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# Thermal Barrier Coating on IC Engine

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**ABSTRACT:** Thermal barrier coatings (TBCs) are advanced material systems primarily used to enhance the thermal insulation properties of components exposed to high temperatures, such as those in gas turbines and aero-engines. These coatings typically consist of a ceramic topcoat, often made from yttria-stabilized zirconia (YSZ), and a metallic bond coat. The ceramic topcoat provides thermal resistance and reduces the temperature of the underlying substrate, thereby increasing the component's lifespan and performance. The bond coat serves as a buffer layer to enhance adhesion and mitigate thermal expansion mismatches.

**KEYWORDS:** Thermal barrier coating (TBC), TBC coating methods, materials using for TBC, TBC coating in diesel engine.

## I. INTRODUCTION

Image Coating is usually a layer of foreign material applied on a material of different nature usually called the substrate. This foreign material can be of different types depending on which the classification of the coatings can be done. The intention of applying the coating can be for aesthetic issues, for a specific functional purpose or for both. The coating itself may be a full-on coating, covering all the parts of the substrate or it may only cover some fewer parts of the substrate.

Depending on the purpose which they are intended for, coatings can be broadly classified as follows: -

1. Erosion resistant coatings
2. Build up and repair coatings
3. Abradable coatings
4. Anti-fretting coatings
5. Wear resistant coatings
6. Oxidation and corrosion resistant coatings
7. Diffusion coatings
8. Overlay coatings
9. Thermal barrier coating

The substrate material will be chosen depending on the requirements for which it is intended for mainly design properties, engineering practices and strength base oriented. Coatings applied on the substrate protects the component from various environmental degradation factors like oxidation, corrosion, wear, erosion and abrasion but there does not exist one such unique coating that is going to meet all the environmental degradation factors.

## II. RELATED WORK

The concept of thermal barrier coating at top coat by aps Wang kai et al. [1] used YSZ (500 $\mu$ m) to perform the top coat by APS and Ni-20CO-22Cr-10Al-1Y (150  $\mu$ m) to perform the bond coat by LPPS. Nickel based super alloy was used as the substrate which is of two types a) Disk shaped ( $\phi$  12.7mm  $\times$  3mm) and b) Tube shaped ( $\phi$  5mm inside,  $\phi$  10mm outside and 13mm long), Zhang Xiaofeng et al. [2] used 7YSZ (7 wt% Y<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub>) as the top coat done by APS and bond coat NiCoCrAlYTa powder done by HVOF technique. The coating was done on K4169 super alloy substrate which were cut into disks of diameter 25.4mm and thickness 5mm, K. W. Schlichting et al. [3] used Ni based super alloy (CMSX-4), disk shape specimens with 25.44mm diameter and 3.18mm thickness. Bond coat used was wt% 51.5% Ni, 20% CO, 20% Cr, 8% Al, 0.5% Y and top coat used was 7YSZ. Plasma spraying method was implemented

for both bond coat and top coat with thickness of 125µm and 250µm respectively, Z. Lu et al. [4] performed atmospheric plasma spray coating for both bond coat and top coat on Nickel based GTD – 111 super alloy substrates with composition Ni=balance, Cr=14%, Co=9.5%, Ti=4.9%, W=3.8%, Al=3%, Ta=2.8%, Mo=1.5%, C=0.1%, Zr=0.03%, B=0.01% and dimensions 25.4mm diameter and 5mm thickness.

### III. METHODOLOGY

Three Aluminium pistons of the LM-13 alloy type were subjected to thermal barrier coatings of TiO<sub>2</sub>. The thickness of coating done was 100 microns. The method used for coating was plasma spray method. Piston was installed in a single cylinder 4-Stroke Diesel engine and the performance and emission parameters were calculated at 180, 200 and 210 bar injection pressure. The list of performance parameters included were volumetric efficiency, mechanical efficiency, brake thermal efficiency, indicated thermal efficiency, brake specific fuel consumption and indicated specific fuel consumption. The list of emission parameters included were carbon monoxide, hydrocarbons, carbon dioxide, oxygen and nitrogen oxides. Before installing the coated piston, the performance and emission parameters of the uncoated piston present in the diesel engine itself were calculated. Graphs for the calculated readings were plotted for various performance and emission parameters versus brake power.

