"Performance of IC Engine by Using Mahua Oil (*Madhuca indica*) Biodiesel"

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Abstract

There is an increasing interest in India, to search for suitable alternative fuels that are environment friendly. This led to the choice of Mahua Oil (MO) as one of the main alternative fuels to diesel. In this investigation, Mahua Oil Biodiesel (MOB) and its blend with diesel were used as fuel in a single cylinder, direct injection and compression ignition engine. The MOB was prepared from MO by transesterification using methanol and potassium hydroxide. The fuel properties of MOB are close to the diesel and confirm to the ASTM standards. From the engine test analysis, it was observed that the MOB, B5 and B20 blend results in lower CO, HC and smoke emissions as compared to diesel. But the B5 and B20 blends results in higher efficiency as compared to MOB. Hence MOB or blends of MOB and diesel (B5 or B20) can be used as a substitute for diesel in diesel engines used in transportation as well as in the agriculture sector.

Keywords: Alternative fuel, mahua oil, biodiesel, engine performance

1. Introduction

During recent years high activities can be observed in the field of alternative fuels, due to rapid decrease in world petroleum reserves. It has been massive demand for diesel in India. Hence, government of India has taken necessary steps to fulfill future diesel and gasoline demand. Biodiesel and alcohol are considered as alternative fuels. These fuels are being looked to provide employment generation to rural people through plantation of vegetable oils and can be beneficial to sugarcane farmers through the ethanol program [1]. Mohibbe et al. [2] reported that the fatty acid methyl esters of oils of 26 species were found most suitable for use as biodiesel. Jamieson [3] listed over 350 oil-bearing crops while Duke and Bagby [4] identified 70 species of oil seeds with considerable potential. Mahua name for a medium to larger tree, madhuca longifolia of family sapotaceae with wider and round canopy and attains a height up to 20 meters. As a plantation tree, Mahua is an important plant having vital socio-economic value. This species can be planted on roadside, canal banks etc. on commercial scale and in social forestry programmes, particularly in tribal areas. The drying and decortication 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% [5]. Transesterification is affected by type of catalyst, reaction time and temperature and purity of reactants [6]. Generally a two step procedures is used to produce biodiesel from MO having high free fatty acids [7] and nuclear magnetic resonance test can be used to determine the biodiesel conversion [8]. Engine manufacturers recommend the use of biodiesel up to 50% in the diesel engines. But most of the engine manufacturers prefer B5 blend due to its better cold starting and lower lubricating oil dilution characteristics. Hence in the present work, B10 and B40 blends were used as fuel and the performance was compared with neat diesel and MOB.

1.1 AN OVERVIEW OF DIESEL ENGINE

The diesel internal combustion engine differs from the gasoline powered Otto cycle by using highly compressed, hot air to ignite the fuel rather than using a spark plug (compression ignition rather than spark ignition).In the diesel engine, only air is initially introduced into the combustion chamber. The air is then compressed with a compression ratio typically between 15:1 and 22:1 resulting in 40-bar (4.0 MPa; 580 psi) pressure compared to 8 to 14 bars (0.80 to 1.4 MPa) (about 200 psi) in the petrol engine. This high compression heats the air to 550 °C (1,022 °F). At about the top of the compression stroke, fuel is injected directly into the compressed air in the combustion chamber. This may be into a void in the top of the piston or a *pre-chamber* depending upon the design of the engine. The fuel injector ensures that the fuel is broken down into small droplets, and that the fuel is distributed evenly. The heat of the compressed air vaporizes fuel from the surface of the droplets vapour is then ignited by the heat from the compressed air in the combustion chamber, the droplets continue to vaporize from their surfaces and burn, getting smaller, until all the fuel in the droplets has been burnt. The start of vaporization causes a delay period during ignition, and the characteristic diesel knocking sound as the vapor reaches ignition temperature and causes an abrupt increase in pressure above the piston. The rapid expansion of combustion gases then drives the piston downward, supplying power to the crankshaft. Model airplane engines use a variant of the Diesel principle but premix fuel and air via a carburetion system external to the combustion chambers.

