

Fig.8: variation of Brake specific fuel consumption against load at a pressure of 2.2 bar

The BSFC reduced with load for all the fuel modes. The BSFC of pure diesel and B20 at 2.2 abs were 24.43% and 3.7% higher than that of the diesel fuel at The BSFC reduced with load for all the fuel modes. The BSFC of pure diesel and B20 at 2.2 abs were 24.43% and 3.7% higher than that of the diesel fuel at full load of the engine. The BSFC increased by 23.27%, 27.63% and 31.63% respectively with the blends B5, B10 and B15 compared with the blend B20. The BSFC increased with the increase of percentage rice bran oil in the diesel at all loading conditions of the engine. It is due to the lower heating values of biodiesel compared with diesel fuel.

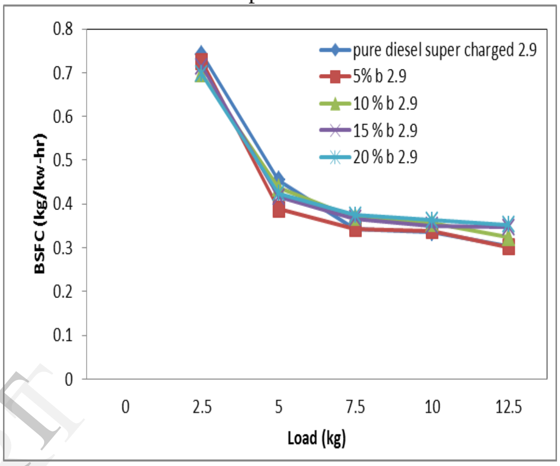

Fig.9: variation of Brake specific fuel consumption against load at a pressure of 2.9 bar

The variation of Carbon Monoxide (CO) with load for different fuels is shown in Fig. 10&11.
The CO emissions slightly increased at low and medium loads and increased significantly at higher loads with all the fuel modes. The CO emissions of the diesel-biodiesel- blends were not much different from that of conventional diesel at low and medium loads as shown in the figure.

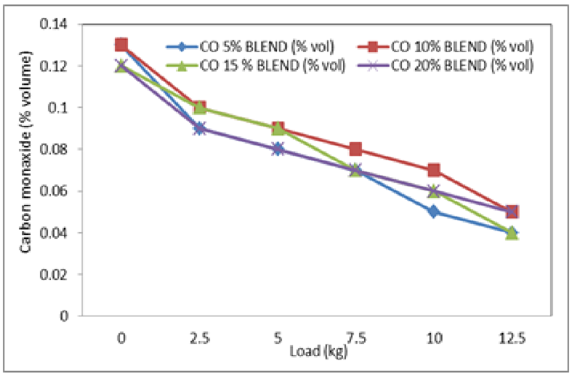

Fig.10: variation of Carbon monoxide against load at a pressure of 2.2 bar

However, the CO emissions of these blends decreased significantly, when compared with those of diesel blends at full load of the engine. This is due to the higher amount of oxygen with the biodiesel addition, which will promote the further oxidation of CO during the engine exhaust process. The results showed that the CO emissions reduced with decrease of percentage of the diesel-biodiesel- blend. The CO emissions of 5B at both 2.2 abs& 2.9 abs reduced than the other diesel blends.

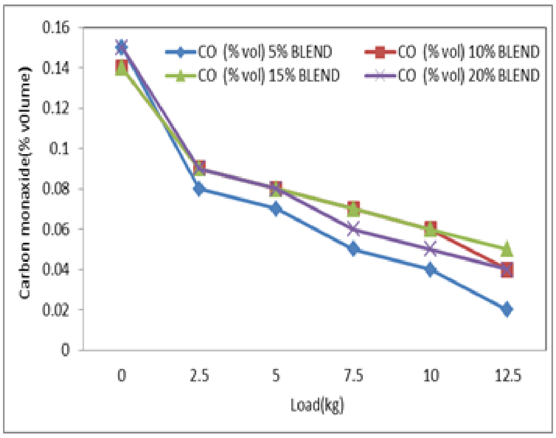

Fig.11: variation of Carbon monoxide against load at a pressure of 2.9 bar

The variation of Hydro Carbon emissions (HC) with load for different fuels is shown in figures12&13. The HC emissions were minimum at medium load and maximum at full load of the engine for all the fuel modes. The HC emissions of the blend B5 were higher at higher loads and significantly lower at lower loads than those of 0ther blends. It is due to the better combustion achieved at a medium speed and with a medium sized load. The HC emissions decreased with increase of rice bran oil percentage in the diesel.. Higher HC emission means that there is some unburned fuel emitted in the exhaust. The HC emissions were lower at lower loads of blend B10. Among these blends, the blend of B10 with diesel at pressures 2.2 abs and 2.9 abs were the lowest HC emissions at the full load of the engine.

