Investigation on Emission Characteristics of An Indirect Diesel Injection (IDI) Engine Replacing Conventional Diesel with Mahua Methyl Ester (MME) Blended with Methanol as An Additive

K. Prasada Rao[1], B. V. Appa Rao[2]

[1]Asst. Professor, Dept. of Mechanical Engineering, GMRIT, Rajam - 532127, A.P., India.
[2] Professor, Dept. of Marine Engineering, Andhra University, Visakhapatnam-530003, A. P., India.

Abstract

Application of alternate fuel combinations which yield lesser emissions is the new concept adopted without changing the design aspect of engine. Bio-diesel is potential fuel, which reduces most of the components of exhaust. Bio-diesel is known as an attractive alternative fuel used in diesel engines. Bio-diesel produced from non-edible oils are much better option. Currently, Mahua biodiesel (MME) is receiving attention as an alternate fuel for diesel engines in view of perennial availability in the Eastern Ghats of India with oil extraction process easier. The aim of the present work is to suppress the crank case oil dilution (Choice proposed: rapid swirl in pre and main combustion chambers prevent leakage of fuel in liquid form into crank case in the case of IDI engine) and exhaust gas component reduction like NO and HC by limiting the combustion temperatures. Methanol encourages low temperature combustion due to its higher latent heat and lower Cetane number and dilutes the biodiesel because of its lower viscosity and density. There will be modified injection spray characteristic with methanol blending because of changes in the density and viscosity properties. Literature indicates usage of raw vegetable oils in IDI engines with some modifications in injection pressures. But it is being tested oil esters in the present study with an additive to create low temperature combustion and to reduce emissions which form at higher temperatures. A Four stroke-Single cylinder, forced air and oil cooled IDI diesel engine adds to the advantage of complete combustion in two combustion chambers. Smoke, NO, carbon monoxide (CO) and carbon dioxide (CO_2) emissions were recorded and various engine performance parameters were also evaluated. Comparative study is conducted using diesel, bio-diesel, and additive blends of bio-diesel on IDI- Diesel engine. Mahua methyl ester (MME) is used with additive Methanol at different proportions viz. 1%,2%,3%,4% and 5% and tested at different loads on IDI Diesel engine. The performance of engine is compared with neat diesel as reference fuel keeping in view engine efficiency and exhaust emissions. Part load efficiency of 3% methanol blend with biodiesel showcased all-round benefits in the vicinity of three fourth full loads. Maximum extent of 1.49% increase in thermal efficiency and 0.0202 kg/kW-hr increase in the specific fuel consumption with the reference fuel is observed. More observations show smoke reduction varying in between 15 and 20 HSU, HC, CO and NO by 4ppm, 0.02 %, 40ppm respectively at higher loads which is appreciable. Crank case oil dilution has disappeared with the usage of neat biodiesel in the prescribed IDI engine in the range of tested horse power and constant speed.

KEYWORDS: additive, bio-diesel, IDI, MME, exhaust gas emissions, Methanol.

