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INVESTIGATION OF PERFORMANCE AND EMISSION CHARACTERISTICS OF DI DIESEL ENGINE FUELLED WITH MAHUA ETHYL ESTERS

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ABSTRACT

The utilization of diesel engine is continuously increasing due to higher fuel to power ratio and efficient. But, it causes increasing the emissions and the fossil petroleum products are also diminishing rapidly. Thus, it is essential to substitute the diesel fuel with non-edible vegetable oils and animal fat oils. In the present investigation diesel was replaced by Mahua Oil Ethyl Esters (MOEE) with a variety of compositions (M10, M20, M30, and M40) to analyse the performance and the emission characteristics of the diesel engine. In the present experimental work, the engine was made to run on constant speed at varied load conditions. Based on the performance analysis of present investigation M30 gave enhanced results, compared to the pure diesel and the other blends. Therefore, M30 was taken as an optimized blend. For that blend, the air preheating and supercharging was used. The air pre- heating at 60ºC of M30 showed the improvement of mechanical efficiency and brake thermal efficiency when compared with the diesel and all other blends of MOEE. Since, the blends of MOEE have more oxygen content it reduces the emissions of HC, CO, and Smoke compared to pure diesel.

Key words: blend, diesel, emission, mahua oil, performance

INTRODUCTION

The present energy scenario entire world mostly depends on the diesel fuel (Premkartikkumar et al., 2015). But the resources of diesel are continuous decreases and price of diesel reaches to peak. The CO_2 emission of diesel engines is causing to global warming (Kumar, et al., 2014); it leads to increase the earth temperature every year. Thus, most of the researchers are going investigations for replacing the diesel with the Non-edible oils such as Mahua, Cotton seed, Mustard, Jatropha, Karanja, Neem, and etc (Syed Adnan Hasan, et al., 2016). Generally, Non edible oils are contain-ing the fatty acids such as Arachidic, oleic, linoleic, palmitic, and stearic (Van Gerpen, 2005). Nayak et al., (2014) conducted the experiments on diesel engine fuelled with mahua oil biodiesel with additives; from that they found, brake thermal efficiency was improved with increase of additives, higher combustion temperature in case of pure biodiesel thus lead to increasing the NO_X emissions, then the higher combustion temperature was controlled by adding the additives to the biodiesel. Kapilan et al., (2008) tested the engine fuelled with mahua biodiesel and they conclude that blend 20 gives higher brake thermal efficiency and less smoke when compared with the pure diesel. Radha Krishna et al., (2016) run the diesel engine fuelled with cotton seed oil methyl esters and they observed that mechanical efficiency of B20 improves by 8.9% compared to the diesel. Huang et al., (2011) studied the properties of biodiesel is an alternative to diesel and they conclude that bio diesel shows the gradual reduction of HC, CO, and PM emission but it causes higher NO_X emission due to high combustion temperature.

Air preheating is a method used to heat the intake air temperature prior to entering the cylinder of a diesel engine. To pre heat the air, the air heater was used, and its temperatures were measured by using the thermocouples. This air preheating technique showed the good effect on controlling the emissions and improves the efficiency of the engine. Papagiannakis (2013) worked on diesel engine with air pre heating technique; he found the reduction of NO_X and CO emissions at an intake temperature of 55ºC compared with intake air at atmospheric temperature. Ramesh Babu et al., (2016) investigated the efficiency of the diesel engine by using the exhaust gas to pre heat the intake air. They found the improvement of mechanical efficiency at a high temperature of intake air when compared with atmospheric temperature condition. Banugopan et al., (2010) conducted the experiments on diesel engine ethanol diesel as a fuel and used the air preheating method; they found that gradual rise in brake thermal efficiency with an increase of inlet air temperature. The effects of air inlet temperature with oxygen enriched hydrogen on diminution of exhaust gas emission and improvement of fuel economy was observed in diesel engine (Premkartikkumar, et al., 2014). Nagaraja et al., (2012) worked on the variable compression ratio multi fuel engine. From that they concluded the palm oil methyl esters exhibits better performance, combustion and great reduction in emissions without any modification of current diesel engines.

EXPERIMENTAL MATERIALS

Mahua: Mahua, it is scientifically called as Madhuca longifolia. It belongs to Sapotaceae family. Mahua trees are grown in all type of climates in India with fast-growing nature. Mahua tree grows to a height of maximum 20m with a life span of 8-18 years. It is a deciduous tree and plays a vital role in socio-economic value; In India, Mahua tree yields nearly 0.35 quintals of seeds per annum and the average yield of MO per year is 1350 billion tons (Nayak, et al., 2014). Mahua seed kernel contains the 50% of oil and it is extracted by screwed pressing technique. Free Fatty Acid [FFA] of raw mahua oil was shown in Table 1. The raw mahua oil is greenish yellow in colour and it contains 36 mg/gms acid values with 18% of free fatty acid. The acid value of raw mahua oil is more than one percent, so transesterification process (Nagaraja, et al., 2016) was carried out by use of a base catalyst to decrease the acidity to below (1-2) mg/gms.