### IV. EXPERIMENTAL RESULTS

Figures On reviewing the above papers on studies related to finding out the performance and emission parameters of internal combustion engines with coated engine parts, it was observed that most of the time the coating material used was zirconia, titanium oxide, copper. But till date coating of titanium diboride was not done on engine parts and used for calculating the performance and emission parameters of an IC engine.



(a)

(b)



(c)

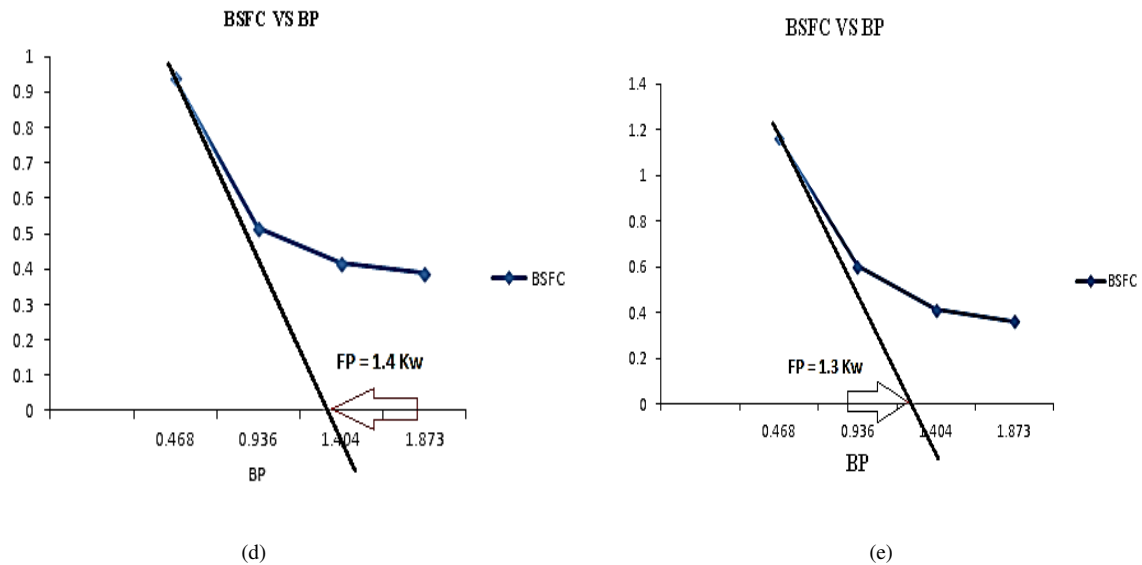


Fig. 2. Thermal barrier coating (a) 4-stroke diesel engine (single cylinder) (b) AVL DIGAS 444 exhaust gas analyser (c) specimen location for performing SEM (d) frictional power uncoated (e) frictional power of TiO<sub>2</sub>