I INTRODUCTION

The gradual depletion of world petroleum reserves increases in prices of petroleum-based fuels and environmental pollution due to exhaust emissions have encouraged studies to search for alternative fuels. In view of these, vegetable oils have been considered as alternative fuels for Diesel engines. Vegetable oils are renewable, nontoxic, biodegradable, and have low emission profiles [1–5]. However, there are some drawbacks related to the use of straight vegetable oils in diesel engines primarily due to their high viscosity, lower volatility and lower heat content [6–8]. The high viscosity causes some problems in atomization of injector systems and combustion in cylinders of diesel engines. Also, in long term operations, high viscosity of vegetable oils may lead to ring sticking, formation of injector deposits, development of gumming, as well as incompatibility with lubricating oils [1, 9]. Different techniques have been developed to solve their high viscosity and low volatility problems of vegetable oils, such as preheating oils, blending or dilution with other fuels, transesterification and thermal cracking / pyrolysis [1,2,10–12]. Biodiesel can be used as a blend only in diesel engines without modification. Neat biodiesel usage is leading to more NO emission and crank case oil dilution in DI –engines especially. Puhan et al. [13] compared the performance and emission of a single cylinder, four stroke direct injection constant speed compression ignition diesel engine (Kirloskar) using biodiesel from mahua oil. The result showed that the performance of diesel engine with biodiesel does not vary significantly. The specific fuel consumption is higher (by 20%) than that of diesel and thermal efficiency is lower (by 13%) than that of diesel. Exhaust pollutant emission are reduced compared to diesel. Carbon monoxide (CO), hydrocarbon (HC), smoke number, oxides of nitrogen (NO) were reduced by 30%, 35%, 11%, 4%, respectively, compared to the reference fuel . The most interesting finding of this study is that oxides of nitrogen reduced even though that Nitrogen oxide is reported by several researchers to be increased with biodiesel. Puhan et al. [14] studied the performance and emission of mahua oil ethyl ester (MOEE) in a 4-stroke natural aspirated direct injection diesel engine. Tests were carried out at constant speed of 1500 rev/min at different brake mean effective pressures. The result showed that the average reduction in carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO) and Bosch smoke number were 58%, 63%, 12% and 70%, respectively, in case of MOEE compared to diesel. However, the results show that a carbon dioxide (CO_2) emission and BSFC from MOEE is greater than diesel. The maximum brake thermal efficiency of Mahua oil ethyl ester (MOEE) was comparable with diesel and it was observed that 26.36% for diesel whereas 26.42% for MOEE at 5.481 BMEP. This small variation of thermal efficiency may be due to the chemical composition of MOEE, which promotes the combustion process. The highest value of exhaust gas temperature of 439°C was observed for MOEE, where as for diesel it was found to be 249°C only. Saravanan et al. [15] investigated the performance and emission of a diesel engine fuelled with Madhuca indica biodiesel. Experiments were conducted on a single cylinder, four stroke, air cooled, direct injection, compression ignition engine using mahua oil methyl ester and diesel as fuel. The result showed that at full load, the power loss was around 13% combined with 20% increase in fuel consumption with Mahua oil methyl ester due to the lower heating value and higher viscosity of biodiesel fuel. Emissions such as carbon monoxide, hydrocarbons were lesser for Mahua ester compared to diesel by 26% and 20%, respectively, due to the higher oxygen contents which promoted combustion. Oxides of nitrogen were lesser by 4% for the ester compared to diesel due to the lower in cylinder temperature. A smoke intensity reduction of 15% for MOME was also observed at full load. It was also observed that the exhaust gas temperature for MOME operation is lower compared to that of diesel. Kalam et al. [16] studied emission and performance characteristics of an indirect ignition diesel engine fuelled with 5% palm (P5) and 5% coconut oil (C5) with diesel fuel at constant 85% throttle position. The results show that there are reductions in brake power of 1.2% and 0.7% for P5 and C5, respectively, compared with B0. This reduction is mainly owed to their respective lower heating values. Compared with B0, P5 increases exhaust gas temperature by 1.42% and C5 decreases it by 1.58%. However, both C5 and P5 reduce CO by 7.3% and 21% respectively, and HC by 23% and 17% respectively. However, C5 reduces 1% and P5 increases 2% of No emission. It was noted that P5 produces higher CO_2 than C5 and B0 fuels. This is mainly the effect of high un saturated fatty acid in palm oil. Usta [17,18] evaluated the performance and exhaust emissions of a turbo charged indirect injection diesel engine using 10%, 17.5% and 25% tobacco seed oil methyl ester blend (TSOME). The author found that the addition up to 25% in volume of TSOME did not cause any significant variation in the engine torque and power. Although the heating value of the TSOME is 10.8% less than that of the diesel fuel. Moreover, it was found that the blending of tobacco seed oil methyl ester to the diesel fuel reduced CO due to the fact that TSOME contains about 11.4% oxygen by weight and SO_2 emissions due to low sulphur content while causing lightly higher NO emissions due to higher combustion temperature. Leevijit and Prateep chaikul [19] studied the performance and emission characteristics of IDI-turbo automobile diesel engine operated using degummed, de acidified mixed crude palm oil–diesel blends at various loads and speeds. The test result showed that all blends produce the same maximum brake torque and power. A higher blending portion results in a little higher brake specific fuel consumption (4.3% to 7.6%), as slightly over brake thermal efficiency (−3.0% to −5.2%), a slightly lower exhaust gas temperature (2.7%to3.4%), and a significantly lower amount of black smoke (−30% to −45%). The CO emission of the 20 vol % blend is significantly lower (−70%), and the No emissions of

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all blends are little higher. The authors concluded that blending of degummed, de acidified palm oil in diesel up to 40 vol % has been found to be satisfactory for short-term usage in the IDI-turbo automotive diesel engine.

