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A Comparative Study of the Performance & Emission Characteristics of a Diesel Engine Operated on Soybean Oil Methyl Ester(SOME), Pongamia Pinata Methyl Ester(PME) and Diesel

S. Ghosh[1], D. Dutta[2]

1. Asst Prof., Camellia School of Engineering & Technology, Barasat, Kolkata - 700124, W.B., India.
2. Asst Prof., Camellia School of Engineering & Technology, Barasat, Kolkata - 700124, W.B., India.

ABSTRACT: *Biodiesel, the methyl ester of vegetable oil is a renewable, low environmental impact and potential as a green alternative fuel for diesel engine. The aim of this present work is to compare the performance and emissions of a diesel engine run on soybean oil methyl ester (SOME), Pongamia methyl ester (PME) and diesel fuel. A 4-stroke single cylinder direct injection water cooled constant speed diesel engine was first run with diesel fuel and then bio-diesel. The performance of the two biodiesels (SOME&PME) and diesel is compared on the basis of brake thermal efficiency and exhaust gas temperature and the emissions compared are carbon monoxide, hydrocarbons, smoke number and oxides of nitrogen. It is found from the results that biodiesels differ very little from diesel in performance and emission. However, oxides of nitrogen are found to be higher for biodiesels but not significantly higher when compared with diesel. It is concluded that the biodiesel can be used as alternative fuel in the Diesel engine without any engine modifications.*

Keywords - *Diesel engine, Emission, Soybean oil methyl ester, Pongamia methyl ester, Nitrogen.*

I. INTRODUCTION

Petroleum products, the actual base of the world energy matrix, are causing serious problems to the environment. In search for alternative fuels which can be used as a substitute to conventional petroleum diesel fuels is in demand due to concerns about depletion of fossil fuel reserves and also growing worldwide environmental stringent of pollution**.** Fuels derived from renewable biological resources for use in diesel engines are known as bio-diesel. It is the mono alkyl esters of long chain fatty acids derived from renewable lipid sources [1]. Biodiesel is typically produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerine and methyl esters [2, 3]. The process of production of biodiesels is called transesterification [4, 5, 6, 7] There are several of species from which biodiesels can be made available. Biodiesel can be harvested and sourced from non-edible oils like Jatropha, Pongamia, Neem (Azadirachta indica), Mahua, castor, linseed, Kusum (Schlechera trijuga), etc and edible oils like coconut, palm, sunflower ,mustered, soybean etc[8-9]. Out of these plants, soybean and Pongamia Pinnata, which can grow in arid and wastelands.

Biodiesel has some important advantages when compared to diesel fuel. Biodiesel contains almost no sulphur; is biodegradable, nontoxic and a natural lubricant. Biodiesel has a high flashpoint, about 130ºC (266ºF), so it not explode spontaneously or ignite under normal circumstance. This feature makes biodiesel much safer to transport and store. Although biodiesel contains 10% less energy per gallon than convectional diesel fuel, it exhibits almost the same performance compared to diesel fuel, because, beyond reduces engine friction between engine parts, biodiesel useable energy is partially offset by approximately 7% increase in the combustion efficiency. Biodiesel has others advantages, compared to conventional diesel fuel, such as: ready availability, renewability, biodegradability, higher centane number, flash point, cloud point and cold filter plugging point (Demirbas, 2008; Kemp, 2005; Faiz, 1996). Since biodiesel comes from a renewable energy source, its production and use as a replacement for fossil fuel provides three main benefits: reduces economic dependence on petroleum oil; decreases gas emissions that cause the greenhouse effect; and diminishes the proliferation of deceases caused by the pollution of the environment (Demirbas, 2009; Gibilisco, 2006; Gevorkian, 2006) The use of biodiesel in diesel engines require no hardware modification because vegetable oils have cetane umbers close to that of diesel fuel High viscosity of the vegetable oil leads to poor fuel atomization, which in turn may lead to poor combustion, ring sticking, injector cocking, injector deposits, injector pump failure and lubricating oil dilution by crank-case polymerization [10, 11].

Agarwal [12] conducted an experiment on a diesel engine and observed significant improvement in engine performance and emission characteristics for the biodiesel fuelled engine compared to diesel fuelled engine. Thermal efficiency of the engine improved, brake specific fuel consumption reduced and a considerable reduction in the exhaust smoke opacity was observed.

Goering et al [13] studied the characteristic properties of eleven vegetable oils to determine which oils would be best suited for use as an alternative fuel source. Of the eleven oils tested, corn, rapeseed, sesame, cottonseed, and soyabean oils had the most favourable fuel properties.

