Thermal Barrier Coating of Piston crown effects on SI Engine Combustion parameters using n-Butanol Blended with Petrol

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Abstract: Thermal Barrier Coating materials will play vital role in IC engine and Gas turbines. This work is mainly focused on Thermal Barrier Coating (TBC) on piston crown in SI engine. Because TBC enhances the combustion chamber parameters which greatly influenced in engine performance. An experimental investigation is carried out on a partially insulated single cylinder SI engine to study the performance characteristics when fueled with two different blends of butanol and petrol. The piston crown surface is coated with a ceramic material consisting of partially stabilized Zirconium dioxide (ZrO_2) to a thickness of 0.3 mm by plasma spray method. Two different fuel blends containing 10% and 15% by volume of butanol in Gasoline are tested on an engine dynamometer using the Noncoated piston crown and Zirconium dioxide coated piston crown engines. The parameters focused for this study are the engine brake power, engine brake thermal efficiency and brake specific fuel consumption. which is one of the present prime concerns. The merits as well as the disadvantages of using butanol as a fuel in Spark Ignition Engines also discussed. The performance of the engine has strongly indicate that combination of ceramic coated piston crown engine and butanol petrol blended fuel has potential to improve the engine Brake Thermal Efficiency.

Keywords: TBC, BTE, BSFC

I. INTRODUCTION

Energy is the primary requirement of economic growth. Indian government has spent 38% money crude oil. The diesel engine is now make a parallel travel with human beings life for the transportation. By chemical and biochemical analysis, it has been derived that 35% of liquid biofuels were available from various biomass feedstock materials will be more competitive and promising method for near future. The Effect of ethanol- unleaded gasoline blends on cyclic variability and emissions in an SI engine the effects of blending a alcohol (C_2H_5OH)with petrol in a heavy duty compression– ignition engine. Studied the influence of the fuel's chemical composition on performance and emission characteristics. Ethanol was also recently found to be suitable as a blending agent with gasoline for homogenous charge compression ignition (HCCI) engines. Long chain alcohols, because they have higher energy content than Pentanol, Butanol and iso-pentanol, are particularly lucrative alternatives. Higher viscosity leads to an advanced start of injection, shifting combustion phasing. Fuels with higher oxygen content should lead to lower soot production in the combustion process.[1-4]. The use of ethanol – gasoline blend as a fuel in an SI engine. Studied about biofuels, that is of particular interest as they have the potentials to reduce our dependence on petroleum derived fuels and the levels of greenhouse gas emissions from transportation. This mechanism consists of 361 chemical species and 2687 chemical analyses reactions. Reaction pathway and sensitivity analyses were performed to interpret the results. In addition, improvements were investigated to optimize the proposed mechanism.[6,7].

Theoretical investigation of flame propagation process in an SI engine running on gasoline –ethanol blends as investigated the ever-increasing environmental hazardous nature of the exhaust from incomplete combustion of petrol fuel engine on human health has necessitated the research into possible mean of eradicating such effects[8-10]. Such environmental hazard includes particulate emission, as well as delayed ignition in temperate region and problem of low acceleration. Thermal Barrier Coatings (TBCs) find extensive applications in aerospace and has a huge potential in automobile field. Coating of the hot metallic part with the materials suitable for coating, generally ceramics, were challenging due to vast property difference between ceramic and metallic surface [11]. From the starting of the TBC development concept, Partially Stabilized Zirconia (PSZ) remains the major candidate for this application due to many of its matching properties to become a good TBC material. In recent studies, theoretical prediction methods are becoming as intriguing as experimental investigations [12]. The theoretical methods which can not only predict the temperature dependent thermal conductivities but also expose the underlying mechanism play a more and more important role. The Ceramic coating act as a heat resisting medium which prevents the thermal stresses, shocks and protects the substrates. Ceramic coatings play a vital role in the emission reduction; it is evident in CO and HC emissions. Many innovative research trends in the application of coating materials are disclosed [13, 14].

