

Evaluation of Performance and Emission Characteristics of CI Diesel Engine using Biodiesel with Adiabatic Concept

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ABSTRACT: In view of the fast depletion of fossil fuel resources, there is a need to search for alternative fuels. Looking at huge demand of diesel for transportation, captive power generation and agricultural sector, the biodiesel is being viewed a substitute fuel to diesel fuel.

In this work experimental investigation are carried out in three phases. In the first phase experiments are carried out with different loads on a single cylinder four stroke water cooled direct injection diesel engine. In the second phase the piston crown coated with Yttria Stabilized Zirconia(YSZ) is used .To evaluate performance and emission of characteristics of engine YSZ is selected which is a suitable material for coating the piston crown because of its desirable physical properties such as high co-efficient of thermal expansion, low thermal conductivity and stable phase structure at high temperature conditions. In the third phase fuel additives are used for reducing the associated viz. as higher viscosity, higher pour point, low calorific value and poor volatility. Experimental results revealed that the heat loss to the cooling water is reduced up to 5-10% and the thermal efficiency is increased by 3-5 %. Experimental results also revealed that hydro carbon (HC) emission is reduced up to 20.17%, Carbon Monoxide (CO) by up to 5.72% and Carbon Dioxide (CO₂) emission is increased by up to 2.6%.

KEYWORDS: Biodiesel, Thermal Barrier coating, Yttria Stabilized Zirconia(YSZ), Diesel Engine, Performance, Emission.

I. INTRODUCTION

Diesel engines play a major role in automotive industry. It has assumed a dominating role in both transport and agricultural industry due to its higher fuel economy and low running cost. However the heat carried away by the coolant and exhaust gases carry considerable amount of fuel energy from a combustion chamber even in diesel engines leaving only 30-40 % of the total energy for conversion into useful works. The engine cooling system observes combustion and friction and friction generated heat energy and dissipates it to the surroundings to ensure engine temperature always remain below the safe level. The lubrication system and exhaust gases are the other sources which carry away the heat from the combustion chamber.

Researchers are continuously striving to improve the performance and emission characteristics of the internal combustion engines due to the continuous demand from the industry for some technological and environmental requirements beside rapid increases in the cost of the fuel. On the other hand the improvement in the engine materials becomes increasingly important by the introduction of new alternative fuels. Thermal barrier coatings are predominantly used by many researchers to increase the heat resistance inside the combustion chamber and thereby improving the thermal efficiency of the existing engines. Ceramic coatings not only act as heat resisting medium but also prevent the thermal fatigue and shocks in protecting the substrates. A ceramic coating also helps in reducing the emission levels of Hydrocarbon and Carbon Monoxide.

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The application of TBC reduces the heat transfer through the cooling water and hence assists the engine for better combustion inside the combustion chamber. Due to the increased after combustion temperature, the exhaust gas temperature also raises proportionately. While there have been numerous research papers in the recent years describing the theoretical benefits obtained from the use of ceramic components in reciprocating engines, the amount of the literature that describes practical results is very limited. Generally in LHR Engines, the thermal barrier coating is done on cylinder head cylinder liners, piston crowns, and valves. Most of the researchers have concluded that the thermal efficiency of TBC coated low heat rejection (LHR) Engines is higher with better break specific fuel consumption. The efficiency of most commercially available engines can be improved by coating the piston crown with an insulating material such as stabilized zirconia. The main requirements of the thermal barrier coating materials include low thermal conductivity, resistance to corrosive and erosive environments, low coefficient of thermal expansion high enough to be compatible with metal and thermal shock resistances. The stabilized zirconia has been successfully tried by several investigators as thermal barrier coating agent for piston crown.

Based on the open literature review, it is found that low heat rejection engines with thin TBC on combustion chamber components coated with YSZ are the most effective one in terms of improving the thermal efficiency and fuel consumption of internal combustion engines. However, a significant number of literatures revealed that NO_x emission levels were increased due to the application of thermal barrier coating inside the combustion chamber. In present work, the piston crown is coated with 100 micron thickness of YSZ by plasma spray coating method and engine is tested for its performance and emission characteristics at various loads and speeds.

