Experimental Investigation of the Effect of Emissions in a Direct Injection VCR Diesel Engine Running on Rice Bran Methyl Ester

V. Nageswara Reddy[1], Dr. G. Srinivasa Rao[2]

[1]Associate Professor, Dept of M.E. RGM Engineering College, Nandyal. (A.P), India

[2]Professors in M.E Department, RVR &JC Engineering College, Guntur, (A.P), India

Abstract: ***The world is confronted with the twin crises of fossil fuel depletion and environmental degradation. The indiscriminate extraction and consumption of fossil fuels have led to a reduction in petroleum reserves. Petroleum based fuels are obtained from limited reserves. These finite reserves are highly concentrated in certain region of the world. Therefore, those countries not having these resources are facing a foreign exchange crisis, mainly due to the import of crude petroleum oil. Hence it is necessary to look for alternative fuels, which can be produced from materials available within the country. Biodiesel is one of the most promising alternative fuels for diesel engines because they are potential renewable, non-toxic, biodegradable, clean burning, high lubricity, low environmental impact, derived from vegetable oils and could be used directly in diesel engines without requiring extensive engine modifications. The major objective of the present work is to investigate the engine exhaust emissions of a single cylinder 4- stroke variable compression ratio (VCR-18, VCR-16 & VCR-14) engine at different injection pressures (220 bar, 200 bar & 180 bar) with different blends of biodiesel rice bran oil.***

Keywords: Bio-diesel; Rice Bran Oil; Variable Compression Ratio (VCR); Injection Pressure (IP); Emissions such as Carbon Monoxide (CO), Nitrogen Oxides (NO_X) & Hydrocarbons (HC).

1. Introduction

Emissions coming from the exhaust tail pipe of an Internal combustion engines causes, the most biggest problem in harmful effect of our present day civilization is global warming, and environmental pollution. It is necessary to make our planet safe for us and for the generations to come. The vehicle population throughout the world is increasing rapidly. In India the growth rate of population and automotive vehicle is one of the largest in the world. It is quite evident that the problem cannot be solved with the conventional fossil fuels, however stringent the emission control norms may be. Day to day increasing the need of automobiles and the shrinking crude oil reserves. India is to be necessarily dependent on imports of crude petroleum and petroleum products. In an Internal combustion engines it is well known fact that 30% of heat energy utilization for useful purposes. The advantages of biodiesel as diesel fuel are ready availability, renewability, higher combustion efficiency.

Rice Bran Oil (RBO) is extracted from the germ and inner husk (called bran) of the rice grain which is heated to produce Rice Bran Oil. The research work is focuses on using the alternative fuel in internal combustion engines and the effect of compression ratio of the engine and the effect of IP. The performance characteristics, combustion and emission characteristics are studied and compared with diesel fuels. Energy demand around the world is increasing at a faster rate as a result of ongoing trends in industrialization and modernization. [1] Investigated Diesel-ethanol blends are a more viable alternative and require little or no change in diesel engines. The use of diesel-methanol blends can significantly reduce the emission of toxic gases and particulate matters when compared to pure diesel.[2]Investigated the performance and emission characteristics of a supercharged direct injection diesel engine using rice bran oil.[3] Investigated the use of rice bran oil as a potential source for biodiesel.[4] Experimentally work is done on a direct injection diesel engine and calculated the Performance, Emission and Combustion Characteristics Rice Bran Oil.[5]Experimentally investigated the effect of Rice Bran oil Emission characteristics with methyl Easter as an additive for compression ignition engine.[6]Investigated the effect of compression ratio and IP in a direct inject diesel engine running on Jatropha methyl ester. [7] The blends of biodiesel and methanol with diesel significantly reduce the emissions of the exhaust gasses coming from engine.[8] Investigated on neem based methyl esters on VCR engine and concluded that neem oil can be directly used in diesel engines without any engine modifications. This model is useful for predicting the trends of pressure, temperature, heat release, thermal efficiency, specific fuel consumption, power and harmful pollutants such as CO, HC and NO_X.

2. Materials and Methods

In the present research work the fuels used were conventional diesel fuel, rice bran oil biodiesel and methanol. The properties of diesel and biodiesel-methanol blends are as shown in the table 1.

2.1 Research Engine Test Setup

Experimental set up for the research work consists of a single cylinder, 4-stroke, variable compression ratio (computerized) diesel engine connected to eddy current type dynamometer for loading. The detailed specifications of the engine used are given in Table 2. Windows based Engine Performance Analysis Software Package „Engine soft" was taken for on line performance evaluation. Figure: 1 shows the schematic diagram of engine test rig. The tests were conducted at the rated speed of 1500 rpm at different loads (3 kg, 6 kg, 9 kg, 12 kg, and 15 kg) and at different compression ratios (VCR-18, VCR-16, & VCR-14). And also the tests were conducted at variable IP (220 bar, 200 bar & 180 bar). The VCR engine specifications are shown in table2.

