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Effect of ethanol on the performance and emission characteristics of biodiesel fuelled diesel engine

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The fossil fuel resources are depleting day –by-day and there is an increasing demand of fuels which increases environmental pollution. This problem leads to stringent emission regulations which pose a challenge to science and technology to find out environmental friendly fuels. Among the renewable energy sources, biodiesel derived from vegetable oils and fats are considered as an immediate substitute for the fossil diesel in the I.C.Engines. In India, biodiesel derived from non-edible oils such as honge, jatropha, neem, mahua, simarouba etc are considered as an alternative fuels to the fossil diesel, as there is demand for the edible oils. In this work, biodiesel was produced from non-edible honge oil by two step transesterification. The honge biodiesel properties were determined and most of the fuel properties are similar to the fossil diesel. However, Biodiesel has high viscosity, lower volatility which affects the atomization and spray formation. In this regard, the alcohol such as ethanol which is having lower flash & fire point, high flammability and is produced from renewable energy sources was used as good additive for biodiesel to improve its fuel properties. In this work, the engine tests were conducted on a single cylinder, four-stroke direct injection diesel engine using diesel, honge biodiesel and ethanol blended bio-diesel in four different compositions by volume ranging from 5% to 20% . The Engine performance and emission characteristics were analysed by varying the load. From the engine test results, it was observed that, the BE5 i.e. 5% ethanol in biodiesel results in better performance than other blends and neat biodiesel operation.

Keywords: *Alternative fuel, honge oil, biodiesel, properties, Transesterification, Ethanol, engine tests.*

1.0 INTRODUCTION

The rapid depletion in the world petroleum reserves and uncertainty in the petroleum supply have stimulated the search for alternatives to petroleum based fuels especially diesel and gasoline. Bulk of these petroleum fuels are being consumed by agricultural and transport sectors for which diesel engine happens to be the preferred prime mover. Vegetable oils have properties comparable to diesel and can be used to run compression ignition engine with little or no modification. They are renewable, available everywhere and have proved to be cleaner fuel and more environment friendly than the fossil fuels. It is also seen that the emissions from the biodiesel engines are comparatively lesser than the engines with the petroleum based fuels [1-3]. The higher viscosity of vegetable oils affects the flow properties of fuel such as spray, atomization and consequent vaporization and air fuel mixing. Some of the works have revealed that converting

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vegetable oils into methyl esters will overcome all problems related with vegetable oils [4-5]. Currently more than 95% of the world biodiesel is produced from edible oils which are easily available on large scale from the agricultural industry. In most of the developed countries sunflower, peanut, palm and several other feed stocks are used as alternative sources, which are edible in the Indian context. Hence use of non edible oils when compared with edible oils is very significant in developing countries like India, because of tremendous demand for edible oils as food and also they are quite expensive to be used as a fuel in the present conditions. The production of biodiesel from different non edible oil seed crops has been extensively investigated over the past several years [6-15]. However, due to technical deficiencies, they are rarely used purely or with high percentages in unmodified diesel engines. In this regard Several researchers [16-22] have carried out experimental investigations to know the feasibility of using additives to improve the performance of engines fuelled by biodiesels.

The aim of this work was to produce biodiesel from honge oil and to study the effect of ethanol as an additive to research the possible use of higher percentages of biodiesel on the engine performance and emissions.

FIG. 1 HONGE TREE

2.0 EXPERIMENT DETAILS

In the present work, honge oil, was used as vegetable oil. A two-step transesterification reaction was used for the production of biodiesel. Biodiesel was produced using a 25 litre biodiesel plant. Figure 2 shows the processes involved in biodiesel production from seeds.