Biodiesel is a renewable and eco-friendly alternative diesel fuel for diesel engine. Biodiesel has higher viscosity, density, pour point, flash point and cetane number than diesel fuel. Biodiesel is an oxygenated fuel which contains 10-15% oxygen by weight. Also it can be said sulphur free fuel. These facts lead biodiesel to total combustion and less exhaust emissions than diesel fuel. Furthermore also the energy content or net calorific value of biodiesel is about 12% less than that of diesel fuel on the mass basis. Using optimized blend of biodiesel and diesel can help reduce some significant percentage of the world's dependence on fossil fuels without modification of CI engine, and it also has important environmental benefits. For example using optimized blend of biodiesel and diesel instead of conventional diesel fuel significantly reduces the exhaust emissions particulate matter (PM), Carbon monoxide (CO), Sulphur oxides (SO_x) and unburned hydrocarbons (HC).

Moreover, additives are an essential part of today's fuels. Together with carefully formulated base fuel consumption, they contribute to efficiency, reliability and long life of an engine. They can have surprisingly large effects even when used in parts per million (PPM) range. With use of fuel additives in the blend of biodiesel and diesel fuelled in CI engines with further more improve performance, combustion and diminish emission characteristics and also improved fuel properties which enhance the combustion characteristics.

The interest in bio-fuels is rapidly growing as these fuels can provide a significant contribution to greenhouse gas emission reduction. The present work examined the use of biodiesel and additives for energy generation, focusing on both in technical and environmental aspects.

II. EXPERIMENTAL SETUP

Experiments were carried out on the Single cylinder, four stroke, vertical, water cooled, direct injection computerized CI engine. This engine can withstand higher pressures encountered and also is used extensively in agriculture and industrial sector. Therefore this engine is selected for carrying experiments.

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Fig.1: Experimental setup

Engine Specifications

The information about the engine components

Make and Model	Kirloskar, TV1
Type of Engine	Four stroke, Variable
No. of Cylinders	Single cylinder
Rated capacity	5.2 KW @ 1500 rpm
Cylinder diameter	87.5mm
Stroke length	110 mm
Connecting rod length	234 mm
Compression ratio	17.5:1
Orifice diameter	20 mm
Dynamometer	Eddy current dynamometer
Dynamometer arm	145mm

Table 1: Specification of the engine

III.RESULTS AND DISCUSSION

Experimental results shows that reduction in rejection to cooling medium had resulted in an increase in exhaust energy at all load levels. In case of Thermal Barrier Coated engine, there in a increase in the volumetric efficiency of the engine at different loading and speed conditions.

Engine performance characteristics:

Engine performance characteristics are measured and compared in terms of power, torque, brake specific fuel consumption, brake thermal efficiency at different loadings an speed conditions.

Brake specific fuel consumption (BSFC)

Brake specific fuel consumption of TBC coated engine and baseline engine with respect to the variation in load as shown in fig 1. It is observed that as compared to standard base line engine, decrease in BSFC is due to the reduction in the fuel consumption and improved energy conversion rate at all loading conditions in the TBC coated engine. This may be due to the increased temperature of the combustion chamber walls, which increases the temperature of the fuel issuing from the heated fuel injecting nozzle resulting in the reduced fuel viscosity and better combustion of the fuel. It is seen that the fuel consumption in pure bio diesel (B100) is maximum and the diesel with TBC coating is minimum. It is found that B100 consumes an average of 811 g/kWh and for fuel diesel with TBC the

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average consumption is 405 g/kWh and fuel B100+2% additive consumes an average of 536 g/kWh, it clear that the addition of some additives are more effective than B100.

