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Engine Performance and Emission Characteristics of a Direct Injection Diesel Engine Fuelled with 1- Hexanol as a Fuel Additive in Mahua Seed Oil Biodiesel Blends

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Abstract

The increasing industrialization and motorization of the world has led to a steep rise for the demand of petroleum products. Petroleum based fuels are obtained from limited reserves. In the wake of this situation, there is an urgent need to promote use of alternative fuel which must be technically feasible, economically competitive, environmentally acceptable and readily available. In the present study, Mahua seed oil methyl esters (MSOME) were prepared through transesterification and evaluation of important physico-chemical properties was carried and the properties were found within acceptable limits. A compression ignition engine was fuelled with three blends of MSOME with diesel (10, 20 and 30% on volume basis) and various performance and emission characteristics were evaluated and results compared with baseline data of diesel. The results suggest the BTE was higher for MSOME blends and BSFC, HC and smoke opacity were lower as compared to diesel fuel. This may be attributed to improved combustion for MSOME are oxygenated fuels and have higher cetane number. The values of NOx were found almost nearer for all blends as compared to diesel. Addition of 1-hexanol (Ignition improver) 0.5%, 1% volume ratios to the optimum blend (MSOME30) for evaluating the engine performance and emissions parameters and the main purpose of ignition improver is to improve combustion process and reduction in engine emissions. Finally results shows that performance and emissions have been to justify the potentiality of the mahua seed oil methyl esters as alternative fuel for compression ignition engines without any modifications.

Keywords: *Mahua seed oil, Transesterification, Bio-diesel, Methanol, NOx*

1. Introduction

Energy is key input for technological, industrial, social and economical development of a nation. Five generations (125 years) ago, wood supplied up to 90% of our energy needs. Due to the convenience and low prices of fossil fuels wood use has fallen globally [2]. Sesame oil at lower blends of biodiesel creased the brake thermal efficiency and reduced the fuel consumption. In addition to this, biodiesel blends produce lower engine emissions than diesel. [3]The present energy scenario now is heavily biased towards the conventional energy sources such as petroleum products, coal, atomic energy etc, which are finite in nature besides causing environmental pollution. Of the available energy, the present energy utilization pattern is heavily biased for meeting the high energy requirement in urban and metropolitan cities. There is growing interest in biodiesel (fatty acid methyl ester or FAME) because of the similarity in its properties when compared to those of diesel fuels. Punnakka oil, non-edible oil available in India, was esterified to produce biodiesel. The procedure involves a two stage process, acid esterification and alkaline esterification. The oil contains high free fatty acid (FFA) content of 19.8%. The acid value of the oil was reduced by acid esterification [4]. The product from this stage was subjected to alkaline esterification to produce biodiesel. The effects of important parameters like methanol to oil ratio, reaction temperature, catalyst concentration and reaction time were studied and optimum conditions were established. A conversion efficiency of 92.5% was obtained with

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the optimized reaction conditions. The viscosity and other measured properties are within Diesel engines operated on biodiesel have lower emissions of carbon monoxide, unburned hydrocarbons, particulate matter, and air toxics than when operated on petroleum-based diesel fuel. Production of fatty acid methyl ester (FAME) from rapeseed (non-edible oil) fatty acid distillate having high free fatty acids (FFA) was investigated. Experiments related tp tobacco seed oil methyl ester (TSOME) blended with diesel could be conveniently used as a diesel substitute in a diesel engine. The test further showed that there was an increase in brake thermal efficiency, brake power and reduction of specific fuel consumption for TSOME and its blends with diesel[6].Keeping in view of above, there is a need to find out variety of alternate fuels to fulfill the ever increasing energy demand of the world without causing environmental degradation. The extensive use of energy operated devices in domestic, industrial, transport and agricultural sectors in urban and rural areas have resulted in overall economical development of the society. The electricity available for farming operations and in rural and urban areas is been generated using the fossil and static energy resources such as petroleum oil, coal and atomic energy and to a limited extent by hydropower [7]. These all sources have a great influence on our economy and environmental aspects. These have resulted in serious considerations for the use and availability of various energy resources. Biodiesel is an oxygenated, renewable, biodegradable and environmentally friendly bio-fuel with low emission profile[12]. Pure coconut oil usage in diesel engine shows lesser smoke, carbon monoxide (CO), hydrocarbons (HC) emissions compared to diesel fuel since it has oxygen molecules which results in enhanced oxidation [13].Also, neat vegetable oil usage tends to create operational and durability problems for long-term operation in diesel engine. From the review of literatures, numerous works in the utilization of biodiesel as well as its blends in engines have been done. However, most of the literatures focused on single biodiesel and its blends. From literature studies, it is evident that single biodiesel offers acceptable engine performance and emissions for diesel engine operation.These problems can be solved by converting vegetable oil into biodiesel as it has similar characteristics like diesel fuel. The present study is focused on mahua seed oil.