The high level of compression allowing combustion to take place without a separate ignition system, a high compression ratio greatly increases the engine's efficiency. Increasing the compression ratio in a spark-ignition engine where fuel and air are mixed before entry to the cylinder is limited by the need to prevent damaging pre-ignition. Since only air is compressed in a diesel engine, and fuel is not introduced into the cylinder until shortly before top dead centre (TDC), premature detonation is not an issue and compression ratios are much higher.

1.2 COMBUSTION IN C.I. ENGINE

The process of combustion in C.I. engine is fundamentally different from that in a S.I. engine. In the S.I. engine a homogeneous carbureted mixture of petrol vapor and air, in nearly stoichiometric or chemically correct ratio, is compressed in the compression stroke through a small compression ratio (6:1 to 11:1) and the mixture is ignited at one place before the end of the compression stroke (say before 30° before TDC) by means of an electric spark.

In C.I. engine, air alone is compressed through a large compression ratio (12:1 to 24:1) during the compression stroke raising highly its temperature and pressure. In the highly compressed and highly heated air in the combustion chamber (well above ignition point of fuel) one or more jets of fuel are injected in the liquid state, compressed to high pressure of 110 to 200 bar by means of a fuel pump. Each minute droplet as it enters the hot air (temperature 450-500°C and pressure 30-40 bar) is quickly surrounded by an envelope of its own vapor and this, in turn and after an appreciable interval, is inflamed at the surface of the envelope.

1.3 MAHUA OIL *(Madhuca indica)*

The two major species of genus Madhuca found in India are Madhuca Indica (syn. Bassia latifolia) and Madhuca longifolia (syn. Brassica longifolia). Mahua is the widely accepted as local name for the fat from both these species. This plant is common in deciduous forests. The seed and oil potential of this tree in the country is 5.00 lakh and 1.8 lakh M. tons.

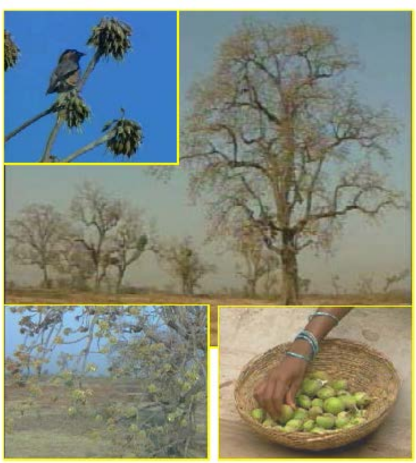

Plate 1.1: Mahua (Madhuca Indica)

a. Botanical Name : Madhuca indica

b. Family : Sapotaceae

c. Common Names

Sanskrit :		Madhuka
A.P	:	Ippe, Yappa
Gujarat	:	Mahuda
Hindi	:	Mahua, Mohwa,
Karnataka	:	Hippe
Kerla	:	Ponnam, Ilupa
Maharashtra	:	Mahwa, Mohwra
Orissa	:	Mahula, Moha,
Tamil Nadu	:	Illupei, elupa
West Bengal	:	Mahwa, Maul,
English	:	Butter tree

1.4. Botanical Features

M. Latijolia is a deciduous tree white M.Congijolia is ever green or semi ever green tree. Attains height upto 70 ft. The tree matures and starts bearing 8 to 15 years, and fruits upto 60 years. The two species are not differentiated in Trade. The kernels are 70% of seed by weight, are seed contains two kernels, having 2.5 cm x 1.75 cm size oil content in latifolia is 46% and 52% in long folia. In seeds oil content is 35% and protein in 16%.

1.5. Flowering

The flowering season extends from February to April. The copious fall of succulent, corollas weave a cream colored carpet on the ground. It is rich in sugar (73%) and next to cane molasses constitute the most important raw material for alcohol fermentation. The yield of 95% alcohol is 405 liters from one ton of dried flowers.

1.6. Fruiting

The matured fruits fall on the ground in May and July in the North and August and September in the South. The orange brown ripe fleshy berry is 2.5 to 5 cm long and contains one to four shining seeds. The seeds can be separated from the fruit wall by pressing. Drying and decortications yield 70% kernels on the weight of seeds.

