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Experimental Investigation on the Performance and Emission Characteristics of Mahua Biodiesel in Single Cylinder Di Engine

Taranjot Singh[1], Dr. Vineet Kumar[2]
1. M.Tech Student, Department of Mechanical Engineering, RBIEBT, Kharar
2. Associate Professor, Department of Mechanical Engineering, RBIEBT, Kharar

ABSTRACT-*Biodiesel derived from nonedible feed stocks such as Mahua, Jatropha, Pongamia, is reported to be feasible choices for developing countries including India. This presents the results of investigation of performance and emissions characteristics of diesel engine using Mahua biodiesel. In this investigation, the blends of varying proportions of Mahua biodiesel with diesel (M5, M10, M15) were prepared, analyzed, and the performance and exhaust emission with diesel using a single cylinder diesel engine. The brake thermal efficiency, brake-specific fuel consumption, CO and HC were analyzed. In the investigation it is found that the smoke, HC, EGT, Smoke and CO emission were lower in case of biodiesel as compared to diesel whereas EGT and* CO_2 *emission were higher for biodiesel and its blend than as compared to diesel.*

KEYWORDS: *Mahua biodiesel, performance, emission, combustion characteristics, Diesel engine*

I. INTRODUCTION

Now the day's fuel is most important part of human's life, in each and every field, fuel plays a crucial role. Fuel is used in transportation vehicles and in other machines as well. Conventionally fossil fuels like Petrol, Coal, Diesel, Kerosene, and LPG are used as fuels in majority. But as population of world increasing continuously day by day, amount of fuel consumption also increased with it. According to a survey, in one year population of New Delhi increased by 2% but with this number of vehicles in New Delhi increased by 24% [10]. From this data we can imagine the rate of increase of fuel consumption and also pollution produced by combustion of this fuel. These conventional fuels are made from non-renewable resources and cannot be used or produce again. With increase in population and use of fuel, demand of fuel is increasing day by day and its requirement is decreasing continuously. To avoid the extinction of conventional fuels, Non–conventional fuels are developed for use.

Mahua (MADHUCA INDICA)

Bio diesel from mahua seed is important it is found abundantly in tribal areas. The annual production of mahua is nearly 181 Kt [2]. Mahua is a non-traditional & non edible oil also known as Indian butter tree. Mahua seed contain 30-40 percent fatty oil called mahua oil**.** Mahua is a medium to larger tree. In India, Mahua plant is found in most of the state e.g. Orissa, Chhattisgarh, Jharkhand, Bihar, Madhya Pradesh, and Tamil Nadu. It can be sucessesfully grown in waste land & dry land. The tree is a strong light demander and gets readily suppressed under shade. The tree has potential of enhancing rural income. The tree may attain a height of up to 20 meters and is well adapted to varied weather conditions it has wide spreading ranches and circular crown which presents a visually appealing structure. The tree has a large spreading root system, though many of them are superficial. The fruit is a kind of berry, egg shaped. Mature seeds can be obtained during June to July. The mahua tree starts bearing seeds from seventh years of planning. Commercial harvesting of seeds can be done only from the tenth year. Seed yield ranges from 20 -200 kg per tree every year, depending on its growth and development. As a plantation tree, Mahua is an important plant having vital socioeconomic value. This species can be planted on roadside and canal banks on commercial scale and in social forestry programs, particularly in tribal areas. Wood can be used as timber, making pulp and paper. Mahua flowers are rich in sugar, minerals, vitamins and calcium. Table 1 show the comparison of different properties of the diesel and mahua oil and the Figure 1 shows the image of the mahua seed from which the oil is extracted and then further treated to obtain the bio diesel.