1.1 Mahua seed oil:

Two major species of the genus Madhuca indica and Madhuca long folia are found in India. These two are so closely related that no distinction can be made in the trade of their seed or oil. The dryings and decortification yield 70% kernel on the weight of seed. The kernel of seed contains about 50% oil. The oil yields in an expeller are nearly 34%-37%. The fresh oil from properly stored seed is yellow in color. Mahua Oil (MO) is an underutilized non-edible vegetable oil, which is available in large quantities in India. The fuel properties of the MO Oil biodiesel were found to be within the limits of biodiesel specifications of many countries. Fuel properties of diesel, mahua oil and blends are comparable. The calorific value of mahua oil was found as 96.30% on volume basis of diesel. It was found that mahua could be easily substituted up to 20% in diesel without any significant difference in power output, brake specific fuel consumption and brake thermal efficiency. The performance of engine with mahua oil blends improved with the increase in compression ratio from 16:1 to 20:1. Based on this study, it has been observed that esters of mahua oil could be used as a substitute for diesel. Mahua crop cultivation will have following advantages: i) Erosion control ii) Soil improvement iii) Poverty reduction iv) Renewable energy.

Fig: 1. Mahuaseed crop and seeds

1.2 Mahua Seed Oil Methyl Esters

Among the non-edible seeds produced in India, Mahua is one of the preferred seed because of its oil content and biodiesel yield. The research work related to the use of methyl esters obtained from the mahua oil in direct injection engines established different results. However the availability of seed is limited, discouraging the use of biodiesel [9, 10].As the availability of mahua seed is found to be less at this time, a certain percentage of biodiesel can be replaced by some other second generation biofuels such as methanol which is commonly used in transesterification. In this process catalysts such as KOH or NAOH are used to increase the reaction to quickly break the triglycerides into glycerol and methyl esters. So, far the major focus on biodiesel research has been mainly of transesterification process. Two distinct layers are formed, the lower layer is glycerin and the upper layer is ester. The upper layer (ester) is separated and moisture is removed from the ester by using calcium chloride. It is observed that 90% ester can be obtained from vegetable oils. The products of the reactions are the biodiesel itself and glycerol. The chemical reactions of biodiesel are shown in below.

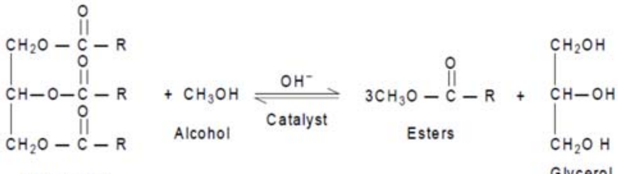

Fig: 2. Equipment for Constant Heating

Fig: 3. Process Of Separation

Table1. Properties of MSOME and Diesel Fuel:

S.No	Type of Oil	Notation	Specific Gravity	Calorific alue KJ/kg)	Kinematic Viscosity cst)	Flash Point C	Fire Point C
1.	iesel	100	.830	2500	.05	6	3
2.	ahuaseed Oil Crude	100	.924	7614	9.45	30	46
3	lends With Bio-Diesel MSOME)	10	.838	2210	.8	29	41
		20	. 847	1920	.2	33	45
		30	.856	1630	.8	37	49

2. Experimental Setup and Procedure

Experimental set up consists of a water cooled single cylinder vertical diesel engine coupled to a rope pulley brake dynamometer arrangement it shown in figure 4 , to absorb the power produced necessary weights and spring balances are induced to apply load on the brake drum suitable cooling water arrangement for the brake drum is provided. A fuel measuring system consists of a fuel tank mounted on a stand, burette and a three way cock. Air consumption is measured by using a mild steel tank which is fitted with an orifice and a U-tube water manometer that measures the pressures inside the tank. The smoke opacity of the exhaust gases was measured by the NETEL make smoke meter. The exhaust emissions were measured by the NETEL make five gas analyzer.

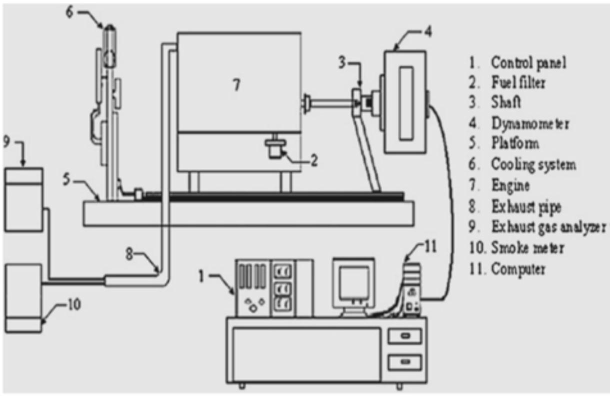

Fig 4. Schematic View of Testing Apparatus

Table 3. Engine Specifications

BHP	5HP
Speed	1500rpm
Bore	80mm
Stroke	110mm
Compression ratio	16.5:1
Orifice diameter	17mm
Method of start	Crank start
Make	Kirloskar
Type of Ignition	Compression Ignition

3. Results and Discussion

The experiments are conducted on the four stroke single cylinder water cooled diesel engine at constant speed (1500 rpm) with varying 0 to 100% loads with diesel and different blends of MSOME like B5, B10, B20 and B30 .

The performance parameters such as brake thermal efficiency and brake specific fuel consumption were calculated from the observed parameters and shown in the graphs. The other emissions parameters such as exhaust gas emissions such as Carbon monoxide, hydrocarbons, and oxides of nitrogen, carbon dioxide, unused oxygen and smoke were represented in the form of graphs from the measured values. The variation of performance parameters and emissions are discussed with respect to the brake power for diesel fuel, diesel-biodiesel blends and obtained optimum blend are discussed in below. Fuel additive such as 1-Hexanol is added to the optimum blend in different proportions for improving the performance parameters and reducing the emissions as discussed below.

3.1 Brake Thermal Efficiency:

The variation of brake thermal efficiency with brake power for different fuels is presented in Fig 5. In all cases, it increased with increase with brake power. This was due to reduction in heat loss and increase in power with increase in load. The maximum thermal efficiency for M30 at full load 33.49% was higher than that of diesel (32.82%). Increase in thermal efficiency due to %of oxygen presence in the biodiesel, the extra oxygen leads to causes better combustion inside the combustion chamber. The thermal efficiency of the engine is improved by increasing the concentration of the biodiesel in the blends and also the additional lubricity provided by biodiesel. The reason may be the leaner combustion of diesel and extended ignition delay resulting in a large amount of fuel burned.