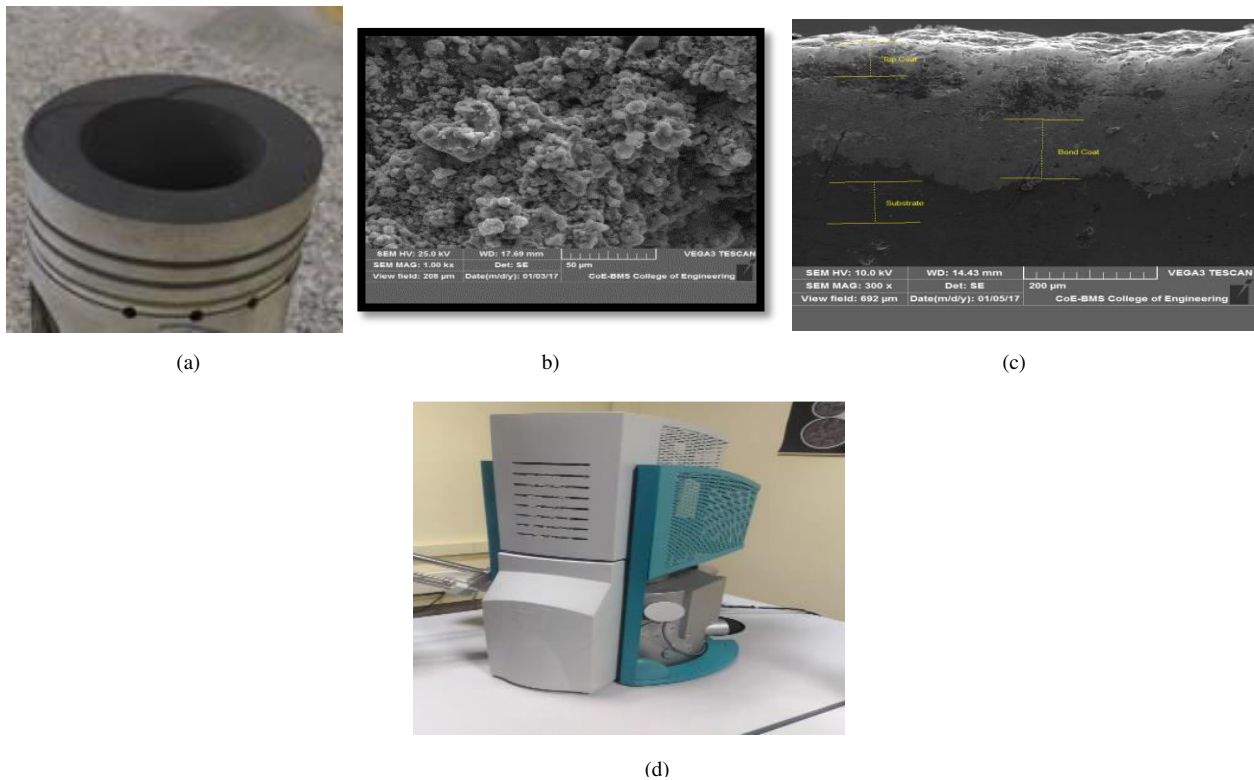


Fig. 3 coating process equipment's (a) TiO<sub>2</sub> coated piston (b) SEM image of TiO<sub>2</sub> coated piston (c) cross sectional SEM image of TBC coated piston (d) scanning electron microscope