Table 1: properties of diesel, rice bran oil biodiesel and bio methanol

Property parameters	Diesel Fuel	Rice Bran Oil Biodiesel	Methanol
Density at 20^0 C (g/cm^3)	0.82	0.96	0.78
Viscosityat 40^0C (mm^2/s)	3.4	4.56	1.35
Flash Point ^{0}C	57	160	21
Fire Point ^{0}C	60	175	25
Cetane Number	45	54	10
Calorific value (KJ/kg)	43,500	39,800	28,700

The baseline parameters were obtained at 20%, 40%, 60%, 80% and 100% of load on the engine with the diesel fuel (DF) at different variable compression ratios different IPS. In the same manner the same test was conducted with the blend of 90% diesel and 5% biodiesel and 5% methanol (B10%) and with the blend of 80%diesel, 15%biodiesel and 5% methanol (B20%),and 70%diesel, 25%biodiesel and 5% methanol (B30%). Different methods are there for using methanol in diesel engines. The directly blended fuel does not require any modifications to diesel engines. Hence direct blending method was used in this test.

Table 2: Specifications of the diesel engine

Make	Kirloskar Model AVL
No of strokes per cycle	04
No of Cylinders	01
Combustion chamber position	Vertical
Cooling Method	Water cooled
Starting Method	Cold Start
Ignition Technique	Compression Ignition
Stroke Length (L)	110 mm
Bore Diameter (D)	87.5 mm
Rated Speed	1500 r.p.m.
Rated Power	3.5 KW
Compression ratio	12:1 To18:1

The experiment tests were conducted with the three blends (B10%, B20% & B30%) by varying the load on the engine, by varying the VCR of the engine and by varying the IP s. The fuel consumption, brake power, brake specific fuel consumption, brake thermal efficiency, mechanical efficiency, volumetric efficiency and exhaust gas temperature were measured. The brake power was measured by using an electrical dynamometer. 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 for diesel fuel, biodiesel, a blend of diesel and biodiesel-methanol blends separately under all load conditions.

Figure 1: Schematic diagram of engine test rig

The results from the engine with diesel and rice bran oil biodiesel-methanol blends (B10%, B20% and B30%) were compared with the baseline parameters obtained at rated speed of 1500 rpm.

3. Results and Discussions

The results obtained from the research work pertaining to the emissions of the engine are demonstrated with the help of graphs. The variation of CO with load for diesel fuel blends at 220 bar IP and VCR 18:1 is shown in the Figure 2.

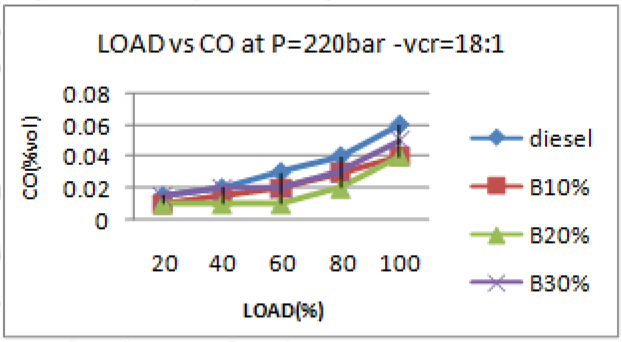

Figure 2: Vary of CO with load at IP 220 bar and VCR-18:1

Fig 2 shows that the CO emissions of diesel and blends are increased significantly at higher loads with all the fuel modes. The CO emissions of blends are minimum as compared with the emissions of diesel. This is due to the higher amount of oxygen with the methanol and biodiesel addition, which will promote the further oxidation of CO during the engine exhaust process. At 220 bar IP and at 18:1 VCR the rice bran biodiesel-methanol blends of 80%diesel, 15% biodiesel and 5% methanol produced the lowest amount of CO.

The variation of CM with load for diesel fuel and blends at 220 bar IP and VCR -16:1 is shown in the Figure 3.

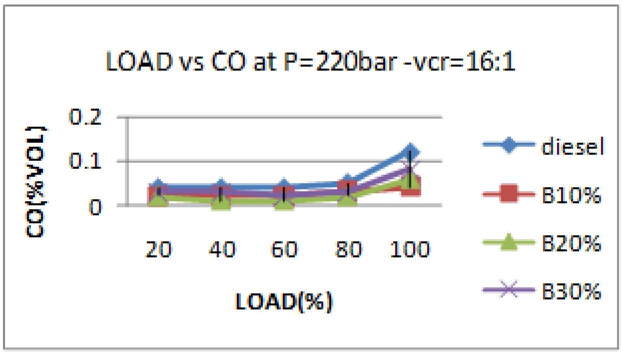

Figure 3: Vary of CO with load at IP 220 bar and VCR-16:1

From figure: 3 it is cleared that the CO emission of diesel is slightly high at low loads and high at full loads. This is due to the increasing the amount of oxygen with the methanol and biodiesel addition. The results show that the CO emissions reduced much, with the increase of rice bran oil percentage in the diesel-biodiesel-methanol blend.

The variation of CO with load for diesel and blends at 220 bar IP and VCR 14:1 is shown in the Figure 4.

