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Effect of Using Mahua as an Alternative Fuel in Diesel Engine

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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 non-edible Mahua Oil (MO) as one of the main alternative fuels to diesel oil in India. The objective of the present work is to use MO as a partial renewable alternative substitute for diesel in the agricultural diesel engine. Since the viscosity of the MO is high, it was blended with conventional diesel oil in various proportions (M5, M10, M15 and M20 on volume basis) and fuel properties of the blends were determined and compared with the diesel. Engine tests were carried out on a single cylinder diesel engine at varying loads (0%, 25%, 50%, 75% and 100%), without making any modification in the fuel injection system and the results were compared with the diesel. The M5 and M10 blends resulted in performance and emission characteristics comparable to diesel operation and also emits lower carbon monoxide, hydrocarbon and smoke emissions as compared to other blends. From the analysis, it is concluded that the MO can be partially substituted for diesel oil in the diesel engine, without making any modification in the hardware of the engine.*

Keywords – Alternative fuel, blend, diesel engine, mahua oil, performance.

1. INTRODUCTION

During recent years high activities can be observed in the field of alternative fuels, due to supply of petroleum fuels strongly depends on a small number of oil exporting countries and increase in the price of the crude oil. In the year 2004 – 2005, India imported 75 % of crude oil from other countries to meet the energy requirements. The demand for diesel and gasoline increased drastically in the year 2008 - 2009. It has been estimated that the demand for diesel will be 66.90 million metric ton for the year 2011-2012. Hence, government of India has taken necessary steps to fulfill future diesel and gasoline demand and to meet the stringent emission norms. Biodiesel and alcohol are being considered to be supplementary fuels to the petroleum fuels in India. These biofuels 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]. Jamieson [2] listed over 350 oil-bearing crops while Duke and Bagby [3] identified 70 species of oil seeds with considerable potential. The interest in using vegetable oils as alternative fuels originated within the agricultural community as a fuel for agricultural tractors and equipment [4]. Mohibbe *et al.* [5] examined the fatty acid profiles of seed oils of 75 plant species having 30 % or more fixed oil in their seed. They reported that the fatty acid methyl esters of oils of 26 species were found most suitable for use as biodiesel.

Many researchers [6]-[8] have tried to use biodiesel derived from mahua oil as fuel for diesel engine. They reported that the properties of the mahua biodiesel meet the major specification of biodiesel standards. From the engine test results, they reported that the B20 blend results in reduction in exhaust emissions and brake specific fuel consumption together with increase in brake power and brake thermal efficiency.

In most of the countries including India, biodiesel is expensive than the diesel and also biodiesel is not available in the market. Most of the work reported in the literature involves only the laboratory studies. Hence in recent years, efforts have been made by several researchers [9]-[17] to use vegetable oils like sunflower, jatropha, coconut, peanut, pongamia, rubber seed, jojoba, karanja *etc.* as alternate fuel for diesel. Few of these vegetable oils are edible in nature. In the literature, it is reported that the use of vegetable oil in diesel engine results in lower efficiency, higher smoke emission, filter clogging, carbon deposits in injector, compression ring grooves, dilution of the lubricant *etc.* This is due to the high viscosity of the vegetable oils and there are several ways to reduce the viscosity of the oil. One of the options is blending or dilution with other low viscous oil or diesel. The engine performance with the blending improves the performance and reduces the emissions compared with the neat vegetable oil.

In rural and remote areas of developing countries, where electrical power is not available, vegetable oils play a vital role in decentralized power generation for irrigation and electrification purposes. In these remote areas, different types of vegetable oils are available locally but it may not be possible to chemically process

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them and hence these oils are not being properly utilized. Hence, blending vegetable oil with diesel is an attractive option. Keeping these facts in mind, a set of experiments were conducted on a diesel engine which is used for agricultural, irrigation and electricity generation purposes, using non-edible MO which available in Asian countries. Use of non-edible oil as fuel in agricultural diesel engine will improve rural economy, sustainability and increase the environmental benefits.

2. CHARACTERIZATION OF MAHUA OIL

Mahua name for a medium to larger tree, madhuca longifolia of family sapotaceae. Figure 1(a) shows the mahua tree. The tree may attain a height up to 20 meters. Mahua is a slow growing species, attains a mean height of 0.9 to 1.2 m, at the end of the fourth year. It is a tree of deciduous nature, of the dry tropical and sub-tropical climate. 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.

