# INVESTIGATION OF CI DIESEL ENGINE EMISSION CONTROL AND PERFORMANCE PARAMETERS USING BIODIESEL WITH YSZ COATED PISTON CROWN

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*Abstract: The fossil fuels play a vital role for socio economic development of any country. For any country the transportation, industrial and agriculture sectors are the major sector. For all these sectors the major energy resources are petro-diesel reservoirs. It is learnt that fossil fuels are going to deplete in near future, on the other hand there is serious alarm regarding environment concern, where the pollutants formation is mainly responsible for global warming. Hence there is a need to search for alternate fuels and also to regulate the emissions from the combusted fossil fuels. The previous researchers conducted experiments to test the suitability of biodiesels as substitute to diesel fuel. There were no proven results regarding commercial viability to biodiesel with regulated control emission. In the present work an attempt is to be made for novel method to improve emission characteristics and performance parameters using biodiesel in connection with experimental investigation is done under different loading circumstances in a single cylinder kirloskar diesel engine with its piston crown coated with Yttria Stabilized Zirconia (YSZ) to understand the influence of the thermal barrier coating (TBC) on performance and exhaust gas characteristics is compared with standard diesel engine characterstics. YSZ is chosen as the candidate material for coating the piston crown because of its suitable physical properties such as high coefficient of thermal expansion, low thermal conductivity, high Poisson's ratio, and stable phase structure at higher temperature conditions. The experiments will be conducted on the engine available in the Department of Mechanical Engineering JNTUCEH.*

Key words: Yettria Stabilized Zirconia (YSZ), TBC,

Palm Stearin Methyl Ester (PSME)

## 1. Introduction:

A major deal for researchers is to improve performance levels and reduce emission characteristics of I C engines by keeping into consideration of cost effectiveness, environmental aspects and various technical conditions. On the other hand modifications in engine materials become a major task for using alternative fuels. Piston crown coated with YSZ material which acts as Thermal Barrier Coating is mostly followed technique by researchers to reduce heat losses inside combustion chamber which leads in increase of thermal efficiency of existing engine. Other method followed to reduce hydrocarbons and carbon monoxide can also reduced by using ceramic coating. Here the optimum technique is to use TBC to reduce heat loses through cooling water as to increase engine performance. Generally in Low Heat Rejection (LHR) engines, the thermal barrier coating is done on Cylinder head, cylinder liners, piston crowns and valves where as in this experiment TBC is done on piston crown itself. With help of this technique most researchers conclude that thermal efficiency increased with decrease in brake specific fuel consumption by using TBC. In most of aero engines for ideal thermal barrier coating plasma sprayed stabilized zirconia was effectively used.

## 2. Plasma Spray Technique :

Thermal spray technique is a coating method melted materials are sprayed onto surface. Plasma spray process is used in our experimental setup work for piston crown coating. Main purpose in method was to comprise a thin coat that has high shield value over other showing surfaces. Yttrium Stabilized Zirconia (YSZ) is sprayed in powder form molten in ionized gas rapidly on the piston crown surface to form a 100 μm and 200 μm thin TBC coating. Fig 1 displays plasma spray coating system. Major parameters in this method include feedstock type, plasma gas composition and flow rate, energy input, torch offset distance, and substrate cooling, etc. Advantages of this technique are corrosion protection, temperature management and wear resistance. Fig 2 shows uncoated standard engine piston and 100 μm and 200 μm YSZ coated piston.