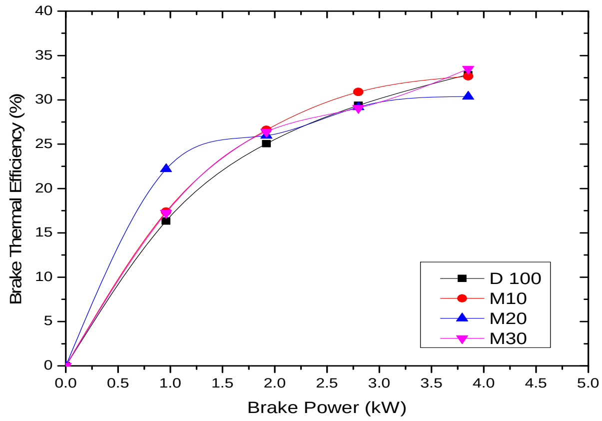

Fig. 5 Variation of Brake Thermal Efficiency with Brake Power

3.2 Brake Specific Fuel Consumption:

The variation in BSFC with brake power for different fuels is presented in figure 6. Brake-specific fuel consumption (BSFC) is the ratio between mass fuel consumption and brake effective power, and for a given fuel, it is inversely proportional to thermal efficiency. BSFC decreased sharply with increase in brake power for all fuels. The main reason for this could be that the percent increase in fuel required to operate the engine is less than the percent increase in brake power, because relatively less portion of the heat is lost at higher loads.

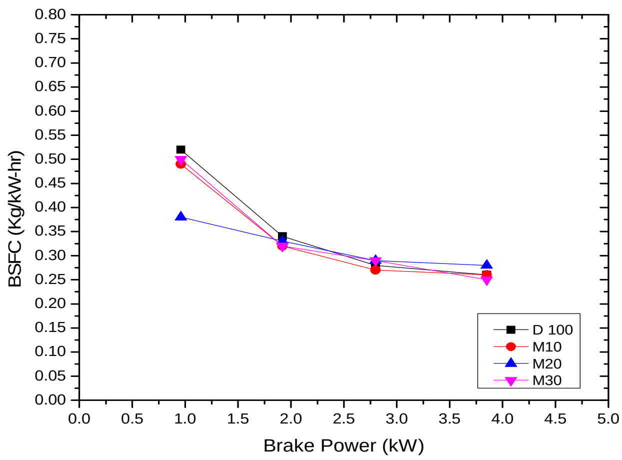

Fig 6. Variation of Brake Specific Fuel Consumption with Brake Power

3.3 Carbon Monoxide:

The comparison of carbon monoxide for various biodiesel blends with respect to brake power shows in Fig. 7 .Carbon monoxide (CO) occurs only in engine exhaust, it is a product of incomplete combustion due to insufficient amount of air or insufficient time in the cycle complete combustion. In diesel engine combustion takes places normally at higher A/F ratio, therefore sufficient oxygen is available to burn all the carbon in the fuel fully to CO2 it was noticed that CO emission of 0.07%vol for diesel and 0.06%vol same for all M10,M20and M30. For MSOME carbon monoxide emission level is lower than that of diesel, in order to gives 10% to 20% extra oxygen. Due to the presence of extra oxygen, additional oxidation reaction takes place between O2 and CO .The decreased CO emissions is 14.28% than diesel fuel for M30 at full load.