Altin et al.[14] (2001) evaluated the performance and exhaust emissions of a diesel engine using100% refined vegetable oil and their biodiesel. The authors concluded that biodiesel have better performance.

Pramanik et al.[15] (2003) evaluated the engine performance using the prepared Jatropha blends as fuel. Author reported that significant improvement in engine performance was observed compared to vegetable oil alone. The specific fuel consumption and the exhaust gas temperature were reduced due to decrease in viscosity of the vegetable oil and emission characteristics closer to the diesel fuel.

Barabas et al.[16] (2010) studied the properties, performance and emissions of the diesel–biodiesel–ethanol blends and comparing them with those of diesel fuel. They reported that, performances decrease, especially at low engine loads. CO emissions decrease significantly due to an increase of CO_2 emissions, as a result of a prolonged oxidation process.

The objective of the present study is to compare the performance and emission characteristics of a 4-stroke single cylinder water cooled constant speed diesel engine using soybean oil methyl ester (SOME), Pongamia piñata methyl ester (PME) and diesel.

II. EXPERIMENTAL SETUP

The experimental work carried out to investigate the performance and exhaust emission characteristics at different load conditions and compared with diesel fuel. Soybean oil methyl ester (SOME), Pongamia piñata methyl ester (PME) and pure diesel were used to test a single-cylinder, four-stroke, and water cooled diesel engine with eddy current dynamometer having a rated output of 5.2kW at a constant speed 1500 rpm. The technical specifications of the engine are given in Table I, and the schematic of the experimental setup is shown in Figure 1. The power output of the engine was measured by an eddy current dynamometer that was coupled with the engine. The exhaust emissions like HC, CO, and NOx were measured by AVL exhaust gas analyzer. For exhaust gas temperature and smoke measurement AVL smoke meter was used. Temperature indicator was used for the measurement of exhaust gas temperature. The engine and dynamometer were interfaced to a control panel, which is connected to a computer. This computerized test rig was used for calculating the engine performance characteristics like brake thermal efficiency and for recording the test parameters like fuel flow rate, temperatures, air flow rate, load etc. The engine was warmed up and before taking all readings the engine was allowed to come at steady state condition. All the observations are taken thrice to get a reasonable value. Properties of the fuel is shown in Table:2.

Table -1: Specification of engine

Type of engine	Four stroke single cylinder Diesel engine
Bore	87.6mm
Stroke	110mm
Compression ratio	17.5:1
Rated speed	1500
Rated power	7HP (5.2 kW)@1500rpm
Displacement volume	661.5cm^3

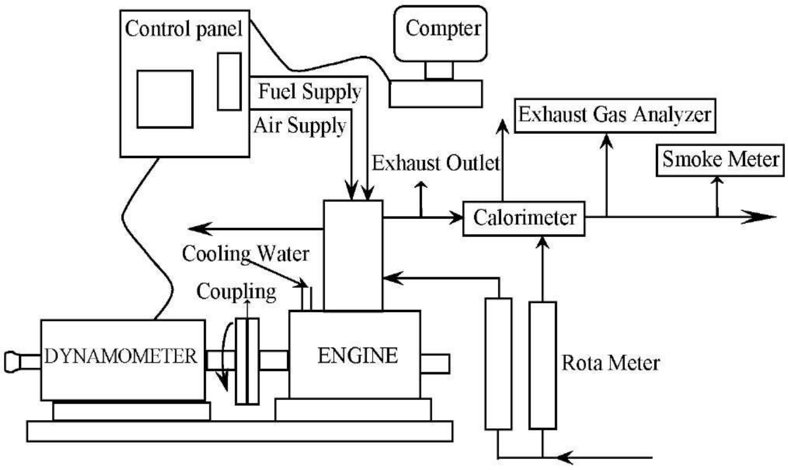

Fig.1: Schematic diagram of experimental setup

Table-2: Fuel property:

Properties	Diesel	SOME	PME
Fuel Density (kg/m^3)	835.8	904	967
Low heating value (kJ/kg)	42500	36200	38860
Cetane number	48	51.12	50
Kinematic viscosity (mm^2/s)	3×10^{-3}	4.62×10^{-3}	4.46×10^{-3}

III. RESULT AND DISCUSSION

The tests were conducted on a direct injection diesel engine for different loads and 20% soybean oil blended with diesel. Analysis of performance parameters and emission characteristics such as brake power, brake specific fuel consumption brake thermal efficiency, exhaust gas temperature, un-burnt hydrocarbon, carbon monoxide, carbon dioxide and nitrogen dioxide are determined.

