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PERFORMANCE AND EMISSION STUDY OF BIODIESEL-LIGHT DIESEL OIL BLENDS IN COMPRESSION IGNITION ENGINE

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ABSTRACT

This work studies the prospect of low cost biodiesel light diesel oil in a compression ignition engine. Four blends of biodiesel light diesel oil were prepared and their properties were studied. A compression engine test rig is setup. The performance characteristics of the blends were found experimentally. Also emission tests and smoke tests were performed. Conventional diesel and blends of pongamia biodiesel were also tested and a comparative study is established. Regression analysis was performed to remove the insignificant parameters and to find the effect of significant parameters on the result. Regression models for carbon monoxide emission, nitrogen oxide emissions and smoke opacity were developed. Optimization of parameters was done using Taguchi's method to find the prominent input variables. Also optimum load to light diesel oil concentration were arrived at using signal to noise ratio plots.

KEYWORDS

Biodiesel light diesel oil, Pongamia biodiesel and Regression analysis.

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INTRODUCTION

Energy is one of the most significant inputs for growth of all sectors including agricultural, industrial services and transport sectors. The demand for energy, around the world is increasing exponentially, specifically the demand for non renewable energy sources such as fossil fuels like petrol, diesel, etc. for energy. These fossil fuels are continuously diminishing. While there are many renewable sources of energy, the usage of such energy resources is very limited. In the current context, the quest for alternative fuels that promise a harmonious connection with sustainable growth, conservation of energy, productivity and protection of the environment has become highly pronounced. The fuels of bio-origin can thus provide a feasible solution to this petroleum based fuel crisis.

Light diesel oil is a lower grade of fuel that is obtained during refining processes of crude oil. The main application of light diesel oil is heating in industries. It is also used for low speed engines below 750rpm. Biodiesel light diesel oil is derived from non edible vegetable oils. The light diesel oil (LDO) used in this project is derived from palm oil. The properties of LDO are shown in Table No.1.

Experimental setup

It is important to have the different instruments mounted at the appropriate position on the experimental setup to perform the desired set of experiments and collect the necessary data from the engine. The photograph of the test rig used is shown in Figure No.2. Overall schematic diagram is shown in Figure No.1.

A single cylinder air cooled, direct injection, diesel engine (Kirloskar AV1 model) is selected for experimental work which is primarily used for agricultural and household electricity generation activities is shown in Figure No.2. The engine's detailed technical specifications are given in Table No.2.

Experimentation

The steps involved are,

- Property study of biodiesel blends namely calorific value, kinematic viscosity and specific gravity.
- Performance and emission characteristic study of test engine with conventional diesel and pongamia biodiesel blends to get the base line data.
- Performance and emission characteristic study of biodiesel light diesel oil blends.
- Comparitive study of performance and emission characteristic of biodiesel light diesel oil blends with pongamia blends and conventional diesel.

RESULTS AND DISCUSSION

Property Study

The blends of 5, 10, 15 and 20 percentage of biodiesel light diesel oil with diesel and blends of 10 and 20 percentage of pongamia biodiesel with diesel are prepared with the help of a mechanical stirrer.

The calorific values of the biodiesel-diesel blends were measured using a bomb calorimeter; viscosity using a Viscometer and specific gravity using a hydrometer. The kinematic viscosity values are calculated at 40^oC.The calorific values of blends are tabulated in the Table No.3. Kinematic viscosity values in Table No.4 and specific gravity values in Table No.5.

Performance Study

The major performance study parameters are brake thermal efficiency and specific fuel consumption. The variation of brake thermal efficiency with load for all the blends and variations are plotted as in Figure No.3 and Figure No.4.

Thermal efficiency is directly proportional to brake power and inversely proportional to fuel power. For a constant speed engine the fuel power remains constant because of constant amount of fuel consumption and the brake power increases with increase in torque. Due to the low calorific value of biodiesel LDO blends when compared to that of neat diesel oil the thermal efficiency is decreasing with the increase in blending concentration of biodiesel LDO in the blend. At 100% load the thermal efficiency of biodiesel LDO5 blend is similar to that of conventional diesel. When compared to that of pongamia biodiesel blends the thermal efficiency of biodiesel LDO is low for all percentage of blending. The thermal efficiency of LDO 20 is 7% lower when compared to that conventional diesel.