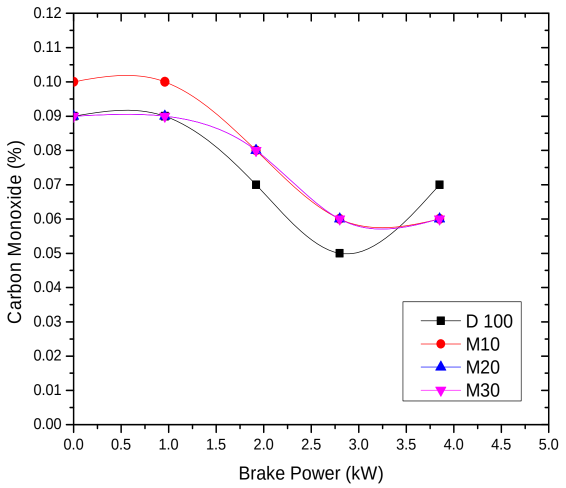

Fig 7. Variation of Carbon Monoxide with Brake Power Using MSOME Blends

3.4 Oxides of Nitrogen:

Variation of NOx with engine brake power for different fuels tested is presented in Fig. 8. The nitrogen oxides emissions formed in an engine are highly dependent on combustion temperature, along with the concentration of oxygen present in combustion products. The amount of NOx produced for M30 is 1210ppm, where as in case of diesel fuel is 1236 ppm for diesel fuel. From figure it can be seen that an increasing proportion of biodiesel in the blends was found to reduce NOx emissions 2.10% for M30 at full load, when compared with that of diesel. Out of these M20 shows minimum amount of oxides of nitrogen 1177ppm at full load.

This may be due to less combustion temperature inside the cylinder at higher load. In general, the NOx concentration varies linearly with the load of the engine. As the b power increases, the overall fuel-air ratio increases, resulting in an increase in the average gas temperature in the combustion chamber, and hence NOx formation increase.

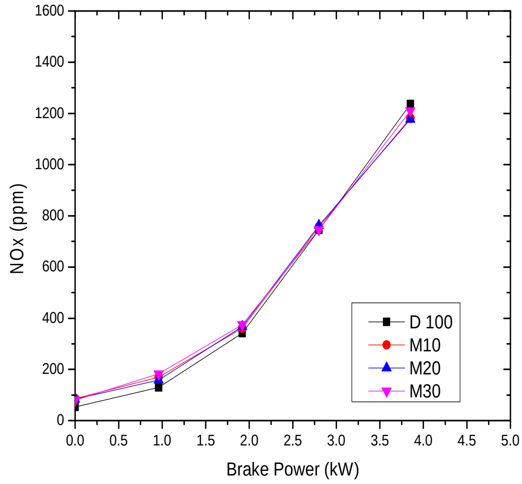

Fig 8. Variation of Oxides of Nitrogen with Brake Power Using MSOME Blends

3.5 Hydro carbons:

The hydrocarbons (HC) emission trends for blends of methyl ester of mahua seed oil and diesel are shown in Fig 9. That the HC emissions decreased with increase in brake power for all biodiesel blends (M10, M20, and M30) at all loads. But in case of diesel fuel HC emissions are increases with load, because of there is no oxygen content present in diesel fuel. At full load diesel contains 58 ppm where as in case of M20 it is 40ppm at same load. So there is a reduction from 58 ppm to 40ppm, these reductions indicate a more complete combustion of the fuel. The presence of oxygen in the fuel was thought to promote complete combustion.As the Cetane number of ester based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low HC emission. Also the intrinsic oxygen contained by the biodiesel was responsible for the reduction in HC emission.

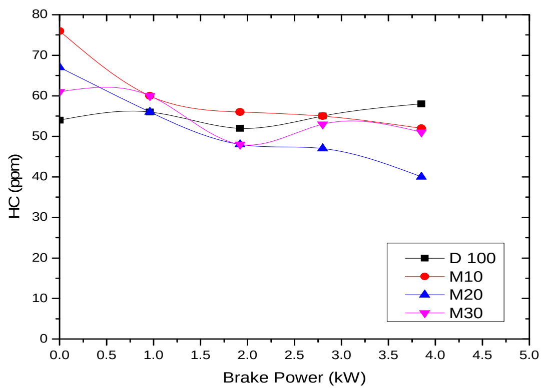

Fig 9. Variation of Hydro carbons with Brake Power Using MSOME Blends

3.7 Smoke Density:

The variation of Smoke density emissions with brake power for diesel fuel, biodiesel-blends is shown in Fig 10. The smoke is formed due to incomplete combustion in engine.The smoke density is lower for M10 and M20 compared to M30 and D100.The maximum smoke density recorded for the diesel was 79.6HSU, 56.57 HSU for M10, 56.76 HSU for M20 and 63.90

HSU for M30 at maximum load. The decrease in smoke density of M10, M20and M30 is 28.93%, 28.69% and 19.72% respectively compared with diesel fuel at full load. In case of MSOME, the smoke emission is low. This is because of better combustion of MSOME. The smoke density increased with the load for diesel fuel and diesel blends. The smoke opacity of the pure biodiesel was higher than those of all the other fuels used generally. Smoke opacity of the blendsM10,M20 and M30 were lower than those of the diesel fuel at all loads on the engine.