Each mahua seed contains two kernel of size 2.5 X 1.75 cm. Figure 1(b) shows the seeds of the mahua tree. The drying and decortification yield 70% kernel on the weight of the seed. The kernel of seed contains about 50 % oil. The oil yield in a screw expeller is nearly 34 % - 37%. The fresh oil from properly stored seed is yellow in color [18]. The seed and oil potential of this tree in India is 0.5 and 0.18 million metric ton respectively [19]. The potential of the MO is less than the diesel demand. In villages, MO is used for oil message and lighting the lamps and does not have any other commercial applications. Hence the natural production of mahua seeds itself become waste. If MO is suitable for fuel in diesel engine, then the value of MO may increase.

(a) (b)

Fig. 1. (a) Mahua tree; (b) Mahua seeds.

The fatty acid composition of the MO is oleic acid (46.3%), linoleic acid (17.9%), palmitic acid (17.8%) and stearic acid (14.0%). The mahua seed paste has medicinal value. It is applied to cure muscle fatigue and relieve pain in the muscle and joints. The mahua oil contains toxic saponins [20]. The multigeneration reproduction study on rats indicated the poor reproductive performance in the second generation of the rats [21]. Hence, MO is non-edible oil.

3. FUEL PROPERTIES

For the present work, double filtered and refined MO was used. Table 1 compares the properties of the MO, blends of MO and diesel (M5, M10, M15, M20) and diesel.

From the table it is observed that, as the mixture strength increases, the value of density, flash point, fire pint, viscosity and specific gravity also increases. This is due to the corresponding higher values of the MO. But the value of calorific value decreases due to lower calorific value of the MO. Also there is a slight difference between the properties of M5, M10 and diesel.

In India, non-edible oils such as honge, mahua, jatropha, neem *etc.* are available in large quantities [19]. Most of these oils have medicinal values. But till today, these oils are not used for medicinal applications commercially. These oils are available in large quantities in rural and remote areas but farmers never use these oils. Hence the natural production of these oils becomes waste. Hence government of India prefers the use of these non-edible oils as partial substitute for diesel, to improve the rural economy and employment. India, imports more than 75% of the petroleum oil from other countries and this affects the economical growth and energy security. Hence government of India encourages use of these oils as substitute for diesel will reduce petroleum oil import, foreign exchange and self reliant in energy [22]. Hence in this work, feasibility study was carried out to use mahua oil as a partial substitute for diesel in agricultural diesel engines.

4. ENGINE TEST

A single cylinder, four stroke, water cooled, direct injection, computerized diesel engine test rig was used for the present work. The schematic of the experimental setup is shown in Figure 2.

Fig. 2. Experimental setup.

An eddy current dynamometer was used for loading the engine. The engine speed was sensed and indicated by an inductive pick up sensor. The fuel flow rate was measured on the volumetric basis using a burette and a stopwatch. A chromel alumel thermocouple in conjunction with a digital temperature indicator was used for measuring the exhaust gas temperature. An AVL smoke meter was used to measure the smoke emission and MRU make exhaust gas analyzer was used for the measurement of emissions in exhaust gases. Table 2 shows the details of the engine.

The engine tests were carried out without making any modification in the fuel injection system. The diesel engine was started with required fuel (Diesel or Blend) and at steady state condition and at no load condition, fuel flow rate, air flow rate, speed and exhaust emissions such as carbon monoxide (CO), unburnt hydrocarbon (UBHC), smoke and oxides of nitrogen (NOx) were recorded. Then the load was increased to 25% of full load and observations were recorded. Similar procedure was followed for 50%, 75% and 100% loads.

Table 1. Properties of MO, blends and diesel.

Properties	Diesel	MO	M5	M10	M15	M20
Density (kg/m^3) at 30°C	828	905	836	843	851	860
Flash Point (°C)	56	225	74	82	91	102
Fire Point (°C)	65	232	79	86	99	113
Viscosity (cst) at 40°C	3.78	26.5	5.02	6.48	8.08	9.74
Calorific Value (MJ/kg)	42.96	35.61	42.61	42.21	41.78	41.31
Specific Gravity	0.828	0.906	0.836	0.843	0.851	0.860

Table 2. Engine details.