Fig.1 Photograph of Mahua Seeds

Table.1 Comparison of Properties of Diesel and Mahua Biodiesel [3]

Fuel	Viscosity mm^2/s at 40°C	Calorific value MJ/kg	Density kg/m^3 at 40°C	Flash point °C
Diesel	3.8	42.8	830	58
Mahua Biodiesel	5.6	36.1	918	207

Biodiesel Production

Transesterification process involves heating the mahua oil, from which the biodiesel fuel is extracted. When the temperature of approximate 65 to70°C. The oil is held in that temperature for certain period of time exactly 25 minutes. In this preparation, for 1000 ml of mahua oil, 250 ml of methanol and 30g of potassium hydroxide are added. The mahua oil chemically reacts with alcohol in the presence of a catalyst to produce methyl esters. After this the whole mixture is stirred for 1 hour. After completing the mixing stage, a separating flask allows the mixture to settle down. Separating and settling can be done on a single flask. When allowing the mixture to be in the flask for 24 hours the settling takes place where the glycerine gets settled down and esters get separated up. After separation of the methyl esters, it is washed in order to get clear solution of methyl esters, obtained by the spraying of distilled water over the solution which has already been separated and the moisture is removed. The complete process of transesterification is shown with help of flow in figure 2.

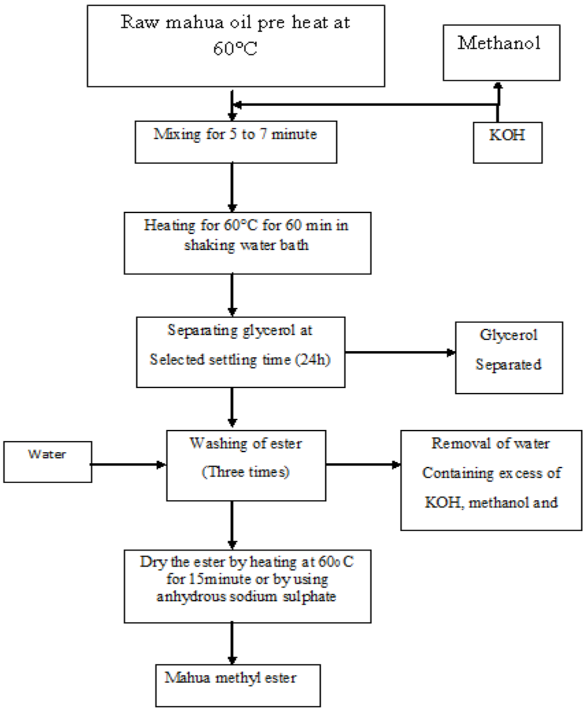

Fig.2 Flow Fig. of Biodiesel preparation from Mahua oil [10]

In the process, triglyceride present in oil reacts with an alcohol in the presence of strong acid or base, producing mixture of fatty acid methyl ester and glycerol. To start with the process about 7.5gm of Potassium hydroxide (KOH) is dissolve in 250ml methanol and stirred vigorously for 20 min in the covered container until the alkali is dissolve completely, forming Potassium hydroxide. The mixture is protected from atmospheric CO_2 and moisture, as both destroy the catalyst. Then 100ml of mahua oil was preheated on hot plate up to 55°C and then alcohol - catalyst mixture is then transferred into it. The mixture was turned into turbid orange brown colour with in the first few minutes and then it was changed to a clear transparent brown colour as the reaction is completed. The mixture again become somewhat turbid and orange due to the emulsified free glycerol formed during the reaction after lapse of 1 hr. The mixture was taken out and poured into a separating funnel soon the glycerol component of the mixture started settling at the bottom.Washed and soap free methyl ester i.e. biodiesel was then heated over 100° C so as to remove water content from it. For a highly converted batch of biodiesel the methanol will remain clear and no oil will settle down. A poorly converted batch of biodiesel will cause the methanol to cloud, and when it eventually settles down. Fig 3 shows the chemical reaction involved in the process of transesterification.