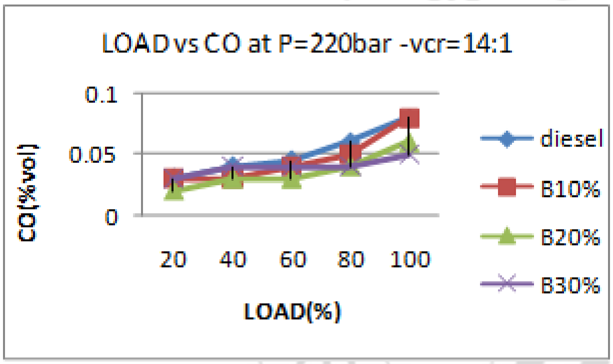

Figure 4: Vary of CO with load at IP 220 bar and VCR-14:1

The CO emissions of the diesel are slightly high, compared to diesel-biodiesel-methanol blends at all loads. Therefore the CO emissions of blends decreased significantly, when compared with those of diesel at all the loads of the engine operated at VCR-14:1. The CO emissions at 220 IP and at VCR 14:1, the rice bran biodiesel-methanol blends of 80%diesel, B20% produced the lowest amount CO.

The variation of CM with load for diesel, and blends at 200 bar IP and VCR-18:1 is shown in the Figure 5.

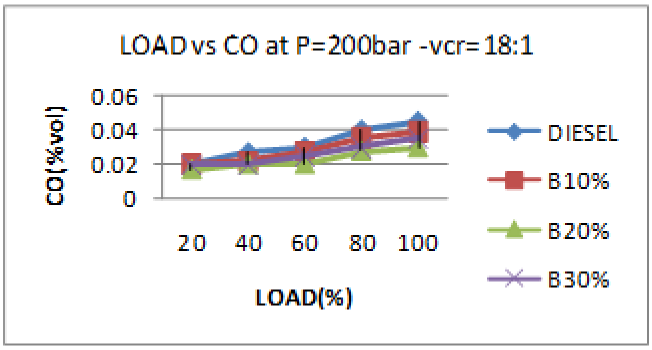

Figure 5: Vary of CO with load at IP 200 bar and VCR-18:1

The CO emissions of diesel are increased significantly at higher loads with all the fuel modes. The CO emissions of diesel-biodiesel-methanol blends are slightly low as compare with the emission of diesel at all loads. The results show that the CO emissions low with the increase of rice bran oil percentage in the diesel-biodiesel-methanol blend up to B20. bran oil mixed in diesel at 200 bar IP and at 18:1 VCR

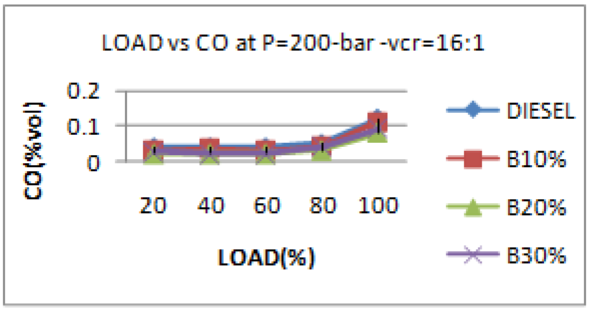

Figure 6: Vary of CO with load at IP 200 bar and VCR-16:1

The variation of CO with load for diesel and blends at 200 bar IP and VCR-16:1 is shown in the Figure 6.

There is not much variation in CO emissions of all diesel and blends up to 80% load on the engine, after that the CO increased significantly at high loads. The CO emissions of the diesel-biodiesel-methanol blends are not much variation from that of conventional diesel at all loads as shown in the figure. This is due to the decrease in IP.

The variation of CO with load for diesel fuel and blends at 200 bar IP and VCR-14:1 is shown in the Figure 7.

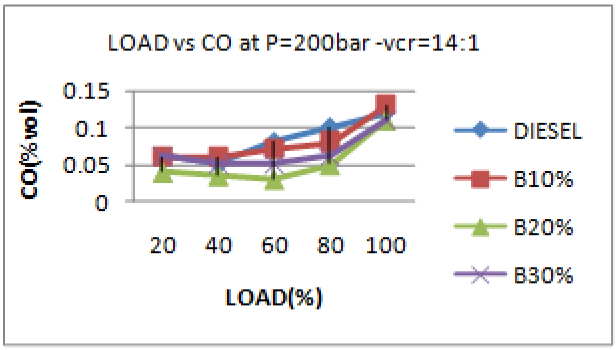

Figure 7: Vary of CO with load at IP 200 bar and VCR-14:1

Results from the figure 7 shows that the CO emissions of pure diesel and B10% are higher than that of the remaining blends at all load conditions. The CO emissions of the diesel-biodiesel-methanol blends of 20% are low at all load conditions on the engine. This is due to the decrease in IP.

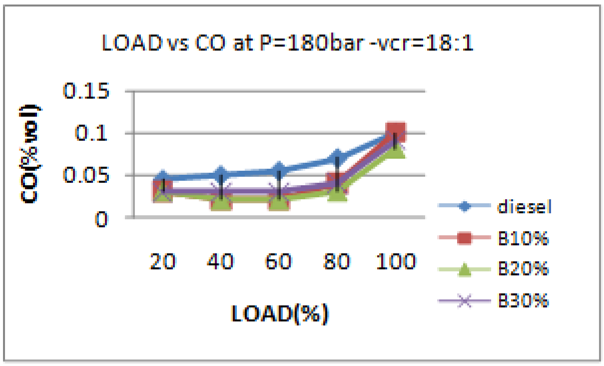

Figure 8: Vary of CO with load at IP 180 bar and VCR-18:1

The variation of CO with load for diesel fuel and blends at 180 bar IP and VCR-18:1 is shown in the Figure 8.

