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EFFECT OF INJECTION PRESSURE ON THE PERFORMANCE AND SMOKE FORMATION OF LOW HEAT REJECTION ENGINE USING PONGAMIA METHYL ESTER

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Abstract

The use of biodiesel is rapidly increasing around the world, making it imperative to understand the impacts of biodiesel on the diesel engine combustion process and pollutant formation. Biodiesel is known as the mono-alkyl-esters of long chain fatty acids derived from renewable feedstock, such as, non-edible vegetable oils or animal fats, for use in compression ignition engines. The high viscosity of vegetable oils leads to problem in pumping and spray characteristics. The best way to use vegetable oils as fuel in compression ignition (CI) engines is to convert it into biodiesel. The important advantages of biodiesel are lower exhaust gas emissions and its biodegradability and renewability compared with petroleum-based diesel fuel. The energy of the biodiesel can be released more efficiently with the concept of Low Heat Rejection (LHR) engine. The aim of this study is to apply Thermal Barrier Coatings (TBC) onto engine parts for improving engine performance when biodiesel is used as an alternative fuel. For this purpose, a Direct Injection (DI) diesel engine was converted to a LHR engine by applying Al_2O_3-TiO_2(TBC) on the Piston Crown and the effects of biodiesel (produced from Pongamia oil) usage in the LHR engine, performance and emission characteristics have been investigated experimentally with injector pressures of 180 bar & 250 bar. The results showed that specific fuel consumption and the brake thermal efficiency were improved, exhaust gas temperature was increased in the LHR engine and the smoke density of the engine is decreased compared to the base engine when it is run with diesel.

Keywords: Low heat rejection engine; Thermal barrier coating (TBC); Biodiesel; Alternative fuel; pongamia Methyl Ester (PME)

1. INTRODUCTION

During the operation of modern DI diesel engines, about 15-30% of the fuel chemical energy input is rejected to the cooling system (water or oil) through the walls of the combustion chamber. Furthermore a major part 30-40%, of the fuel chemical energy input is lost with the exhaust gases exiting into the atmosphere with the temperature much higher than ambient [1]. This fact has motivated extensive research into ways of improving the efficiency of engines (reduce fuel consumption), by thermal insulation of the combustion chamber leading to lower heat losses to the coolant. And also the desire to increase thermal efficiency or reduce fuel consumption of engines makes it tempting to adopt higher compression ratios, in particular for diesel engines, and reduced in-cylinder heat rejection. Insulating the combustion chamber components of engine can reduce heat transfer between in-cylinder gas and cylinder liner. The LHR concept is based on suppressing heat rejection to the coolant and recovering the energy in form of useful work. Average in-cylinder gas temperature increases due to insulation in LHR engine. Measured temperatures of the piston and the cylinder head were increased by about 300 to 400^0C by using ceramics [2].In compression stroke around TDC in-cylinder gas temperature increases by 250K in LHR engine in comparison to standard engine. This reduces ignition delay period of fuel injected to cylinders. So combustion starts before sufficiently mixing of air and fuel. Sun et al. reported that combustion characteristics of LHR diesel engines are different from standard diesel engines in four ways:

(a) Ignition delay period shortens

(b) Diffusion burning period increases while premixed burning period decreases

(c) Total combustion duration increases

(d) Heat release rate in diffusion burning period decreases.

Although, trans esterification makes the fuel properties of vegetable oil closer to petroleum diesel fuel, the viscosity of vegetable oil esters (biodiesel) is still higher (approximately 2 times) than that of petroleum diesel fuel. Biodiesel can be heated to reduce its viscosity further, so biodiesel can be used more efficiently in diesel engines. The concept of a LHR engine is believed to be useful in this regard. The increased in-cylinder gas and cylinder liner temperatures of the LHR engine make possible the usage of biodiesel without preheating. So the energy of biodiesel can be released more efficiently. The difficulties associated with using raw vegetable oils in diesel engines identified in the literature are injector coking, severe engine deposits, filter gumming problems, piston ring sticking, and injector coking and thickening of the lubricating oil [2–11]. The high viscosity and low volatility of raw vegetable oils are generally considered to be the major drawbacks for their utilization as fuels in diesel engines. The high viscosity of vegetable oils deteriorates the fuel atomization and increases exhaust smoke. The low volatility leads to oil sticking to the injector or cylinder walls, resulting in deposit formation. However, these effects can be eliminated or reduced through transesterification of the oil to form monoesters. The process of transesterification removes glycerol from the triglycerides and replaces it with radicals from the alcohol used for the conversion process. This process decreases viscosity and improves the Cetane number and heating value.