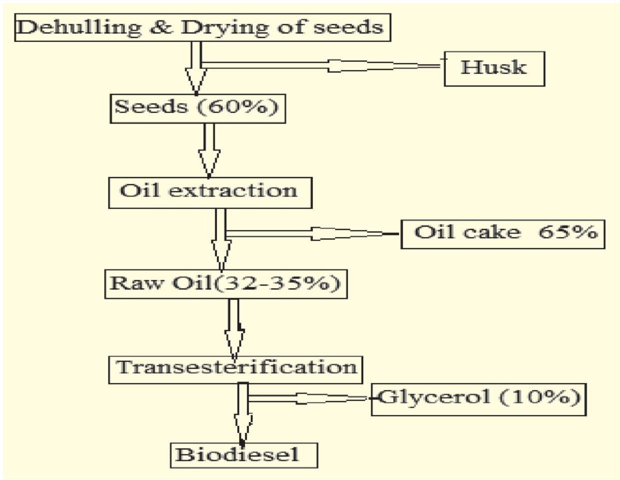

FIG. 2 PROCEDURE FOLLOWED FOR BIODIESEL PRODUCTION

2.1 Production of Biodiesel

Biodiesel is a methyl ester formed by a process called transesterification. Oil can be extracted from seeds of honge tree with a simple oil mill. The honge oil is reacted with methanol in the presence of a catalyst to yield methyl esters and glycerol. Sodium hydroxide and potassium hydroxide are commonly used catalyst. Oil is heated to 65°C, and sodium hydroxide tablets are dissolved in methanol to make a solution. The quantity of NaOH & methanol should be 2.5 and 10% respectively of the total quantity of honge oil. After mixing this solution into hot honge oil, the solution is stirred for 5 to 10 minutes. Then the solution was undisturbed at least for 4 hours. Glycerol being heavy will slowly settle down at the bottom & can be easily separated from the bottom using gravity separation. To strain the impurities like sodium, oil is subjected to 2 to 3 washings with water. After 5 minutes oil floating on surface is collected and finally oil is heated to evaporate the water to extract the biodiesel.

2.2 Fuel Properties

The biodiesel and biodiesel-ethanol blends were tested for different chemical and physical properties and the values are shown in the Table 1 and 2. From the table, it is observed that most of the properties of biodiesel-ethanol blends are better than crude honge oil as well as neat biodiesel and close to the fossil diesel.

TABLE 1

FUEL PROPERTIES OF CRUDE HONGE OIL

Density(kg/m^3)	915
Kinematic Viscosity at 40^{0}C(cst)	28.3
Calorific value(kj/kg)	35800
Flash point(^{o}C)	230
Colour	Dark Brown

TABLE 2

PROPERTIES OF DIESEL, HONGE BIODIESEL AND ETHANOL-BIODIESEL BLENDS

Fuel	Density kg/m^3	Kinematic viscosity@40^{0}C (centi stokes)	Flash point(^{0}C)	Calorific value (kJ/kg)
Diesel	820	3.985	56	42414
B100	896.5	5.4	170	38479.02
BE5	891.22	5.184	84	37474.14
BE10	885.95	4.968	80	36971.7
BE15	880.675	4.752	77	34961.94
BE20	875.4	4.536	73	31402.5

2.3 Engine Tests

In this work, engine tests were conducted on a single cylinder water cooled four stroke direct injection compression ignition engine. The engine has a compression ratio of 16.5: 1, bore of 80mm and stroke of 110mm, developing 3.7 kW power at 1500 rpm. An eddy current dynamometer was used for loading the engine. An AVL Digas 444 exhaust gas analyser was used to measure the CO, UBHC and NOx emissions in the engine exhaust. An AVL 437C smoke meter was used to measure the smoke opacity in the engine exhaust. Experiments were conducted initially with neat diesel at various loads and then with the honge methyl ester and ethanol blended biodiesel in four different compositions referred as BE5, BE10, BE15 and BE20. Experiments were repeated by changing the percentage of load, for an increment of 25%.

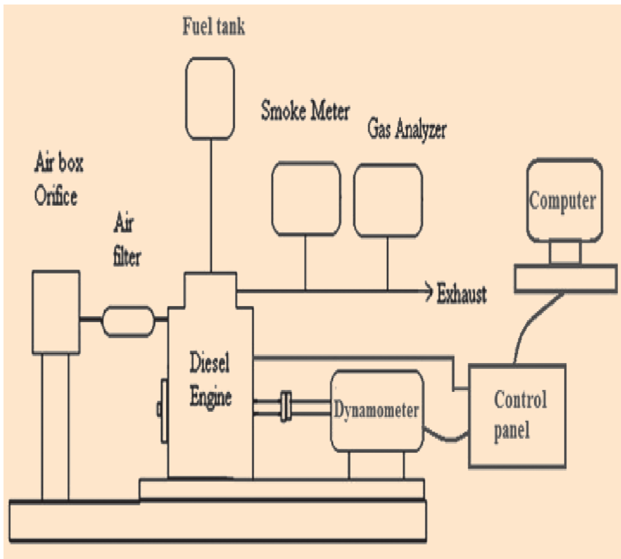

FIG. 3 SCHEMATIC DIAGRAM OF ENGINE EXPERIMENTAL SETUP

3.0 RESULTS AND DISCUSSIONS

The engine was running without any problem with the honge biodiesel and its ethanol blends. The engine parameters such as Load, speed, air flow rate, fuel flow rate, exhaust gas temperature, exhaust emissions of hydrocarbon, carbon monoxide, carbon dioxide, oxygen, oxides of nitrogen and smoke were recorded and the results were compared.