The objective of this study envisage the effect of low temperature combustion in the emission characteristics and elimination of crank case oil dilution with 100% biodiesel usage with alcohol blend without changing the basic design parameters of the engine.

2. Experimentation

Experimental test rig details shown in table.1 and figure.1 are used to conduct experiment as on the engine without any modifications. Experiments were conducted with diesel, neat MME and MME with Methanol additive blend at different percentages on a variable speed IDI engine. During the test performance, exhaust emissions and smoke density parameters were measured by using instruments indicated in the diagram. Fuel consumption is measured to calculate BSFC, fuel air ratio and thermal efficiency. Exhaust gas temperatures were also recorded for all loads. Delta 1600-L exhaust gas analyzer(German Make) is used to measure CO_2, CO, HC, NO in exhaust gases at all loads and graphs are drawn to analyze the emissions.

Table 1. Specifications of engine test rig

Engine manufacturer	**Bajaj RE Diesel Engine**
Engine type	Four Stroke, Forced air and Oil Cooled
No. Cylinders	One
Bore	86.00mm
Stroke	77.00mm
Engine displacement	447.3cc
Compression ratio	24±1:1
Maximum net power	5.04 kw @ 3000 rpm
Maximum net torque	18.7 Nm @ 2200 rpm
Idling rpm	1250±150 rpm
Injection Timings	8.5^0 to 9.5^0 BTDC
Injector	Pintle
Injector Pressure	142 to 148 kg/cm^2
Fuel	High Speed Diesel
starting	Electric Start

