Review on use of Mahua Oil as a Diesel Fuel Extender

Gaurav Atravalkar, Vijay Desale, Aakash Nemade (S.E. Mechanical)
G.H.Raisoni Institute of Engineering and Management, Jalgaon

Abstract - Vegetable oils offer an advantage of comparable fuel properties with diesel. Due to considerable pressure on edible oils in India, short-term performance of diesel engine was evaluated using Mahua oil as a fuel and its blends with diesel. 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.

***Keywords* -** Kinematic viscosity; Calorific value; Compression ratio; Brake thermal efficiency.

INTRODUCTION

The various biomass based resources which can be used as an extender or a complete substitute of diesel fuel may have very significant role in the development of agriculture, industrial and transport sectors in the energy crisis situation. The role of diesel fuel in these sectors cannot be denied because of its ever increasing use. In fact, agricultural and transport sectors are almost diesel dependent. The various alternative fuel options researched for diesel are mainly biogas, producer gas, ethanol, methanol and vegetable oils. Out of all these, vegetable oils offer an advantage because of its comparable fuel properties with diesel and can be substituted between 20%-100% depending upon its processing. The various edible vegetable oils like sunflower, soybean, peanut, cotton seed etc have been tested successfully in the diesel engine. Research in this direction with edible oils yielded encouraging results. But as India still imports huge quantity of edible oils, therefore, the use of non-edible oils of minor oilseeds like Mahua (Madhuca indica) oil has been tested as a diesel fuel extender.

MATERIALS AND METHODS

Mahua Oil

Two major species of the genus Madhuca indica and Madhuca longifolia 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 yield in an expeller is nearly 34%-37%. The fresh oil from properly stored seed is yellow in colour. The range of characteristic of Mahua oil is given in Table 1.

Properties	Value
Refractive index	1.452.1.462
Saponification value	187.197
Iodine vale	55.70
Unsaponifiable matter, %	1.3
Fatty acid composition, %	
Palmitic $c_{16:0}$	24.5
Stearic $c_{18:0}$	22.7
Oleic $c_{18:1}$	37.0
Lionoleic $c_{18:2}$	14.3

Table 1. Characteristics of Mahua oil

Experimental Technique

The important fuel properties of Mahua oil was determined according to standard procedure of IS 1448/IP methods mentioned in Table 2. The Ricardo E6/S variable compression, single cylinder, four stroke, water cooled engine having a bore (76.2 mm) and stroke (111.1 mm) was used for this study as shown in Figure 1. The normal speed range was 1000 rpm to 3000 rpm but the experiments were conducted at constant speed of

1500 rpm as applicable for stationary engine. The engine was coupled with a swinging field dynamometer and simple switch gear mechanism which enable the dynamometer to be operated as a motor to start the engine. The standard instrumentation was used to measure the fuel consumption, exhaust gas temperature, coolant temperature and air consumption (Figure 1). The injection pressure was set to 180 kg/cm2 and injection timing of 37.5°before TDC for diesel and all fuel blends as per instruction manual.

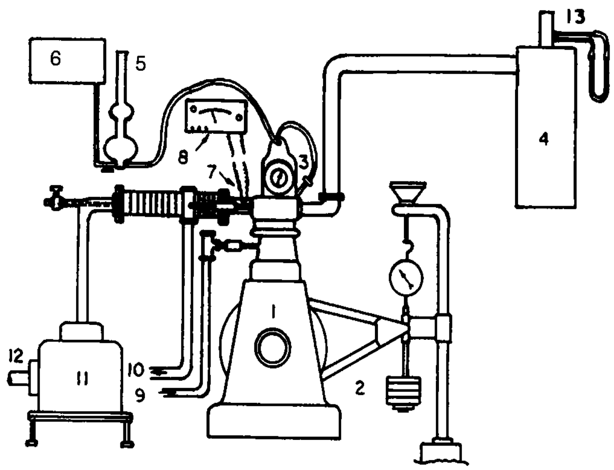

Fig. 1 Schematic Representation of the set-up
1. Engine; 2. Dynamometer; 3. Injector; 4. Surge Tank; 5. Fuel Consumption Metering Device; 6. Fuel Tank; 7. Exhaust Gas Thermocouple; 8. Mili-Volt Meter; 9. Cooling Water Inlet; 10. Cooling Water Outlet; 11. Silencer; 12. Main Exhaust Line; and 13. Orifice Meter with Manometer