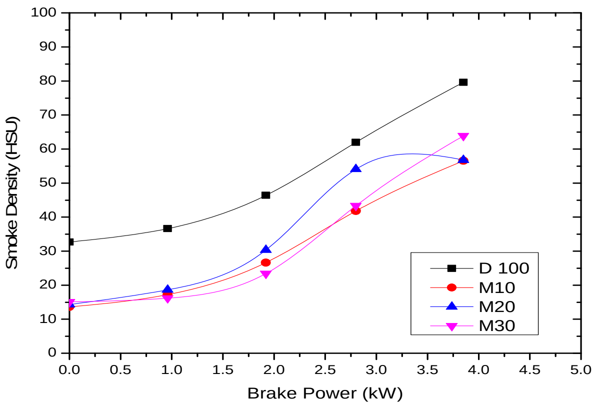

Fig 10. Variation of Smoke Density with Brake power using msome blends

4. Performance and Emission Analysis for M30 with Ignition Improver (1-hexanol):

For the obtained optimum blend (M30), 1-hexanol is added as a fuel additive. The main purpose of Ignition improver is to improve the combustion rate, reduce the emissions and increase brake thermal efficiency due to presence of oxygen in chemical structure. It was added as 0.5% and 1% by volume to the blend M30.The single cylinder water-cooled CI engine at rated speed of 1500 rpm was tested to evaluate its performance under variable load conditions with diesel fuel. The plots of performance results and emissions are shown in bellow.

4.1 Brake Thermal Efficiency:

The variation of brake thermal efficiency with brake power for different fuels is presented in Fig 11. In all cases; it is increased with increase in brake power. BTE of diesel at full load is 32.82% while the blends of M30 are 33.49%, M30D69.5H0.5 is 34.03%, and M30D69H1 is 34.57%, among the three the maximum break thermal efficiency is obtained for M30D69H1. The BTE of bio-diesel is increases up to 3.22% as compared with optimum blend at full load condition. The increment in brake thermal efficiency due to better combustion because of adding ignition improver it effects to decrease the viscosity and due to increase %of oxygen presence to the biodiesel-diesel blend, the extra oxygen leads to causes better combustion inside the combustion chamber.

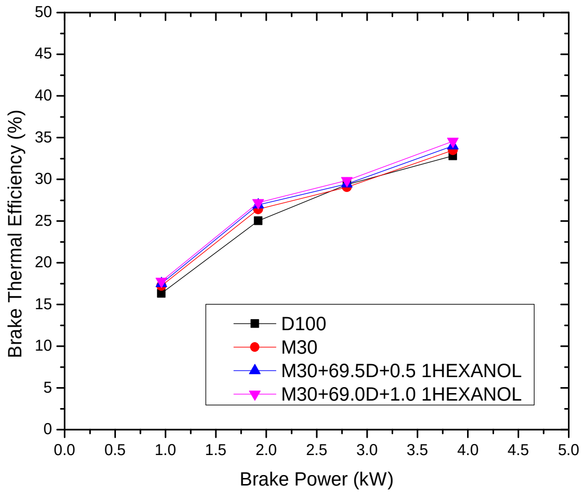

Fig 11. Variation of Brake Thermal Efficiency with Brake Power Using Ignition Improver

4.2 Brake Specific Fuel Consumption

The variation of brake specific fuel consumption with brake power is shown in Fig. 12. BSFC decreased sharply with increase in brake power for all fuels. The main reason for this could be that the percent increase in fuel required to operate the engine is less than the percent increase in brake power, because relatively less portion of the heat is lost at higher loads.
It can be observed that the BSFC of 0.26kg/kW-hr were obtained for diesel, 0.258kg/kW-hr for M30, 0.25kg/kW-hr forL30D69.5H0.5 and0.24kg/kW-hr forL30D69H1.Out of these M30D69H1 shows less BSFC.As the percentage of 1-hexanol is increased, mass flow rate is not affected. BSFC is constant for all the blends and these are decreased 7.69% compared to diesel fuel at full load for M30D69H1.