The CO emissions of the diesel are much higher than the diesel-biodiesel-methanol blends at all loads. The CO emissions of the diesel-biodiesel-methanol blends are much lower than that of conventional diesel at all loads.

The variation of CO with load for diesel fuel blends at 180 bar IP and VCR-16:1 is shown in the Fig. 9.

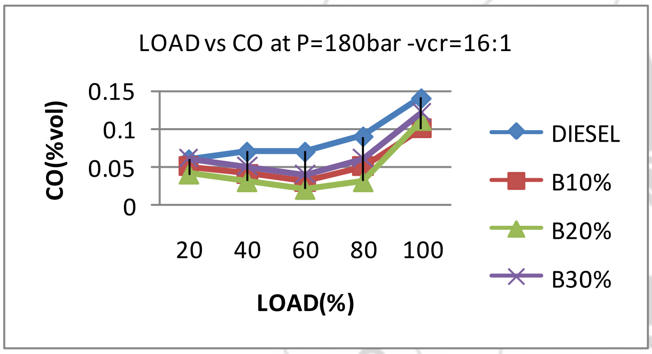

Figure 9: Vary of CO with load atIP 180 bar and VCR-16:1

At IP 180 bar and at 16:1 VCR, the CO emissions of the diesel are higher than the diesel-biodiesel-methanol blends at all load and all the fuel modes.. The CO emissions of the diesel-biodiesel-methanol blends of B20% are lower than that of the remaining diesel-biodiesel-methanol blends. The emissions of all the fuel modes are increased at full load conditions.

The variation of CO with load for diesel fuel blends at 180 bar IP and VCR-14:1 is shown in the Figure 10.

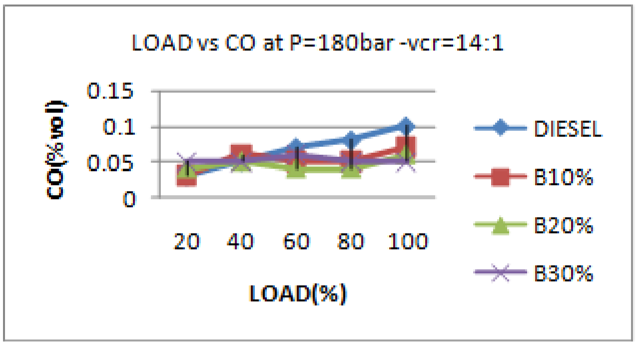

Figure 10: Vary of CO with load at IP 180 bar and VCR-16:1

At IP 180 bar and at VCR 14:1, the CO emissions of the diesel are slightly more than that of the biodiesel-methanol blends. The CO emissions of B30% biodiesel- methanol blend are increased at low loads and decreased at full load conditions. Similarly the emissions of B20% biodiesel-methanol blend are decreased at low loads and increased at full load conditions.

The variation of NOx with load for diesel fuel and blends at 220 bar IP and VCR-18:1 is shown in the Figure 11.

The NOx emissions of biodiesel, blend (B10) and diesel-biodiesel-methanol blends are low at low loads and high at medium and high loads. The NOx emissions of B10%, B20% and B30% are 12%, 40% and 12% lower than those of the diesel fuel at full load of the engine.

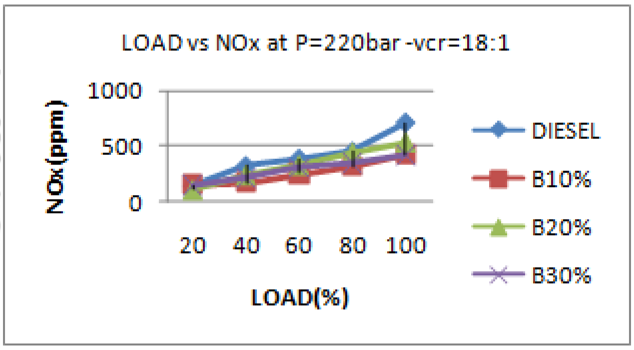

Figure 11: Vary of NO_X with load atIP 220 bar and VCR-18:1

The variation of NOx with load for diesel fuel blends at 220 bar IP and VCR-16:1 is shown in the Figure 12.

The NOx emissions of biodiesel, and diesel-biodiesel-methanol blends at IP 220 bar, are lower at low loads and high at medium and high loads on the engine. As increases of the load on the engine the NO_x emissions of diesel fuel are increased.

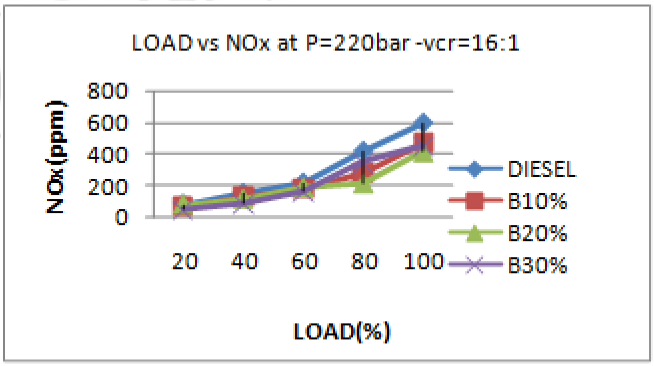

Figure 12: Vary of NO_X with load at IP 220 bar and VCR-16:1

The variation of NOx with load for diesel fuel and blends at 220 bar IP and VCR-14:1 is shown in the Figure 13.