Vegetable oil (Transfatty acids) + Sodium or potassium methoxide $\rightarrow$ Methyl Ester (Bio-diesel) + Glycerine

$$\begin{array}{l} CH_2-OCOR \\ CH-OCOR \\ CH_2-OCOR \end{array} + 3\,CH_3OH \quad 3\,RCOOCH_3 + \begin{array}{l} CH_2-OH \\ CH-OH \\ CH_2-OH \end{array}$$

Fig.3 Chemical reaction during the process of transesterification

II. EXPERIMENTAL SET-UP

ENGINE DESCRIPTION

Diesel engine selected for the experimentation is the maker of the Kirloskar Oil Engines Limited, India. It is a single-cylinder; 4-stroke, air-cooled diesel engine of 6 HP rated power. Direct injection diesel engine that has been designed for petroleum diesel combustion. The fuel injector is located near the combustion chamber centre. The single cylinder diesel engine test rig consists of a generator machine coupled to a load cell and it is used to load the engine. The starting of the engine is done by manual cranking with the help of detachable pawl type handle. The fuel is supplied to the engine from the fuel tank through fuel filter after fuel measurement using burette. The pressure and temperature of the air supplied to the engine is also measured. The rotation is clock-wise facing the flywheel in the engine. A centrifugal governor is mounted to maintain the constant speed. The engine is properly balanced and flywheel is statically balanced for the smooth operation of the experimental work. Table.2 gives the specification of diesel engine used for the experiment.

Table.2 Specifications of the Diesel Engine

Engine manufacturer	Kirloskar Oil Engines Limited, India
Engine type	Vertical, Four-Stroke, Single cylinder, DI
Cooling	Air cooled
Dynamometer	Eddy current dynamometer
Rated power	4.5 KW at 1500 rpm
Bore/Stroke	80/110 (mm)
Compression Ratio	16.5:1
Injection pressure	200kg/cm^2
Engine weight (kg)	175

Parts of the Test Rig

1. Fuel tank
2. Burette (for fuel measurement)
3. Fuel filter
4. Air filter
5. Diesel engine
6. Generator
7. Load cell
8. Thermocouple
9. Emission gas analyzer

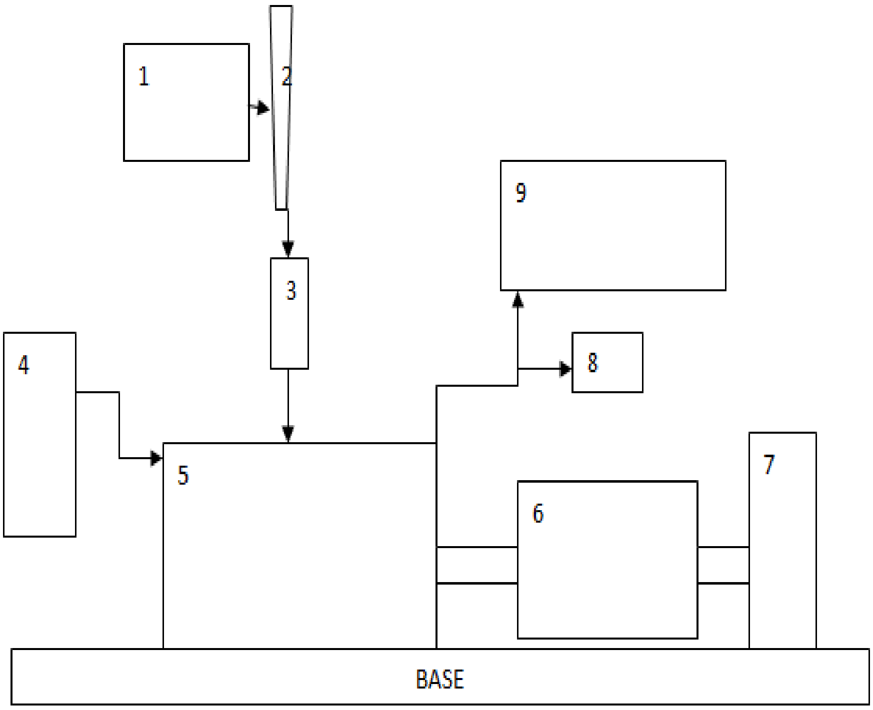

Fig.4 Schematic arrangement of the test rig (block diagram)