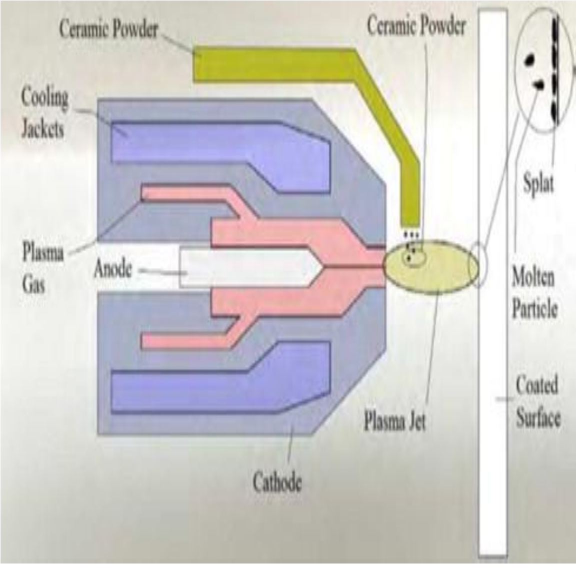



Fig 1: Plasma spray Technique

Fig 2: 100 μm and 200 μm

Plasma coating specification

Coating parameters - Specifications

Plasma gun - 3 MB plasma spray gun

Nozzle - GH Type nozzle

Pressure of organ gas - 100–120 PSI

Flow rate of organ gas - 80–90 LPM

Pressure of hydrogen gas - 50 PSI

Flow rate of hydrogen gas - 15–18 LPM

Powder feed rate - 40–45 g per minute

Spraying distance - 3–4 in.

3. Experimental test setup:

A four stroke, direct injected, water-cooled, single cylinder, naturally aspirated diesel engine is used for investigation. The base engine specifications are presented in table.

| | |
|---|---|
| Number of cylinders | 1 |
| Number of strokes | 4 |
| Fuel | diesel |
| Rated Power | 5.2 KW/7 hp @ 1500 RPM |
| Cylinder bore | 87.5mm |
| Stroke Length | 110mm |
| Compression Ratio | 17.5:1 |
| Dynamometer arm length | 185mm |
| Dynamometer Type | Eddy Current |
| Type of cooling | water cooled |

- The experiments were conducted at six load levels, viz. 2kg, 4kg, 6kg, 8kg, 10kg, 12kg using Eddy current dynamometer at different speeds.
- The mass flow rate of air is measured using a manometer setup by Air Box method. Fuel flow rate is measured by a gravimetric type Fuel consumption meter.

- Pressure and temperature sensors are mounted at important locations in engine exhaust, water inlet, water outlet, air intake, lube oil for online recording of pressure and temperature values using a Digital Dyno Controller unit and Data Acquisition System.
- Emission characteristics such as Carbon monoxide (CO), Hydro carbon (HC) and carbon dioxide ($CO_2$) were measured by using exhaust gas analyzer.
- All the readings were carried out using ARAI–EDACS controller setup and the readings were stored in a personal computer automatically.
- The Schematic of experimental setup is shown in Fig 3.

Fig 3: Computerized I C Engine setup.

All the exhaust gases were measured by using exhaust gas analyzer as shown in Fig 4.


Fig 4: Multiple Gas Analyzer

4.Fuel characteristics:

Palm bio diesel is used in this experimental work. Palm biodiesel is an substitute fuel extracted from palm oil and can be used in IC engines, i.e. diesel engines without any necessary changes. It refers to methyl esters derived from palm oil through a process known as 'transesterification'. Palm biodiesel is renewable, biodegradable, non-toxic and safe to handle (flash point is higher than petroleum diesel) and essentially free of sulphur. It also provides a safety net to stabilize the price of palm oil by removing surplus stock.[1] General properties of palm bio diesel are

| Properties | Diesel | Palm Biodiesel |
|---|---|---|
| Kinematic viscosity | 1.2 – 3.5 | 5.7 |
| Density (kg/m³) | 830 | 880 |
| Heating value (mj/kg) | 45 | 37 |
| Cloud point (ºC) | | 13 |
| Pour point (ºC) | 3 | ------ |
| Flash point (ºC) | 35 | 164 |
| Cetane Number | 51 | 62 |
| Carbon residue (w/w) | 0.3 | ------- |