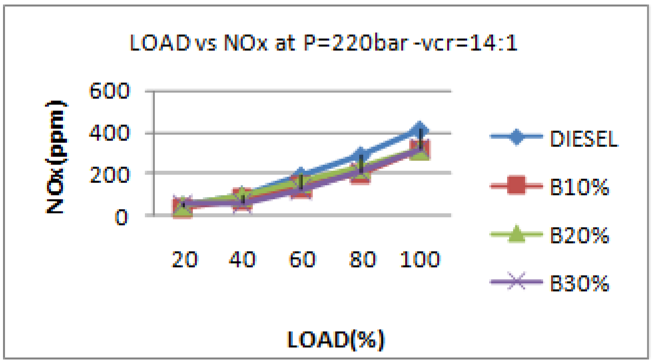

Figure 13: Vary of NO_X with load at IP 220 bar and VCR-14:1

Result from the above figure 13, shows that the NOx emissions of diesel are slightly high at medium load and full load conditions, when compared with emissions of diesel-biodiesel-methanol blends at IP 220 bar and at 14:1 VCR. The NO_x emissions of all diesel and blends increased with the increasing of the load on the engine.

The variation of NOx with load for diesel fuel and blends at 200 bar IP and VCR-18:1 is shown in the Figure 14.

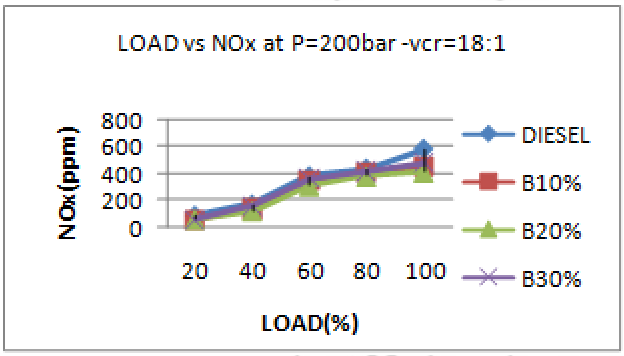

Figure 14: Vary of NO_X with load at IP 200 bar and VCR-18:1

At full load conditions of the engine, the NO_X emissions of l diesel fuel are high at IP 220 bar and compression ratio of the engine is 14:1.

The variation of NOx with load for diesel fuel and blends at 200 bar IP and VCR-16:1is shown in the Figure15.

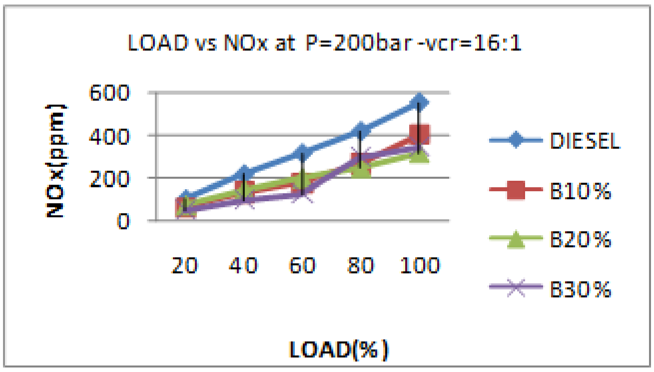

Figure 15: Vary of NO_X with load at IP 200 bar and VCR-16:1

The result from figure 15 shows that the NOx emissions of diesel are high at all load conditions. The NOx emissions of blends are increased with the increasing the load on the engine under all load conditions. The NO_x emissions of diesel- biodiesel –methanolblends B20% and 30% are lower than that of the conventional diesel fuel under all loads on the engine.

The variation of NOx with load for diesel fuel, and blends at 200 bar IP and VCR-14:1 is shown in the Figure 16.

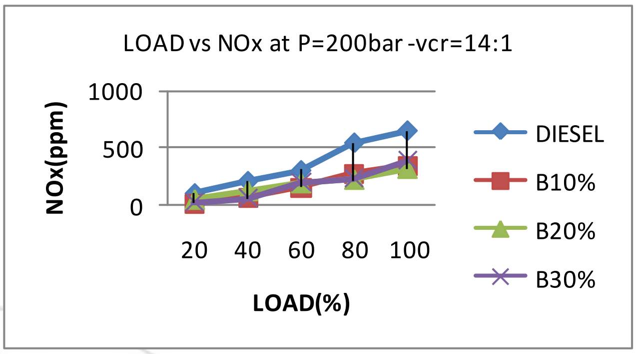

Figure 16: Vary of NO_X with load atIP 200 bar and VCR-14:1

The NOx emissions of diesel fuel are increasing at all load conditions, when compared with emissions of diesel-biodiesel-methanol blends at IP 200 bar and at compression ratio of the engine is 14:1.