As shown in the Figure No.4, it is observed that the thermal efficiency of the pongamia biodiesel blends and conventional diesel for various percentage of loads are almost similar. This is due to the higher calorific value of pongamia biodiesel when compared to that of biodiesel LDO. The calorific value of pure pongamia biodiesel blends is higher than that of conventional diesel. The thermal efficiency of biodiesel LDO5 is 3% lower than that of pongamin blend B10. The thermal efficiency of biodiesel LDO20 is 6% lower than that of pongamia blend B 20.

The variation of specific fuel consumption with load for all the blends and variations are plotted as in Figure No.5 and Figure No.6.

For all blends tested, brake specific fuel consumption is found to decrease with increase in load as shown in the Figure No.5. In case of LDO 20, the brake specific fuel consumption is found to be higher than that of diesel. With increase in biodiesel percentage in the blends, the calorific value of fuel decreases. Hence, the specific fuel consumption increases for higher percentage of biodiesel in blends compared to that of diesel. The specific fuel consumption of biodiesel LDO is 20% higher than that of conventional diesel.

For B10, the BSFC is slightly higher than diesel fuel. But at higher load percentage the brake specific fuel consumption of both the blends of pongamia biodiesel and diesel are the same. As brake specific fuel consumption is exactly inverse of brake thermal efficiency, it follows opposite trend of thermal efficiency variation.

Emission Study

The major emission characteristics for the various blends of biodiesel are measured experimentally using an exhaust gas analyzer and smoke meter. The experimental results are plotted in Figure No.7, Figure No.8, Figure No.9 and Figure No.10 as follows.

Carbon monoxide increases with load as evident in Figure No.7 and Figure No.8 because air that is inducted into the engine is constant and mixture becomes richer at higher loads. For biodiesel LDO blends, CO emission was lower than diesel fuel, because biodiesel LDO itself has inbuilt oxygen content that resulted in complete combustion of the fuel supplied and the necessary oxygen to convert CO to CO_2. Compared to neat diesel fuel, biodiesel LDO20 blend mixtures reduced CO emissions by 18%. Figure No.8 shows the CO emissions of the diesel fuel and two blends of Pongamia oil.

From Figure No.8 CO emissions for all load conditions were found to be lesser than diesel. But, CO emission is also higher when compared to light diesel oil blends. This is because Pongamia is a purer form of biodiesel than LDO. For 20% load, the emission values of LDO and Pongamia are almost similar. This is because at lesser load condition, the differences in blend structures are not so prominent.

The CO_2 emission increases with increase in load as shown in Figure No.9. The biodiesel LDO-diesel blends emits more amount of CO_2, as compared to neat diesel operation. Due to inbuilt oxygen in biodiesel, more amount of CO_2 in exhaust emission is an indication of the complete combustion of fuel. This leads to the higher value of exhaust gas temperature. The CO_2 emission using neat diesel as fuel is lower because of the incomplete combustion. Even after an addition of 5% of biodiesel LDO, CO_2 emission of LDO5 is almost equivalent to that of neat diesel oil.

From Figure No.10, CO_2 emission is lesser compared to Light Diesel Oil. This is because Pongamia has higher calorific value which makes it more combustible. For 20% load, the emission values of LDO and Pongamia blends are almost similar.

From the Figure No.11 it is evident that NO_X emission increases with the increase in load. At about 1500°C, oxidation of nitrogen takes places in presence of oxygen inside the cylinder.

From Figure No.11 and Figure No.12 NO_X level was higher for biodiesel blends than diesel fuel at the same load. Because of the presence of extra oxygen in the molecules in biodiesel blends, this can be clarified. This additional oxygen was responsible for higher NO_X emission.

If the fuel used is partially oxygenated, locally over-rich regions can be reduced and primary smoke formation can be limited. It can be seen that smoke is high mainly at high power outputs Figure No.13 and Figure No.14 compares the smoke opacity of diesel and biodiesel blends.

As it is evident from Figure No.13 and Figure No.14 Smoke Opacity values of LDO blends are nearly equal to that of diesel and LDO blends. This is due to the complete combustion with the presence of more oxygen content in biodiesel LDO and less calorific value. When compared to biodiesel LDO smoke opacity is less when compared to pongamia biodiesel.