For the stabilization of measuring parameters at each load setting and at the start of each test, time period of 10 min and 30 min were allowed. The overall period of test was spread over to more than 90 h. Four blends of Mahua oil with diesel and pure oil were tested in the engine at compression ratio of 20:1, 18:1 and 16:1.The fuel blends were prepared in the proportion of 20%; 40%, 60% and 80% volume by volume with diesel, respectively. The baseline test was conducted with diesel only. In the process of testing with Mahua oil-diesel fuel blends, no change was made in the engine. The engine was directly started on the fuel blends without any change over from diesel fuel. The engine performance was compared on the basis of parameters, i.e., power output, brake specific fuel consumption, brake specific energy consumption, brake thermal efficiency, exhaust gas temperature, air/fuel ratio and volumetric efficiency as shown in Figures 2.

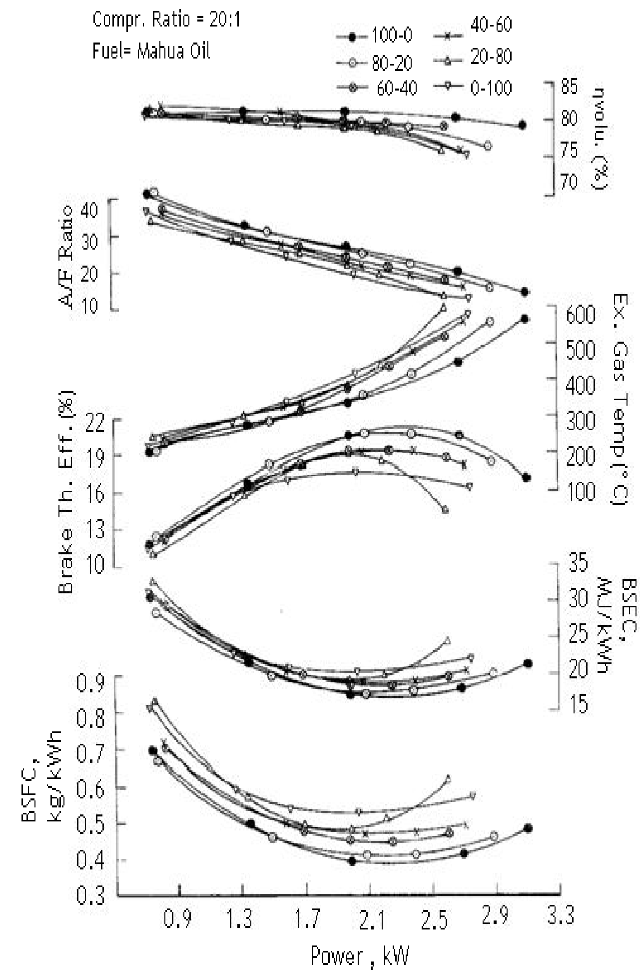

Fig.2 Engine performance for diesel, Mahua oil and blends with diesel at compression ratio 20:1

The least square technique was used to calculate the optimum values of engine performance parameters fitted in polynomial equation with high correlation coefficients of 0.99 in all cases. The optimum values of power output, brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC), and brake thermal efficiency were compared with diesel using statistical t-test at 0.05 level of significance.

RESULTS AND DISCUSSION

Fuel Properties

The important fuel properties of diesel with its Indian Standard (IS) limits and Mahua oil are summarized in Table 2. The specific gravity of Mahua oil was 9.11% higher than that of diesel. The kinematic viscosity of Mahua oil was 15.23 times more than that of diesel at temperature of 40°C . The kinematic viscosity of Mahua oil reduced considerably with the increase in temperature to 80°C and by increasing the proportion of diesel in fuel blends as indicated in Figure 3. The kinematic viscosity of fuel blends with 20%, 40%, 60% and 80% Mahua oil and pure oil was 1.71, 3.41, 5.21, 7.89 and 11.66 Cst at 80°C. The viscosity values were 0.7, 1.39, 2.31, 3.23 and 4.77 times higher than that of diesel at 40°C , respectively which indicates the significant effect of temperature on viscosity of Mahua oil and its blends. The kinematic viscosity of 60% Mahua oil with diesel at 80°C and 20% Mahua oil at 40°C was within the limits for grade A diesel. The high viscosity of Mahua oil may be due to higher molecular attraction of the long chains of its glyceride molecules. The calorific value of Mahua oil was observed as 88.26% of diesel on weight basis and 96.30% on volume basis. The calorific value of Mahua oil was found nearer to diesel fuel in comparison with other liquid fuel options like ethanol and methanol. The carbon residue of Mahua oil was found higher than that of the limit specified for grade A diesel and this may increase the chances of carbon deposition in the combustion chamber. The higher carbon residue may be due to difference in chemical composition and molecular structure of Mahua oil. The pour point of Mahua oil was higher in comparison with diesel.