Table-1: Mahua oil FFA composition

Free fatty acid	Structure	Chemical formula	Weight %
Palmitic	16.00	$C_{16}H_{32}O_2$	23.1
Stearic	18.00	$C_{18}H_{36}O_2$	21.6
Arachidic	20.00	$C_{20}H_{40}O_2$	01.8
Oleic	18.11	$C_{18}H_{34}O_2$	38.2
Linoleic	18.20	$C_{18}H_{32}O_2$	11.3

EXPERIMENTAL SETUP AND TEST PROCEDURE

The experiments are carried out on a single-cylinder diesel engine with mechanical loading. The smoke meter and AVL gas analyzer are used for measuring the emissions. The engine was initially run on the diesel fuel at no load condition with rated speed of 1500 rpm; run the engine up to the stabilized cooling water and lubricating temperature. The parameters are taken at the rated speed by varying the loads with an increment of 25% from the no load condition. The experimental engine set up is shown in Fig. 1

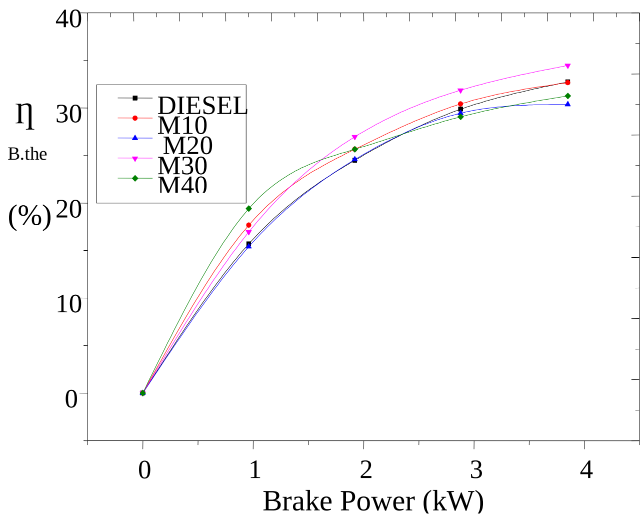
Fig. 1. Experimental engine setup

Diesel fuel was replaced with the MOEE (M10, M20, M30, and M40) and all the parameters were tested. From the obtained result M30 blend was selected as the optimized blend. For that blend, preheating and supercharging techniques were applied for further improvement of the performance and reduction of emissions.

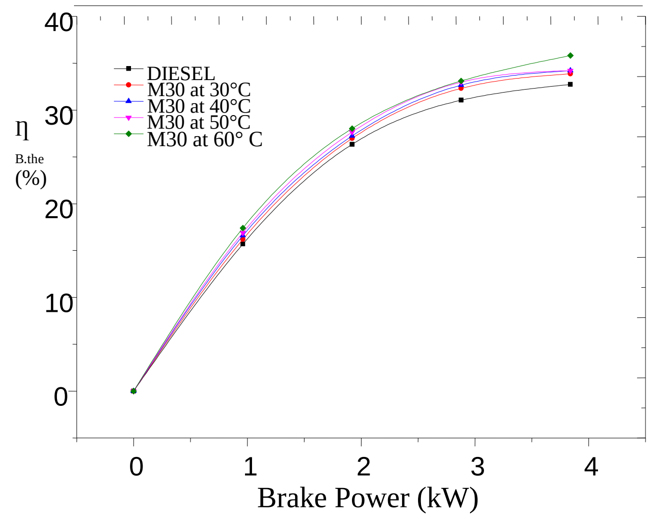
RESULTS AND DISCUSSION

In the present experimental work, the mechanical efficiency, the brake thermal efficiency, and the brake specific fuel consumption were calculated from the observed parameters and were shown in the graphs. The emissions parameters such as Carbon monoxide, unburned hydrocarbons, nitrogen oxides, carbon dioxide, and smoke were shown in the form of graphs.

Brake Thermal Efficiency (η_{Bthe}): It was a significant for how the engine transfers the chemical energy into mechanical energy. The relation between the brake thermal efficiency and BP for different fuels plotted in Graph 1. The utmost η_{Bthe} for M30 at full load 34.48% was higher than that of diesel (32.16%). The MOEE blends are having high oxygen content so that it shows the improvement in thermal efficiency. The additional oxygen leads to better combustion (Nagaraja, et al., 2015). The increment of η_{Bthe} was observed with the best blend of M30 at full load is 11.38% superior to diesel fuel of air preheating at 60^0C. The comparison of brake thermal efficiency and BP for diesel at atmospheric condition and M30 at given air preheating conditions are shown in Graph 2.