Regression Analysis on Emission

Regression analysis on emission is performed using MINITAB 16. The steps involved are as follows.

- Create Taguchi design.
- Define Taguchi design.
- Analyze Taguchi design.

Analyzing Taguchi design quantitatively relates the dependent and the independent variables.

The regression equations for emissions as given by the software are as follows.

1. CO Emission in % Volume = 0.0277 - 0.000667 (LDO Concentration) + 0.000646 (Load %).
2. NOx Emission in ppm = 107 + 0.640 (LDO concentration) + 1.15 (Load %).
3. Smoke Intensity % = 7.69 - 0.0263 (LDO concentration) + 0.230 (Load %).

Table No.1: Light diesel oil properties

Density	895kg/m^3
Calorific value	40,000kJ/kg
Viscosity	9 cSt
Flash point	66^{o}C
FFA	2.7%

Table No.2: Engine specification

Make	Kirloskar model AV1
Number of strokes	4
Number of cylinders	1
Combustion chamber position	Vertical
Rated Power	3 .7 kW at 1500rpm
Speed	1500Rpm
No. of Cylinder	Single cylinder
Compression Ratio	16.5:1
Bore	80mm
Stroke	110mm

Table No.3: Calorific value

Biodiesel Blend	Calorific Value (kJ/kg)
Diesel	42,200
B10	42,567
B20	42,982
LDO5	41,985
LDO10	41,324
LDO15	41,132
LD020	41,054

Table No.4: Kinematic viscosity

Biodiesel Blend	Kinematic viscosity @ 40^{o}C (cSt)
Diesel	2.40
B10	3.29
B20	3.73
LDO5	2.90
LDO10	3.43
LDO15	4.10
LDO20	4.87

Table No.5: Specific gravity

S.No	Biodiesel Blend	Specific Gravity
1	Diesel	0.820
2	B10	0.840
3	B20	0.860
4	LDO5	0.835
5	LDO10	0.850
6	LDO15	0.865
7	LDO20	0.890