3.1 Experimental observations for Engine Performance and Emissions

The effect of honge biodiesel on the engine performance parameters and emissions are discussed in the following paragraphs.

3.1.1 Brake Thermal Efficiency

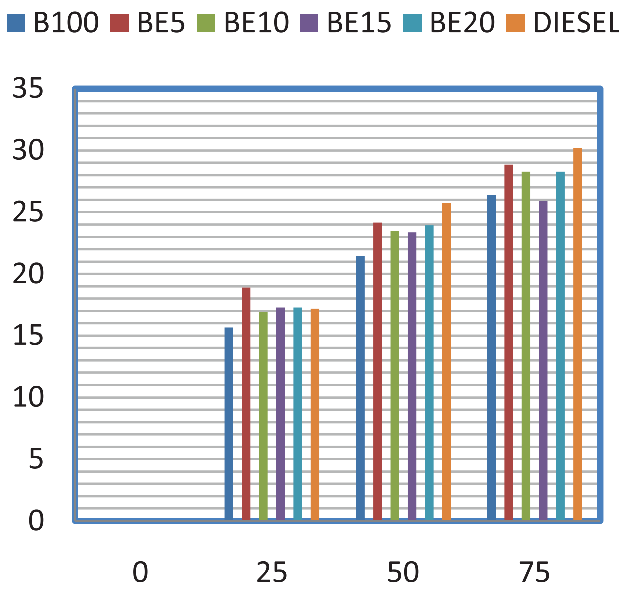

FIG. 4 BRAKE THERMAL EFFICIENCY(BTE%) V/S LOAD **(%)**

The Figure 4 shows the variation of BTE at different loads for neat biodiesel, biodiesel-ethanol blends and diesel. From the figure, we observed that, as the load increases, the BTE also increases for all fuel modes. The lowest BTE is observed for B100 & the reason may be due to its lower volatility, higher viscosity etc, which results in poor atomisation and poor combustion. Among biodiesel-ethanol blends the highest BTE is observed for BE5 i.e. with the addition of 5% ethanol in biodiesel and the reason may be due to high volatility and flammability of ethanol. For remaining higher percentage alcohol blends BE10, BE15 & BE20 decrease of thermal efficiency is observed, the reason could be the phase separation of alcohol in biodiesel which leads to cavitation problem. The BTE of BE5 was slightly less than diesel by about 4.5% at 75% load. However it is best matching with the diesel fuel with regard to brake thermal efficiency compared to neat biodiesel and its alcohol blends.

3.1.2 Brake Specific Fuel Consumption

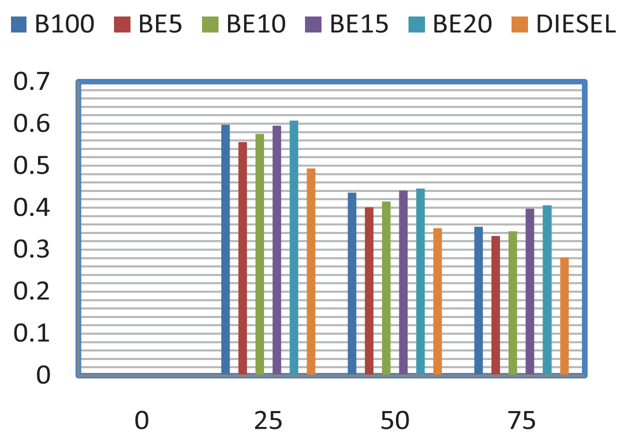

FIG. 5 BRAKE SPECIFIC FUEL CONSUMPTION (BSFC) (kg/kwh) V/S LOAD(%)

The variation of brake specific fuel consumption (BSFC) with respect to load is shown in the Figure 5. From the figure, it is observed that as the load increases, the BSFC decreases for all tested fuel samples. Among biodiesel-ethanol blends and neat biodiesel the lowest BSFC is observed for BE5 as well as BE10. The BSFC increased with further increase of ethanol percentage in the biodiesel at all loading conditions of engine. It is due to the lower heating values of ethanol compared to biodiesel. The higher percentage of highly oxygenated ethanol blending in biodiesel leads to leaner combustion resulting in higher BSFC. However BSFC values for BE5 and BE10 are comparable to diesel and for BE5 it is 18.3% more than diesel at high load.

