Performance and Emission Characteristics of Diesel Engine Fueled with Mahua Oil Methyl Ester Blended Diesel with Methanol Additives

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Abstract

Objectives: This work investigates the emission and performance characteristics of compression ignition engine fuelled with Mahua oil biodiesel blended with commercial diesel fuel with additives as methanol. At first, the fuel was prepared by blending 10%, 20% and 30% of Mahua oil biodiesel with diesel on volume basis after that in the same fuel mixture 5%, 10% of methanol is added as additive in volume basis. Methods: Experiment was conducted in water cooled, 4 stroke single cylinder naturally aspirated CI engine, at continual speed of 1500rpm by changing the load from 0% to 100% and performance and emission characteristics has been obtained. Findings: The result shows that the performance of the engine is improved marginally with 5% methanol in biodiesel (B10) in comparison with diesel fuel and 10% of Mahua biodiesel with 5% of methanol has higher Brake thermal efficiency (BTE). As compared to diesel fuel, the Mahua diesel blends leads to reduced NOX emission of the aspired diesel engine. With the high amount of methanol in the Mahua biodiesel blends the HC and CO emissions are increased. Novelty: As the engine performances increases with Mahua blended oil in low blended fuels and also the low emission proves that the Mahua oil blended biodiesel can be an alternative fuel for the CI engine.

Keywords: Biodiesel, Blended Diesel, Combustion, Mahua Oil

1. Introduction

Search of non-conventional energy sources like biodiesels is constantly increasing due to the high demands of the diesel products and their increased costs and global changes in climatic condition. Biodiesel is a suitable alternative energy source for diesel and has various remarkable properties like it is biodegradable and less toxic in nature, better emission characteristics and it has very good lubricity. At present in many other countries biodiesel is produced from the various kinds of feedstock’s that are easily available and can be cultivated domestically. A Planning Commission Committee (PCC) was established which concluded that biodiesels have to be produced from inedible oils like Mahua, Jatropha etc. Recently, Mahua methyl ester and methanol have become popular for diesel engines. Mahua methyl ester with methanol additives and diesel fuel blends are capable of being used on existing diesel engines to achieve energy and ecological benefits. This biodiesel can be made from feedstock’s that are considered viable. Agarwal et al. compared diesel with Mahua oil and their blends on the basis of emission and performance characteristics by using it in 4-stroke single cylinder, diesel engine. From the results it was clear that Mahua oil blend, compared to diesel, was thermally more efficient and also has better Brake Specific Energy.

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Consumption (BSFC) than other oil blends. Raheman and Ghadge tested various blends of the methyl ester of Mahua oil (MOME) in a (Ricardo E6) 4-stroke water-cooled diesel engine. There was a reduction in exhaust emissions with increased BTE. This paper deals with the performance, combustion and emission characteristics of four strokes, water cooled diesel engine fuelled with Mahua oil methyl ester blended diesel fuel with methanol additives. The experiment was conducted for the blend ratio B10, B20 & B30 with 5% and 10% of methanol additives. The result shows that the performance of the engine is improved slightly with 5% methanol additives in Mahua methyl ester (B10). B10M5 biodiesel has higher BTE at higher load as compared to diesel fuel. On overall comparison with diesel fuel, the BE blends had reduced emissions and NO\textsubscript{X} and particulate matter. Higher percentage of methanol in the BE blends, could increase the hydrocarbon and CO emissions but using B10M5 methanol could reduce the HC and CO emissions as well.

2. Materials and Methods

2.1 Experimental Setup

An experimental setup was made with necessary equipment to evaluate the performance and emission specifications of the engine. The overall view of the experiment setup is shown in figure 1. The present paper discusses the details of the experimental setup, instruments used and software needed for the work. The figure below represents testing setup for diesel engine used to study engine characteristics like performance, emission and combustion. All the specifications of an engine are listed in the Table given below. In our experiment all the temperature was measured using K type thermocouples and resistance temperature detector (RTD) like Coolant temperature, exhaust gas temperature, and engine lubricating oil temperature. To maintain constant engine temperature, cooling system (mixing water type) was used.

