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Performance of a CI Engine with Different Blends of Mahua (Madhuca Longifolia) Biodiesel under Varying Operating Conditions

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ABSTRACT

This paper presents the results of investigations carried out on performance of biodiesel obtained from mahua oil and its blends with diesel from 20%, 40% and 60% by volume for running a diesel engine. The properties of these blends were found to be comparable to diesel and confirming to both the American and European standards. Engine performance (brake specific fuel consumption, brake thermal efficiency) and emissions (CO, smoke density) were measured to evaluate and compute the behavior of the diesel engine running on biodiesel at two injection pressures i.e. 180 bar and 240 bar and temperatures of 30, 50 and 70° C. The increase in power output, brake thermal efficiency and reduction in brake specific fuel consumption were observed. Injection pressure and fuel temperature were found to have significant effects on engine performance parameters. The power output decreased with increase in the concentration of mahua methyl ester in diesel and increased with the increase in injection pressure and fuel temperature. The reductions in exhaust emissions and brake specific fuel consumption together with increase brake power, brake thermal efficiency made the blend of biodiesel (B20) a suitable alternative fuel for diesel and thus could help in controlling air pollution.

Keywords: *Alternative fuel, Mahua biodiesel; Engine performance; Emissions*

1. INTRODUCTION

Out of all alternative fuel options for diesel, plant/vegetable oils in the form of blends or transesterified form emerged as a promising source as a fuel extender. There exists numbers of vegetable/ plant which produce oil and hydrocarbon substances a part of the natural metabolism. These vegetable oils from oil seed crops like soyabean, sunflowr, groundnut, mustard etc. and oil seed from tree origin have got 90 to 95% energy value of diesel on volume basis, comparable cetane number and can be substituted between 20-100 percent. It seems that vegetable/plant oil are better proposition as alternative fuel for diesel engine as they are liquid in nature and have many advantage over other alternative fuel option. The review of literature revealed that the use of vegetable oil ester as a fuel in diesel engines, a comparable engine performance with diesel was achieved. Also, harmful exhaust emissions, particularly hydrocarbon, smoke and carbon monoxide are considerably reduced as compared to diesel with the use of vegetable oils as a fuel. The major problems associated with direct use of vegetable oils, as a fuel for compression ignition engine is their high viscosity. It interferes with the fuel injection and atomization and contributes to incomplete combustion, nozzle choking, excessive engine deposits, ring sticking, contamination of lubricating oil etc. One possible method to overcome the problem of higher viscosity is transesterification of potential oils. The investigators reported that with the use of vegetable ester as a fuel for diesel engines, comparable performance with diesel was achieved [1-5]. Most of the esterified oils tried in diesel engines were rapeseed, soybean, sunflower and safflower. These oils are essentially edible oils in the Indian context and use of biodiesel from these oils as a substitute to diesel fuel is costlier. With the abundance of forest and tree borne non edible oils available in India, not much attempt has been made to use esters of these non edible oils as a substitute for diesel. Mahua (Madhuca longifolia) is one such forest based tree borne non-edible oil with a production potential of 135,000 million tons [10]. Hence, a study was undertaken to run a diesel engine with esterified mahua oil and its blend with diesel.

2. MATERIAL AND METHODS

The basic composition of vegetable oil is triglyceride, which is the ester of three fatty acids and one glycerol. The fatty acid composition of mahua oil is summarized in Table 1 [6] in the year 2005.

The methyl ester of mahua oil (MEMO) was prepared by transesterification. The transesterification reactions were performed in a round bottom vessel of 1000 ml in volume.

First, the vessel reactor was filled with 420 ml of mahua oil. Then, measured amount of the methanol potassium hydroxide was added to the reactor. For refluxing purpose, a vertical water cooled condenser was placed on the top portion of the vessel and the reactor was immersed in a constant-temperature water bath. The temperature of the water bath was maintained at 65 °C and agitation was provided with a magnetic stirrer during the reaction. This reaction was carried out for two hours. After the transesterification, the products were shifted to 1000 ml separator funnel, for phase separation. The top layer containing esters were washed with warm distilled water to remove impurities like soap and other residues, and then the oil is heated for removal of water.