3.1.3 Exhaust Gas Temperature

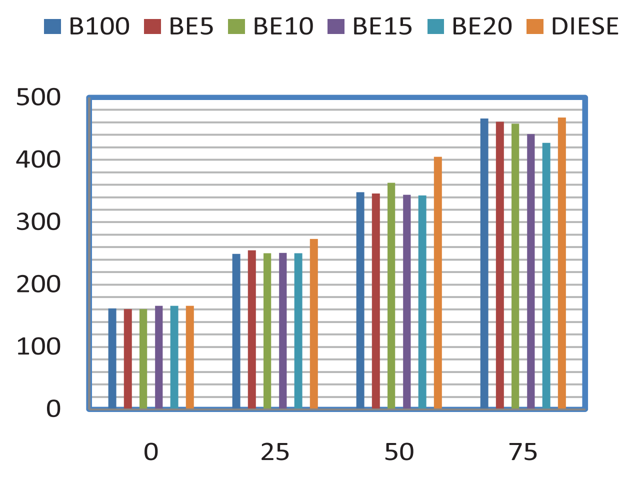

FIG. 6 EXHAUST GAS TEMPERATURE (°C) V/S LOAD (%)

The Figure 6. Shows the effect of increase in load on the exhaust gas temperature for neat biodiesel, biodiesel-ethanol blends and diesel. From the figure, it is seen that the EGT increases with increase in load for all fuel samples. The EGT for diesel is higher in comparison to other tested fuels. Other than diesel the highest EGT is observed for B100 at higher percentage of loads and as the ethanol percentage increases in the biodiesel, the EGT decreases the reason could be high evaporative heat and low heating values of ethanol, which takes off the heat from combustion space.

3.1.4 *Carbon-monoxide Emission*

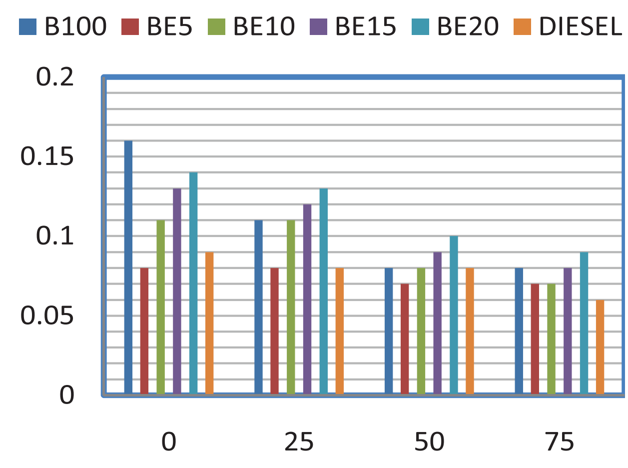

FIG. 7 CARBON MONOXIDE EMISSION (%) V/S LOAD(%)

The variation of CO emissions with increase in load for different fuel samples is shown in the Figure 7. The CO emission decreases with increase in load for all the fuels. From the figure, we noticed that at 75% loading, compared to diesel the CO emission is 33.33% higher for biodiesel due to incomplete combustion caused by high boiling point, lower flammability and high flash and fire points associated with B100. When ethanol is added to biodiesel it is observed that lowest CO emission takes place for BE5 and it is only 16% more than diesel and highest for BE20. The addition of high percentage of alcohol in the biodiesel increases the CO emission & it is due to the fact that the incomplete combustion due to the phase separation of high percentage of alcohol in the biodiesel.