1. Brake thermal efficiency

Figure 2: shows variation of brake thermal efficiency with brake power for diesel, SOME and PME at constant speed of the engine. There is no remarkable change of brake thermal efficiency up to part load conditions. But beyond that the brake thermal efficiency increases in all cases. The brake thermal efficiency for all the fuel tested is very close to each other. The highest value of brake thermal efficiency for diesel, SOME and PME are respectively 34%, 29.54% and 27.25%.The lower calorific value and higher viscosity of SOME and PME are responsible for lower brake thermal efficiency compared to diesel fuel. The brake thermal efficiency of SOME and PME is 4.46% and 6.75% respectively lower than diesel fuel at full load condition. Also at full load condition brake thermal efficiency of SOME is 2.29% higher than PME.

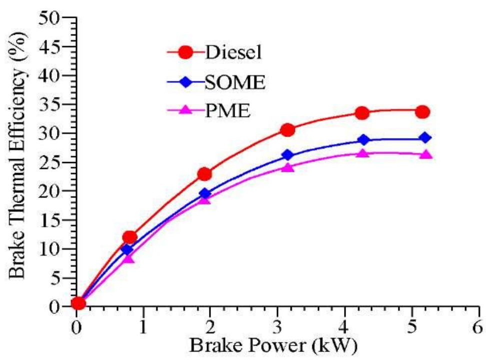

Fig.2: Variation of brake thermal efficiency with brake power

2. Exhaust Gas Temperature (EGT)

Figure 3: shows variation of exhaust gas temperature with brake power for diesel, SOME and PME at constant speed of the engine. It is observed that the exhaust gas temperature increases with the increase of the brake power in all cases. The exhaust gas temperature of SOME and PME is higher than diesel at all load condition due to high flash point temperature and high viscosity of biodiesel. At full load condition the exhaust gas temperature of diesel fuel is close to PME. The highest exhaust gas temperature of SOME, PME and diesel are 430°C, 400°C and 392°C respectively. At full load condition exhaust gas temperature of SOME and PME is 38°C and 8°C respectively higher than diesel fuel and exhaust gas temperature of SME is 30°C higher than PME.

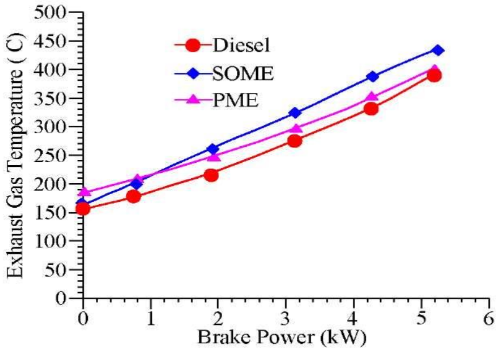

Fig.3: Variation of Exhaust Gas Temperature with Brake Power

3. Carbon Monoxide emission (CO)

Figure 4: shows variation of carbon monoxide emission (CO) with brake power for diesel, SOME and PME at constant speed of the engine. It is observed that the biodiesel emits higher CO than diesel at all load condition. The percentage of CO emission with SOME, PME and diesel is 0.325, 0.45 and 0.19 respectively. CO emission with SOME and PME is 13.5% and 26% respectively higher than diesel at full load condition due to poor spray characteristics and improper mixing. At full load CO emission of PME is 12.5% higher than SOME.

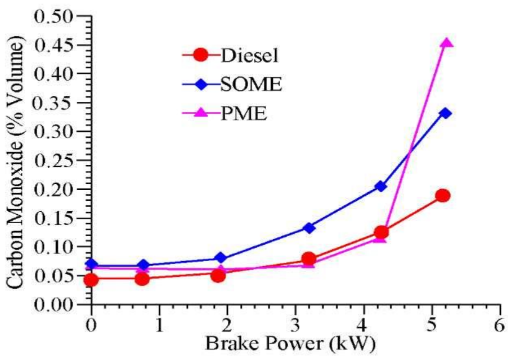

Fig.4: Variation of Carbon Monoxide Emission with Brake Power

4. Hydrocarbon emission (HC)

Figure 2: shows variation of hydrocarbon (HC) emission with brake power for diesel, SOME and PME at constant speed of the engine. At full load condition HC level of SOME, PME and diesel is respectively 75ppm, 61ppm and54ppm. HC level of SOME and PME is 21ppm and 7ppm higher than diesel fuel respectively at full load condition due to high viscosity that leads to bigger fuel droplets and hence non-uniform mixing with air. At full load HC emission of SOME is 14ppm higher than PME.