Table 1: Fatty Acid and Composition of Mahua Oil

Fatty acid	Structure	Formula	Weight (%)
Palmitic	16.0	$C_{16}H_{32}O_2$	24.5
Stearic	18.0	$C_{18}H_{36}O_2$	22.5
Arachidic	20.0	$C_{20}H_{40}O_2$	1.5
Oleic	18.1	$C_{18}H_{34}O_2$	37.5
linoleic	18.2	$C_{18}H_{32}O_2$	14.3

Table 2: Fuel Properties

Property	Mahua oil	Mahua Methyl Ester	Diesel
Flash point, °C	212	129	56
Fire point, °C	223	141	63
Calorific value, kJ/kg	35614	36914	42960
Kinematic viscosity at 40 °C, cst	37.63	5.10	2.68
Density at 40 °C, kg/m^3	891	863	828

Fuel properties were determined as per the test code prescribed by the Institute of Petroleum, London (5) for raw mahua oil, mahua methyl ester (B 100) and its blends with varying proportion of high -speed diesel from 20% to 60% by volume (B20, B40 and B60). The mahua methyl ester (biodiesel, B100) and its blends (B20, B40 and B60) were used for testing a single cylinder diesel engine. The engine performance test was done according to BIS:5994-11(2). Parameters like speed, temperature of water, exhaust gas temperature and fuel consumption was measured from which power output, brake specific fuel consumption, brake specific energy consumption and brake thermal efficiency were computed (8). All observations recorded were replicated thrice to get average value.

3. EXPERIMENTAL SETUP AND PLAN

The test bed consists of a diesel engine, an eddy current dynamometer; fuel tank with thermostat-controlled heater is inbuilt in control panel with fuel measuring unit, and a data acquisition system. Two filters are installed: one at exit of tank and other one at fuel pump. Fuel is fed to the injector pump under gravity. Lubricating oil temperature is measured by using a thermocouple. The cooling water temperature is maintained constant (65 to 700°C) throughout the work by controlling the flow rate of fuel. Smoke opacity was measured using smoke opacity meter. The engine tests were conducted for entire load range (0 to 100%) at constant speed of 1500rpm.

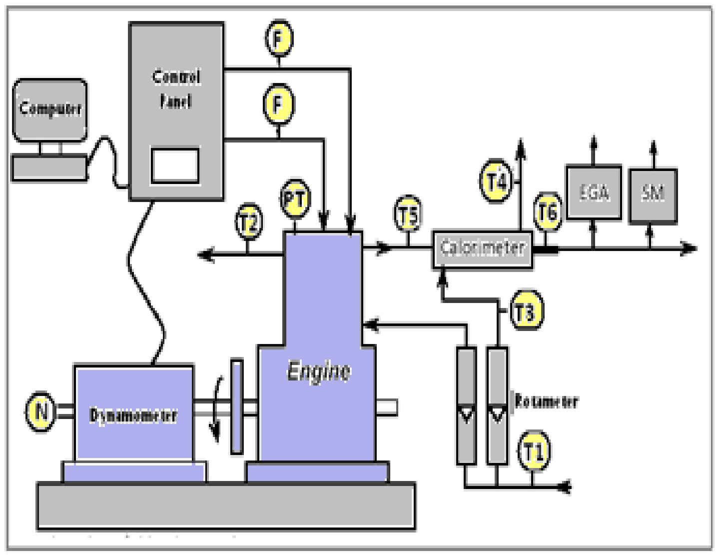

Fig 1: Experimental Test Rig.

Nomenclature:

PT	Pressure transducer
T1	Jacket water inlet temp.
T2	Jacket water outlet temp.
T3	Calorimeter water inlet temp.
T4	Calorimeter water outlet temp.
T5	Exh gas to calorimeter temp.
T6	Exh gas from calorimeter temp.
N	Rotary encoder
EGA	Exh Gas Analyzer
F1	Fuel flow
SM	Smoke Meter
F2	Air flow

3.1 Engine Specifications

Manufacturer	Kirloskar Oil Engines Ltd., India
Model	TV–SR II, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
Compression ratio	17.5:1
Speed	1500 r/min, constant
Rated power	5.2kW
Working cycle	Four stroke
Injection pressure	240 bar/23 deg TDC
Type of sensor	Piezo electric
Response time	4 micro seconds