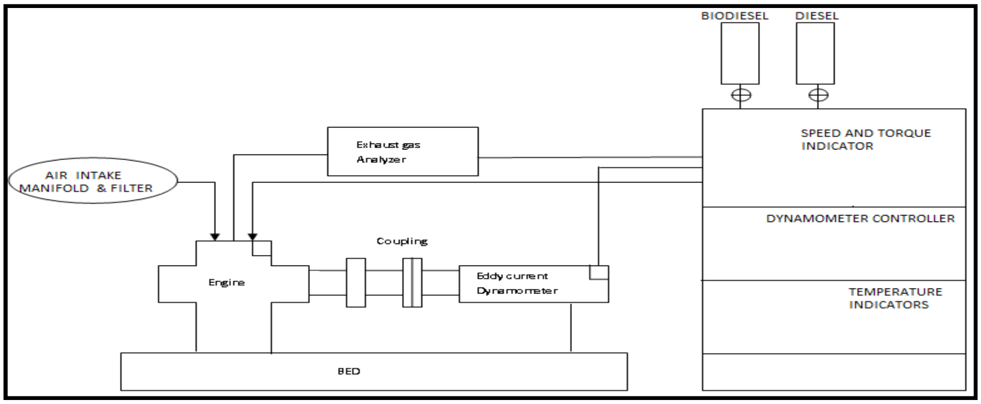

Figure No.1: Schematic view of experiment setup

Figure No.2: Test engine

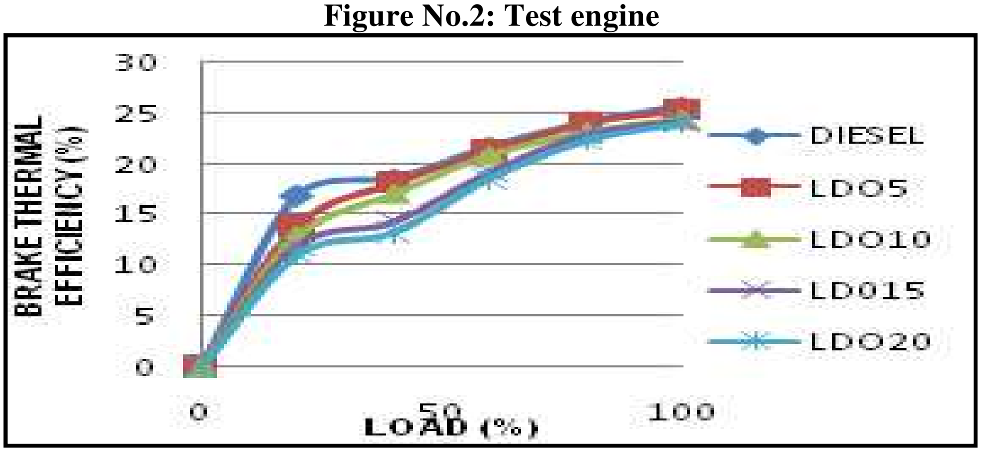

Figure No.3: Load vs. Brake thermal efficiency of LDO blends and diesel

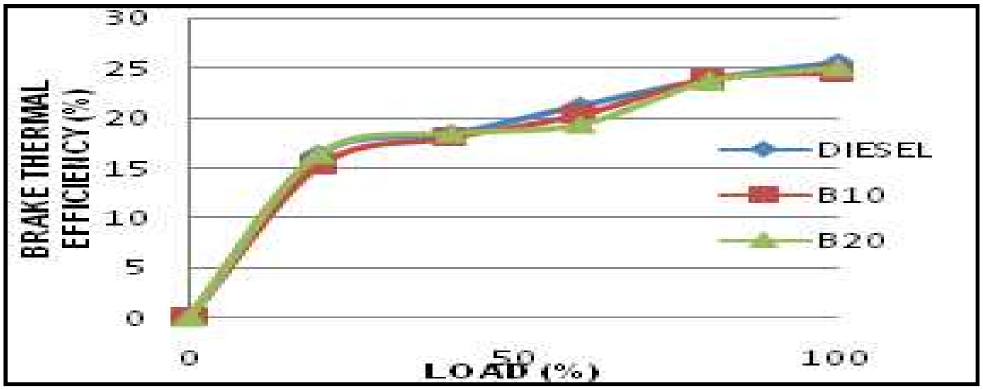

Figure No.4: Load vs. Brake thermal efficiency of pongamia oil blends and diesel

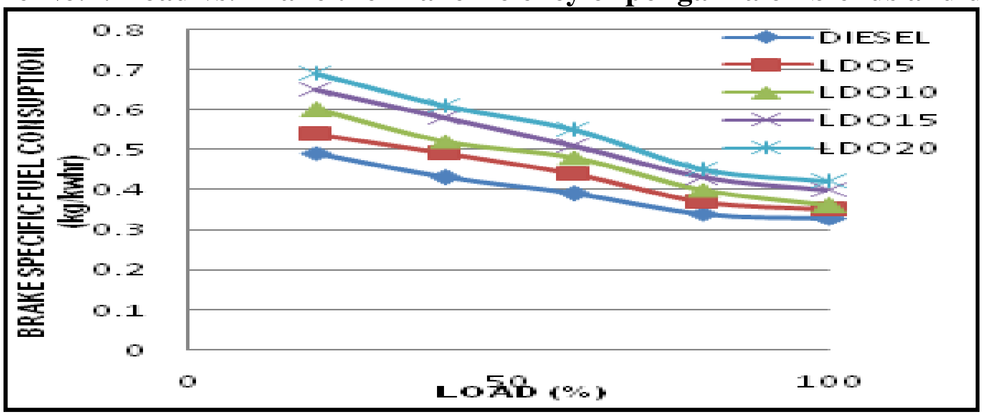

Figure No.5: Load vs. Brake specific fuel consumption of LDO blends and diesel

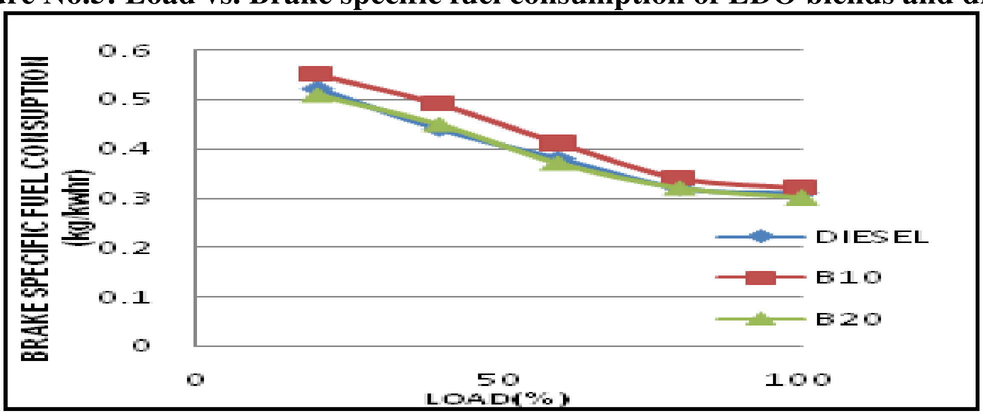

Figure No.6: Load vs. Brake specific fuel consumption of pongamia oil blends and diesel