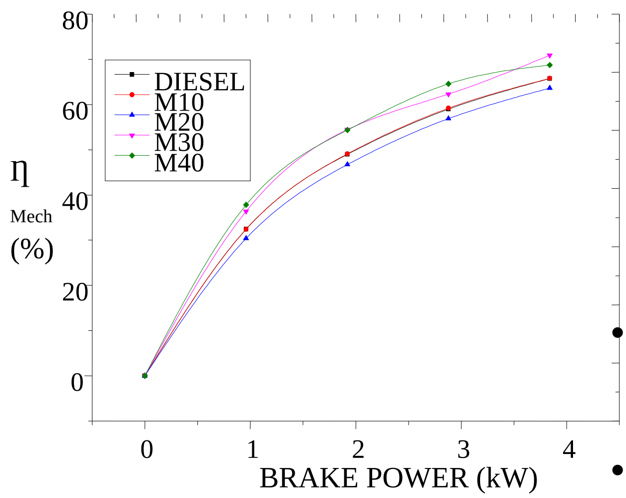


Graph 1: η_{Bthe} Vs Brake Power



Graph 2: $\eta_{B.the}$ Vs Brake Power for M30 blend at air preheating condition

Mechanical Efficiency (η_{Mech}): Mechanical efficiency measures the effectiveness of a machine in transforming the energy and power.



Graph 3: η_{Mech} Vs Brake Power

The Graph 3 shown the diesel and MOEE blends of mechanical efficiency are approximately equal at full load conditions. The considerable improvement in η_{Mech} was observed by the blend M30 was 70.91% because of lowest frictional power than to diesel. M30 having the satisfactory lubricate properties it leads to drastically decline of frictional power and significant improvement in mechanical efficiency.

Emission Analysis: The different emission parameters in the sense of Carbon monoxide (CO), Oxides of Nitrogen (NO_X), smoke density, unburned hydro carbons (HC), and unused oxygen are investigated in this work.

CO emission of the diesel mode was 0.10% by vol. The CO emission was reduced for the blends of MOEE as 0.06% by vol. This is due to more reaction of oxygen with CO. The NO_X was produced higher in the case of blends of MOEE compared with diesel due to higher combustion temperature. The amount of NO_X released with M30 is 975 ppm, whereas in the case of diesel fuel is 872 ppm for diesel fuel. The HC emissions are less for the blends of MOEE compared with pure diesel due to the high oxygen content of the blends. The ester based fuel contain higher cetane number than diesel, it gives a shorter ignition delay period and leads to better combustion (Nagaraja, et al., 2013). So that it leads to low HC emissions. The smoke is formed due to incomplete combustion in the engine. At full load condition, diesel contains 58 ppm whereas in the case of M10 it is 32 ppm at the same load. Here M10 gives lower HC compare with the other fuels. The smoke densities of blends of MOEE were lesser when contrast with the diesel. The smoke density of the diesel was recorded as 83.57 (Hatridge Smoke Unit) HSU. The smoke densities of MOEE blends are 62.96 HSU for M10 61.9 HSU for M20 and 67.16 HSU for M30 at maximum load. The smoke density of M30 was further reduced by using the supercharging technique at a pressure of 1.6 bar.

CONCLUSION

The experiment was conducted on the diesel engine with pure diesel and various blends of MOEE. From the above experimental results, the following conclusions were drawn.

- The brake thermal efficiency increased with increase in biodiesel fraction. Out of these blends, M30 shows best performance and emissions parameters.
- The maximum brake thermal efficiency obtained with M30 blend with air preheating at 60°C.

- The volumetric efficiency increases with increase in biodiesel percentage. Out of all the blends, M30 shows the best performance. The maximum volumetric efficiency obtained with M30 blend with supercharging at1.6bar.
  - The mass flow rate is increasing as compared to diesel and biodiesel of remaining blends.
  - M30 blend shows the 19.6% reduction in smoke densities on normal operation.
  - Maximum reduction in CO emissions is 40% compared to diesel.
  - Significant increase in NO_X emissions and is 11.8% more when compared with diesel.
  - Reductions in unburned hydrocarbon emissions were 8.6% to diesel with M30.
  - M30 blend decreases the environmental pollutants to a greater extent at the same time it increases thermal efficiency of the engine. This confirms MOEE is one of a promising renewable energy sources.

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