1.7. Mahua Oil

Mahua seed contains 35% oil and 16% protein. The characteristics of fat are as under:

Characteristics of Fat

Characters Characteristic/valve

1. Color Pole yellow
2. Consistency Plastic
3. Refractive index at 40 degree C1.452 to 1.462
4. Specific gravity at 15 degree C 0.856 to 0.870
5. Iodine valve 58.00 to 70.00
6. Specification valve 187 to 196
7. Sponification valve 1.00 to 3.00

2.1 EXPERIMENTAL PROCEDURE

1) Switch on the mains of the control panel and set the supply voltage from servo stabilizer to 220 volts.
2) The main gate valve is opened, the pump is switched ON and the water flow to the engine cylinder jacket (300 liters/hour), calorimeter (50 liters/hour), dynamometer and sensors are set.
3) Engine is started by hand cranking and allowed to run for a 20 minutes to reach steady state condition.
4) The engine software Lab view 7.1 optimized for engine analysis by Deepti Engineering Services, Bangalore is used for taking readings.

The engine has a compression ratio of 17.5 and a normal speed of 1500 rpm controlled by the governor. An injection pressure of 200 bar, 250 bar and 300 bar are used for the analysis. The engine is first run with neat diesel at loading conditions such as 6.5, 13, 19.5 and 26 N-m. Between two load trials the engine is allowed to become stable by running it for 3 minutes before taking the readings. At each loading condition performance parameters namely speed, exhaust gas temperature, brake power, peak pressure are measured under steady state conditions. The experiments are repeated for various load conditions for S10, S20 and S30 bio-fuel. With the above experimental results, the parameters such as total fuel consumption, brake specific fuel consumption, indicated specific fuel consumption, specific energy consumption, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency are calculated. Finally graphs are plotted for these parameters against various load conditions for diesel and S10, diesel and S20, diesel and S30 bio-diesel. From these plots, performance characteristics of the engine are determined.

2.2 EXPERIMENTATION

The experiments were conducted on a direct injection compression ignition engine for various loads and blends of biodiesel & pure diesel. Analysis of combustion characteristics and performance parameters like peak pressure, specific fuel consumption (SFC) and Brake thermal efficiency are evaluated.

3 RESULTS AND DISCUSSIONS

3.1 PERFORMANCE CHARACTERISTICS

3.1.1 Brake thermal efficiency

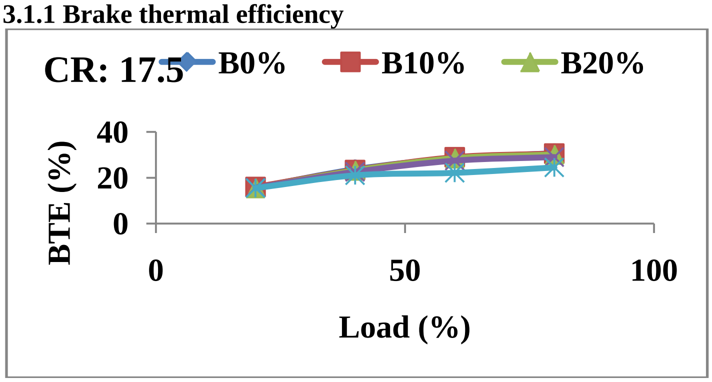

Fig 3.1 Variation of BTE with load for different percentage of Mahua oil and diesel with CR 17.5

The variation of brake thermal efficiency with load at different percentage of diesel- Mahua oil biodiesel blends are shown in figures 3.1 From the figure it was observed that the brake thermal efficiency increases with load in all cases. It was further observed that the Brake Thermal Efficiency of the Mahua-biodiesel is marginally less by 1.0-2.0% compared to neat diesel operation for normal injection timings.

3.1.2Total fuel consumption

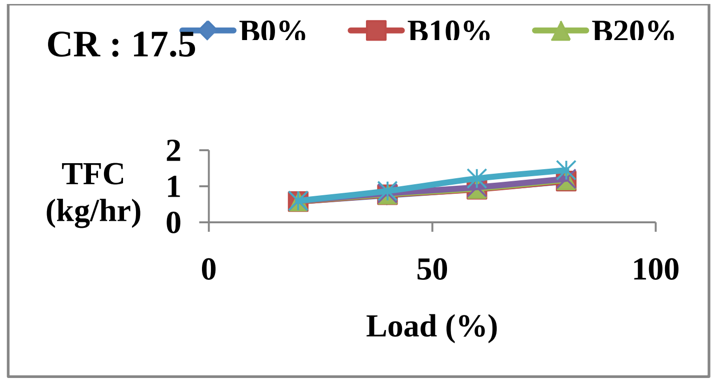

Fig 3.2 Variation of TFC with load for different percentage of Mahua oil and diesel with CR17.5