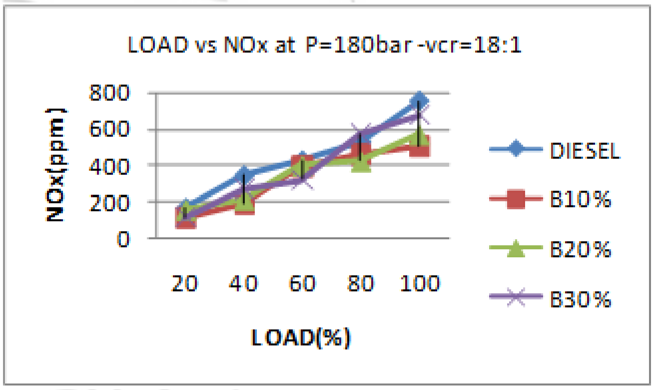

Figure 17: Vary of NO_X with load at IP 180 bar and VCR-18:1

From figure it is cleared that the NO_x emissions of diesel-biodiesel-methanol blendsB10%, B20% and B30% are almost similar under all load conditions. The NOx emissions of diesel fuel are increased at full load on the engine. The NO_X emissions of diesel-biodiesel-methanol blends at IP 200 bar and at compression ratio 18:1, are high at full load on the engine.

From figure it is cleared that the NOx emissions of diesel-biodiesel-methanolblendsB10%, B20%B 30% are almost similar under all load conditions of the engine.

The variation of NOx with load for diesel and 180 bar IP and VCR-18:1 is shown in the Figure 17.

The variation of NOx with load for diesel fuel, and blends at 180 bar IP and at VCR-16:1 is shown in the Figure 18.

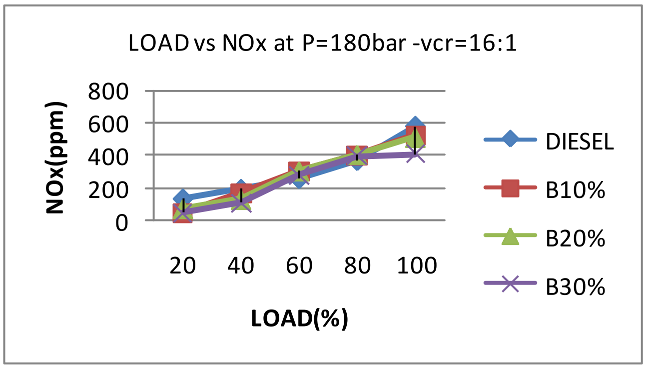

Figure 18: Vary of NO_X with load atIP 180 bar and VCR-16:1

The NO_X emissions of diesel-biodiesel-methanol blends at IP 200 bar and at compression ratio 16:1, are increased with increasing the load on the engine. From figure it is cleared that the NO_x emissions of diesel-biodiesel-methanol blendsB10%B20%andB30%arehigh at full load on the engine.

The variation of NOx with load for diesel fuel, and blends at 180 bar IP and at VCR-14:1 is shown in the Figure 19.

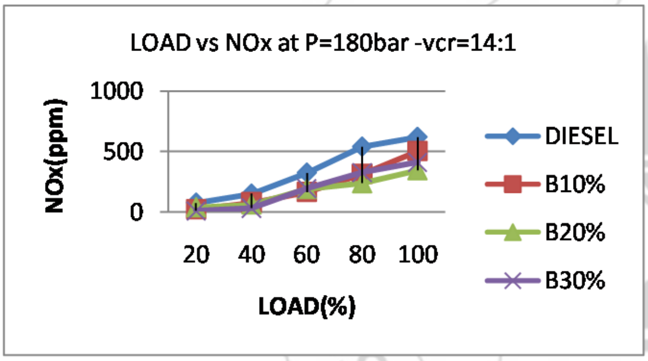

Figure 19: Vary of NO_X with load at IP 180 bar and VCR-14:1

The NOx emissions of diesel fuel at 180 bar IP and at 14:1 VCR are high as compared to that of the NO_X emissions of diesel-biodiesel-methanol blends at all loads on the engine.

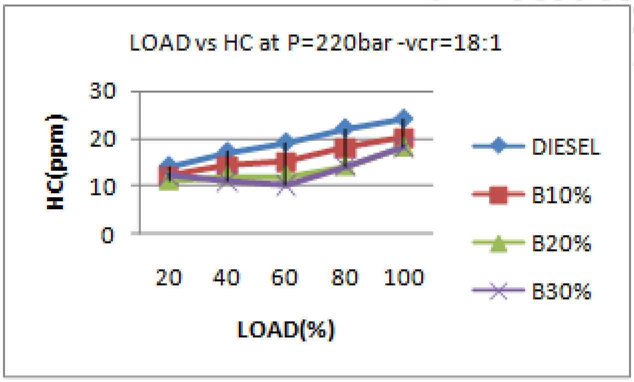

Figure 20: Vary of HC with load at IP 220 bar and VCR-18:1

The variation of HC with load for diesel fuel, and blends at 220 bar IP and at VCR-18:1 is shown in the Figure 20.

From figure it is cleared that the NO_x emissions of diesel-biodiesel-methanol blends B20% and B 30% are low at full load on the engine

From the figure HC emissions are low medium load and high full load of the engine for all the fuel modes. The HC emissions of the diesel and biodiesel blend B10% are high at all loads. The HC emissions of blend B20% and B30% are low medium speed and with a medium load.

The variation of HC with load for diesel fuel, and blends at 220 bar IP and at VCR-16:1 is shown in the Figure 21.