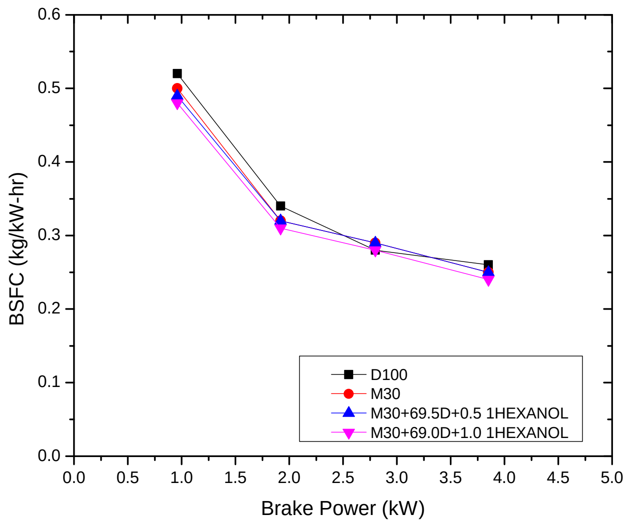

Fig 12. Variation of BSFC with Brake Power Using Ignition Improver

4.3 Carbon Dioxide Emissions (CO_2):

The variation of CO_2 emission with brake power is shown in Fig. 13. The plot it is observed that the CO_2 emission increased with increase in load for all blends. Blends M30, M30D69.5H0.5and M30D69H1emit low emissions8.70%, 5.6%, 4.9% respectively compared with diesel fuel 8.5% at full load condition. While using of ignition improver to optimum blend the CO_2 emissions are decreased by 35.63%, 43.67% compared with M30.Because of ignition improver contains oxygen itself. Using higher content biodiesel blends, an increase in CO_2 emission was noted, which is due to the high amount of oxygen in the specified fuel blends which converting CO emission into CO_2 emission contents

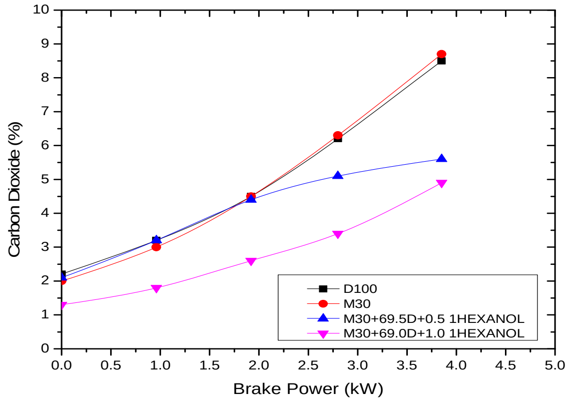

Fig 13. Variation of Carbon Dioxide with Brake Power Using Ignition Improver

4.4 Oxides of Nitrogen Emissions (NO_x):

The variation of NO_x emission with brake power is shown in Fig. 14. The plot it is observed that at full load diesel contains 1236 ppm, M30 contains 1210 ppm, M30D69.5H0.5 contains 709 ppm and M30D69H1 contains 630 ppm.The reduction in oxides of nitrogen with the ignition improvers was 41.40%, 47.93% than M30.The NO_x emission for all the fuels tested followed an decreased trend with respect to load.