3.1.5 *Hydro-Carbon Emissions*

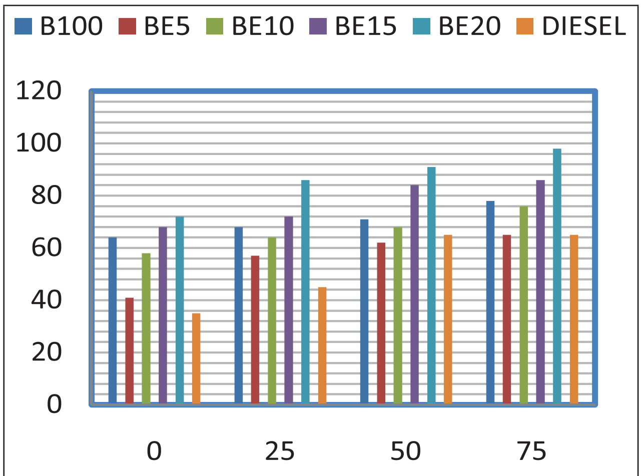

FIG. 8 HYDROCARBON EMISSION (ppm) V/S LOAD(%)

The variation of emission of HC with respect to load for biodiesel, biodiesel-ethanol blends and neat diesel is shown in Figure 8. From the figure we observed that the HC emission increases with increase in load and lowest HC emissions were observed for BE5 and then for BE10 compared to neat biodiesel. The HC emissions increased with further increase of ethanol percentage in the biodiesel. This may be due to the fact that there is some unburned ethanol emitted in the exhaust due to the larger ethanol dispersion region in the combustion chamber. Among biodiesel based fuels the emission of HC with respect to BE5 is satisfied and it is comparable to diesel.

3.1.6 *Carbon-Dioxide Emission*

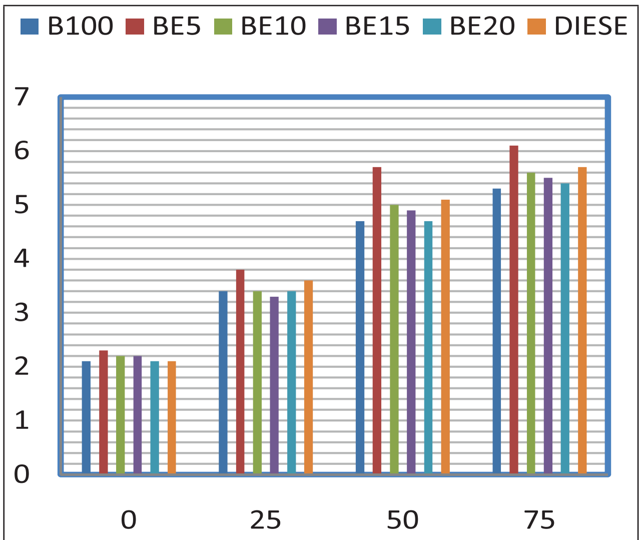

FIG. 9 CARBONDIOXIDE EMISSION(%) V/S LOAD(%)

Figure 9 shows the variation of emission of CO_2 with increase in percentage of load. The figure revealed that the CO_2 emission increases with increase in load. Compared to diesel the CO_2 emissions for biodiesel is lower and the reason could be the poor combustion associated with B100 due to lower volatility and flammability. When biodiesel based fuels are seen the lowest CO_2 emissions were observed for B100 & CO_2 emissions increased with increase in ethanol percentage up to 10% in biodiesel and the reason could be the better combustion of biodiesel in presence of ethanol due to its high volatility and shorter ignition delay and the CO_2 emission for BE5 is even better than that of diesel by about 7% at high load.

3.1.7 Oxides-of-Nitrogen Emission

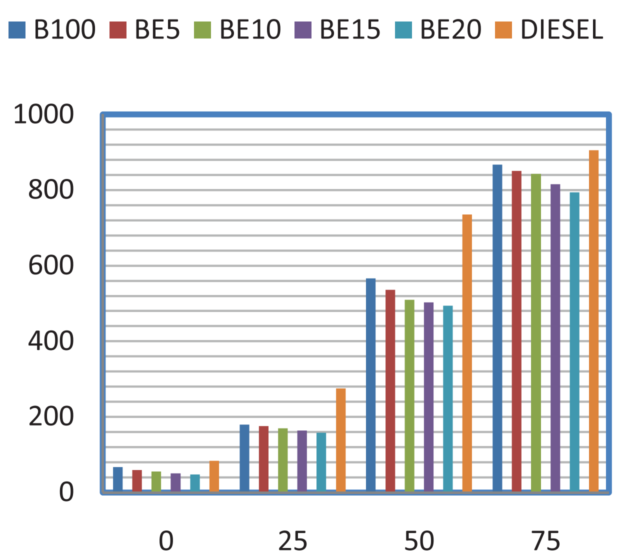

FIG. 10 OXIDES OF NITROGEN EMISSION (ppm) V/S LOAD(%)