Engine	Single cylinder, four stroke, water cooled diesel engine
Make and Model	Kirloskar AVI
Rated Power	3.74 kW at 1500 rpm
Bore X Stroke	80 X 110 mm
Compression Ratio	16.5 : 1

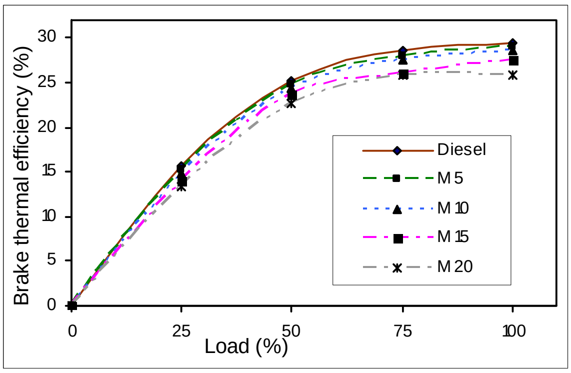

Fig. 3. Variation of brake thermal efficiency with load.

5. RESULTS AND DISCUSSION

The different blends of MO with diesel were prepared. The properties of M5 and M10 were comparable to diesel and better than M15 and M20. The engine was running without knocking for blend operation. The performance and emission characteristics of the diesel engine with different blends are discussed below.

Brake thermal efficiency is defined as the ratio of brake power to the heat supplied. Figure 3 shows the variation of brake thermal efficiency at different loads. From the figure it is observed that as the blend strength increases, the efficiency decreases. This is due to lower volatility, higher ignition-related temperatures (flash point, fire point) and higher viscosity of the blend, which results in poor fuel utilization and increased fuel consumption. Also as the load increases, the variation in thermal efficiency of the blends increases. This is due to the higher fuel consumption at higher loads. At low loads, the variation in efficiency of diesel, M5 and M10 blends is small. But at full load, M5 and M10 blends result in slightly lower efficiency as compared to the diesel. The M5 blend results in higher efficiency as compared to other blends. Also there is a slight variation in efficiency of M5 and M10 blends.

The variation of smoke emission with load is shown in Figure 4. From the figure it is observed that as the blend strength increases, the smoke emission also increases. This is due to the higher viscosity of the blend, which results in poor spray formation and penetration of the fuel. This results in poor combustion and higher smoke emission. There is a slight variation in smoke emission of all blends at low loads. But at higher loads, M15 and M20 blends result in higher smoke emission due to consumption of large quantity of fuel. The variation in smoke emission of M5 and M10 is small and M5 blend results in lower smoke.

Figure 5 shows the variation of carbon monoxide (CO) emission with load. From the figure, it is observed that the CO emission of M10, M15 and M20 were higher than the diesel. This is possible because of the higher viscosity of the blends which result in poor atomization. This results in locally rich mixtures in the combustion chamber. In consequences it caused more carbon monoxide generated during the combustion due to lack of oxygen locally. Among the blends M5 results in lower CO emission due to its lower viscosity as compared to the other blends. This results in better combustion and lower products of incomplete combustion (CO).

The variation of unburnt hydro carbon (UBHC) emission with load is shown in Figure 6. At low loads, the variation in UBHC of different blends is less. This is due to fuel homogeneity and higher oxygen availability. But as the load increases, the difference also increases. This may be due to induction of higher quantity of fuel at higher loads which results in less oxygen available for the combustion when more fuel is injected into the engine at higher load. The M5 and M10 blends result in lower UBHC emission than the other blends.

Figure 7 shows the variation of NOx emission with load. The NOx emission depends on the combustion temperature. If the combustion temperature increases, the NOx emission also increases. From the figures, it is observed that the blends result in lower NOx emission. This is due to poor combustion of the fuel, which results in lower combustion temperature and hence lower NOx emission. The lower exhaust gas temperature also indicates the same trend.

Figure 8 shows the variation of exhaust gas temperature (EGT) with load. From the figure, it is observed that the EGT of all blends were lower than the diesel. This may be due to incomplete combustion of the injected fuel, which results in lower combustion temperature and hence lower EGT.

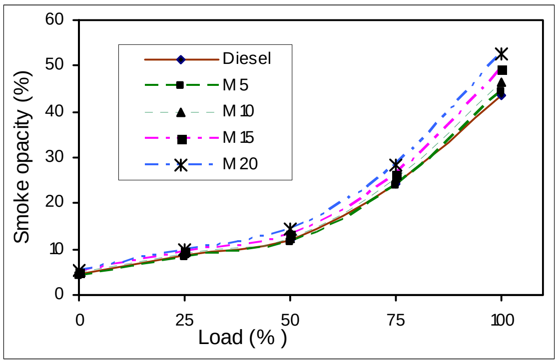

Fig. 4. Variation of smoke opacity with load.