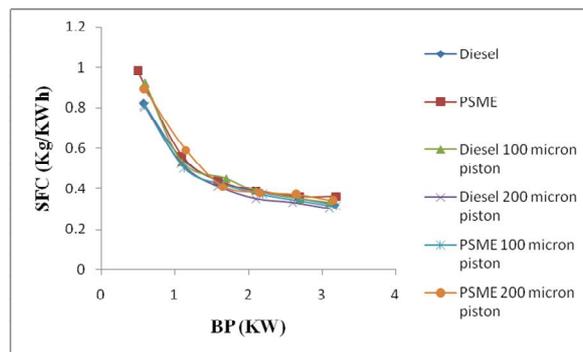


Fig 1. Variation of SFC with Brake Power

Brake Thermal Efficiency

Brake thermal efficiency with increasing load for TBC coated engine and baseline engine is shown in fig 2. It is significant that TBC coated engine has higher efficiency than that of base line engine at all loading conditions. This may be due to thermal resistance on the piston crown which cannot allow the heat energy to the coolant and other medium. The maximum brake thermal efficiency obtained for TBC coated engine and baseline engine is increased respectively. From the graph it is concluded that brake thermal efficiency increases with increase in engine loads at different engine speeds. The maximum Brake thermal efficiency obtained is 29.88% for diesel with TBC at 1350 rpm engine speed. Brake thermal efficiency is higher for diesel and B100+2% with TBC compare to both Diesel and Biodiesel at every engine load and engine speed.

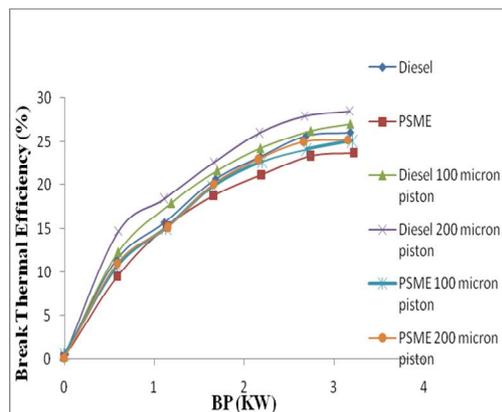


Fig 2. Variation of Break Thermal efficiency With Brake Power

Indicated Thermal Efficiency

From the figure 3, it is concluded that Indicated thermal efficiency increases with increase in engine loads at different engine speeds. The maximum indicated thermal efficiency obtained is 41.28% for diesel with TBC at 1350 rpm engine speed. Brake thermal efficiency is higher for diesel and B100+2% with TBC compare to both Diesel and Biodiesel at every engine load and engine speed.

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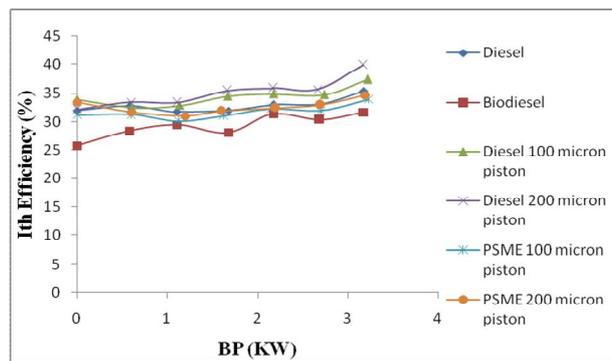


Fig 3. Variation of Indicated Thermal Efficiency with Brake Power

Mechanical Efficiency

From figure 4, it has been observed that increase in mechanical efficiency for TBC coated piston crown from low load conditions to high load conditions. Coated piston crown always have higher efficiency 10% compared to low load due to increase of indicated power in coated piston when compared to uncoated piston. The parameters effected the indicated power are brake power and frictional power. Though brake power is same for both cases at all loads, the frictional power is higher in uncoated piston. Therefore the mechanical efficiency is always higher in case of coated piston. It was experimentally determined that TBC coated engine with Diesel and B100+2% additive causes a increase in average of 10% mechanical efficiency at all loads and speed conditions compared to Diesel and B100.