Figure 10 shows the trend of NO_x emission at different loads. From the figure we observed that the NO_x emissions increased with increase in load for all fuel modes. Among diesel and biodiesel, biodiesel emitted less No_x and the reason may be low combustion temperature associated with biodiesel which also leads to lower exhaust gas temperature compared to diesel as observed in Figure 4. The addition of ethanol in the biodiesel again decreases NOx emissions and the lowest value is observed for BE20. The reason may be low combustion temperature on addition of ethanol to the biodiesel.

3.1.8 Unused Oxygen Emission

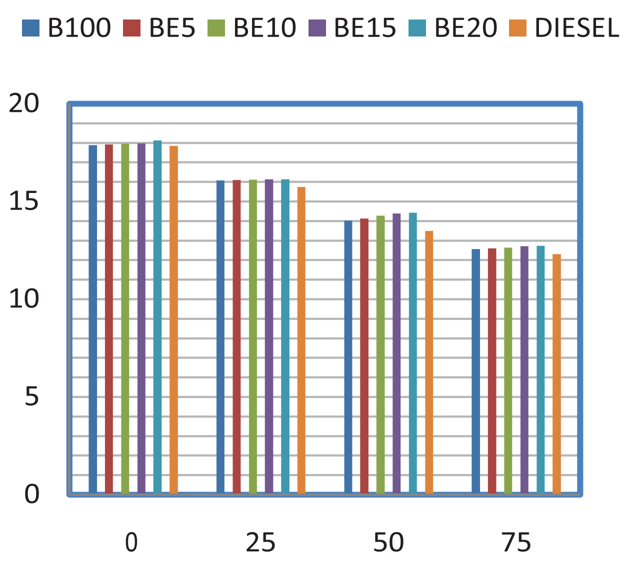

FIG. 11 UNUSED OXYGEN EMISSION (%) V/S LOAD(%)

The variation of unused oxygen emission with respect to load for tested fuels is plotted in Figure 11. From the figure we observed that the unused oxygen emissions reduced with increase in load for all fuels. The oxygen emission for biodiesel is slightly more than diesel and the reason may be due to incomplete oxidation and high oxygen content associated with the biodiesel. Oxygen emissions increased slightly with increase in ethanol addition in biodiesel and there is no significant variation in percentage of oxygen for all fuel samples.

3.1.9 Selection of optimized Biodiesel-Alcohol blend

From the performance and emission characteristic graphs plotted above for variety of biodiesel based fuel samples it has been observed that the biodiesel-alcohol blend BE5 is showing significant results with respect to brake thermal efficiency, BSFC and major emission parameters. Hence, this blend was selected as the optimum blend for further investigations and long-term operation. In the following section the blends BE5 is compared with fossil diesel and neat biodiesel with regard to Smoke opacity and maximum pressure rise. The results were discussed as follows.

3.1.10 Smoke Opacity

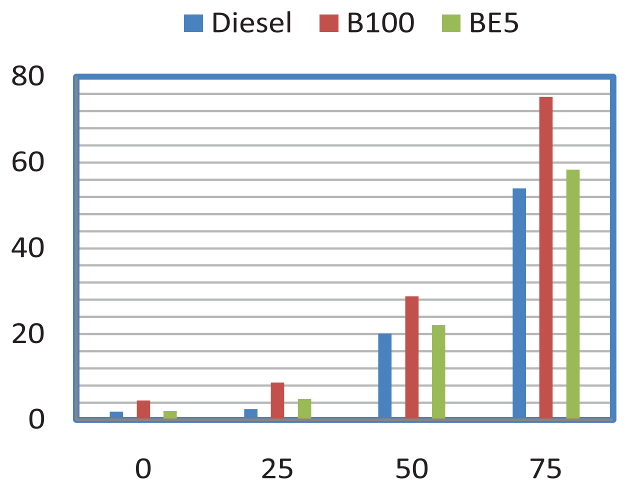

FIG. 12 SMOKE OPACITY (%) V/S LOAD(%)