II. EXPERIMENTAL SETUP

The setup which comprise of single cylinder, four stroke SI engine connected to rope brake dynamometer loading. Functional specifications and the reference diagram of the engine are presented in Figure.1 and Table 1, respectively. The Default compression ratio can be used with frequent running of the engine and non-altering the combustion chamber geometry and cylinder block arrangement. The setup has stand-alone type independent panel box consisting of air box, fuel tank, and manometer, fuel measuring unit, digital speedometer and digital temperature indicator. Engine has fins which was air-cooled. Experiments were conducted on base engine (without any modification) with petrol and butanol–petrol fuel blends for benchmarking. After completion of base readings, engine piston crown which was coated with ceramic coating was installed on the base engine by replacing the original uncoated piston crown. Fuel blends of different proportions by volume such as 90% petro, 10% n- butanol (B10P90), 85% petrol, and 15% n-butanol (B15P85) were used for testing the engine with non-coated piston crown and coated pisto crown. The tests were conducted by maintaining engine rpm at 2000, and the responses in performance characteristics due to variation in brake loads were noted down periodically.

Figure.1 Experimental setup of SI Engine

Table.1 Experimental Setup

Model and Make	GK 200
Type	Four stroke air cooled, side valve, horizontal shaft, single cylinder.
Displacement	197 cc
Bore and stroke	67 mm and 56 mm
Rated power	3.1 HP at 3600 rpm
Compression ratio	4.5:1
Dynamometer	Rope brake dynamometer with loading unit
Bore diameter	67 mm
Stroke length	56 mm
Ignition System	Contact Braker
Ignition Timing	20 degree BTDC
Maximum Torque	0.8 kg-m/2500 rpm
Air Cleaner	Oil Bath type
Fuel Tank Capacity	3.9 litre(Petrol)
Lubricating oil Capacity	0.7 litre
Dry weight	18 kg
Dimension LxWxH	338x404x423 mm

III. Thermal Barrier Coating

TBC coating which enhancing the lower heat rejection will led to increase in Brake Thermal Efficiency. For present investigation GK 200 model piston were selected after the initial cleaning process partially stabilized zirconia was coated using an atmospheric plasma spray gun. The piston crown were coated with a 0.3mm thickness. ZrO2 was evenly deposited over the surface of piston crown. With the spray coating applied, the original dimensions of the coated parts of the engine were restored. Figure 2 and 3 shows the photograph of the non-coated and coated piston crowns. Table 2 & 3 shows the specifications of the ceramic coating [5].

Figure.2 Uncoated piston crown

Figure.3 Coated piston crown

Table.2 Properties of ceramic material

Properties	**Zirconium dioxide (ZrO2)**
Appearance	White powder or Black powder
Molar mass	123.218 g/mol
Density	5.68 g/cm3
Melting point	2715oc
Boiling point	4300oc
Solubility in water	Negligible
Refractive index	2.13

Table.3 Plasma Spray Specification

Properties	**Plasma Spray**
Particle velocity	500-550 m/s
Oxide content	1-2%
Porosity	1-8%
Deposition rate	1-5 kg/hr
Current	530 A
Voltage	72 V
Spray distance	100 mm
Torch nozzle diameter	6 mm

IV. PREPARATION OF BLENDS

Fuel blends of different proportions by volume such as 90% gasoline, 10% n-butanol (B10P90), 85% gasoline, and 15% n-butanol (B15P85) were used for testing the uncoated engine head (UCTD) and ceramic coated engine head (CTD). The tests were conducted by maintaining engine rpm at 3000, and the responses in performance characteristics due to variation in brake loads were noted down periodically.

- Petrol (P100).
- 10% Butanol + 90% Petrol (B10P90).
- 15% Butanol + 85% Petrol (B15P85).

The Table.4 shows the Fuel Properties of Petrol, Butanol.

Table.4 Properties of Fuels

Fuel Properties	**Petrol**	**Butanol**
Molecular formula	C_8H_{15}	C_4H_9OH
Density at 20 ˚C(kg/l)	60	20
Boiling point in ˚C	<15	<15
Air/fuel ratio	14	11
Octane number	96	114
Calorific value in MJ/kg	45	33

The Table.5 shows the Calorific values for various blends such as P100, B10P90, B15P85.