Properties	**Unit**	**Diesel**	**Mahua Oil**	**I.S. Limits For Diesel**
Sp.Gravity	--	0.828	0.9040	--
Kinematic Viscosity	Cst (40°C)	2.44	37.18	2.0-7.5 At 38°C
Calorific Value	MJ/kg	44.03	38.863	--
Pour Point	°C	-5	15	Max. 6
Flash Point	°C	47	238	Min 55
Carbon Residue	%	0.033	0.4215	Max. 0.2
Ash Content	%	0.006	0.021	Max. 0.01
Water Content	%	Trace	Trace	Max. 0.05

Table 2. Fuel properties of Mahua oil & diesel

This may be due to higher percentage of saturated fatty acids in Mahua oil composition (Table 1). However, being temperate climate in India, the higher pour point may not pose any problem except in cold weather conditions. The ash content of Mahua oil was also higher than the limits specified for grade A diesel. The flash point of Mahua oil was very high as compared to diesel thus indicating its low volatile nature. The water content was present in only trace amount in both the fuels. The distillation temperature range of Mahua oil was found lower as compared to diesel.

Short-term Engine Test

Effect of Concentration of Mahua Oil in Diesel on Power Output

The results of increase in concentration of Mahua oil in diesel revealed that the power output decreases at all compression ratios. However, at compression ratio of 20:1, the blends up to 60% Mahua oil did not reveal any significant difference at 5% level of significance in power output as indicated by statistical analysis of data (Table 3). Similarly, at compression ratio of 18:1 and 16:1 Mahua oil up to 20% & 40% did not reveal any significant difference, respectively. The decrease in power output may be attributed to the lower energy content with increased concentration of Mahua oil in diesel. This may also be due to the poor atomization of Mahua oil and blends due to high viscosity, which may cause poor combustion leading to reduce power output of the engine. Similar trends were also reported by Mazid, while working with peanut, soybean, cotton seedand Chinese tallow and their blends. In the following table, D indicates diesel while M indicates the Mahua oil. The test is done at 0.05 level of significance.

Table 3 Test of Significance for blends of MO with Diesel

Compr. Ratio	Power O/p (kW)	BSFC, Kg/kWh	BSEC, MJ/kWh	η_{th} %
20:1	D80,M20	D80,M20	D80,M20	D80,M20
18:1	D80,M20	D60,M20	D60,M20	D80,M20
16:1	D60,M20	D80,M20	D80,M20	D80,M20

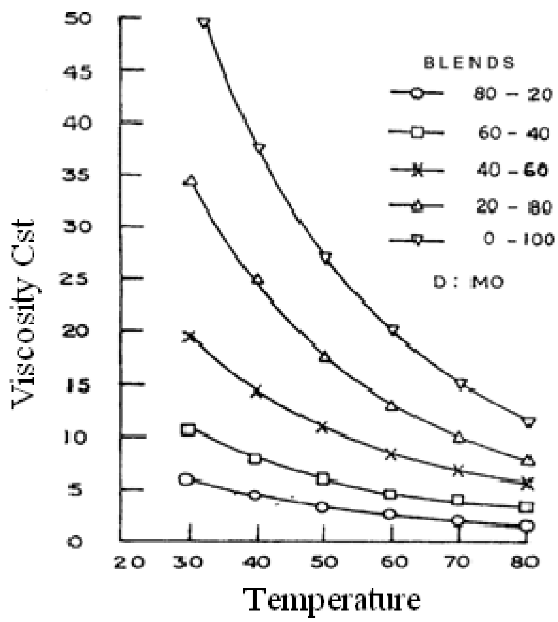

Fig. 3 Effect of temperature on Mahua oil

Effect of Concentration of Mahua Oil in Diesel on BSFC and BSEC

The BSFC and BSEC increased with the increase in concentration of Mahua oil in diesel at all tested compression ratio. However, statistical analysis of data indicated that Mahua oil up to 20% at compression ratio of 20:1 does not reveal any significance difference at 5% level with that of diesel (Table 3). The increase in BSFC of Mahua oil and their blends may be due to their lower calorific value to the extent up to 88.26% and 96.30% on weight basis and volume basis than that of diesel, respectively. The ultimate effect was thus increase in energy consumption for the same level of power output.