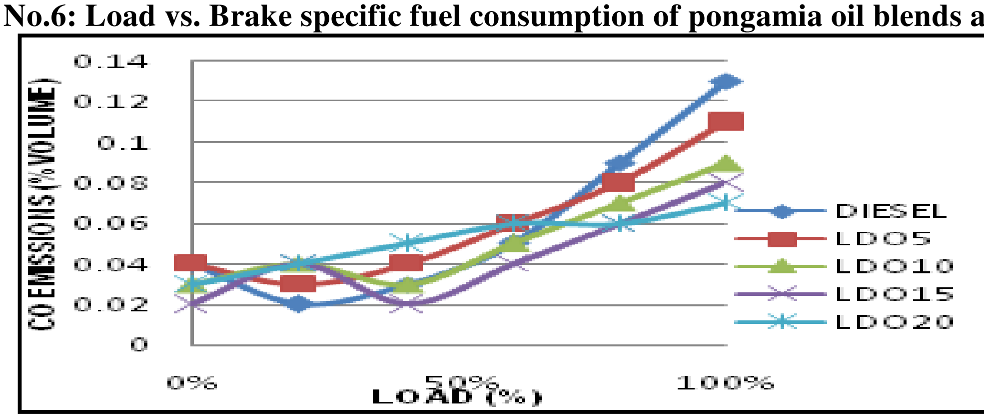

Figure No.7: Load vs. CO emissions of LDO blends and diesel

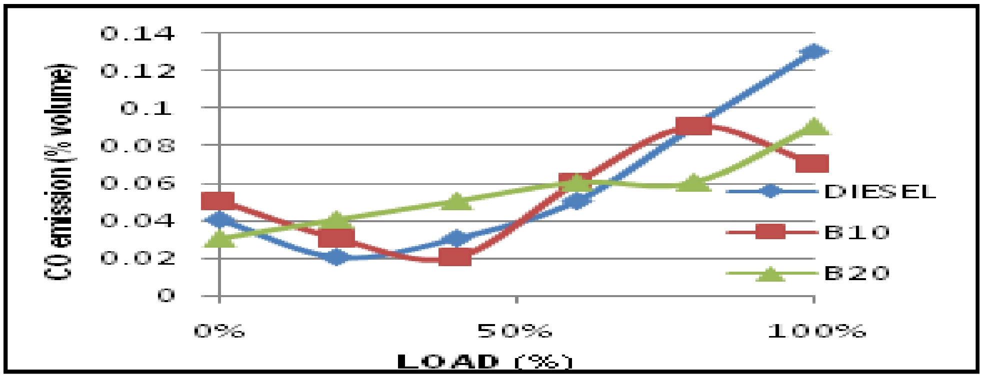

Figure No.8: Load vs. CO emissions of blends of pongamia oil and diesel

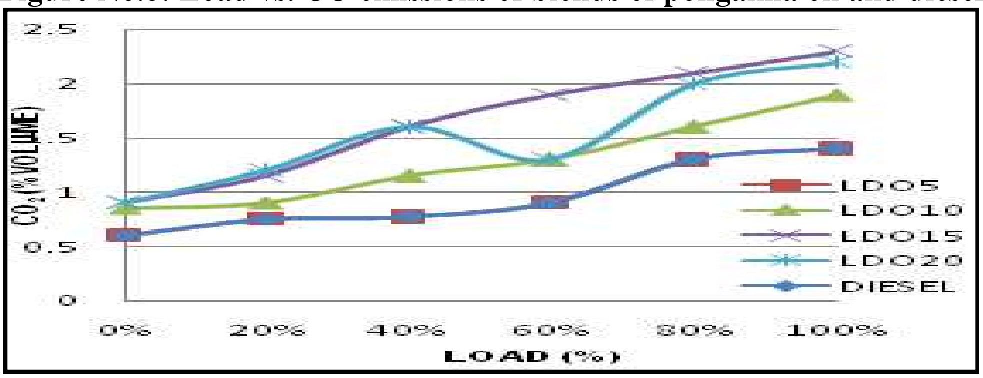

Figure No.9: Load vs. CO_2 emissions of LDO blends and diesel

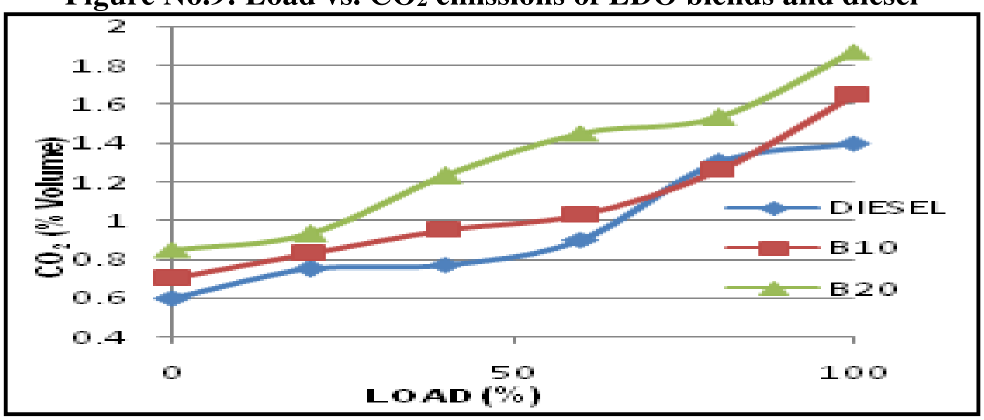

Figure No.10: Load vs. CO_2 emissions of pongamia oil blends and diesel

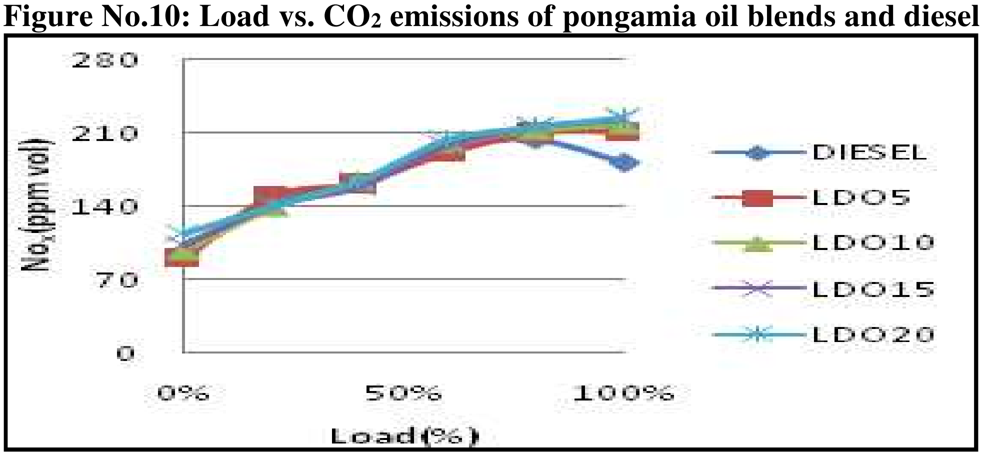

Figure No.11: Load vs. NO_x emissions of LDO blends and diesel

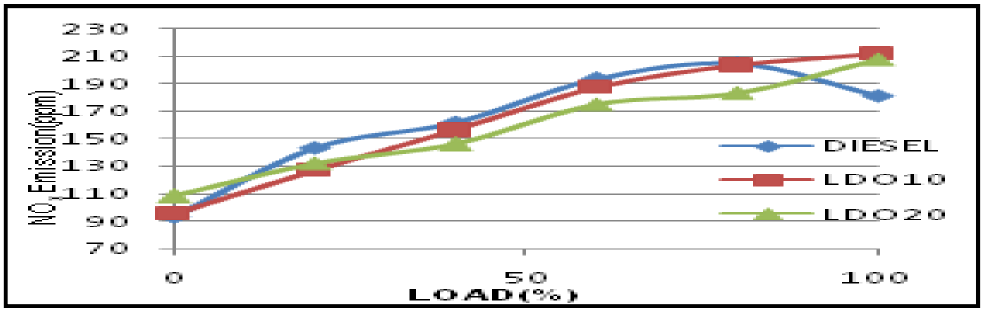

Figure No.12: Load Vs NO_x emissions of pongamia oil blends and diesel

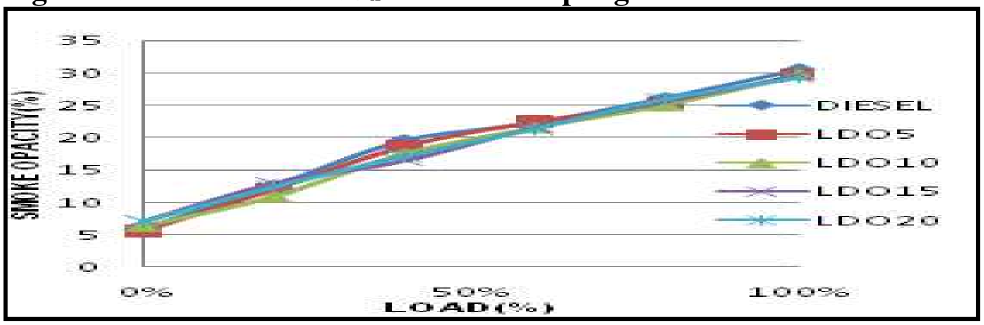

Figure No.13: Load vs. Smoke opacity of LDO blends and diesel

