

Performance Analysis of CI Diesel Engine using Methyl Esters and Carbonate Blends with Biodiesel as Substitute Fuel

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ABSTRACT The increasing industrialization and motorization of the world has led to a steep rise for the demand of petroleum products. Petroleum based fuels are being obtained from limited reserves. These finite reserves are highly concentrated in certain regions of the world. Therefore, those countries not having these resources are facing a foreign exchange crisis, mainly due to the import of crude oil. Hence, it is necessary to look for alternative fuels, which can be produced from renewable sources. Rapid escalation of fuel prices and depleting hydrocarbon resources of the world have forced us to concentrate on alternative fuels. The use of vegetable oils as a fuel in diesel engines cause some problems due to their high viscosity compared with conventional diesel fuel. Transesterification is the technique applied to solve the problems encountered with the high fuel viscosity. It is important process to produce the cleaner and environmental safe fuel from vegetable oils.

In this work, the transesterification process of palm stearin is used in order to obtain biodiesel. In the first phase different parameters like viscosity, density, flash point, fire point etc., are investigated for the optimization of biodiesel products. While in the next phase the blends of various proportions of Dimethyl Carbonate (DMC) are prepared, analyzed and compared with diesel fuel. The comparison is made to suggest the better option among different PSME and DMC blends to give better performance parameters.

KEYWORDS: Biodiesel, Palm stearin methyl ester, Dimethyl carbonate, Diesel engine, Performance.

I. INTRODUCTION

Energy is the key input for technological, industrial, social and economic development of a nation. Five generations (125 year) ago, wood supplied up to 90% of our energy needs. Due to the convenience and low price fossil fuels use has fallen globally. The present energy scenario now is heavily biased towards the conventional energy sources such as petroleum products, coal, atomic energy etc. which are finite in nature besides causing environmental pollution. Of the available energy, the present energy utilization pattern is heavily biased for meeting the high energy requirement in urban and metropolitan cities. The extensive use of energy operated devices in domestic, industrial, transport and agriculture sectors in urban and rural areas have resulted in overall development of the society. The electricity available for forming operations and in rural and in urban areas is been generated using fossil and static energy resources such as petroleum oil, coal and atomic energy and to a limited extent by hydropower. These all sources have a great influence on our economy and environmental aspects. These have resulted in serious consideration for the use and the availability of various energy resources.

Biomass sources, particularly vegetable oil (edible or non-edible) derived from plants and trees have attracted much attention as alternative sources. Though it is renewable, available everywhere, cleaner and eco-friendly than fossil fuels, it has not been paid much attention. Edible oils have been replaced by non-edible oils, owing to their availability and cost of production. Among these fuels, [1] alcohols can be used as either blends with fossil fuels in the

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engine or as additives in biodiesel production. There are many oxygenated compounds that can be added to diesel, viz., ethanol, acetoacetic esters, dimethyl ether, dimethyl carbonate, dimethoxy methane, and a mixture of methanol and ethanol. The purpose of adding oxygenated additives to diesel is to produce a cleaner burning of diesel fuel [2]. Guarieiro *et al.* [3] evaluated the performance and emission characteristics of a diesel engine run with oxygenated fuels. In this study, three categories of fuels were employed such as B5 (diesel blend with 5% biodiesel), B5E6 (with 6% ethanol) and 100% biodiesel for evaluating the performance and emission characteristics. It is noticed that, the presence of higher oxygen content in biodiesel as well as in additives can increase the fuel consumption for the same power output, irrespective of the blend ratio. However, B5 shows an increase in HC emission with a reduction in NO_x , due to the high latent heat of vaporization and low cetane number. Further, B100 showed a reduction in HC emission with the highest rise in NO_x .

Imtenan *et al.* [4] studied the effect of oxygenated additives blended with two different biodiesels on the performance and emissions of a diesel engine. The studies have carried out with jatropha and palm biodiesel-diesel blended with three types of additives, such as ethanol, n-butanol or diethyl ether in the ratio of 80% diesel, 15% biodiesel and 5% additive. Compared with the fuel with no additives, P20 blended with diethyl ether significantly improved the brake power and brake thermal efficiency by about 4.10% and 4.4%, respectively, at 2200 rpm. Further, for the entire operation, the HC emission increased slightly, and the CO and NO_x emissions reduced marginally, for all blends using additives except P20 and J20. With the ethanol additive, the CO emission reduced by up to 40% and with diethyl ether as an additive, NO_x reduced by up to 13%. However, the oxygen content, volatility and latent heat of evaporation of the oxygenated additives can control the emission characteristics of the blends. The effects of the addition of antioxidants to the biodiesel blends have been reported by Fattah *et al.* [5] Coconut and Jatropha are two promising feed stocks taken for this investigation, added with synthetic antioxidants, 2(3)-tert-butyl-4-methoxyphenol (BHA) and 2,6-di-tert-butyl-4-methylphenol (BHT). It was reported that, the addition of antioxidants increased the brake power and reduced the BSFC slightly. Further, the NO emission reduced by 2.6–5.0%, and CO and HC increased by 4.9–20.8% and 23.2–40.2% respectively, for the antioxidant blended biodiesel compared to that without the additive blend. Varatharajan *et al.* [6] made an attempt to mitigate NO_x emissions from a diesel engine fueled with jatropha biodiesel, blended with antioxidant additives. The results proved that the addition of p-phenylenediamine additive in 0.025%-m concentration substantially reduced the NO_x level for the entire engine operations compared with that of biodiesel alone. Besides, it is found that, HC and CO emissions were increased significantly with antioxidant additives. Cheung *et al.* [7] investigated the effect of gaseous and particulate emissions of a CI engine with diesel-dimethyl carbonate blends. Four blends comprising of 4.5 to 18.6% by volume of DMC and 3 to 12% respectively, by mass of oxygen blended with diesel were used for the test. Due to the cooling effect of the oxygen content in the biodiesel, the brake specific carbon monoxide (BSCO), brake specific hydro carbon (BSHC) emission increase, and the brake specific nitrous oxide (BSNO_x) emissions reduce. However, there is an improvement in the brake thermal efficiency for the diesel-DMC blends, due to improved combustion.