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

Brake thermal efficiency decreased with the increase in concentration of Mahua oil in diesel at all three compression ratio in comparison with pure diesel. However, concentration of Mahua oil up to 20%, there was no significant decrease in brake thermal efficiency at 5% level of significance (Table 3). The general trend of decrease in brake thermal efficiency of Mahua oil and their blends may be attributed 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.

Effect of Concentration of Mahua Oil on Exhaust Gas Temperature, Air-Fuel Ratio and Volumetric Efficiency

It appears from the Figure 2 that exhaust gas temperature increased with the increase in concentration of Mahua oil in diesel. The exhaust gas temperatures of the blends were in between the limits of pure diesel and 100% Mahua oil. However, the variation in exhaust gas temperature was less up to half of the power output for all blends but was more pronounced at higher loads. The maximum increase in exhaust gas temperature was 2.65% from diesel to pure Mahua oil at optimum load. The increase in exhaust gas temperature may be due to delayed combustion because of slower combustion characteristics of vegetable oil. As appeared from the same figure, the air-fuel ratio and volumetric efficiency decreased with increase in concentration of Mahua oil in diesel with the maximum 6.5% and 2.47%, respectively. The reduced air-fuel ratio may be due to increase in BSFC for same level of power output in comparison with diesel. The increase BSFC and poor mixture of fuel with air resulted in appearance of smoke even at lower loads and lowered the power output with decrease in brake thermal efficiency and increase in exhaust gas temperature. The increase in exhaust gas temperature may be responsible for reduction in volumetric efficiency.

Effect of Compression Ratio on Engine Performance Parameters

With the Increase in the Concentration of Mahua Oil in Diesel The comparison of engine performance parameter (Table 4) revealed that with the increase in compression ratio from 16:1 to 20:1, the per cent increase in power output (29.86) and brake thermal efficiency (18.20) with the decreasing brake specific fuel consumption (15.20) and brake specific energy consumption (15.21) for Mahua oil was observed. The change in engine performance parameters for diesel is non-significant when compression ratio is changed from 18:1 to 20:1. However, with the change in concentration up to 20% and 40% of Mahua oil, the performance is nearly comparable and it indicates the suitability of higher compression ratio engine for vegetable oil fuel blends.

Parameter	Blends D :MO	**Compression Ratio** 20:1	18 : 1	16 : 1
Power Output (kW)	80 : 20	2.140	2.060	1.860
	60 : 40	2.170	1.910	1.720
BSFC, kg/kWh	80 : 20	0.404	0.415	0.465
	60 : 40	0.441	0.452	0.494
BSEC, MJ/kWh	80 : 20	16.630	17.880	19.970
	60 : 40	18.530	18.860	20.760
Brake Thermal Efficiency (%)	80 : 20	20.670	20.060	17.890
	60 : 40	19.180	18.610	17.280

Table 4 Effect of comp. ratio on engine performance

CONCLUSIONS

The results obtained from the study conclude that

1. Fuel properties of diesel, Mahua oil and blends are comparable.
2. Short-term engine performance indicates suitability of Mahua oil fuel blends up to 40% concentration.
3. Suitability of higher compression ratio engine for Mahua oil and its blends.
4. The Mahua oil can serve well as a substitute for diesel in upcoming ages.

REFRENCES

1) A research paper on **Mahua oil** by Y C Bhatt, N.S.Murthy, R.K. Datta.

2) M A Mazid, J D Summers and D G Batchelder, “Peanut, Soybean and Cottonseed Oil as Diesel Fuel” Transactions of ASAE,

3. N V Bringi, “Non-traditional Oil Seed and Oils of India.”
4. Indian Standard, “Methods of Test for Petroleum and its Products”. IS: 1448, 1960, and 1960.
5. W D Samson, C G Vidrine and J W D Robbins. “Chinese Tallow Seed Oil as a Diesel Fuel Extender”. Transactions of ASAE
6. K V Gopalkrishnan , “Use of Vegetable Oil as a Substitute for Diesel.”
7. Proceedings of Bio-energy Society, First Convention and Symposium, New Delhi, October 14-16, 1984.
8. Google Search engine.
9. IEEE Online Guidance Services
10. A informative Blog on DISEL SUBSTITUTES by HPCL