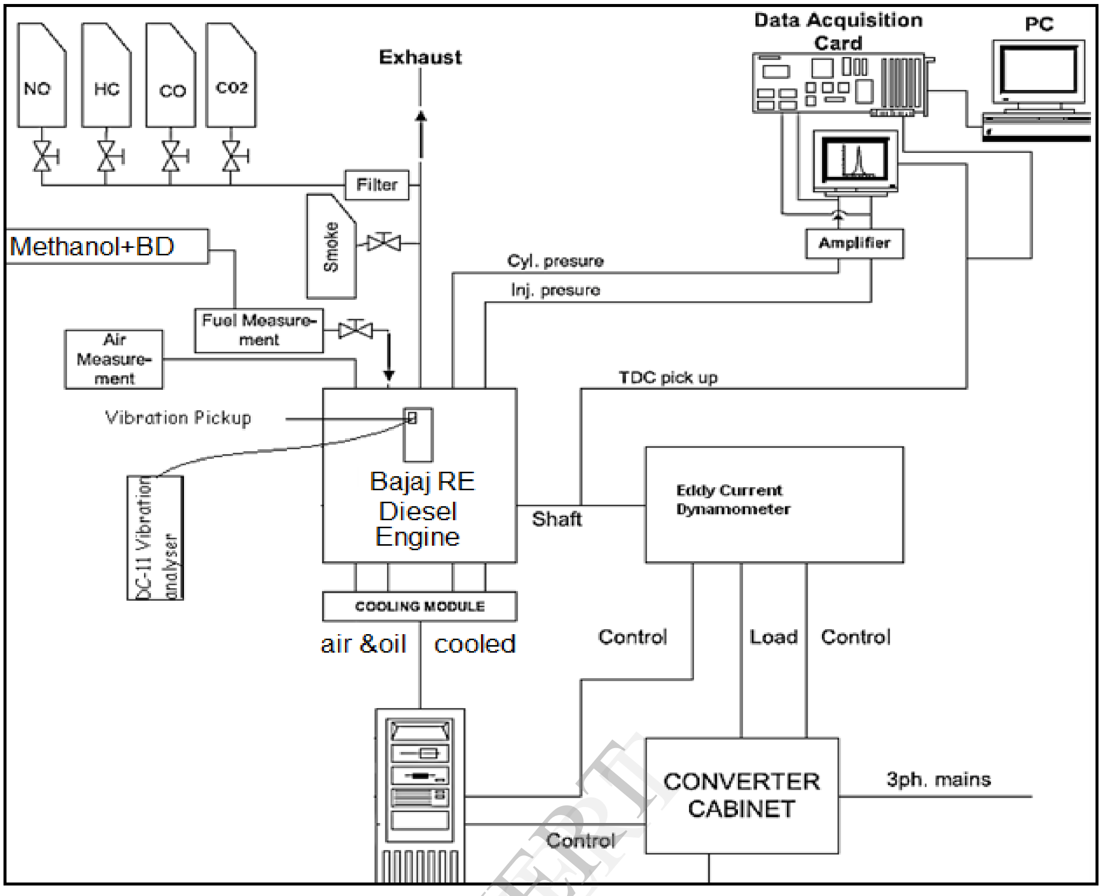

Fig.1. Schematic Diagram representing the engine and instrumentation

3.0 RESULTS AND DISCUSSIONS

3.1 Engine performance

The performance test results of the engine were compared for diesel, Mahua methyl Ester (MME) and Methanol additive blends for various percentages.

• Brake Specific Fuel Consumption: Figure (2) envisages that the brake specific fuel consumption (BSFC) verses Break Power. The Brake Specific Fuel consumption is observed to be within limits for the part load operation of the engine at 1500 rpm. A smoother trend of the curve is observed for the additive blend of 3% (yellow line).The Brake Specific Fuel Consumption for the 3% additive blend is observed on higher side i.e. 0.3209, albeit not shown in the figure. The performance can be rated better when compared to other samples.

• Brake Thermal Efficiency: Figure (3) gives the details of brake thermal efficiency versus Break power of neat diesel, bio-diesel and additive blends. The figure shows that the thermal efficiency is increasing with Methanol additive percentage even though calorific value of additive is low compared to the main biodiesel. This is due to improved rate of combustion with additive. At 3% Methanol additive blend yielded maximum Brake thermal efficiency of 29.33 % at a brake power of 2.31 kW.