The variation of total fuel consumption with load at different percentages of diesel- Mahua oil biodiesel blends are shown in figures 3.5 From the figure it was observed that the total fuel consumption increases with load in all cases. From the figure it was observed that the total fuel consumption of the Mahua oil -biodiesel was marginally increases compared to neat diesel operation for normal compression ratio. At 80% load, the total fuel consumption of engine when run an engine with neat diesel is 1.132 kg/hr, where as it is 1.146kg/hr, 1.177 kg/hr, 1.201 kg/hr, and 1.450 kg/hr when engine is run on diesel with 10% Mahua oil-biodisel, 20% Mahua oil-biodisel, 30% Mahua oil -biodisel and 40% Mahua oil -biodisel respectively.

3.1.3 Brake specific fuel consumption

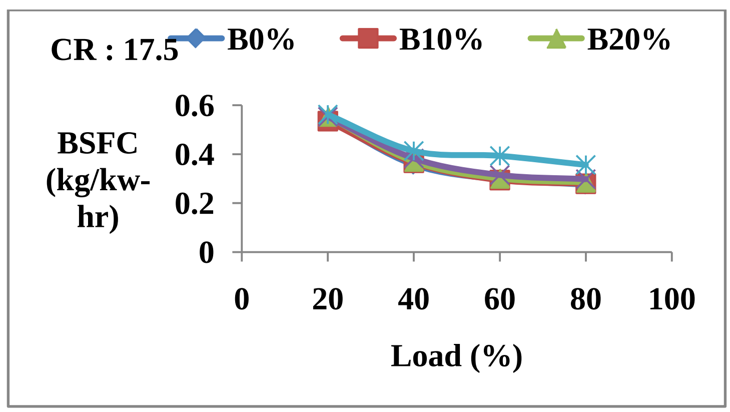

Fig 3.3 Variation of BSFC with load for different percentage of Mahua oil and diesel with CR17.5

The variation of brake specific fuel consumption with load at different percentages of diesel- Mahua oil biodiesel blends are shown in figures 6.9 to 6.12. From figure it was observed that the brake specific fuel consumption decreases with load in all cases. At 80% load, the brake specific fuel consumption of the engine when run on neat diesel is 0.275 kg/kW-hr, where as it is 0.300 kg/kW-hr, 0.290 kg/kW-hr, 0.300 kg/kW-hr, 0.358 kg/kW-hr when engine is run on diesel with 10% Mahua oil -biodisel, 20% Mahua oil -biodisel, 30% Mahua oil -biodisel and 40% Mahua oil -biodisel respectively.

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3.1.4 Air Fuel Ratio

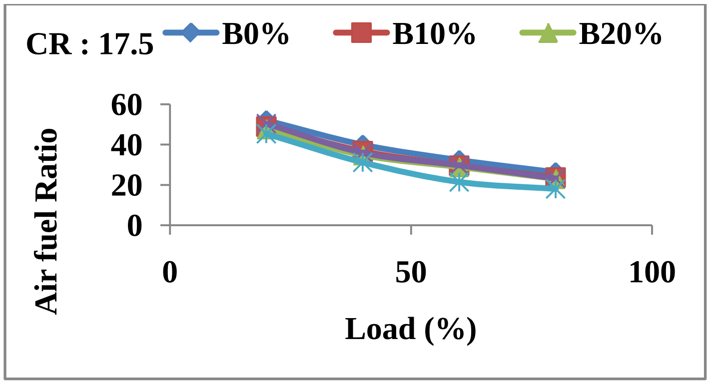

Fig 3.4 Variation of AFR with load for different percentage of Mahua oil and diesel with CR17.5

The variation of air fuel ratio with load at different percentages of diesel- Mahua oil biodiesel blends are shown in figures 6.21 to 6.24. From the figures it was observed that the air fuel ratio decreases with load in all cases because as the load increases the consumption of fuel increases hence air fuel ratio reduces.