Technical features of Smoke meter:

Make & Model:	Neptune Equipments, India, OPAX200 II/DX200P
Smoke sampling :	Partial flow
Zeroing :	Automatic

4. RESULTS AND DISCUSSION

4.1 Properties of Mahua Biodiesel and its Blends

Abbreviations used to represent the fuel is as follows-

D100	Biodiesel 0% + Diesel 100%
B20	Biodiesel 20% + Diesel 80%
B40	Biodiesel 40% + Diesel 60%
B60	Biodiesel 60% + Diesel 40%
B80	Biodiesel 80% + Diesel 20%

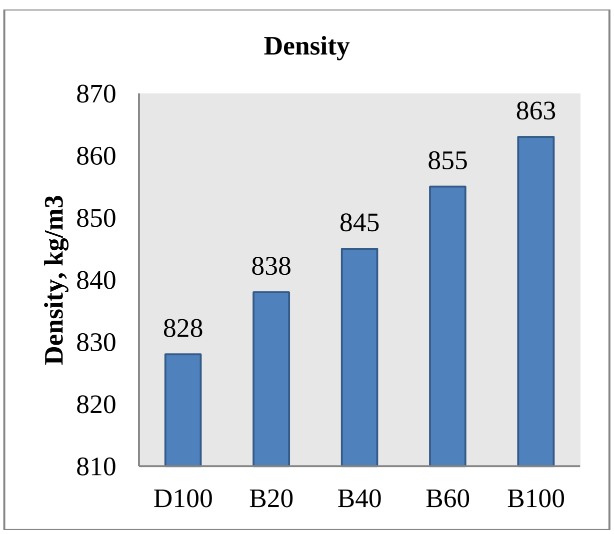

Fig. 2(a) Variation of density with concentration of mahua

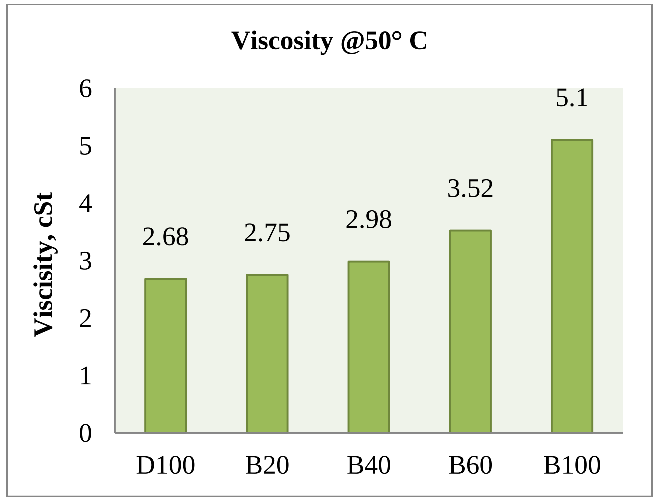

Fig. 2(b) Variation of viscosity with concentration of mahua

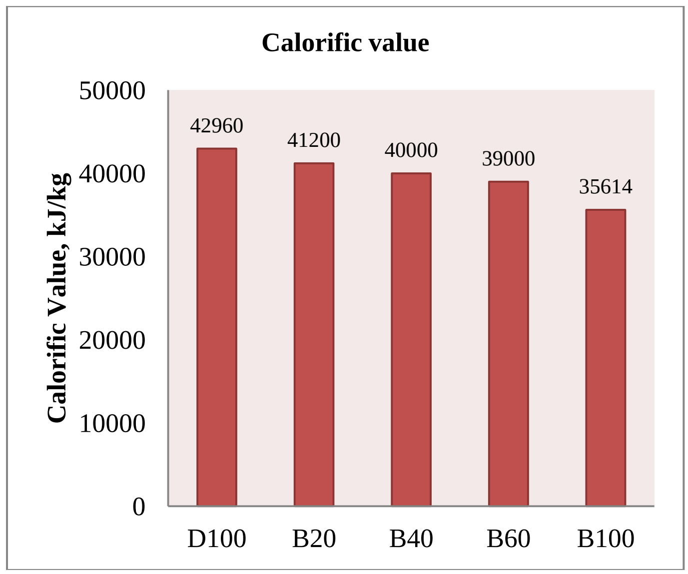

Fig. 2(c) Variation of calorific value with concentration of mahua

The kinematic viscosity of mahua oil was found to be 14 times more than that of diesel determined at 40°C. After estrification, the kinematic viscosity reduced to 7.4 times than that of pure mahua oil. It further reduced with increase in diesel amount in the blend. A similar reduction in the specific gravity was also observed. However, the calorific value of biodiesel was found to be 35.614 MJ/kg, which is less than the calorific value of diesel (42.960MJ/kg). As the percentage of biodiesel in the blends increased, the calorific value decreased. The flash points of mahua oil and biodiesel were found to be greater than @70°C, which is safe for storage and handling.

4.2 Engine Performance

4.2.1 Effect of Fuel Temperature on Power Output for Blends at Different Injection Pressure

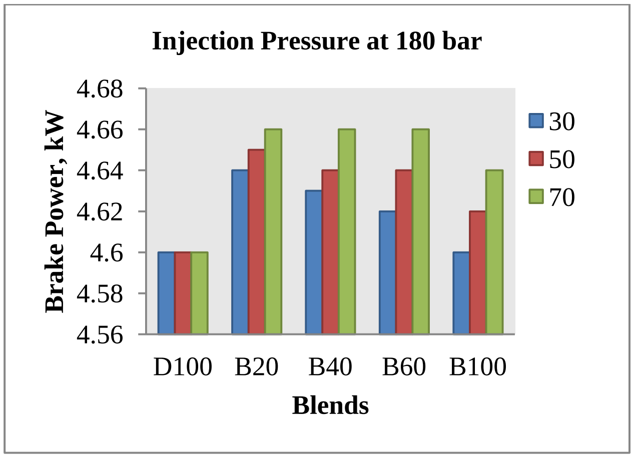

Fig. 3(a) Effect of fuel temperature on power output for blends at injection pressure of 180 bar

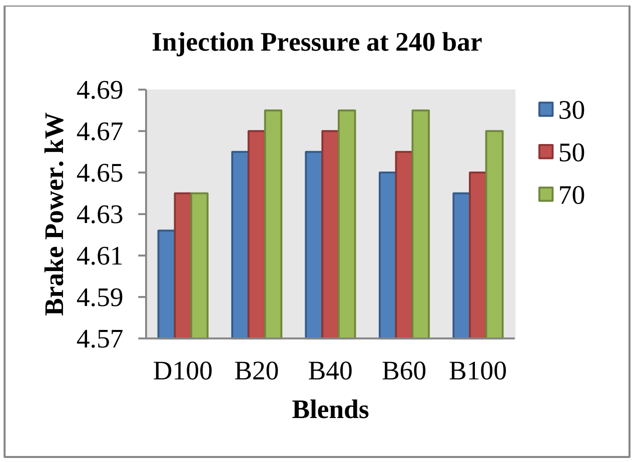