5.Methodology

The engine is first started by using Diesel as a fuel at injection pressure of 180 bars and the operating characteristics and emissions such as Oxygen ($O_2$), Carbon Monoxide (CO), Carbon Dioxide ($CO_2$), Hydrocarbons (HC) and Nitrous Oxide ($NO_x$) of the engine from the exhaust gas are noted down. The obtained results of diesel are standard parameters and are used for comparison of performance and emissions of biodiesels with different TBC coated piston crown. The engine is then runned by palm biodiesel at an injection pressure of 180 bars. The engine after starting is allowed to run for 10-15 minutes to reach steady state conditions before noting the readings. After the steady state conditions are achieved the observations are made for incremental loads ranging from no load to full load. For each loading the inlet air flow rate, the time for 10 cc of fuel consumption, the ambient temperature, the exhaust gas temperature, the outlet cooling water flow rate, the temperature readings and the five emissions such as $O_2$, CO, $CO_2$, HC and $NO_x$ from the gas analyzer are noted.

## 6.Results and discussion:

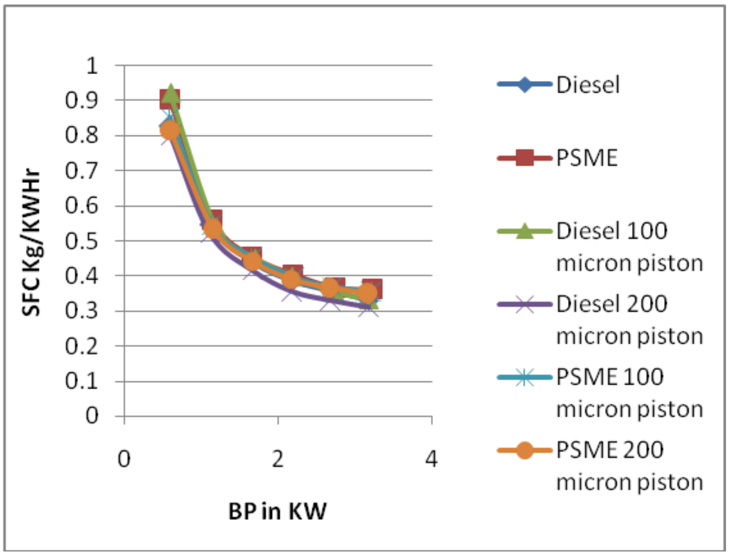
After conducting experiments at different loads result shows that there is reduction in heat loss to cooling medium and increase in exhaust energy. In case of Thermal Barrier Coated engine, there is a increase in the mechanical efficiency and decrease in specific fuel consumption of the engine at different loadings and speed conditions.

### 6.1 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 and speed conditions.

### 6.2 Brake specific fuel consumption (BSFC):

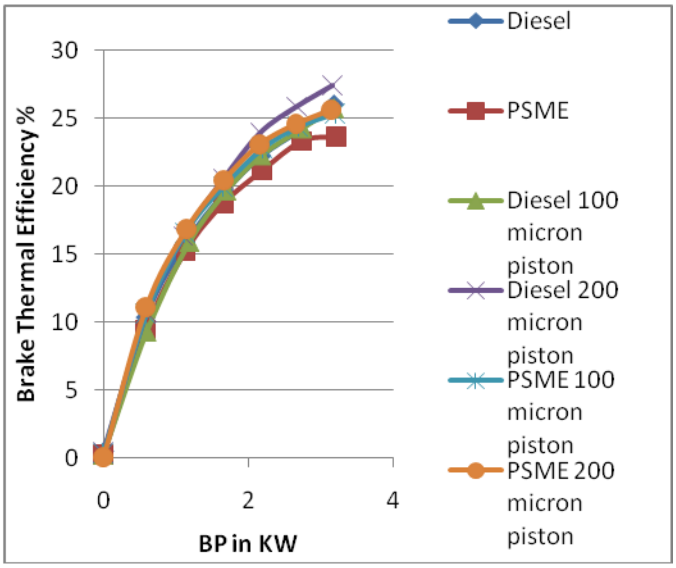
Graph 1 shows the deviation in brake specific fuel consumption of TBC coated piston crown of 100μm and 200μm and standard engine with respect to the variation in load. It is observed that, as compared to standard baseline engine, the BSFC is reduced. Decrease in BSFC is due to the reduction in the fuel 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. Experimental results showed that the reduction in BSFC trend is increasing gradually.