III. RESULT AND DISCUSSION

All tests were steady state and were set at constant engine speed 1500 RPM. To study the effects of mahua biodiesel and its blends with diesel, the engine was kept running at various loads with mahua biodiesel blend variation of 0 %, 5 %, 10 % and 15 %.

1. Performance Characteristics

The performance of an engine is evaluated on the basis of the following:

Brake Thermal Efficiency
Brake Specific Fuel Consumption.
Exhaust Gas Temperature

Effect on Brake Thermal Efficiency

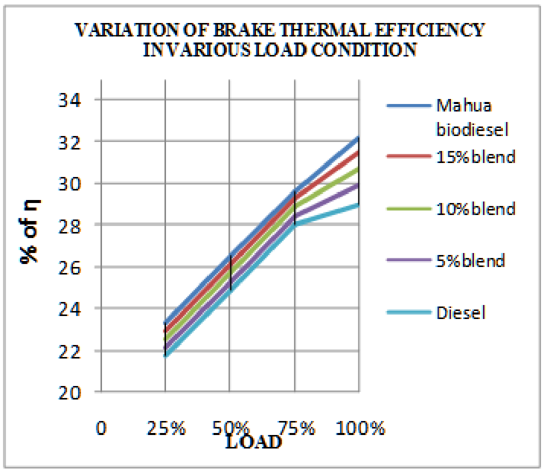

Fig.5 Variation of BTE

Figure 5 shows the variation of BTE with respect to load for diesel and mahua biodiesel blends. The BTE increases with increase in load for diesel as well as blends. The improvement is due to oxygen molecule preset in the biodiesel which leads to better combustion efficiency especially at higher loads. So, it is clear from the chart that the mahua gives good result in terms of BTE as compared to diesel and other blends.

Effect on Brake Specific Fuel Consumption

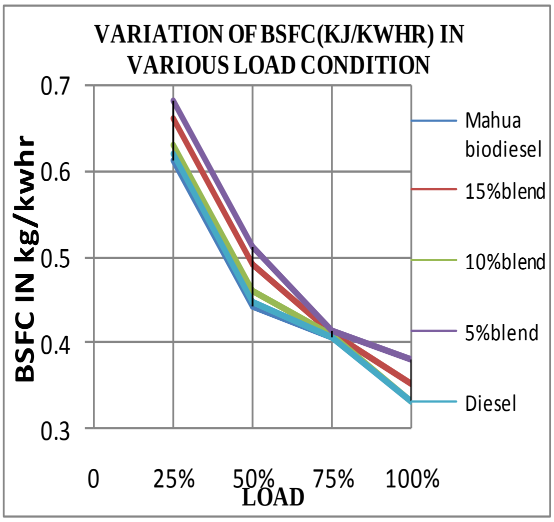

Fig.6 Variation of BSFC

It is observed from the figure 6 that the variation of BSFC with respect to load in the fuel consumption. It is observed from the figure that BSFC for all the fuel blends tested decrease with increase in load. This is due to higher percentage in Break power with load. For 10% blend, the BSFC is almost same as that of diesel. For blends with Oxygen fuel greater than 10%, the BSFC was observed to be greater than that of diesel. This could be due to the presence oxygen in the blend. Therefore the calorific value of diesel is higher than biodiesel. Therefore for the same power output more fuel is required in burning biodiesel and its blend.