Fig. 3(b) Effect of fuel temperature on power output for blends at injection pressure of 240 bar

Fig.3(a) and (b) shows the power output of blends at varying fuel temperature and fuel injection pressure for all the blends studied. In pure diesel as a fuel, the power output of engine showed increasing trends, but a decreasing trend was observed with an increase in the concentration of Mahua methyl ester in diesel. The minimum power output of 4.61 kW was obtained using B100 fuel at temperature of 30°C at an injection pressure of 180 bar to 240 bar, the power output increased with the increase in fuel temperature. For the all the blend the power output increased with the increase in injection pressure. The increase in power output with increase in injection pressure may be due to improved atomization of mahua methyl ester fuel. The decreasing trend in power output with increase in concentration of mahua methyl ester in diesel may be because of lower energy input of mahua methyl ester than that of diesel. It may also be poor atomization of mahua methyl ester for its higher viscosity. The increased power output with the increase in fuel temperature might be influenced by the better atomization of the blends due to their reduced viscosities at higher temperature.

When the injection pressure increased from bar to 240 bar the rate in increase of power output for all bends was more at fuel temperature of 70°C than at 30°C . The slight increase in power output with the increase in the injection pressure may be attributed to improved atomization and reduce viscosity due to increase in fuel temperature which might have improved combustion characteristics of the blends.