Graph1: Brake power v/s specific fuel consumption

### 6.3 Brake thermal efficiency (BTE):

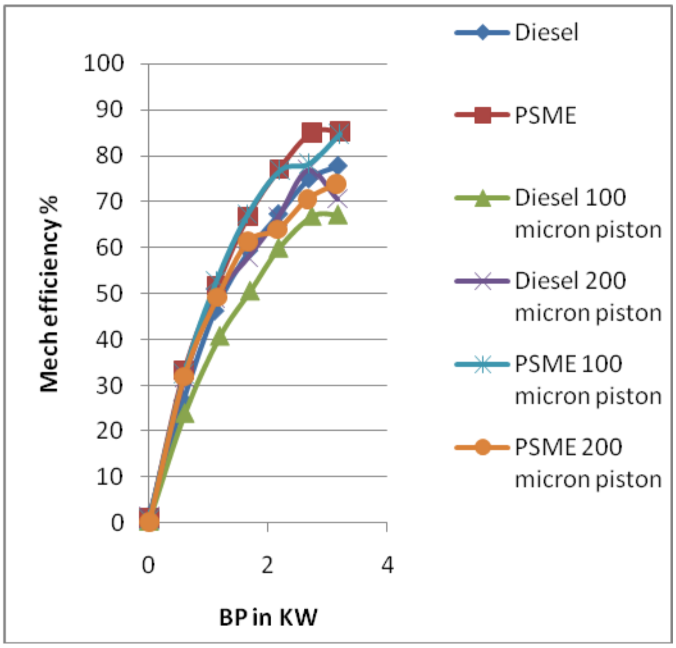
Graph 2 shows the deviation in brake thermal efficiency with increasing load for TBC coated engine and standard engine. It is significant that TBC coated engine has higher efficiency than that of standard engine at all loading conditions. This may be due to thermal resistance on the piston crown which cannot allow the heat energy to the coolant and other medium. This can clearly be seen from graph below.




Graph 2: Brake power v/s brake thermal efficiency

6.4 Mechanical efficiency

From Graph 3 it has been observed that increase in mechanical efficiency for TBC coated piston crown from low load conditions to a high load conditions. Coated piston crown always have higher efficiency 10% compared to low load due to the increase of indicated power in the 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 the cases at all loads, the frictional power is 0.6KW higher in the uncoated piston. therefore the mechanical efficiency is always higher in the case of coated piston.



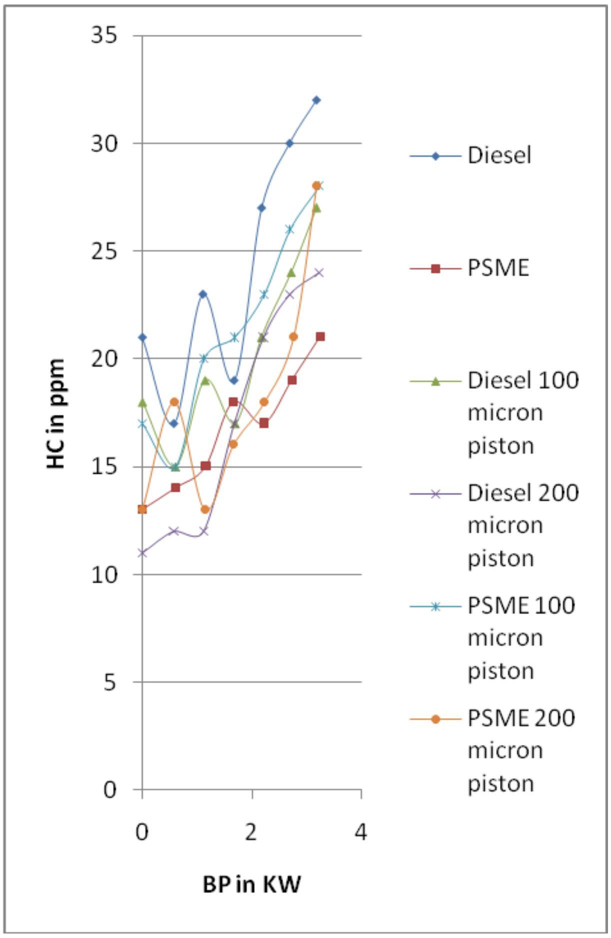

Graph 3: Brake power vs. Mechanical efficiency

7.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 emissions have been reduced in TBC coated engine when compared to standard diesel engine.