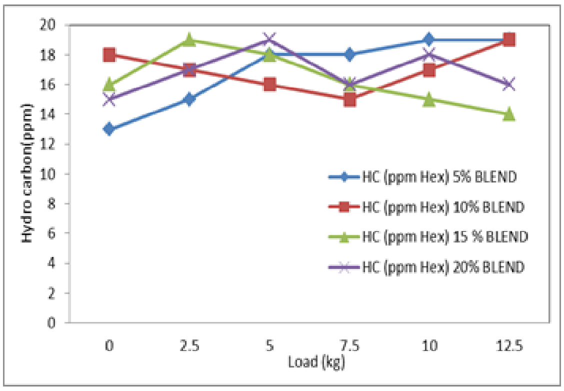

Fig.12: variation of Hydro Carbon against load at a pressure of 2.2 bar

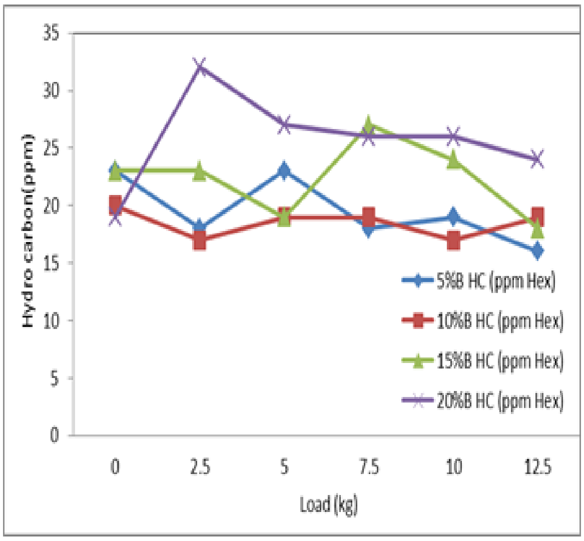

Fig.13: variation of Hydro Carbon against load at a pressure of 2.9bar

The variation of Oxides of Nitrogen (NOx) with load for biodiesel blends is shown in the Fig. 14& 15. The NOx emissions of biodiesel blend (B10) at pressures 2.2 abs and 2.9 abs were less at low loads and more at medium and high loads than those of other blends. It is due to the higher oxygen content and combustion temperature of the biodiesel at medium and high loads. The NOx emissions increased with the increase of percentage in rice bran oil blends. The NOx emissions of B5, B15 and B20 were higher than those of the blend B10 at full load of the engine.

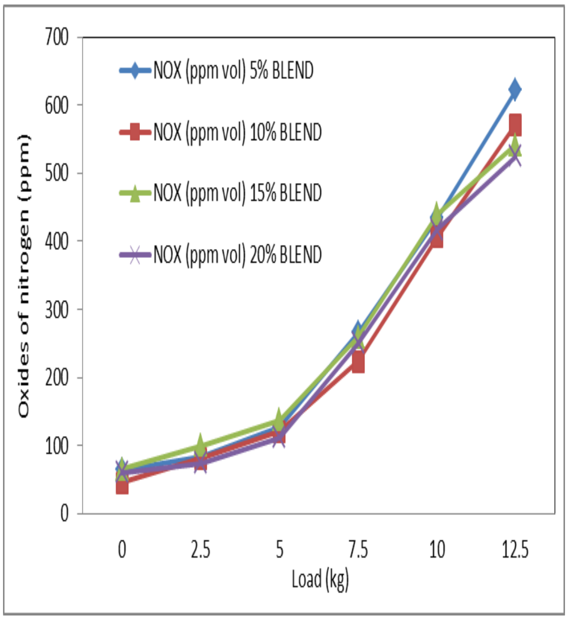

Fig.14: variation of Nitrogen oxides against load at a pressure of 2.2 bar

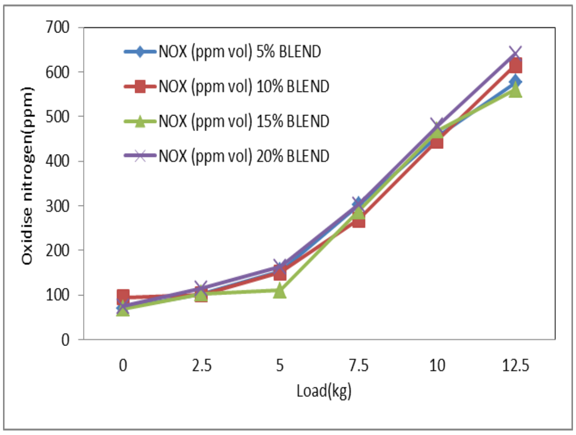

Fig.15: variation of Nitrogen oxides against load at a pressure of 2.9 bar

The variation of Carbon Dioxide (CO2) emissions with load for and biodiesel blends is shown in the figures 16&17.