The Figure 12 shows the variation of smoke opacity of diesel, biodiesel and optimised biodiesel-alcohol blend BE5 at different loads. From the figure, it is observed that, as the load increases, the smoke emission increases. This is due to the consumption of higher quantity of fuel at higher loads. The smoke emission of biodiesel is higher than the diesel by about 39% at final load. This is due to poor volatility and higher viscosity of the biodiesel which results in poor combustion thereby increasing the products of incomplete combustion. However, smoke opacity of BE5 is 29% lower than neat honge biodiesel and only 7.9% more than diesel at high load. This is because viscosity of BE5 was brought less than biodiesel and volatility increases with the addition of alcohol to biodiesel which leads to better combustion results in less smoke.

3.1.11 Pressure-Rise

The Figure 13 shows the variation of maximum pressure rise with respect to different loads. From the figure we observed that P_{max} increases with increase in percentage of load for all fuel samples. It has been observed that the minimum pressure rise was observed for diesel compared to B100, BE5. This is due to the fact that, in a CI engine, the peak pressure depends on thecombustion rate in the initial stages, which is influenced by the amount of fuel taking part in theuncontrolled combustion phase, which in turn governed by the delay period. Thus, the slight higher viscosity and poor volatility of the biodiesel fuels results in lower peak pressure and maximum rate of pressure rise as compared to neat diesel. Also when alcohols are burnt it forms more moles of exhaust gases which gives higher pressure.

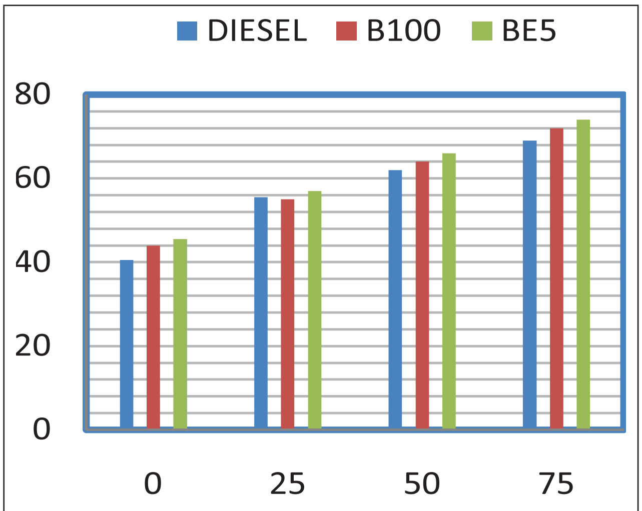

FIG. 13 MAXIMUM PRESSURE RISE, P_{MAX}(BAR) V/S LOAD (%)

4.0 CONCLUSION

Based on the performance and emission tests on the diesel engine, the following conclusions are drawn.

1. The biodiesel can be produced from high fatty acid honge oil by a two-step transesterfication. The biodiesel yield from this method is 91%.
2. The transesterfication reduces the viscosity of the oil drastically.
3. The honge biodiesel properties are close to the diesel and satisfy the ASTM fuel specifications.
4. As the fuel viscosity of honge biodiesel oil is higher than that of diesel, the engine results in lower brake thermal efficiency and higher emissions due to its lower volatility.
5. The experimental results showed that, among the biodiesel-ethanol blends studied BE5 is showing significant results with respect to brake thermal efficiency, BSFC & major emission parameters and which are nearly comparable to the fossil diesel and better than neat biodiesel.

6. The addition of higher percentage of alcohol (Ethanol) in biodiesel leads to higher BSFC, lower BTE and higher exhaust emissions due to the lower calorific value of ethanol and phase separation problem as it can observed in oil bath test of biodiesel-ethanol blends.
7. Smoke opacity of BE5 is slightly lower than neat Honge biodiesel due to better combustion process.
8. The higher volatile renewable substances such as ethanol can be blended with biodiesel, to improve the engine performance. The blend BE5 can be used in an existing diesel engine without any modification of the engine, for better performance and lower emissions. With the current diesel fuel price rise, this would be definitely economical.
9. From the overall study of performance as well as emission characteristics of diesel, biodiesel and biodiesel-ethanol blends, we can conclude that the addition of lower percentage of ethanol in honge biodiesel as in BE5 is appreciable and can be successfully used as alternative to the fossil diesel.

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