These monoesters are known as biodiesel [11–13]. There have been many studies about LHR engines and biodiesel usage in standard diesel engines in the literature. However, there have not been many studies about biodiesel usage in LHR engines. Prasad et al. tested a single-cylinder diesel engine with Superni-90 coated piston top and cylinder liner of which had a maximum engine power of 3.68kW and a compression ratio of 16:1. They used raw jatropha and pongamia oils and esterified jatropha oil as fuels. They found that the performance of the LHR engine improved, nitrogen oxide (NO_X) levels decreased and exhaust gas temperatures were increased with all three non-edible vegetable oils in comparison with diesel fuel. They also found that the combustion parameters of the non-edible vegetable oils were within reasonable limits and revealed that non-edible vegetable oils can be successfully utilized as substitute fuels in a LHR diesel engine. The injection pressure and timing plays a vital role in engine performance and pollutant formation since the injection pressure ensures the atomization rate and the injection timing attributes to the completeness of combustion [14, 15].

The objective of this study is to apply LHR engine for improving engine performance when biodiesel is used as an alternative fuel at different injection pressures. For this purpose, a single cylinder Kirlosker direct injection (DI) diesel engine was converted to a LHR engine and the effects of biodiesel usage in the LHR engine on the performance and emission characteristics were investigated experimentally.

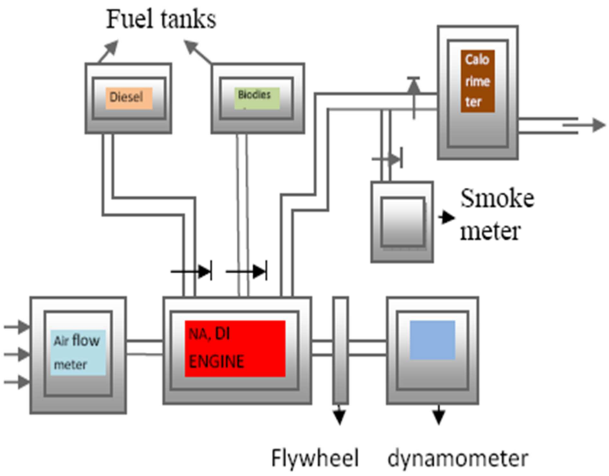

Fig 1: Schematic diagram of the experimental setup

2. EXPERIMENTAL PROGRAMME:

A single cylinder, four stroke, constant speed, water cooled, direct injection diesel engine is used for the experiments conducted. The schematic of the test system is shown in Fig. 1 and the important engine specifications are given in Table 1. A hydraulic dynamometer was used to load the test engine. It has a capacity of 0–999Nm and precision of 0.1Nm for engine torque.

Refined Pongamia oil was selected to produce the biodiesel. 1.5 grams of Sodium Hydroxide (NaOH) and 400 ml of methyl alcohol (CH_3OH) were used for transesterification of 1 liter of Pongamia oil. NaOH, the catalyst was dissolved in the alcohol then the alcohol–catalyst mixture was poured into the pongamia oil which was kept on heating meanwhile. The temperature and the mixing speed of the pongamia oil, alcohol and catalyst mixture was kept constant (60 ^oC and 1250 rpm) during the transesterification (up to an hour). When the transesterification was finished the mixture was taken to a tank to settle. After the settlement of the biodiesel and the glycerin, the glycerin was drained. The biodiesel was washed with pure water to remove alcohol and catalyst residue. To eliminate the water
in the biodiesel which remains from washing, it was dried by heating up to 100 ^0C. The water in the biodiesel was evaporated during the drying process. To convert the base engine to low heat rejection engine a TBC of Al_2O_3-TiO_2 was applied on the piston crown as shown in fig2. The properties of the TBC are shown in Table 2.

Make	Kirloskar
Model	AV1
No. of cylinders	One
Bore	80.0 mm
Stroke	110.0 mm
V_{disp}	552.94 cc
Rated output	3.68 kW (5.0 hp)
Connecting rod length	230.0 mm
Compression ratio	16.5:1
Injection advance	27° BTDC
Speed	1500 rpm

Table 1. Specifications of the engine

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Fig 2: Al_2O_3-TiO_2 applied on Piston Crown

Density (gm/cc)	3.72
Elastic Modulus (GPa)	300
Shear Modulus (GPa)	124
Bulk Modulus (GPa)	172
Poisson's Ratio	0.21
Compressive Strength (GPa)	2100
Hardness (Kg/ mm^2)	1100
Thermal Conductivity (W/m°K)	25
Coefficient of Thermal Expansion (10^{-}	8.2
Specific Heat (J/Kg°K)	880