4.2.2 Effect of Concentration of Mahua Oil in Diesel on BSFC

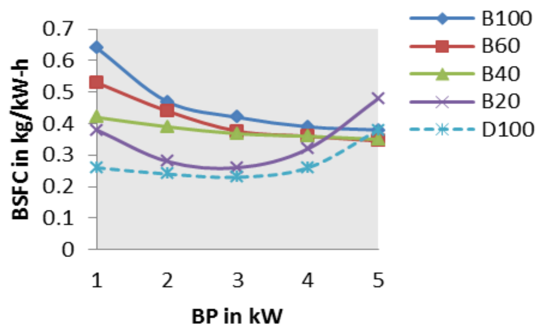

Fig. 4 Variation of BSFC with concentration of mahua at different loads

Fig4 shows that brake specific fuel consumption (BSFC) increased with the increase in concentration of mahua oil in diesel at all operating loads. However, statistical analysis of data indicated that mahua oil up to 20% does not reveal any significance difference at 5% level with that of diesel. The increase in BSFC of mahua oil and their blends may be due to their lower calorific value.

4.2.3 Effect of Concentration of Mahua Oil in Diesel on Brake Thermal Efficiency

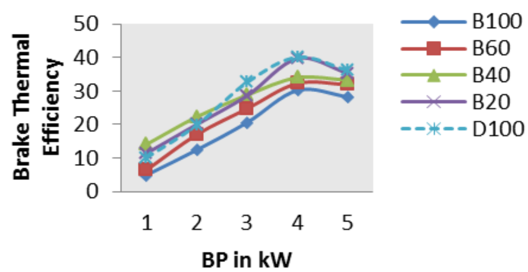

Fig. 5 Variation of bte with concentration of mahua at different loads

Fig 5 shows that brake thermal efficiency decreased with the increase in concentration of mahua oil in diesel at all operating range of loads in comparison with pure diesel. However, concentration of mahua oil up to 20%, there was no significant decrease in brake thermal efficiency. The general trend of decrease in brake thermal efficiency of mahua oil and their blends may be attributed due to their poor spray characteristics, which is again due to higher viscosity and surface tension than that of diesel. The poor spray pattern may affect the homogeneity of air fuel moisture which in turn lower the heat release rate thereby reduction in brake thermal efficiency.

4.2.4 Effect of Concentration of Mahua Oil in Diesel on smoke density

Fig. 6 shows the variation of smoke density with engine load. It is found that the smoke density of the engine increased with increase in concentration of mahua oil in diesel. This negative effect is mainly due to the high viscosity and poor volatility of mahua oil compared to diesel.

The high viscosity and poor volatility of mahua oil caused poor fuel injection and mixing characteristics and incomplete combustion. Further, the mean diameter fuel droplet was higher for vegetable oil than diesel. The smoke density was higher for all blends at full load operation.

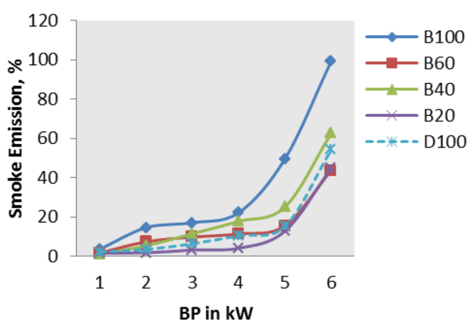

Fig. 6 Variation of smoke emissions with concentration of mahua at different loads

5. CONCLUSION

Based on the results of the study, conclusions drawn were methyl ester of mahua oil was prepared and blended with diesel in varying proportions. Engine starting was normal with mahua methyl ester and its blend with diesel. Injection pressure and fuel temperature were found to be significant effects on engine performance parameters. The power output decreased with increase in the concentration of mahua methyl ester in diesel and increased with the increase in injection pressure and fuel temperature.

Hence from the above study it is concluded that,

a. Fuel properties of diesel, mahua methyl ester oil and its blends are comparable.

b. Short-term engine performance indicates suitability of mahua oil fuel blends up to 20% concentration.

c. Suitability of higher injection pressure (240 bar) and higher inlet fuel temperature (70°C) for mahua oil and its blends.

d. B20 (20% blend) can be a better substitute fuel for DI engine without any modification.

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