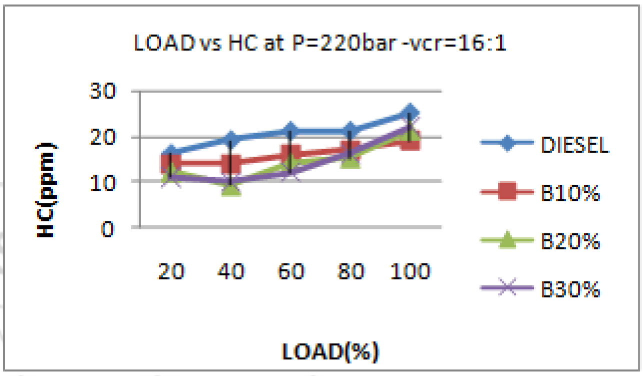

Figure 21: Vary of HC with load at IP 220 bar and VCR-16:1

From the figure HC emissions of diesel are high at all loads and all the fuel modes. The HC emissions of the biodiesel blend B20% and biodiesel blend B30% are low at low loads and high at full loads on the engine.

The variation of HC with load for diesel fuel, and blends at 220 bar IP and VCR-14:1 is shown in the Figure 22.

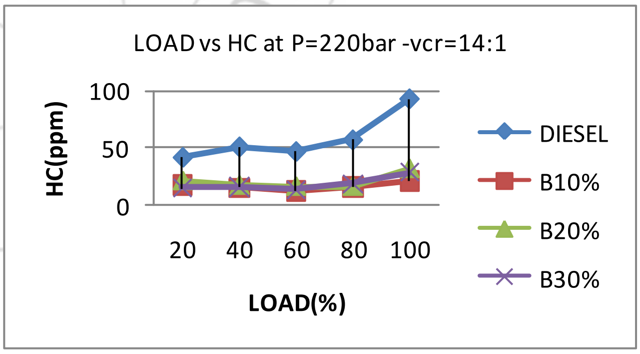

Figure 22: Vary of HC with load atIP 220 bar and VCR-14:1

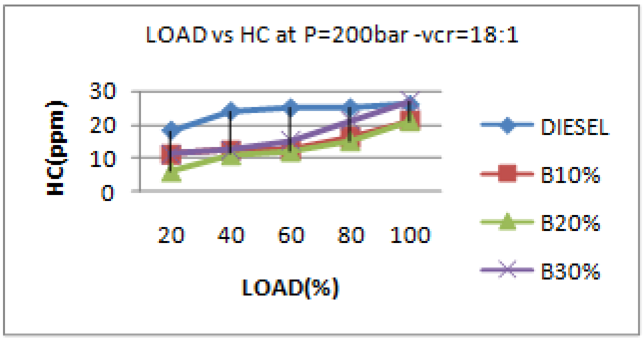

Figure 23: Vary of HC with load at IP 200 bar and VCR-18:1

The variation of HC with load for diesel fuel, and blends at 200 bar IP and at VCR-18:1 is shown in the Figure 23.

The HC emissions of diesel at 220 bar IP are high at all loads and all speeds of the engine as compared to that of the HC emissions of biodiesel blend B10%, B20% and B30%. The HC emissions of diesel-biodiesel-methanol blends are similar at almost all the loads.

The variation of HC with load for diesel fuel, and blends at 200 bar IP and VCR-16:1 is shown in the Figure 24.

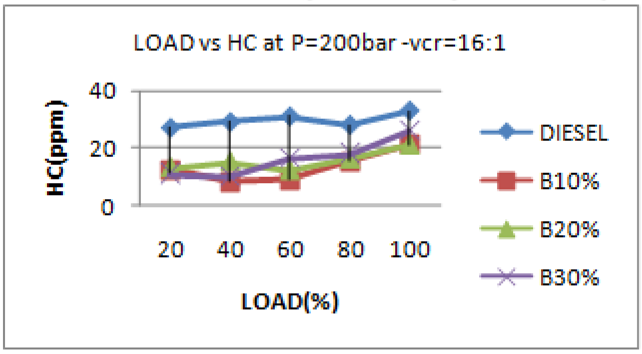

Figure 24: Vary of HC with load at IP 200 bar and VCR-16:1

The result from figure, HC emissions of conventional diesel at 200 bar IP are maximum at all loads and all speeds of fuel modes as compared to that of the HC emissions of biodiesel blend B10, B20 and biodiesel blend B30 . The HC emissions of biodiesel blend B20 are low at low loads of the engine. The HC emissions of biodiesel blend B10% are low at medium load of the engine. The variation of HC with load for diesel fuel, and blends at 200 bar IP and VCR-14:1 is shown in the Figure 25.

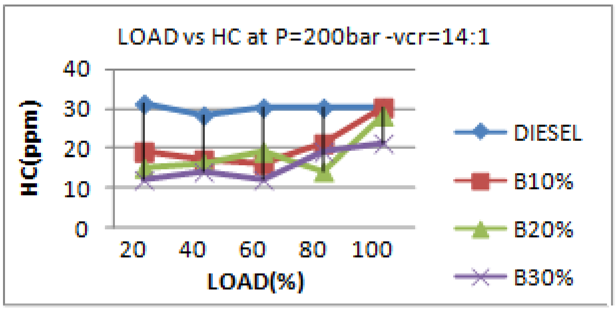

Figure 25: Vary HC with load at IP 200 bar and VCR-14:1

From the figure 25, the HC emissions of diesel at 200 bar IP and at 16:1VCR compression ratio is increasing maximum at low and medium load on the engine at all fuel modes. The HC emissions of biodiesel blends B10%, B20% and B30% are low at medium loads.