Table 2: Properties of Al_2O_3-TiO_2

RESULTS AND DISCUSSIONS:

Before comparing the results with injection pressures of 180 and 250 bar, engine was tested with manufacture's specification. As per the manufacturers specification the injector pressure was 200 bar. At this Pressure the fuel consumption and brake thermal efficiency of the engine with and without coating are shown in fig 3 & 4. Fig.5 shows the graph of Specific Fuel Consumption Vs Load. It is observed that there is steady increase of Fuel consumption from No load to 60% load at 250 bar and without Coating. There is almost no change FC at 180 bar with/without coating. However SFC has reduced at 180 bar injection pressure.

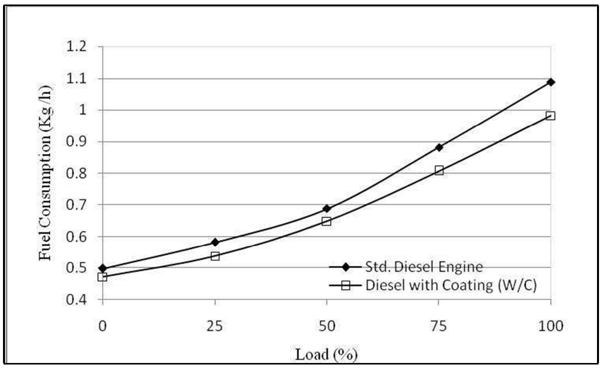

Fig 3: Fuel Consumption Vs Load at 200 bar

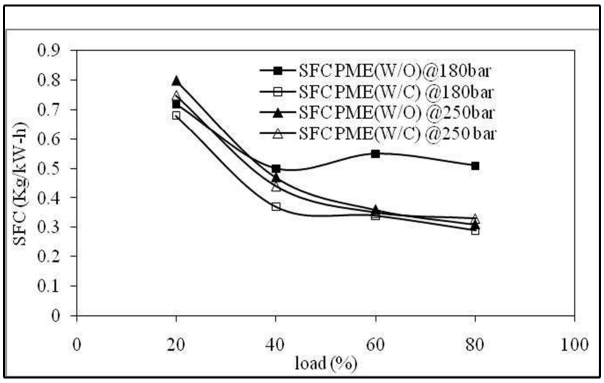

Fig 5: Sp. Fuel Consumption Vs Load

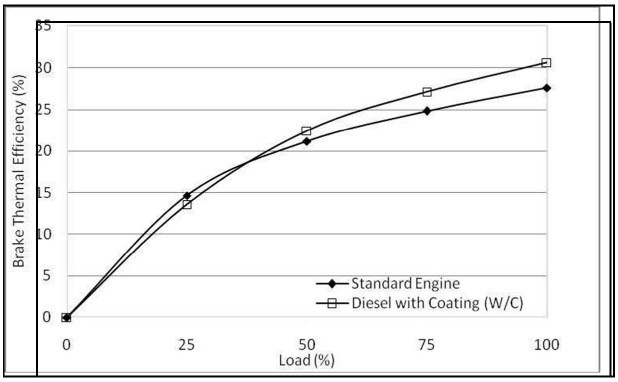

Fig 4: B. Th .Efficiency Vs Load at 200 bar

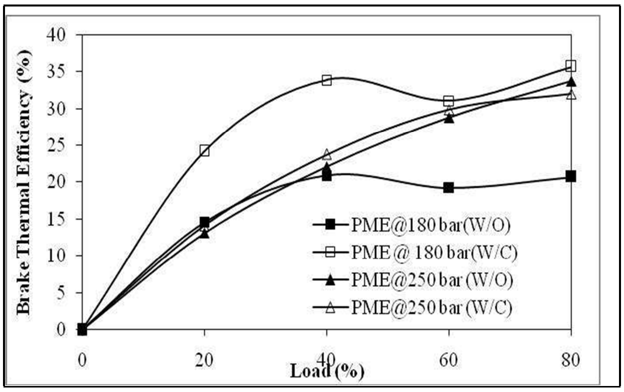

Fig 6: B. Th. Efficiency Vs Load

Fig.6 shows the graph of Brake Thermal Efficiency Vs Load. It has been observed that at all loads Brake thermal efficiency is improved in case of PME at 180 bar pressure with coating. Increase in pressure increases the fuel consumed and thus reduction in Brake Thermal Efficiency. Fig.7. shows the variation of exhaust gas temperature with load. At all loads improvement in exhaust gas temperature is observed at 250 bar and with coating. It is obvious that Exhaust gas temperature increases when heat rejection to the coolant reduced or fuel consumption is increased when all the parameters are same. Variation of Volumetric Efficiency with load is shown in fig.8. It has been observed that there is no change in volumetric efficiency with the change in injector pressure in the case of thermal barrier coated engine. However the