Table.5 Calorific Value of blended Fuels

Type of Fuel	**Calorific Value (kJ/kg)**
Petrol	45500
B10P90	40230
B15P85	39300
Butanol	33100

V. Results & Discussion

5.1 Brake Thermal Efficiency (BTE)

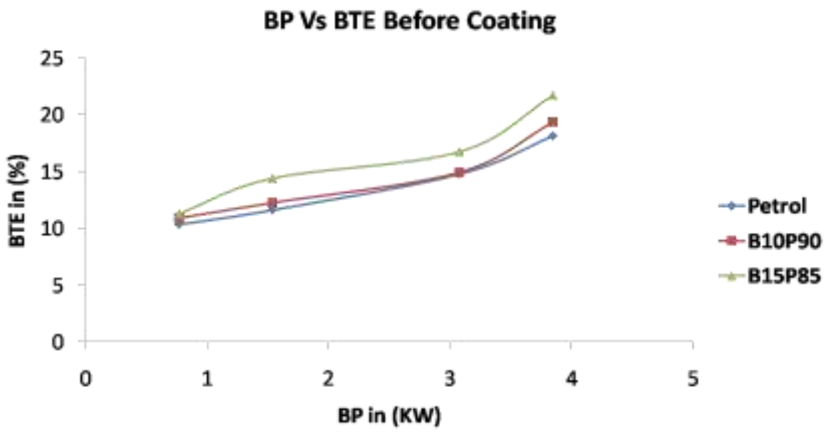

Figure.4 Brake Power Vs Brake Thermal Efficiency (Non coated piston crown effects)

Brake Thermal efficiency is the ratio between work output and heat available which may introduced through spark ignition. The variation of Brake Thermal efficiencies using various blends and petrol fuel is shown in figure.4. It can be revealing that the BTE values for petrol, B10P90 and B15P85 where 18%, 19% and 21% respectively at peak loads. The curve trend which shows butanol blend of BTE at peak load almost 3.5% increase when compared to petrol fuel. It may be due to higher octane and calorific value of fuel.

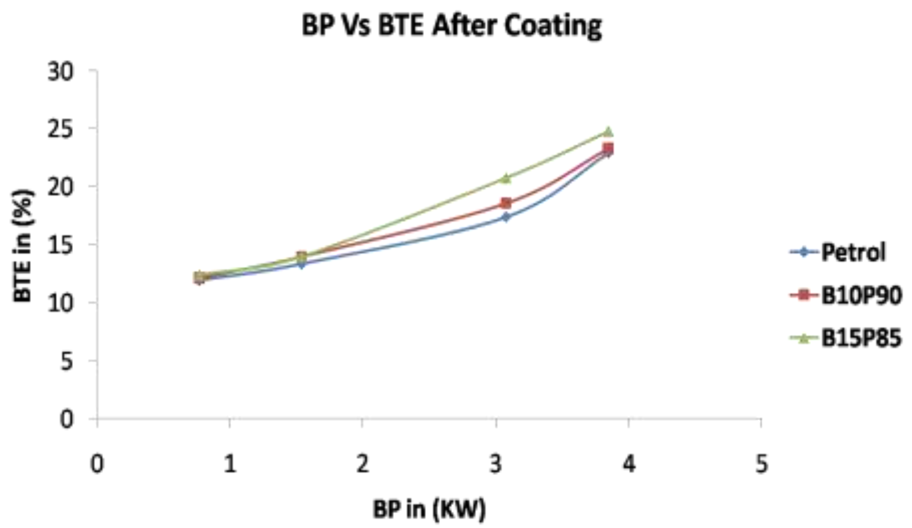

Figure.5 Brake Power Vs Brake Thermal Efficiency (Coated piston crown effects)

The brake thermal efficiency of the Petrol-Butanol blends was calculated and plot the graph between Brake Power (BP) and Brake Thermal Efficiency (BTE) in Figure.5. Comparison of brake thermal efficiency (BTE) of coated piston crown chamber with petrol B10P90 and B15P85 is shown in Figure.5. Increase in break thermal efficiency is observed with all three fuels the coated engine chamber with increase in load. Petrol in ceramic coated engine showed 1.6% rise in break thermal efficiency at lower loads and peaks to 4.76% at maximum load when compared to petrol in non-coated engine. At peak load With B15P85 blend which shows 3% rise in BTE in TBC engine.