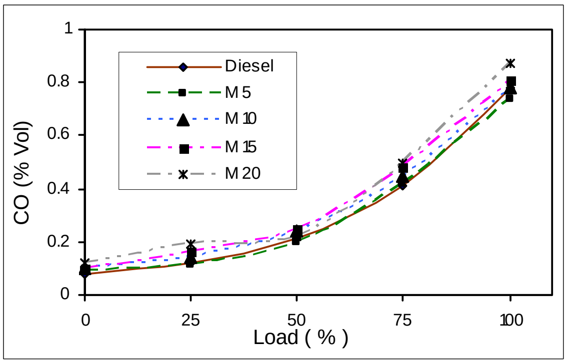

Fig. 5. Variation of carbon monoxide with load.

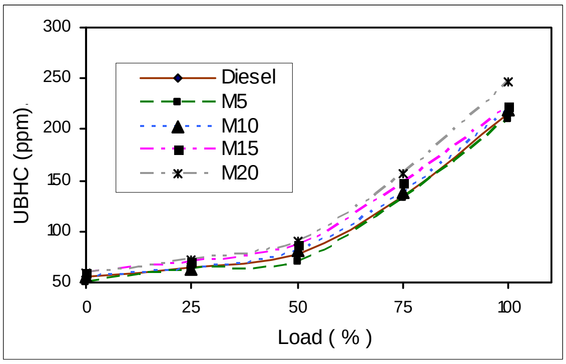

Fig. 6. Variation of unburnt hydrocarbon with load.

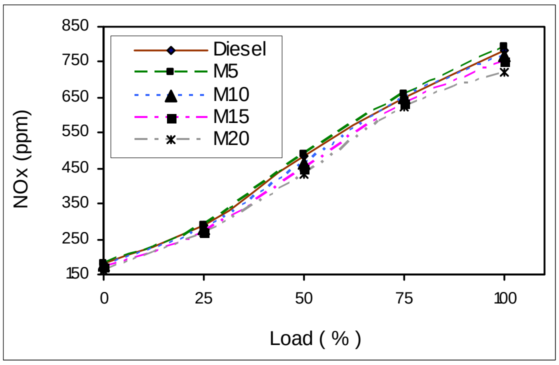

Fig. 7. Variation of NOx with load.

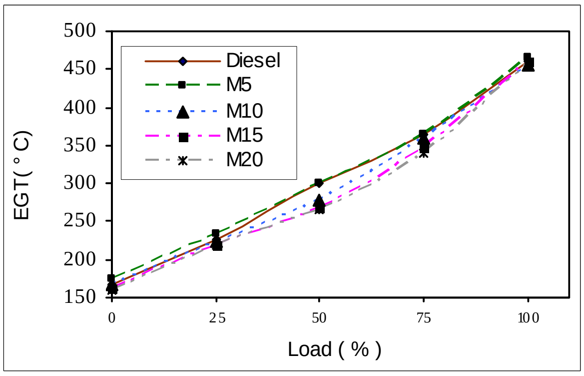

Fig. 8. Variation of NOx with load.

Since MO is non-edible oil, its cost is ¼ of the diesel. This oil is available in rural India and is underutilized. Using MO as a partial replacement to the diesel will help the farmers to save the diesel and for rural development.

6. CONCLUSION

The flash point, density and viscosity of the MO are higher than the diesel, but it has lower calorific value. Mixing diesel with the MO reduces the viscosity of the blends of MO and diesel. But the property of the M5 is close to the diesel. The engine performance and emission characteristics of M5 and M10 blends are better than the other bends and close to diesel, due to their lower viscosity and higher volatility. But the higher blends (M15 and M20) result in lower thermal efficiency and higher smoke emission due to poor utilization and higher fuel consumption. The experimental results agree with the similar type of work reported by the other researchers [11]-[17] for other vegetable oils. Based on the engine tests, it can be concluded that the MO can be adopted as an alternative fuel for application in agricultural diesel engine as a partial replacement for diesel. Use of MO as fuel in agricultural diesel engine will improve rural economy, sustainability and increase the environmental benefits. Further study is required to study the feasibility of using higher blends of MO and diesel, without compromising efficiency and emissions of the engine.

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