volumetric efficiency decreases at high loads in the case of low heat rejection engine. Reason for this is that the inner surface of engine cylinder is hot which makes the residual gases and fresh air to expand more thus reducing the flow rate of incoming air. Fig.9. shows the graph drawn between smoke density and Load. Smoke density is observed less with coating at 250 bar that too with PME. At high pressures diesel or PME enters into the combustion chamber in more atomized form which results less Smoke density.

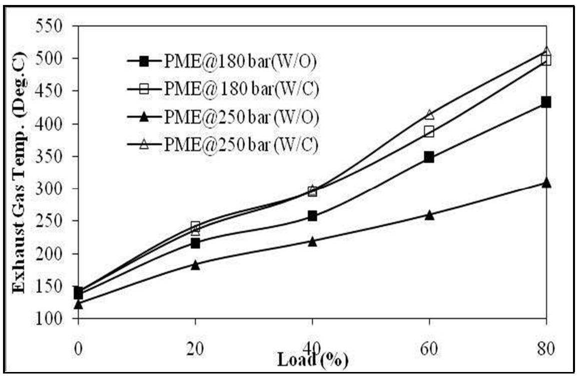

Fig 7: Exhaust Gas Temp. Vs Load

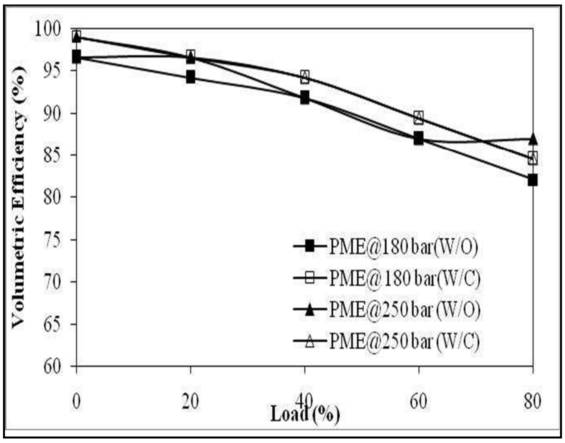

Fig 8: Volumetric Efficiency Vs Load

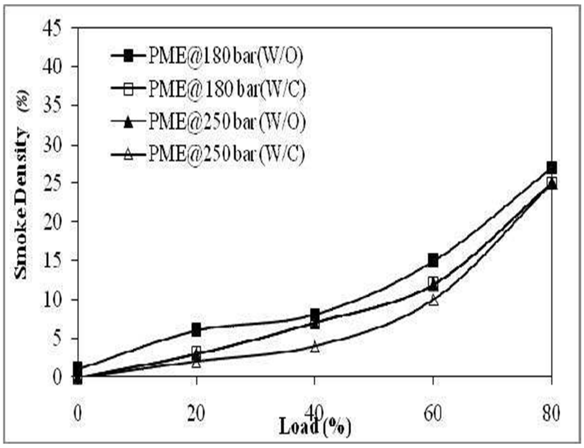

Fig 9: Smoke Density Vs Load

CONCLUSION:

1. Pongamia oil having high viscosity and low volatility makes the oil unsuitable for a diesel engine.
2. By transesterification process the fuel properties are closer to diesel fuel.
3. At 250 bar injection pressure, the thermal efficiency improved with increased emissions. This may probably be due to the changes in the fuel spray structure which affects combustion. The changes in the spray may be shorter breakup length, lower sauter mean diameter, higher dispersion and higher spray tip penetration.
4. Thermal efficiency at 180 bar injection pressure was comparatively lower than that of diesel. On the whole it can be concluded that 250 bar injection pressure could improve the performance and smoke characteristics with Pongamia methyl ester in a diesel engine.

NOMENCLATURE:

TBC : Thermal Barrier coating PME : Pongamia Methyl Ester LHR : Low Heat Rejection
Bp : Brake Power
Std : Standard
W/O : Without Coating
W/C : With Coating
SFC : Specific Fuel Consumption Q.Water : Heat Rejected to Cooling Water Q.Un : Heat Unaccounted

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