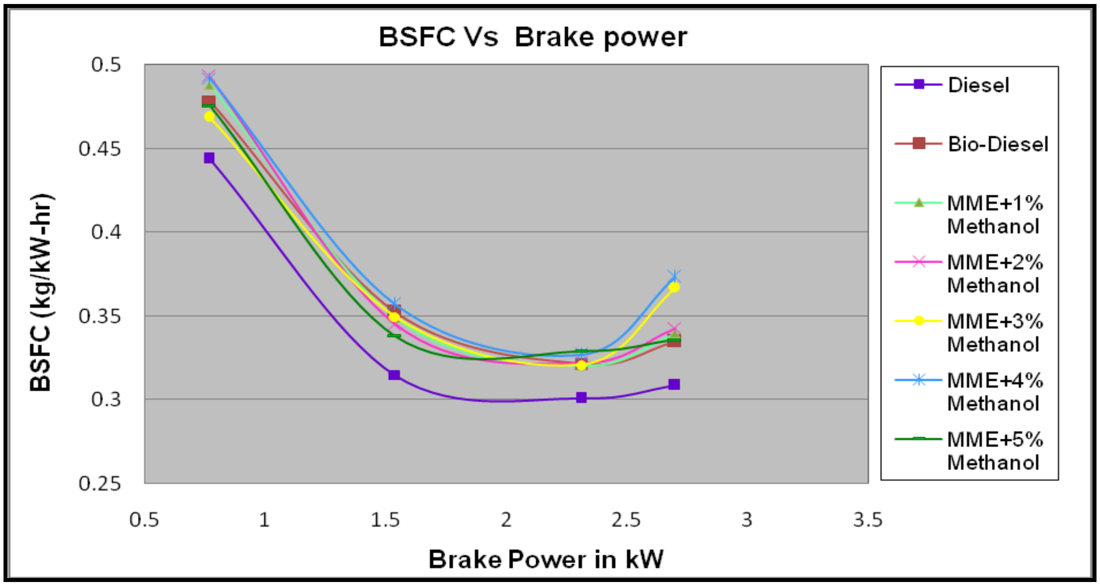

Fig.2. Variation of BSFC verses Brake power

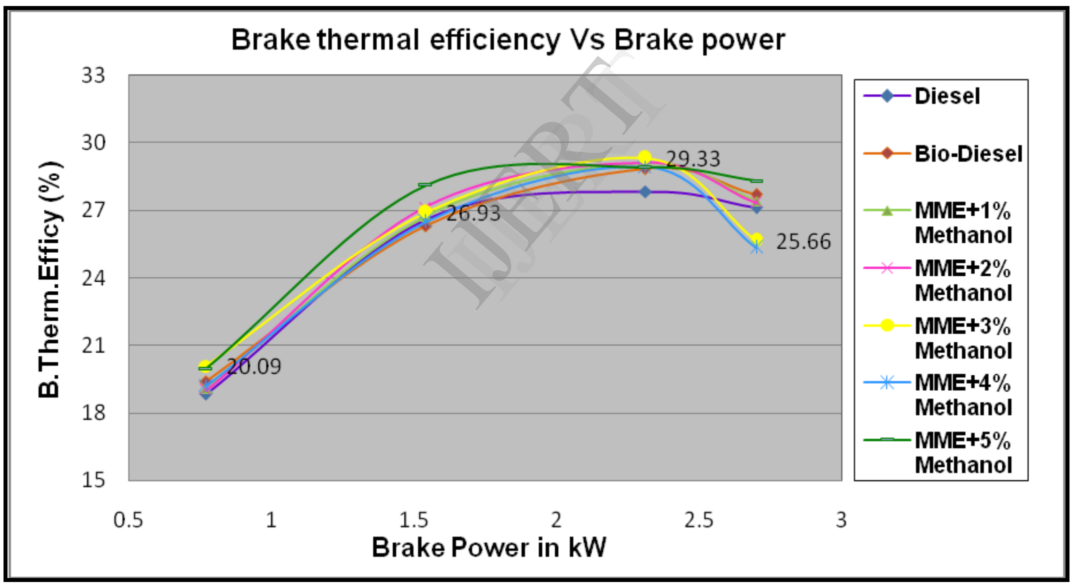

Fig.3. Variation of brake thermal efficiency verses Brake power

3.2 Engine Emissions

• Exhaust Gas Temperature: Figure (4) gives the details of Exhaust gas temperature versus Load of neat diesel, bio-diesel and additive blends. Exhaust temperature decrease of -14^{0}C is observed in the case of 3% additive with biodiesel and this decrement is with respect to the diesel fuel. This observation of lower exhaust temperature is indicative of lower combustion temperatures in both the combustion chambers depending on the Cetane number and auto ignition temperature of methanol.

• Engine smoke levels: The decrease in smoke level in exhaust with respect to the neat diesel fuel operation is appreciable (19 HSU reduction at maximum load operation).This is an indication of better combustion with 3% additive of methanol in biodiesel as shown in figure (5).Methanol is famous for smokeless burning and 3% methanol in biodiesel may be appropriate in reducing smoke levels to minimum.