DMC (dimethyl carbonate) which possesses an oxygen content of 53.3% can be used as an oxygenated additive to blend with diesel fuel, to improve combustion and to reduce the emissions of the diesel engines [8]-[9]. Venkateswara Rao *et al.* [10] conducted a performance and combustion characteristics test on a DI diesel engine, using Triacetin (T) as an additive with biodiesel. It was reported that 10% Triacetin additive with biodiesel blends (at different percentages) shows significant improvements in the performance and emissions. Shahabuddin *et al.* [11] conducted an investigation on a DI diesel engine, using IRGANOR NPA (product name) a corrosion inhibitor, as an additive with diesel and biodiesel. The final outcomes were compared with those of diesel fuel. It was observed that 20% biodiesel with 1% additive shows the best performance and reduced emissions of NO_x . Litzinger *et al.* [12] studied the effects of oxygenated additives on the aromatic species in fuel-rich ethane combustion. In this study, 5% oxygen by mass of fuel was added to ethane using dimethyl ether and ethanol. A significant reduction in the aromatic species relative to pure ethane was observed and also, the addition of DME was found to play a vital role in reducing the aromatic species than ethanol.

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II. EXPERIMENTAL SETUP

Experiments were carried out on the Single cylinder, four stroke and direct injection diesel engine. Krishi engine has the bore of 80mm, and having the stroke length of 110mm. This is an internal combustion engine having one cylinder of bore 80 mm. This engine works on diesel cycle. The rated speed of the engine is 1500 rpm. This works with diesel and other fuels like biodiesel. Engine is connected to an A.C. generator. The eddy currents will apply load on the shaft of the engine which rotated by the piston.



Fig.1. Experimental setup

Engine Specifications:

The information about the engine components

Name	KRISHI
Bore	80 mm
Stroke length	110 mm
Speed	1500 rpm
Power	6 HP
Dynamometer	A.C generator
Fuel	High speed diesel, PSME, PSME+additive
Specific gravity	0.85
Maximum load	15 amp
Voltage	220v

Table 1: Specification of the engine

III. RESULTS AND DISCUSSION

The experiment conducted on the biodiesel (Palm Stearin Methyl Ester) using additive (dimethyl carbonate). This additive is added in specific range i.e., 5, 10, 15 percentages respectively.

Fuel Consumption: On consideration of the experimental values obtained from experiment and graph the total fuel consumption of fuel is observed. The Fig. 2 shows the total fuel consumption of biodiesel and its additives is increased compared to standard diesel fuel. Further with the increase of additive percentage the total fuel consumption is increased.

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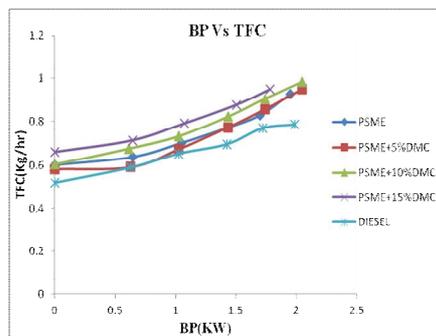


Fig.2. Variation of fuel consumption with Brake power

Brake Power: Form the figure 3 it is observed that with the increase of additive percentage the brake power is increased compared to standard diesel fuel. The brake power is depends on indicated power and frictional losses of the engine. The friction losses decrease the brake power will increase.