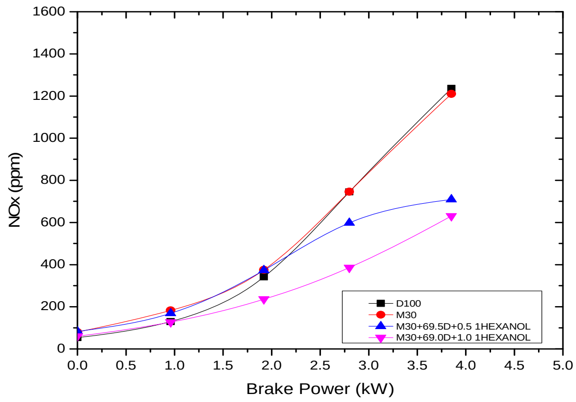

Fig 14. Variation of Oxides of Nitrogen with Brake Power Using Ignition Improver

4.5 Hydrocarbon Emissions (HC)

The variation of HC emission with Brake power is shown in Fig. 15. From the graphs it is observed that the HC emissions variations at different blends indicated. HC decreases with increase in load. At full load diesel contains 58 ppm, M30 contains 51 ppm, M30D69.5H0.5 contains 39 ppm and M30D69H1 contains 29 ppm. By these experimental observations it has observed that there is maximum decrease of unburned hydrocarbons taken place in M30D69H1. Out of these M30D69H1 shows lowest emissions than diesel fuel and M30 at full load. The decreased in HC emissions ofM30D69.5H0.5, M30D69H1 was 23.52%, 43.13% compared with M30. It is due maximum possible combustion takes place while using ignition improver to optimum blend.

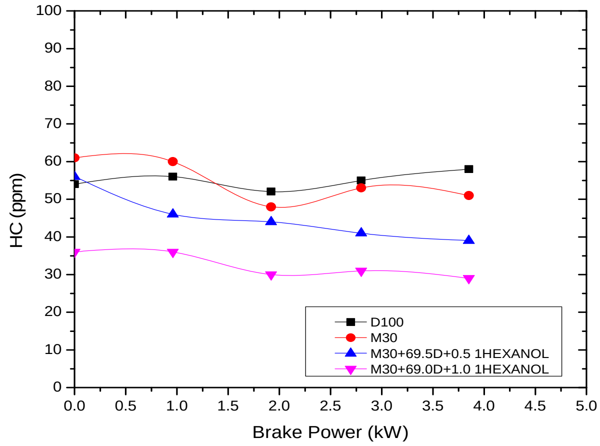

Fig 15. Variation of Hydro Carbons with Brake Power Using Ignition Improver

5. Conclusion

The performance and emission characteristics of conventional diesel, biodiesel blends and optimum blend with 1-Hexanol as fuel additive were investigated on a single cylinder diesel engine. The conclusions of this investigation are as follows:

- The brake thermal efficiency increases with increase biodiesel percentage. Out of all these, M30 shows best performance. The maximum brake thermal efficiency obtained is 33.49% in M30 blend.
- As a CI engine fuel, M30 blend results in an average reduction of 19.72% smoke density, CO emissions reduced by 14.28%, with a marginal decrease in NOx emission when compared with diesel. Brake specific fuel consumption is decreases in blended fuels. In M30 fuel the BSFC is lower than the diesel in 0.76%. Reductions in unburned hydrocarbon emissions were 12.06% compared to diesel.
- The highest decrease in CO emissions was obtained with M30 as 14.28% compared to diesel fuel. On the other hand, NOx emissions were decreased with M30 compared to diesel fuel. NOx emissions were decreased by 2.10% with M30 compared diesel.
- The ignition improver of 1-hexanol of 10ml shown the best performance in the sense of brake thermal efficiency and BSFC. The maximum brake thermal efficiency obtained is 34.57%.
- The increased amount of ignition improver to M30 blends increased, brake thermal efficiency, and decreased in emissions CO, CO_2, NO_x, HC observed. So that while using ignition improver to optimum blend its performance increased and emissions was decreased.

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