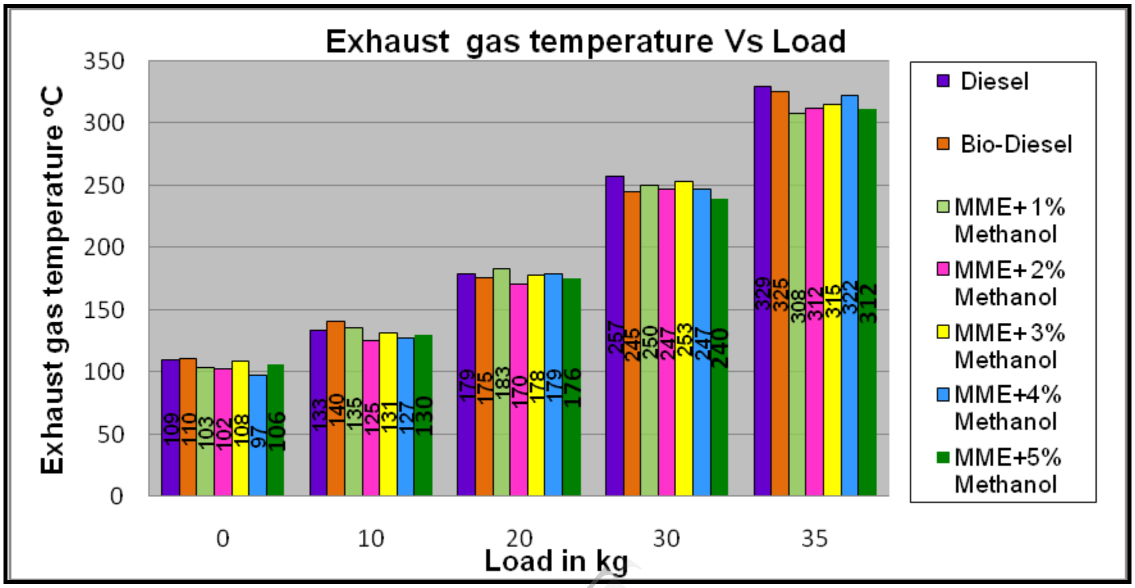

Fig.4. Variation of exhaust gas temperature verses load on the engine

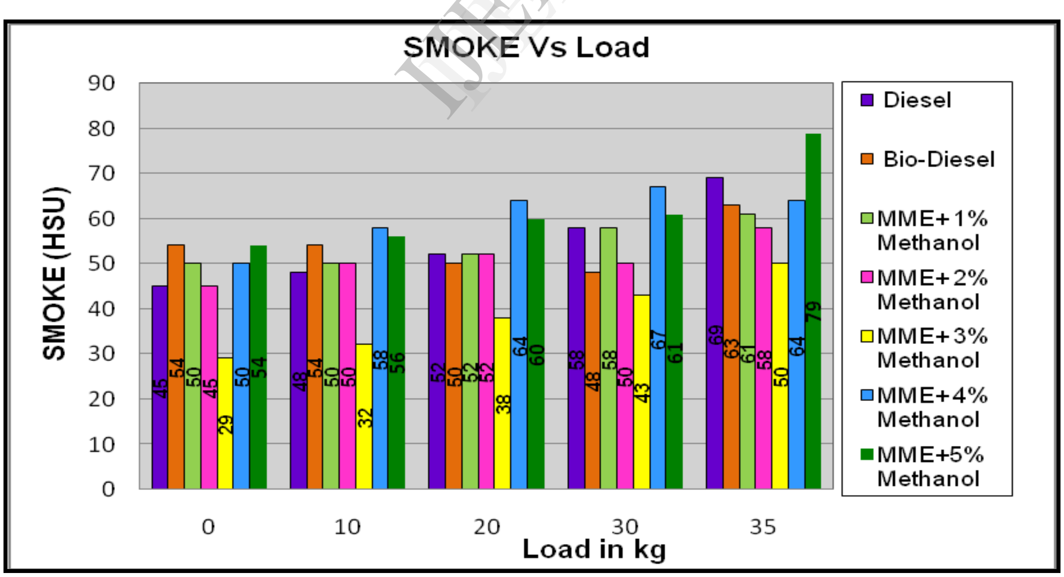

Fig.5. Variation of smoke level verses load on the engine

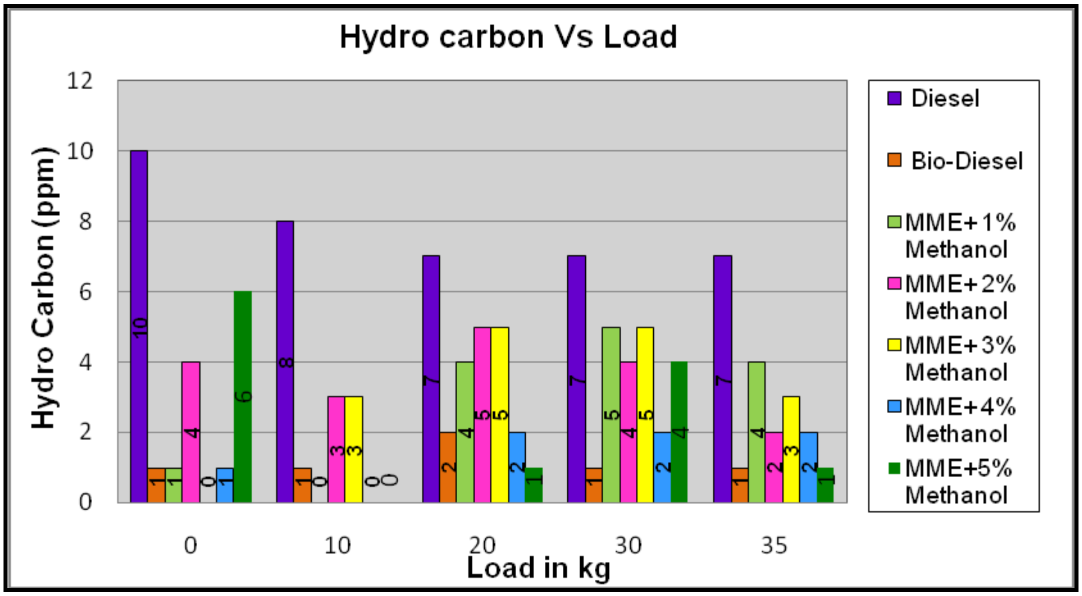

Fig.6. Variation of hydrocarbon emission verses load on the engine

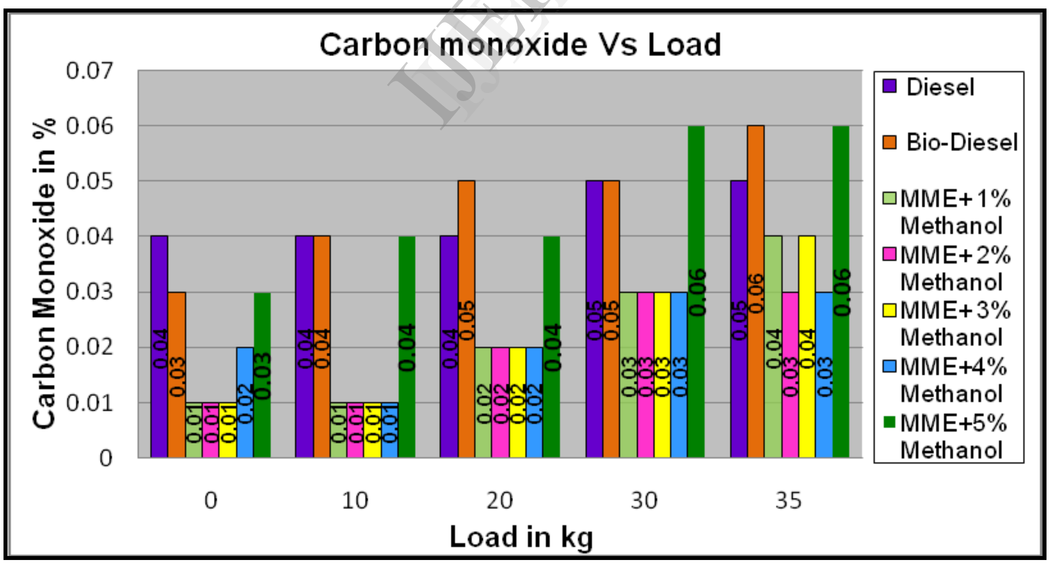

Fig.7. Variation of carbon monoxide emission verses load on the engine

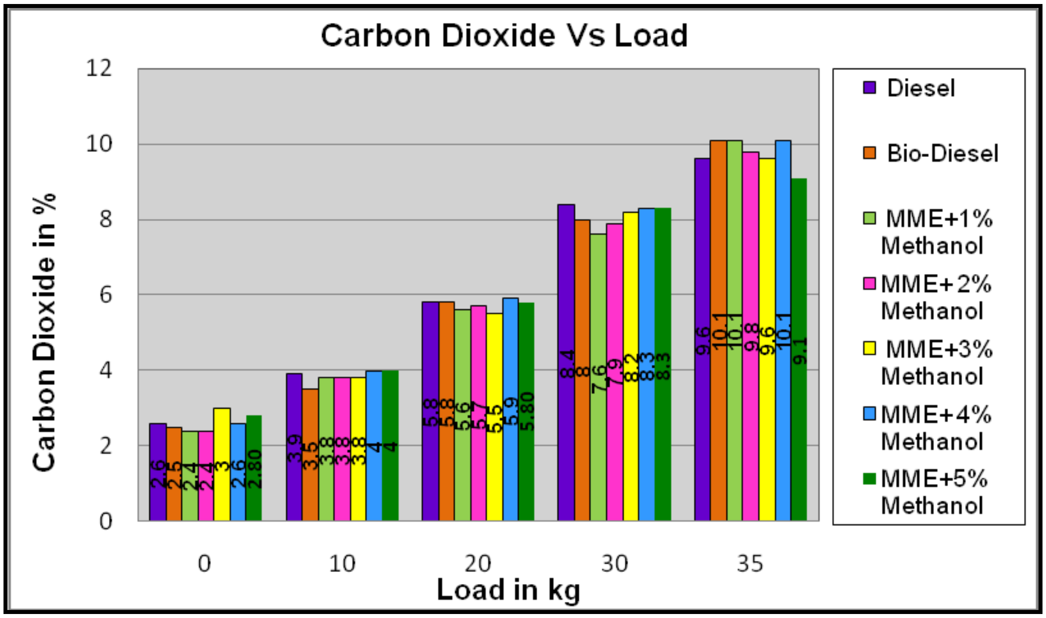

Fig.8. Variation of carbon dioxide emission verses load on the engine

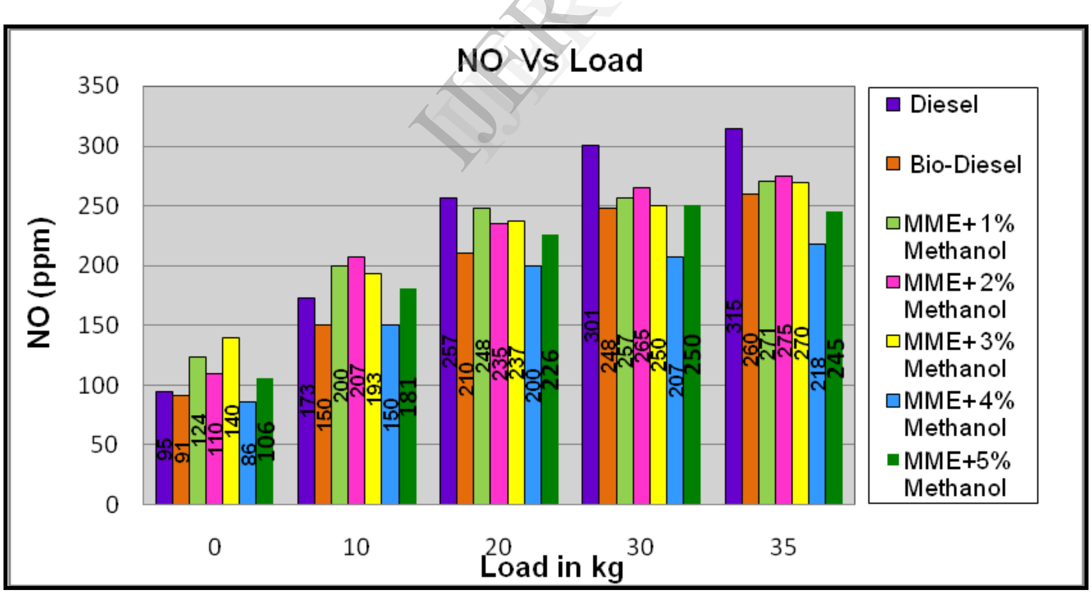

Fig.9. Variation of NO emission verses load on the engine

• Hydrocarbon (HC) and Carbon monoxide (CO) emissions: Research on IDI engine indicates lower emissions in exhaust. Additive mixing further reduced the HC emission and CO emission to greater extent which can be observed from the figures (6&7).