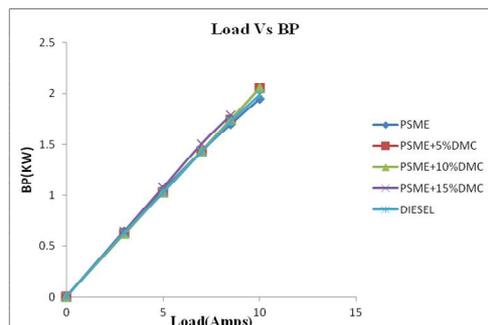


Fig.3. Variation of Brake power with load conditions

Indicated Power: Form the figure 4 it is observed that with the increase of additive percentage the indicated power is increased compared to standard diesel fuel. The indicated power depends on temperature of the cylinder valves and exhaust gases temperature. By reducing exhaust gas temperature the indicated power increases.

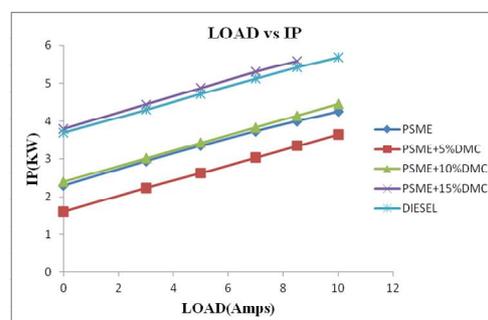


Fig.4. Variation of Indicated power with load conditions

Brake Thermal Efficiency: From the Fig.5 it is observed that the brake thermal efficiency is increased with increase in engine loads at different engine speeds. Brake thermal efficiency is higher using diesel fuel compared to PSME additives.

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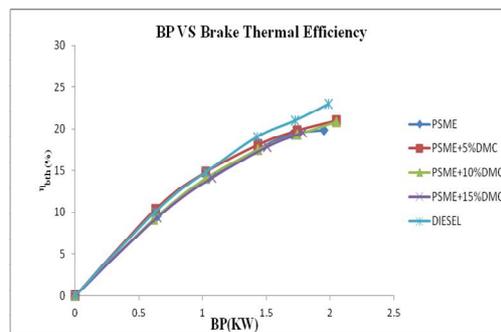


Fig.5.Variation of Brake thermal efficiency with Brake power

Mechanical Efficiency: The experimental results shows that the mechanical efficiency increases with the increase of load. High mechanical efficiency is observed incase of PSME+5%DMC . In case of PSME the mechanical efficiency is greater than diesel without adding additive.

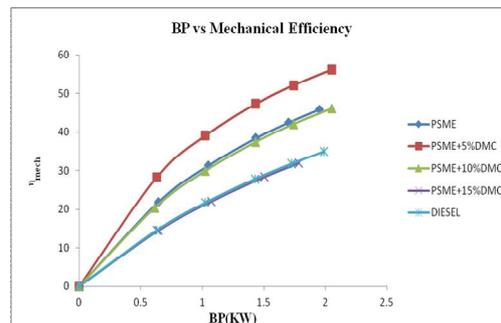


Fig.6.Variation of mechanical efficiency with brake power

Indicated thermal efficiency: It is the ratio of indicated power to actual energy in the fuel. From the Fig.7 it is observed the Palm stearin methyl ester with 15% dimethyl carbonate shows higher indicated thermal efficiency compared to diesel and other PSME blends.

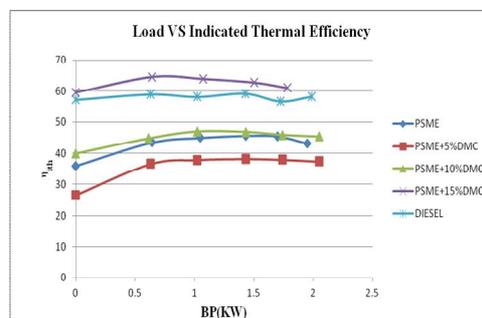


Fig.7.Variation of indicated thermal efficiency with brake power

IV. CONCLUSION

The experimental investigation is performed on a single cylinder, 4 stroke, diesel engine, to compare and evaluate the performance characteristics of Palm Stearin methyl ester-Bio diesel with dimethyl carbonate additive (PSME,PSME+5%DMC, PSME+10%DMC, PSME+15%DMC). The tests are conducted for the above fuels by

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varying the load from no load to maximum load at a constant speed of 1500 rpm. The performance parameters such as TFC, BP, IP, BTE, ME, and ITE are calculated.

The following conclusions are drawn:

- The total fuel consumption is increased 23.35% by using PSME with DMC additives compared to standard diesel fuel engine. This is due increased temperature of combustion chamber walls, cooling water temperature and viscosity of the fuel.
- The Brake power increased by 3.44% PSME with DMC additives compared to standard diesel fuel engine. The additives (DMC) added with PSME, which possesses rich amount of oxygen content compared with diesel fuel. Therefore it enhances the overall performance of the engine.
- The indicated power is increased by 2.93% using PSME with DMC additives compared to standard diesel fuel engine.
- The brake thermal efficiency is increased by 5.88% by using PSME with DMC additives compared to PSME fuel.
- The mechanical efficiency is increased by using PSME with DMC additives compared to standard diesel fuel engine.
- The indicated thermal efficiency is increased by 7.67% using PSME with DMC additives compared to standard diesel fuel engine.

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