Effect on Exhaust Gas Temperature

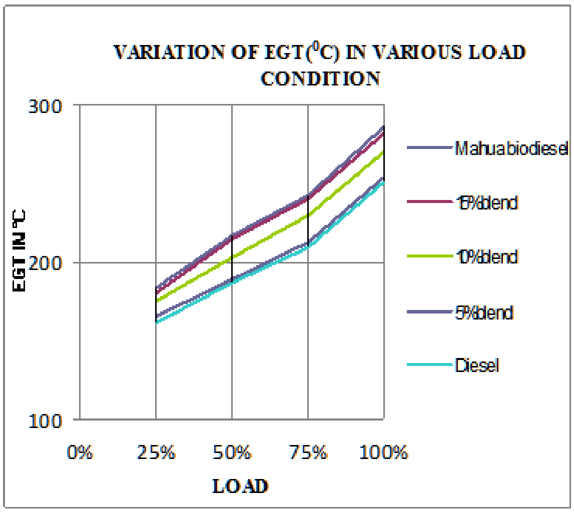

Fig.7 Variation of EGT

Figure 7 shows the variation of exhaust gas temperature (EGT) with respect to load. In general, the exhaust gas temperature increases with increase in the oxygen content. It can be seen from the figure that the variation of (EGT) increases with increase in load for diesel as well as biodiesel and its blend. This is due to the fact that at higher load more fuel is burnt which leads to higher temperature. It is also observed that biodiesel and its blend have higher EGT. This may be due to presence of oxygen molecule in the structure of biodiesel which leads to complete combustion and hence higher temperature.

2. Emission Characteristics

Smoke and other exhaust emissions such as oxides of nitrogen, unburned hydrocarbons, etc. is nuisance for the public environment. With increasing emphasis on air pollution control all efforts are being made to keep them as minimum as it could be. Smoke is an indication of incomplete combustion. It limits the output of an engine if air pollution control is the consideration.

Effect on CO

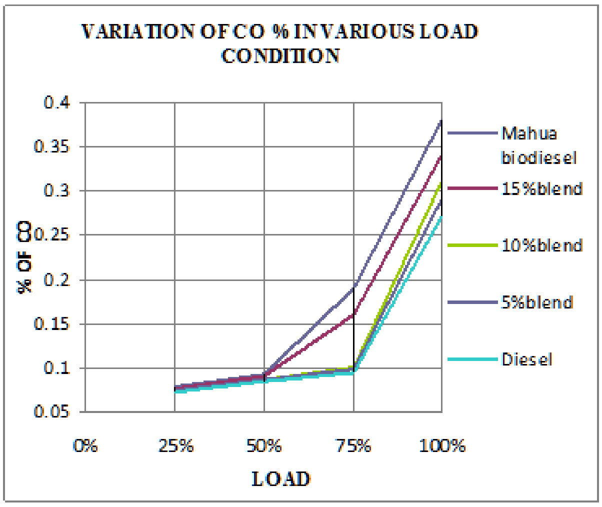

Fig.8 Variation of CO

Figure 8 shows the variation of CO in various conditions, CO increases as load increases for diesel as well as for biodiesel, also the amount of CO decreases with biodiesel. The decrease in CO shows the change in chemical reactions involved in the combustion of an oxygenated fuel. The CO gets converted to CO_2 after getting an extra molecule oxygen atom.

Effect on HC

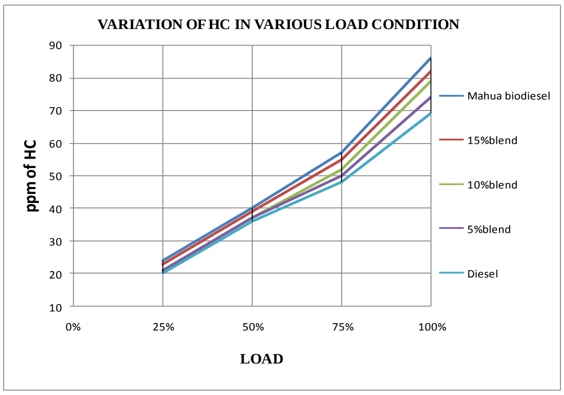

Fig.9 Variation of HC

Figure 9 shows the variation of HC in various load condition, with Fuel-borne oxygen aids the reduction of hydrocarbon emissions. As the proportion of biodiesel is increased, the reduction in HC increases. As the Cetane number of methyl ester based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low HC emission. In ideal combustion, air is mixed completely with the atomized fuel.