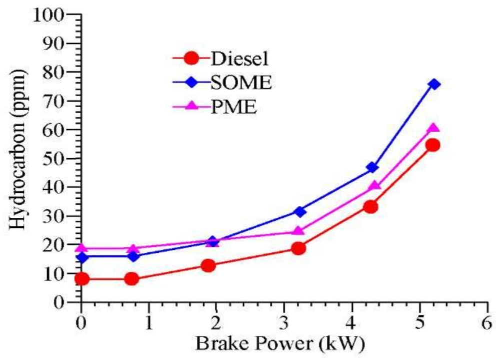

Fig.5: Variation of Hydrocarbon Emission with Brake Power

5. Oxides of Nitrogen emission (NO_x)

Figure 6: shows oxides of nitrogen emission (NOx) with brake power for diesel, SOME and PME at constant speed of the engine. It is observed that NOx emissions increase with the increase in brake power for all fuels at constant speed of the engine. At part load condition NOx emission of both biodiesel are higher than diesel fuel. At medium load condition NOx emission of SOME and diesel fuel is same. At full load condition NOx emission of SOME, PME and diesel fuel is 781ppm, 823ppm and 756 ppm respectively. NOx emissions for biodiesel is higher at all load conditions due to presence of higher oxygen content and complete combustion of the biodiesel. At full load condition NOx emission of PME is 42ppm higher than SOME and 67ppm higher than diesel fuel.

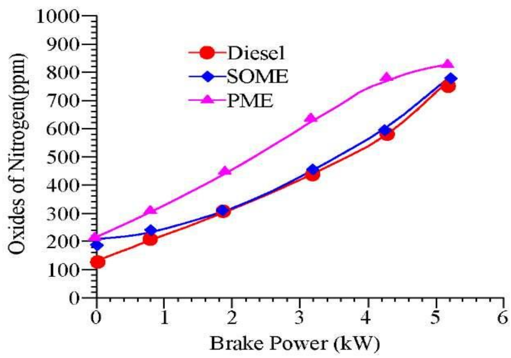

Fig.6: Variation of Oxides of Nitrogen with Brake Power

6. Smoke Density (BSU)

Figure 6: shows smoke emission with brake power for diesel, SOME and PME at constant speed of the engine. It is observed that smoke emission increase with the increase of brake power for all fuels. At full load condition smoke density of SOME, PME and diesel fuel is respectively 3.62BSU, 3.7BSU and 3.16BSU. At full load condition smoke density of SOME and PME is 0.46BSU and 0.54BSU higher than diesel fuel due to higher viscosity resulting poor atomization and that leads to larger droplets size and consequently higher smoke emission.

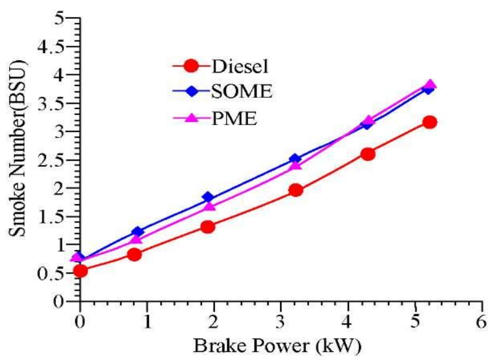

Fig.7: Variation of Smoke density with Brake Power

IV. CONCLUSION

A four stroke water cooled single cylinder direct injection diesel engine was run successfully using soybean oil methyl ester, Pongamia oil methyl ester and diesel as fuel. The performance and emission characteristics have been analyzed and compared to baseline diesel fuel. The following conclusions are made with respect to the experimental results.

1. At full load condition brake thermal efficiency of SOME and PME is 4.46% and 6.75% respectively lower than diesel and brake thermal efficiency of SOME is 2.29% higher than PME
2. Exhaust gas temperature of biodiesel blends were higher than neat diesel fuel at all load conditions and at full load condition exhaust gas temperature of SOME and PME is 38°C and 8°C respectively higher than diesel fuel and exhaust gas temperature of SME is 30°C higher than PME.
3. HC level of SOME and PME is 21ppm and 7ppm higher than diesel fuel respectively at full load condition.
4. At full load condition NOx emission of PME is 42ppm higher than SOME and 67ppm higher than diesel fuel..
5. At full load condition smoke density of SOME and PME is 0.46BSU and 0.54BSU higher than diesel fuel.

SOME and PME, biodiesel is renewable and biodegradable can be successful y used as alternative fuels in existing diesel engine without any major modification of the engine hardware.

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