• Carbon Dioxide (CO_2) Emission: CO_2 emission has increased because of combustion improvement which can be observed from the figure (8)

• Nitrogen Oxide (NO) Emission: NO emission has also reduced at higher loads especially with the additive as shown in figure (9).

4. CONCLUSION

Small quantities of methanol are used as an additive to the Mahua methyl ester and used in an IDI engine. The performance and emissions are to evaluate the suitable methanol percentage which gives maximum benefits. It is observed that fuel containing 3% additive in biodiesel performed maximum as replacement to the diesel fuel. The benefits are as follow:

- The engine load of 2.70 kW was tried at 1500 rpm for stable operation for the variable speed engine selected. It is observed that 3% additive in biodiesel has given smoother performance curve.
- Thermal efficiency and specific fuel consumption have improved with 3% additive in biodiesel.
- There is maximum relief of exhaust temperature for 3% additive which indicates that the ensued combustion is low temperature combustion in which methanol has burned at later stages because of lower cetane number.
- Research on IDI engine indicates lower emissions in exhaust. Additive mixing further reduced the HC emission and CO emission to greater extent.
- NO emission has also reduced at higher loads especially with the additive. The plots are self explanatory as the trends indicate differential reductions with 4% methanol with biodiesel at the lowest emission. But considering reductions in other aspects 3% methanol is adjudged better.
- CO_2 emission has increased because of combustion improvement.

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