At 80% load (fig 6.21), the air fuel ratio of engine when run on neat diesel is 25.94, where as it is 23.78, 23.16, 23.64 and 17.93 when engine is run on diesel with 10% Mahua oil -biodisel, 20% Mahua oil -biodisel, 30% Mahua oil -biodisel and 40% Mahua oil -biodisel respectively.

3.1.5 Volumetric efficiency

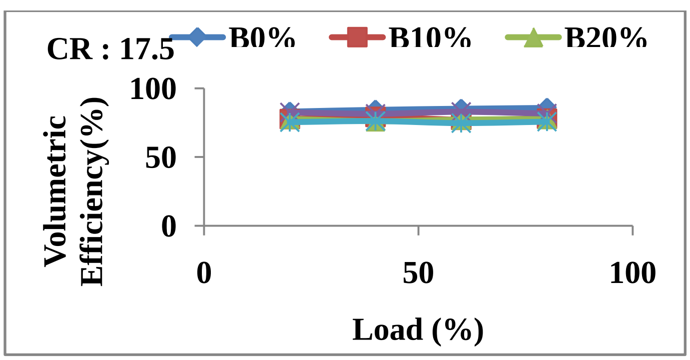

Fig 3.5 Variation of volumetric efficiency with load for different percentage of Mahua oil and diesel with CR17.5

The variation of volumetric efficiency with load at different percentages of diesel- Mahua oil biodiesel blends are shown in figures 6.25 to 6.28. From the figure it was observed that the volumetric efficiency almost keeps constant for biodiesel blends. This is because of no much variation in airflow.

3.1.6Indicated thermal efficiency

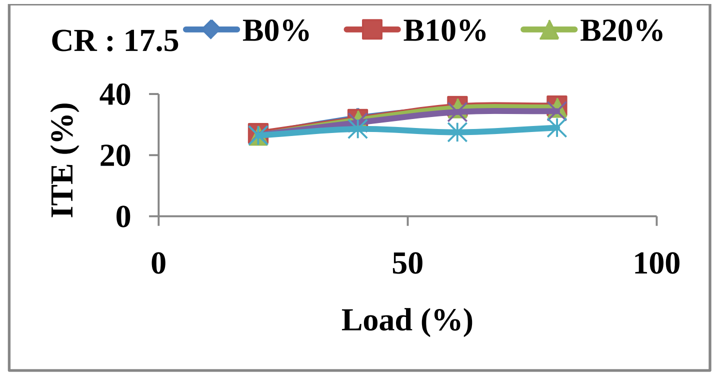

Fig 3.6 Variation of ITE with load for different percentage of Mahua oil and diesel with CR17.5

The variation of indicated thermal efficiency with load at different percentages of diesel- Mahua oil biodiesel blends are shown in figures 6.28 to 6.32. From the figure it was observed that the indicated thermal efficiency increases with load in all cases. From the figure it was further observed that the indicated thermal efficiency of the Mahua oil -biodiesel is marginally less by 1.0 - 5% compared to neat diesel operation for normal compression ratio. From the figure 6.28 it was observed that the indicated thermal efficiency for neat diesel at 80% load is 36.27%, where as it is 36.05%, 36.18%, 35.13%, 29.03% when run an engine with B10, B20, B30, & B40 Mahua oil - biodiesel blends. Thus for Mahua oil -biodiesel blend the indicated therma1 efficiency will be 0.11% less for 10% Mahua oil blend, 0.72% less for 20% blend, 1.89% less for 30% blend, 7.30% less for 40% blend at 80% load.

4. Conclusions

In the present work the performance evaluation of single cylinder four stroke DI diesel engine using neat diesel and Mahua oil for different blends and compression ratios are carried out.

- Performance of the 20% Mahua oil -biodiesel blend was only marginally poorer at part loads compared to the neat diesel performance.
- At higher loads engine suffers from nearly 1 to 1.5% brake thermal efficiency loss for 20% and 30% blends.
- As the blend increases that is for 30% and 40% at full load engine suffers nearly 3 to 4.5% of the break

thermal efficiency loss due the lower heating value of the biodiesel and incomplete combustion.

- The decrease in compression ratio the break thermal efficiency also decreased because of decrease in airflow leads to incomplete combustion.

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