Effect on CO_2

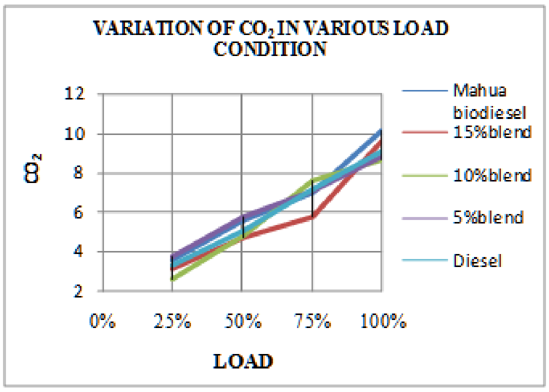

Fig.10 Variation of CO_2

Figure 10 shows the variation on CO_2 with load conditions. The lower percentage of diesel blends emits less amount of CO_2 in comparison with biodiesel. This is due to the fact that diesel is a low oxygen fuel and has a lower elemental carbon to hydrogen ratio.

Effect on Smoke Opacity

Smoke or Particulate emissions are of concern for health, environmental, legislative, and aesthetic reasons.

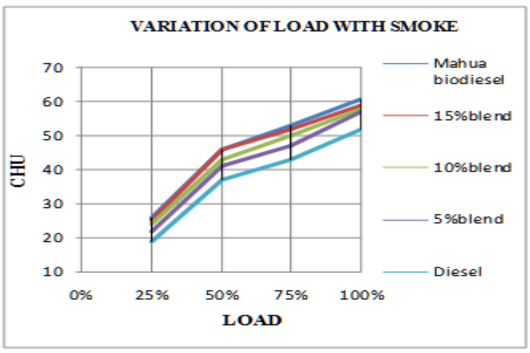

Fig.11 Variation of Smoke Opacity

It can be seen that figure 11 shows the variation of smoke with the load typical smoke levels under various engine loads conditions. Smoke increase with load because more fuel is required at higher load which produce more smoke. It is also observed that biodiesel and its blends produce less smoke as compare to diesel. It is clearly confirmed that the oxygenated reduces the total amount of smoke fuel.

IV. CONCLUSION

The performance, emission, and combustion characteristics of blends are evaluated and compared with diesel. From the above results, the following conclusions are drawn. Fuel consumption using mahua biodiesel and methanol is more at all loads. Brake thermal efficiency is high at low and medium loads. The present experimental results show that methyl esters of mahua oil can be used as an alternative fuel in diesel engine. Biodiesel is a popular and promising environment friendly alternative fuel due to its renewable nature, clean burning characteristics less greenhouse effect and more greenery. Biodiesel is a promoter of the rural economy.

The following conclusions are made based on the experimental results.

1. Brake thermal efficiency for fuel is very close to that of diesel. At full load, the maximum brake thermal efficiency for mahua is 32.23% for M15 the value is 31.47%, M10 is 30.71%, M5 is 29.95% and diesel is 28.95%. This increase in values is due to better combustion.

2. More the proportion of Mahua biodiesel in the blend more is the increase in brake specific fuel consumption for any given load because biodiesel is having low calorific value. Therefore more fuel is required for brake power.
3. The carbon monoxide emissions are less with Mahua biodiesel due to the presence of oxygen.
4. HC emissions for Mahua biodiesel and blends are lower as compare to diesel at all load.
5. Smoke for mahua biodiesel and its blends is lower at all loads due to presence of oxygen molecule in biodiesel

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