3. Results and Discussion

Here the results have the main aim to form new ideas of blended fuel investigation on the performance and emissions of engine. For Mahua methyl ester blends and added methanol additives with high ethanol content.

3.1 Brake Specific Fuel Consumption

From the results it is clear that as the amount of Mahua methyl ester blends with added methanol addi-
| Product                     | Specification                                      |
|-----------------------------|----------------------------------------------------|
| **Engine**                  |                                                    |
| Model                       | Make Kirloskar, Model TV1                          |
| Type                        | 1 cylinder                                         |
| Strokes                     | 4 Stroke                                           |
| Cooling system              | Water cooling                                      |
| Power                       | power 5.2 kW at 1500 rpm                           |
| Dimension                   | Stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5       |
| **Dynamometer**             | Type eddy current, water cooled, with loading unit |
| **Air box**                 | M S fabricated with orifice meter and manometer    |
| **Fuel tank**               | Capacity 15 lit with glass fuel metering column    |
| **Data acquisition device** | NI USB-6210, 16-bit, 250kS/s.                      |
| **Crank angle sensor**      | Resolution 1 Deg, Speed 5500 RPM with TDC pulse.   |
| **Piezo powering unit**     | Make-Cuadra, Model AX-409                         |
| **Piezo sensor**            | Range 5000 PSI, with low noise cable               |
| **Temperature sensor**      | Type RTD, PT100, and Thermocouple, Type K         |
| **Temperature transmitter** | Type two wire, Input RTD PT100, Range 0–100 Deg C, Output 4–20 mA and Type two wire, Input Thermocouple, Range 0–1200 Deg C, Output 4–20 mA |
| **Load indicator**          | Digital, Range 0-50 Kg, Supply 230VAC              |
| **Load sensor**             | Load cell, type strain gauge, range 0-50 Kg       |
| **Fuel flow transmitter**   | DP transmitter, Range 0-500 mm WC                  |
| **Air flow transmitter**    | Pressure transmitter, Range (-) 250 mm WC          |
tives increases the value of the Brake Specific Fuel Consumption (BSFC) increases. From the figure 1 it is clear that with the increase in load, the BSFC of Mahua methyl ester and blend decreases. Possible reasons for this decrease in BSFC could have been the increased percentage of increase in load with brake power as compared to fuel consumption. At the same time, for the same volume the amount of Mahua methyl ester blends was injected more into the combustion chamber as compared to diesel, due to higher density of Mahua oil. The Graph1 shows the BSFC trend for Mahua methyl ester blends with added methanol additives and diesel are more over similar in nature. From the result, it is clear that by increasing methanol additives proportion in the fuel blend, BSFC also increases. The heating value of the methanol additives is less than diesel this can be reason for high BSFC. With a rise in combustion temperature BSFC decreases with respect to power as heat energy is converted to mechanical energy.

3.2 Brake Thermal Efficiency

Brake thermal efficiency is used to study and analyse how well an engine converts the heat from a fuel to mechanical energy\textsuperscript{12,13}. BTE results are presented in Figure 2. The experimental results showed no general correlation can be confirmed between the biodiesel blend ratio and BTE, however, at high power, BTE increases for B10M5 blend as compared to diesel fuel. This can be attributed to methanol blend’s oxygen enrichment that causes rapid premixed combustion, leading to increase in the percentage of volume combustion, lower heat losses and better mixing while ignition delay. Due to excess oxygen, Mahua methyl ester and blends there is improvement of diffusive combustion phase. With this, the total combustion duration becomes shorter as the process of heat release is completed at the position of the same crank angle that supports the fast diffusive combustion phases in the Mahua methyl ester blends and added methanol addi-

![Figure 1. BSFC vs BP.](image-url)
tives. Due to these reasons, the energy consumption rate decreased for blends and increased for BTE.