5.2. Brake Specific Fuel Consumption (BSFC)

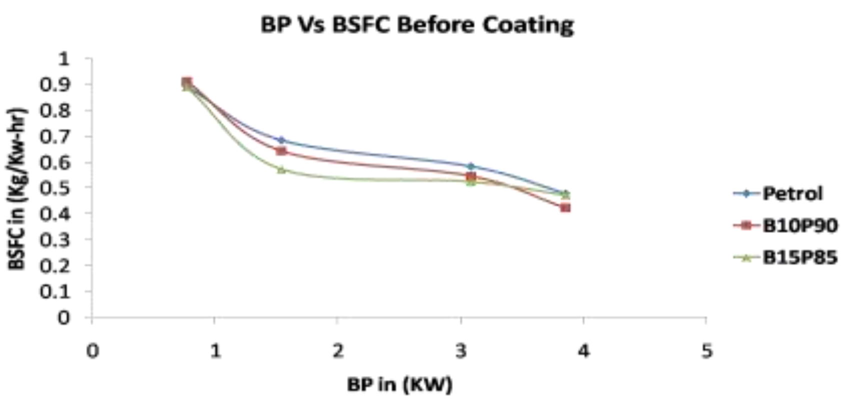

Figure.6 Brake Power Vs Brake Specific Fuel Consumption (Non coated piston crown effects)

BSFC for different blends of fuels in unaltered engine which shows in Figure.6. BSFC linearly decreases with increases of BP; It was observed that density of fuel is a primary factor which increases flow rate of blends due to non-presence of fatty acid content. Addition of n-butanol which causes the suitable homogeneous mixture achieved in different blends compared to petrol fuel which will result in better combustion the BSFC for blend B15P85 were decreases by 1.12% than diesel at medium load condition.

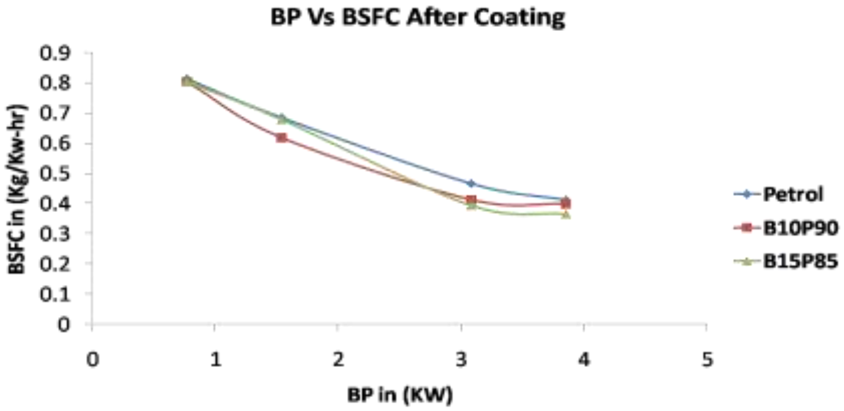

Figure.7 Brake Power Vs Brake Specific Fuel Consumption (Coated piston crown effects).

Comparison of Brake Specific Fuel Consumption (BSFC) of the piston crown coated engine chamber when fueled with petrol B10P90 and B15P85 were showed in Figure.7. The energy content of n-butanol blended fuel is lower than that of unblended petrol fuel; therefore, BSFC values of n-butanol and its mixtures are higher than that of petrol fuel. The trends of BSFC are similar in both the engines with all three fuels. At maximum load, fuel consumption slightly decreases in coated engine with all three fuels. When compared to petrol in coated engine BSFC is higher by 0.47% at maximum loads when fueled with B15P85. BSFC trend normally decreases in coated condition.

VI. CONCLUSION

In the present work, the influence of 10% and 15% concentration of n-Butanol blended with petrol and piston crown coating effects on the performance characteristics are investigated. The results have been compared with petrol fuel and this study reveals that following conclusions.

a) Thermal barrier coating is the one of the important methodology in order to decrease the thermal fatigue and heat lost in internal combustion engines and to improve the combustion and thermal efficiency.
b) Hence in this experimental study, piston crown will coat with a ceramic material of partially stabilized Zirconium dioxide with 0.3 mm thickness in order to achieve low heat rejection will result improved BTE and BSFC.
c) The Brake Thermal Efficiency for non-coated piston crown engine with petrol and its butanol blends B10P90, B15P85are 18.13%, 19.36% and 21.79% respectively Among

these blends B15P85 have 3.5% higher than petrol.

d) BTE for coated piston crown engine with with petrol and its butanol blends B10P90, B15P85are 20.89%, 23.32% and 24.78% respectively. Among these blends B15P85 have 3.89% higher than petrol.

e) BSFC for different blends with non coated piston crown and coated piston crown which produces almost similar trends at various load conditions. With reference of coating piston crown effects petrol, B10P90, B15P85 are 0.412kg/kW-hr, 0.398kg/kW-hr, 0.365kg/kW-hr respectively. Compare to these blends B15P85 have 0.47% less than petrol.

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