7.1 Hydro carbon emission(HC):

When compared with standard diesel engine hydro carbon emissions are very low in TBC coated engine This have been occurred in TBC coated engine due to the decrease in heat loses going to the cooling system and subsequent increase in the after combustion temperature. This result clearly proved that the TBC coating modifies the mixture ratio and different parameters like pressure, amount of oxygen and local condition specifying temperature which makes combustion continues in diesel engine.

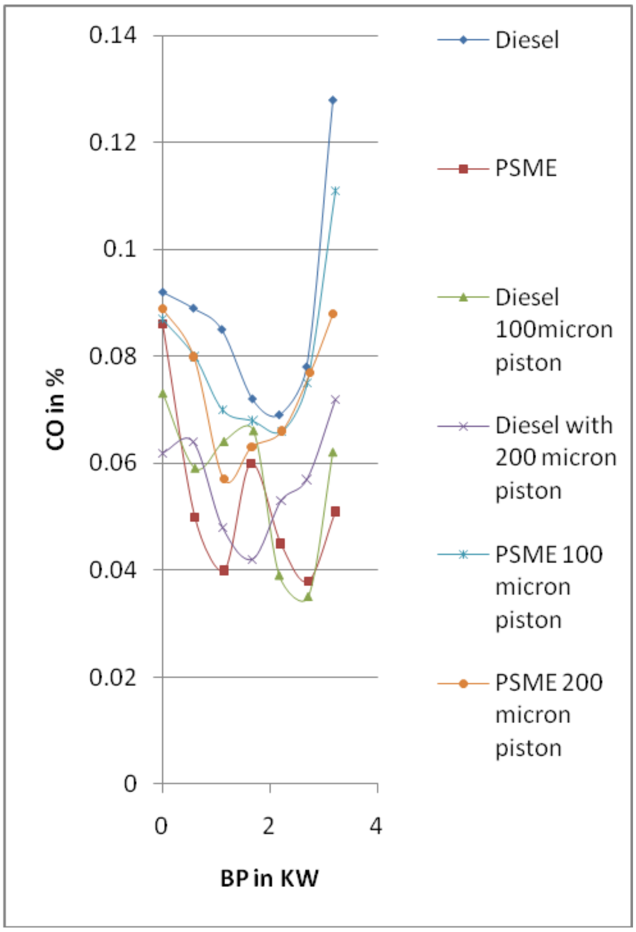



Graph 4: Brake power vs. HC emissions.

7.2 Carbon monoxide emissions (CO):

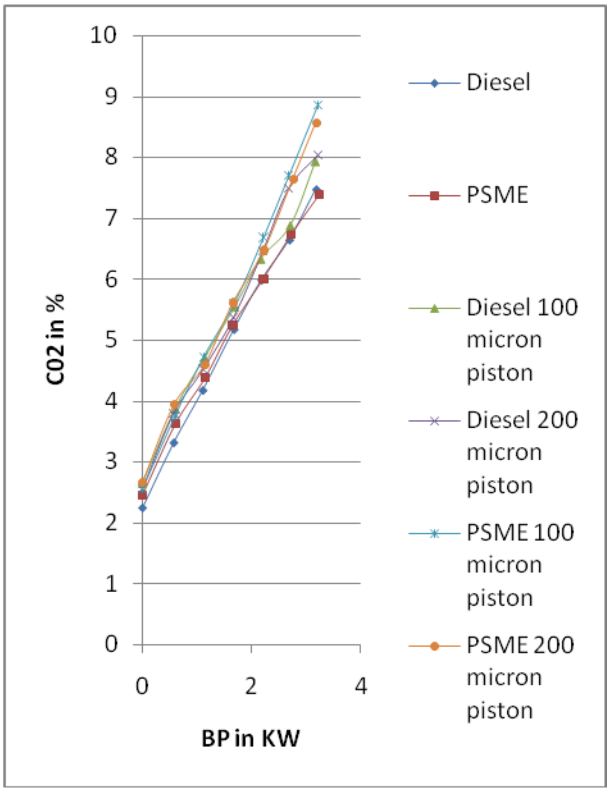
The experiments conducted for various loads and speed conditions show the variations in co emissions. it has been measured for TBC coated engine emissions of CO are very less for better fuel combustion. The CO emissions in this experiment are gradually decreased due to total combustion of fuel.