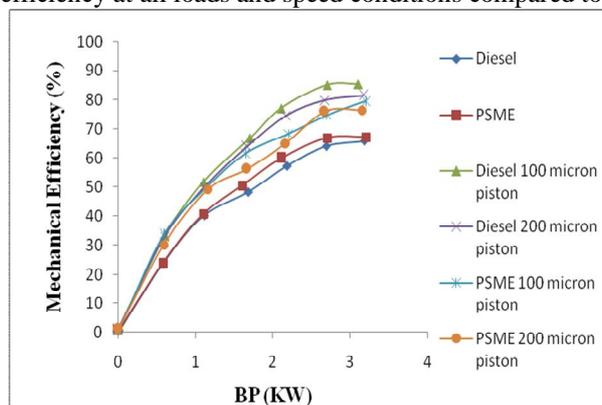


Fig 4. Variation of Mechanical Efficiency with Brake power

Emission Characteristics

After conducting experiments on different coated piston crown emission Hydrocarbon, Carbon monoxide and carbon dioxide emissions have been calculated and it is proved that overall CO and HC emission have been reduced in TBC coated engine when compared to standard diesel engine.

Hydro Carbon Emission (HC)

Figure 5 shows variations in HC emissions. HC emissions are low in the TBC coated engine when compared to the standard base line engine. In TBC coated engine, the hydrocarbon emission is reduced by up to 25%, when compared to the baseline engine. The decrease in HC emission in the TBC coated engine is due to decrease in the heat losses going to the cooling system and subsequent increase in the after-combustion temperature. The experimental results clearly indicate that the ceramic coating improves the local conditions specifying temperature, pressure, mixture ratio, amount of oxygen and makes the combustion continuous in diesel engines.

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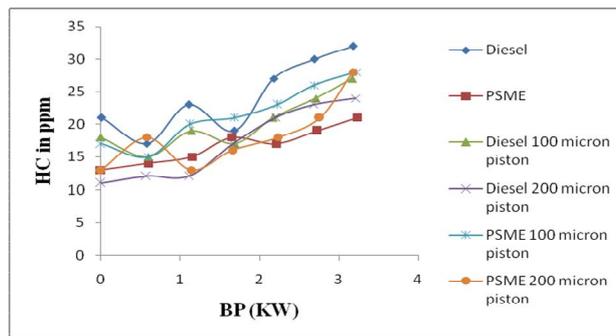


Fig 5. Variation of HC with Brake Power

Carbon monoxide Emission (CO)

The measured CO emissions for TBC coated engine and the baseline engine are shown in figure6. It shows CO variations with respect to various load and speed conditions it decreases gradually. It is well known that better fuel combustion usually results in lower CO emission. It was experimentally determined that TBC coated engine with Diesel and B100+2% additive causes 2.72% average reduction in CO emission at various load and speed conditions compare to Diesel. The reduction in CO emission is due to complete combustion of the fuel.

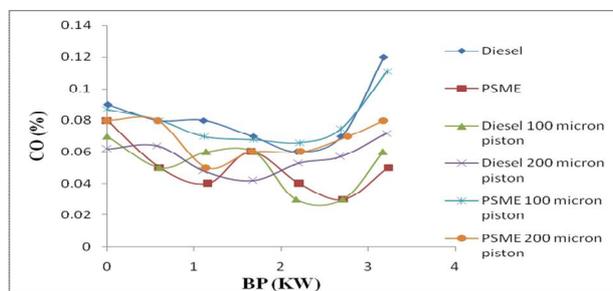


Fig 6. Variation of CO with Brake Power

Carbon dioxide emission (CO₂)

Figure7 shows CO₂ variations with respect to various load and speed conditions. CO₂ emission from diesel engine is related to the fuel properties as well as combustion characteristics. It is well known that better fuel combustion increases the O₂ and hence carbon di-oxide emission is higher in Thermal Barrier coated Engine. It was experimentally determined that TBC coated engine with Diesel and B100+2% additive causes a increase in average of 2.5% CO₂ emission at all loads and speed conditions compared to Diesel and B100.