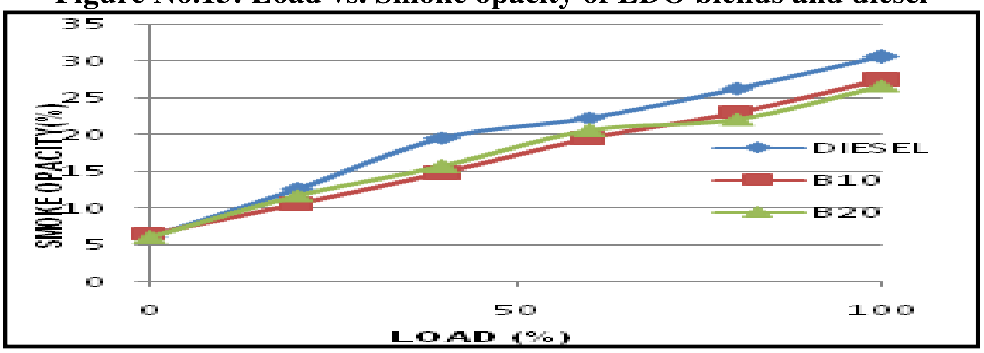

Figure No.14: Load vs. Smoke opacity of pongamia blends and diesel

CONCLUSION

Blends of biodiesel light diesel oil and pongamia oil were prepared and their properties were studied. From the series of exhaustive experiments, the following conclusions can be derived.

The brake thermal efficiency of biodiesel light diesel oil blends were less than that of diesel. LDO20 blend had a brake thermal efficiency of 7% less than that of conventional diesel and 6.5% less than that of pongamia B20 blend.

The brake specific fuel consumption is higher for all blends than conventional diesel. It is 20% higher for LDO20 than conventional diesel.

Carbon monoxide emission is found to decrease with increase in load for all test fuels. For biodiesel LDO blends, CO emission was lower than diesel fuel as B 20 reduced drastically.

The biodiesel LDO- diesel blends emits more amount of CO_2, as compared to conventional diesel operation.

The nitrogen oxide level was higher for biodiesel blends than conventional diesel fuel. Approximately 10% increase in NOx emission was observed with 20% biodiesel blend.

From the results, the regression equations for emissions are generated. An R-square value of 96.9% indicates the accuracy of experimental plots over the regression equation. Also, residual plots confirm the consistency of the model.

From optimization results, it is observed that LDO20 at 80% load condition gives minimum emission.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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