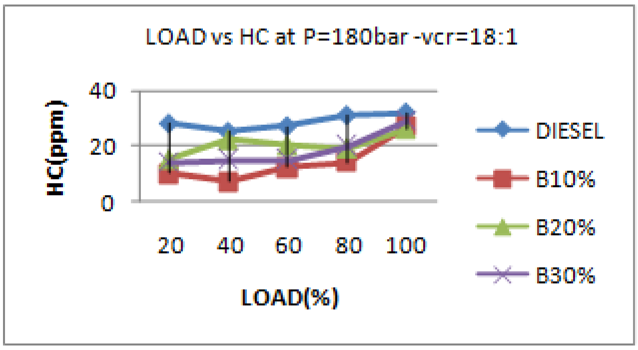

Figure 26: Vary of HC with load at IP 180 bar and VCR-18:1

The variation of HC with load for diesel fuel, and blends at 180 bar IP and VCR-18:1 is shown in the Figure 26.

The HC emissions of diesel fuel at 180 bar IP and at 18:1 VCR are maximum at all loads on the engine at all fuel modes as compared to that of the HC emissions of biodiesel blends B10%, B20% and B30%.

The variation of HC with load for diesel fuel, and blends at 180 bar IP and at VCR-16:1 is shown in the Figure 27.

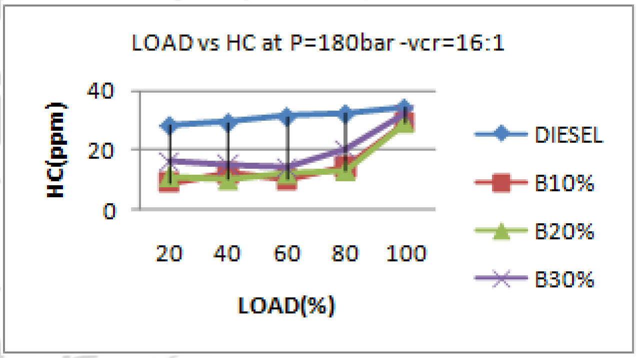

Figure 27: Vary of HC with load at IP 180 bar and VCR-16:1

The HC emissions of the biodiesel blend B10% are low at low and medium load of all fuel modes and high at full load on the engine. The HC emissions of diesel fuel at 180 bar IP and at VCR 16:1 are high at all loads on the engine, compared to that of the HC emissions of biodiesel blends B10%, B20% and B30%.

The variation of HC with load for diesel fuel, and blends at 180 bar IP and VCR-14:1 is shown in the Figure 28.

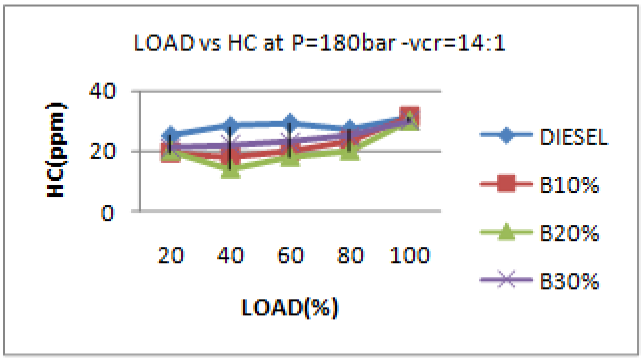

Figure 28: Vary of HC with load at IP 180 bar and VCR-14:1

The HC emissions of diesel fuel at 180 bar IP and at 14:1 VCR are maximum at low load and at medium load on the engine, at all fuel modes as compared to that of the HC emissions of biodiesel blends B10%and B20%.The HC emissions of the biodiesel blend B10% and B20% are minimum at medium load and medium speeds.

4. Conclusion

The emission characteristics of diesel, rice bran oil biodiesel-methanol blends were investigated at different IP s on a single cylinder computerized variable compression ratio diesel engine. The conclusions of this research work are as follows:

- The CO emissions of the rice bran oil biodiesel were lower than that of the conventional diesel fuel at all the IP s (220 bar, 200 bar and 180 bar) and at all the compression ratios (VCR-18, VCR-16, and VCR-14).The minimum CO emissions were observed with the blend B20% at 220 bar IP and at VCR-16.
- The HC emissions were increased with increased of rice bran oil percentage in diesel-biodiesel-methanol blends and lower than those of the conventional diesel at all loads on the engine at all IPs and all compression ratios. The minimum CO emissions were observed with the blend B20% at 220 bar IP and at VCR-14.
- The NOx emissions were increased with increased of the rice bran biodiesel at all loads and speeds of the engine. But NO_X emissions were low at all loads and all compression ratios of the engine compared with the conventional diesel fuel at all IP and all compression ratios. The minimum NO_X emissions were observed with the blend B20% at 220 bar IP and at VCR-14.

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Author Profile

V.Nageswara Reddy received the B.E degrees in Mechanical Engineering from Marathwada University, Aurangabad, and M.Tech degree from J.N.T.U. Hyderabad in 2005 respectively. At present working as an associate professor in M.E. Department in R.G.M. Engineering College, Nandyal. Now pursuing Phd at Nagarjuna University, Guntur- A.P.-India.