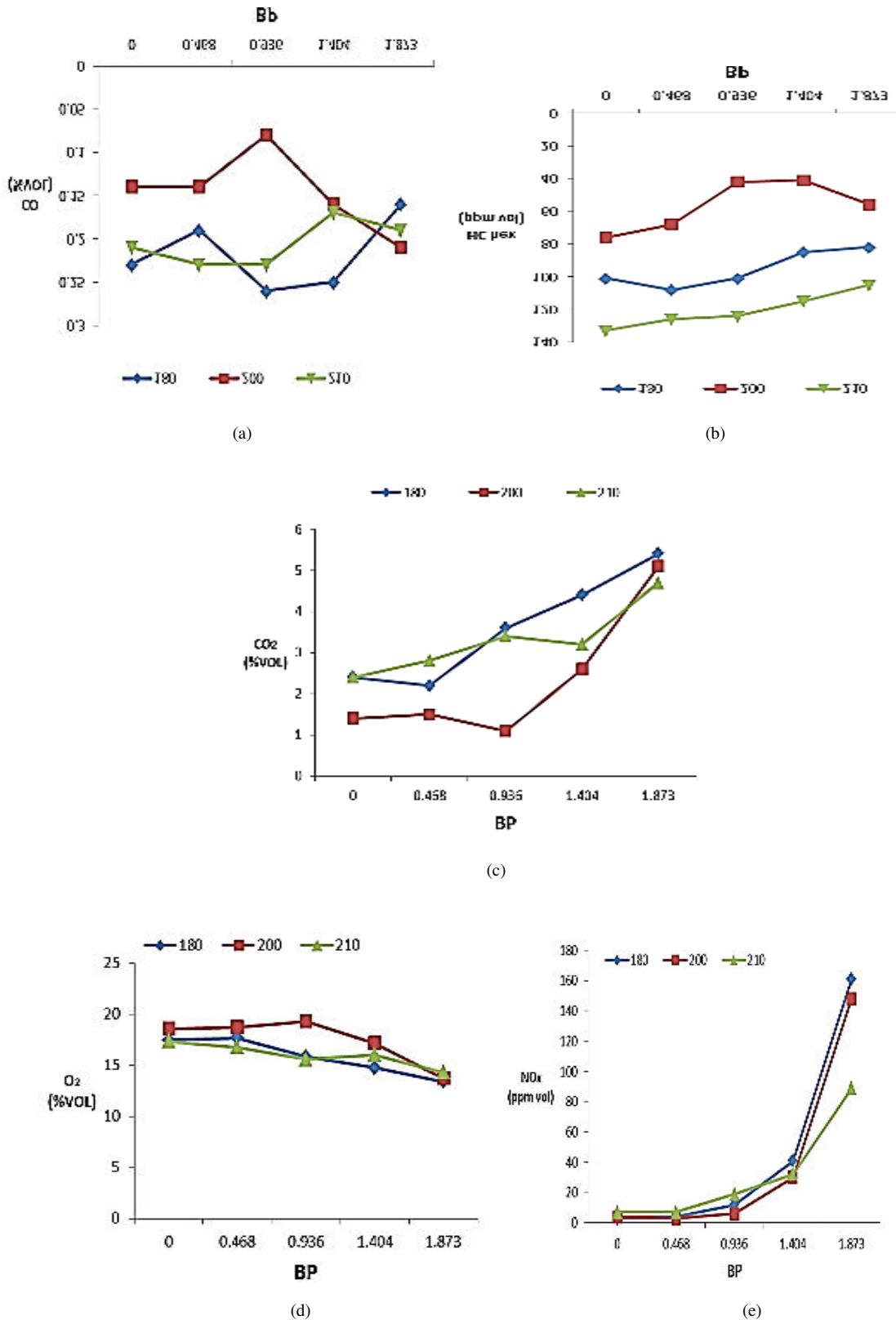


Fig. 4 tested results in graph (a) Carbon Monoxide Vs Brake Power of TiO<sub>2</sub> Coated Piston (b) Hydrocarbon Hex Vs Brake Power of TiO<sub>2</sub> Coated Piston (c) Carbon Dioxide Vs Brake Power of TiO<sub>2</sub> Coated Piston (d) Oxygen Vs Brake Power of TiO<sub>2</sub> Coated Piston (e) Nitrogen Oxides Vs Brake Power of TiO<sub>2</sub> Coated Piston

## V. CONCLUSION

In the present study, thermal barrier coatings of TiO<sub>2</sub> were compared on the grounds of performance and emission parameters tested in a four-stroke diesel engine with uncoated piston. At 180 bar pressure the volumetric efficiency was higher compared to that of the readings at 200 and 210 bar pressures while mechanical efficiency remains constant for all pressures. Indicated and brake thermal efficiencies were highest at 210 bar pressure. ISFC and BSFC were highest for 210 bar pressure at 200 bar pressure the TiO<sub>2</sub> coated piston showed the best results for reduction in emissions. Carbon monoxide, carbon dioxide and oxygen emissions are maximum at 180 Bar compared to 200 and 210 bar. Hydrocarbon emissions are maximum at 180 Bar while Nitrogen oxide emissions are maximum at 200 bar During combustion of fuel the surface of the piston crown underwent delamination cracking leading to formation of cracks, pores and voids on the coated surface which as a result led to the reason for the low thermal conductivity behaviour of the thermal barrier coatings enhancing the brittle nature of them and enhancing its thermal efficiency

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