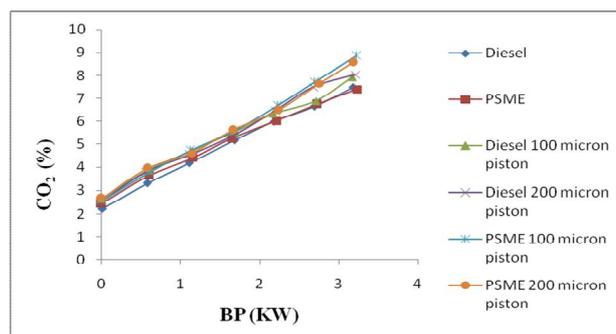


Fig 7. Variation of CO₂ with Brake Power

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Nitrogen oxide emission (NO_x)

In general it is known that NO_x increase with increase in cylinder temperature of the combustion chamber. From the experimental results it is predicted that NO_x is increase in TBC coated engine compared with standard engine due to increase in combustion temperature. The main cause for increase in combustion temperature is due to better air-fuel mixture in TBC coated engine and NO_x emissions are mainly increased due to increase in after combustion temperature. It was experimentally determined that TBC coated engine with Diesel and B100+2% additive causes a increase in NO_x emission at all loads and speed conditions compared to Diesel.

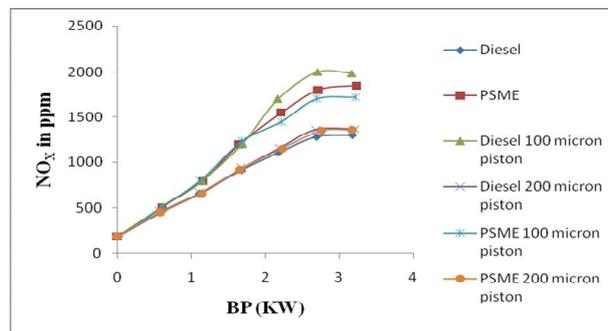


Fig 8. Variation of NO_x with Brake Power

IV. CONCLUSION

In the present experimental work engine is allowed to run at different engine speeds with respective change in engine loads. The emissions (NO_x, CO, HC, and CO₂) and engine performance parameters were obtained at each stage for different TBC piston crown with fuels used are Diesel and Bio Diesel. Based on the experiment the following conclusions have been derived.

- The Brake thermal efficiency is increased 9.36% with TBC coating compared to standard test engine. This is due to decrease in heat rejection of heat produced during the combustion process.
- The indicated thermal efficiency is increased about 12.71% with TBC coating compared to standard test engine.
- Mechanical efficiency is always higher in the case of coated piston. Mechanical efficiency is increased about 29.8% with TBC coating compared to standard engine. Coated piston crown always have higher efficiency compared to uncoated piston.
- Specific fuel consumption in pure bio diesel is maximum and the diesel with TBC coating is minimum. This is due to the increased temperature of the combustion chamber walls, which increases the temperature of the fuel issuing from the heated fuel injecting nozzle resulting in the reduced fuel viscosity and better combustion of the fuel.
- HC emissions are low in the TBC coated engine when compared to the standard base line engine. In TBC coated engine, the hydro carbon emission is reduced up to 25% when compared to the baseline engine. The decrease in HC emission in the TBC coated engine is due to the decrease in the heat loses going to the cooling system and subsequent increase in the after combustion temperature.
- CO emissions variation with respect to various loads and speed conditions it decreases gradually. It is well known that better fuel combustion usually results in lower CO emission. By using TBC coated Biodiesel engine CO emissions are reduced 40% standard diesel engine
- By using TBC coated Biodiesel engine CO₂ emission are increased 18.47% compared with standard diesel engine. It is well known that better fuel combustion increases the CO₂ and hence the carbon dioxide emission is higher in thermal barrier coated engine.

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