Graph 5: Brake power v/s CO

7.3 Carbon di-oxide emissions ($CO_2$):

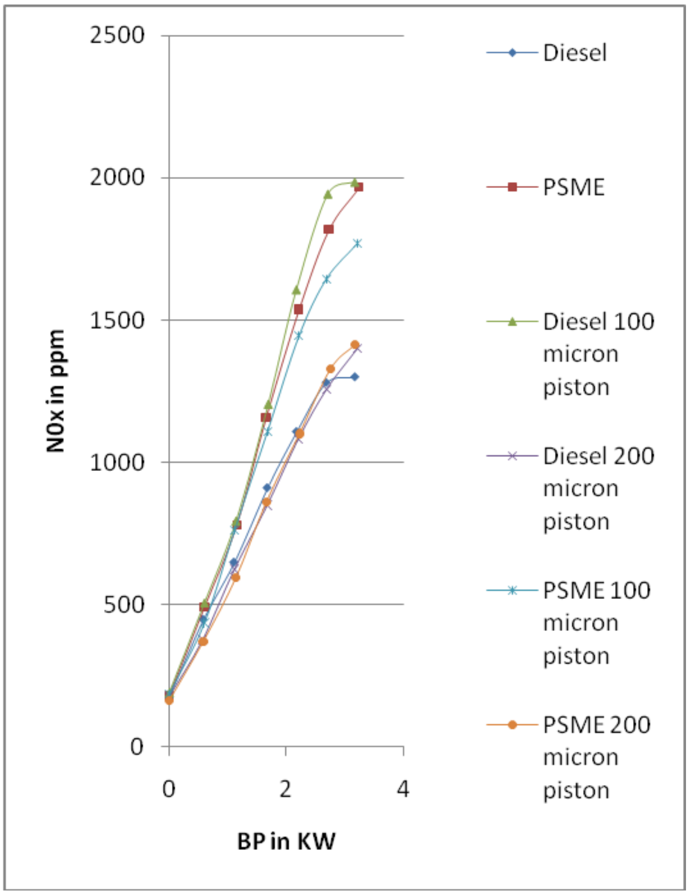
From the experimental results it is known that cabon di-oxide emission is higher in TBC coated engine compared to standard engine as it is well known that better fuel combustion increase the $O_2$. After conduction experiments on different loads and speeds it is determined that $CO_2$ emissions are increased in TBC coated engine.




Graph 6: Brake power v/s $CO_2$

7.4 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.




Graph 7: Brake power v/s $NO_x$

## Conclusion

A conventional single cylinder diesel engine was converted to a LHR Engine by coating its piston crowns by a 100 μm and 200 μm layer of Yttrium Stabilized Zirconia by plasma spray method. Engine parameters, namely brake thermal efficiency, brake specific fuel consumption, power and emission characteristics were measured to investigate the effects of YSZ on its performance and emission characteristics of the engine. The following conclusions can be drawn from the experimental results. The TBC coated engine shows better Brake thermal efficiency and better BSFC compared to the baseline engine. Brake thermal efficiency is improved at all loads and speed conditions in the TBC coated engine. Mechanical efficiency is also improved at all loads and speed in TBC coated engine. HC and CO is gradually decreased in TBC coated engine compared to $CO_2$ where it is increased with various loads and speed conditions.

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## BIOGRAPHIES:

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