The CO2 emissions increased with load for all the fuel modes. The CO2 emissions of B5 at 2.2 abs, B15 at 2.2 abs, B10 at 2.9 abs and B15 at 2.9 abs were slightly higher than the other blends. The CO2 emissions increased by 1.03%, 1.91% and 2.94% respectively with B10 and B15 biodiesel blends.

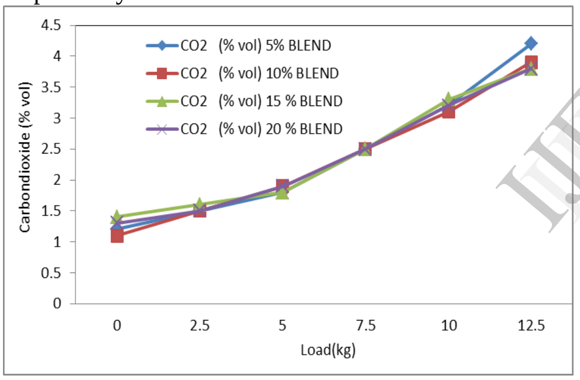

Fig.16: variation of Carbondioxide against load at a pressure of 2.2 bar

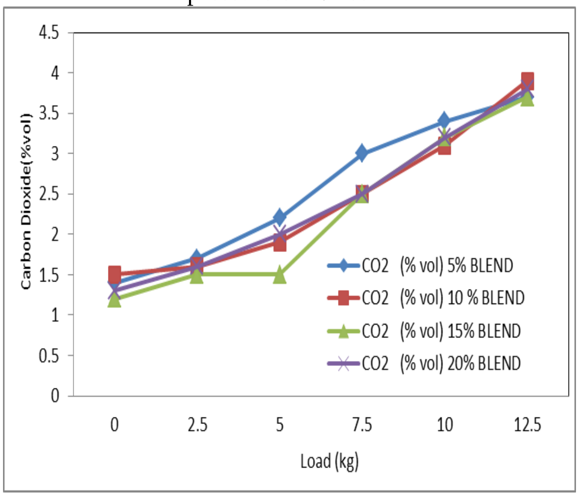

Fig.17: variation of Carbon dioxide against load at a pressure of 2.9 bar

4. CONCLUSIONS

The performance and emission characteristics of conventional diesel, rice bran oil biodiesel, diesel and biodiesel blend were investigated on a single cylinder diesel engine. The conclusions of this investigation are as follows.

- Supercharging improved the engine performance in terms of brake power, mechanical efficiency, indicated power and knocking characteristics. But it is associated with a slight decrease in Brake thermal efficiency, increase in BSFC and increased levels of pollutants such as CO, Unburnt HC and Smoke density in both pure diesel and straight rice bran oil operation, except NO_x which are reduced with supercharging.
- The maximum brake thermal efficiency of 28.2% was observed with the blend B5 at 2.2 abs and B15 at 2.9 abs. The BSFC of the biodiesel and all the other fuel blends was higher than that of the diesel fuel.
- The exhaust gas temperature of the blend B10E15 was slightly lower than that of diesel fuel throughout the range of the load on the engine.
- The CO emissions of the biodiesel and all the other fuel blends were lower than that of the diesel fuel. The minimum CO emissions were observed with the blend B10E15 well below the diesel fuel and the biodiesel.
- The HC emissions increased with the increase of ethanol percentage in diesel-biodiesel-ethanol blends, but lower than those of the diesel at higher loads on the engine.
- The NOx emissions of the biodiesel and all the other fuel blends were low at lower loads and high at higher loads compared with the diesel fuel
- The CO2 emissions of the biodiesel and all the other fuel blends were higher than that of the diesel fuel.
- As the brake thermal efficiency increases and carbon monoxide, unused oxygen, hydrocarbons and smoke reduces with the increase of rice bran oil in diesel-biodiesel blends, the rice bran oil biodiesel can be used as an additive to mix higher percentages of diesel-biodiesel- blends for a diesel engine.

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