3.3 Indicated Thermal Efficiency

When the load of the engine increases the indicated thermal efficiency first increases and then decreases at intermediate load and increases at higher load. The indicated thermal efficiency (ITE) for Mahua methyl ester and blends are lower as compared to the diesel as seen in the Figure 3 except B10M10 due to considerable friction loss. At the same time, for the same volume, more Mahua oil methyl ester or its blends were injected into the combustion chamber. In addition to these parameters, parameters like atomization ratio and viscosity were also taken in account since they affect the indicated thermal efficiency.

Figure 2. BTE VS BP.

Figure 3. ITE vs BP.
3.4 CO Emission

During the combustion of a hydrocarbon fuel, a colourless but toxic gas called carbon monoxide is emitted as an intermediate product which means it is a result due to improper premixed combustion. Therefore, CO emission is based on the ratio of air–fuel mixture. Figure 4 shows results of CO emissions. The results showed that lower loads of Mahua methyl ester blends increased the CO emissions whereas higher loads slightly decreased the emissions, compared to diesel fuel. The increased percentage of CO for low load for Mahua methyl ester and diesel is attributed to delayed combustion process. CO emissions are slightly reduced in Mahua methyl ester blends at high load as compared to diesel and this is due to improved combustion which is due to better mixing. There is the reduction in CO emission for B10M5 as compared to other biodiesel and diesel is due to better mixing of fuel at full load condition.

![Figure 4. CO vs. BP.](image)

3.5 CO$_2$ Emission

CO$_2$ exists naturally in the earth’s atmosphere and is a by-product of burning hydrocarbon fuels. The Figure 5 describes an effect of using methanol blended Mahua

![Figure 5. CO$_2$ vs BP.](image)
methyl ester fuels on CO$_2$ emission. Compared to diesel fuel, apart from B10 and B10M5 working conditions, the CO$_2$ emissions are unaffected for other blends. But for high load, blends show poor combustion characteristics due to more consumption of fuel to obtain similar power and thus CO$_2$ emissions increased for blends. There is the decrease in B10 and B10M5 due to proper mixing and better combustion as compared to other blends at working conditions.

### 3.6 HC Emission

HC emission is irritants, carcinogenic and odorant. They combine with atmospheric gases and form photochemical smog. At no load condition, when there is inadequate oxygen to react with all the carbon, high levels of HC exist in the exhaust products. This holds true during start of the process when the air–fuel mixture is purposely made very rich. Figure 6 shows that there is the increase in HC emission at high load condition due to poorer combustion, improper mixing and leakage past the exhaust valve. The HC emission of B10M5 is lower than other blends and diesel due to proper mixing, proper combustion and high content of carbon.

### 3.7 NO$_x$ Emission

Most harmful emissions are NO$_x$ emissions. The amount of NO$_x$ produced is dependent on oxygen content and cylinder temperatures. The variations in NO emissions at different brake powers are shown in Figure 7. It was noted that NO emissions were higher for methanol blended fuels as compared to diesel fuel at workloads other than B10 and B10M5. Because of the lower Cetane index, blend's ignition is delayed because of which fuel collection increases in the delay period. Due to longer delay period the temperature of the combustion increases and the NO$_x$ formation takes place. As observed from the above graph that there is a drastic rise in NO$_x$ for increasing load due to improper mixing and in-cylinder temperature.

![Figure 6. HC vs BP.](image-url)
4. Conclusions

The Break Specific Fuel Consumption (BSFC) of the Mahua methyl ester increases with increasing the blends and methanol additives. Brake thermal efficiency of B10M5 is 9% greater than the diesel at full load condition. The CO emission is 33% decreased at intermediate load and 55% decreased at full load condition as compared diesel. The CO₂ emission is 40% decrement decreased at intermediate load and 58% decreased at full load condition as compared diesel. The HC emission is 40% decrement decreased at intermediate load and 57% decreased at full load condition as compared diesel. The NOₓ emission is 44% decrement decreased at intermediate load and 57% decreased at full load condition as compared diesel.

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