Vol 21, No 3 (2014): Journal of Faculty of Engineering & Technology (JFET), Pages 92-98

COMPARATIVE STUDY OF TRIBOLOGICAL PROPERTIES OF THERMAL BARRIER COATINGS ON MILD STEEL AND STAINLESS STEEL SUBSTRATES

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ABSTRACT:

Thermal barrier coatings are used for insulation of hot components. The thermal barrier maintains the metal temperature of a coated component at moderate temperature levels during operation. These coatings prevent the material from severe creep damage and oxidation. Therefore this gives better coating integrity for a reliable assessment of coating life.

In the present work, NiAl bond coats with yttria partially stabilized zirconia top coat are studied on two different substrates (Mild steel and stainless steel) using air plasma system with 9 MB gun. Tribological and wear behavior of coatings was assessed at different temperatures to check which substrate gives better wear resistance. **MS/ SS** is more wear resistant when used as substrate.

Key Words: Thermal Barrier Coatings, Life assessment, Tribometer, bond coat, top coat, wear resistance.

1. Introduction

Thermal barrier coatings (TBC) have gained prime importance for some twenty-five years as insulator coatings for the hot oxidative environment in combustor and turbine [1]. Top coat (TC) acts as the thermal insulator as it has low thermal conductivity and is used together with the metallic bond coat (BC), which will provide adherence for the ceramic outer layer. Yttria partially stabilized zirconia (YPSZ) is used as TC. Aluminum-rich alloy based on either nickel or cobalt is used as BC to provide oxidation resistance. The layer thickness of TC usually ranges from the 300μm up to approximately two millimeters. A thermally grown oxide (TGO) layer is formed between TC and BC during the deposition of the coating. This TGO layer grows further when exposed to a high temperature environment [2] and if not controlled, leads to a severe damage of the component. Therefore a special concentration must be taken to control TGO. J. Toscano concludes that TGO spallation usually results in the severe failure of TBC [3].

Life of the component is prolonged many times by lowering the metal substrate temperature [4]. Microstructure of TBC coatings always plays a prime role for the life assessment. For further assessment of their life, it is necessary to know the tribological behavior and wear characteristics. Wear is related to interactions between surfaces and more specifically the removal and deformation of material on a surface as a result of mechanical action of the opposite surface [5]. These characteristics of the coating are assessed by using pin on disc or ball on disc tribometer, in which a ball or pin of known material is rotated on the coated surface for the known number of cycles and desired speed. These tests can be performed in the desired conditions (dry, wet or any other inert environment) depending upon the application of the material.

1.1 MATERIAL SYSTEM

The material used in the present study is an air plasma sprayed thermal barrier coating system. Substrate materials have been manufactured to rectangular specimens. By the air plasma process, a thin TBC system has been applied to bond coat and top coat with thicknesses of 200µm and 550µm respectively. **For the present coating system the BC/TC interface roughness has been measured to be R_a=8µm.**

2. Experimental Work

The experimental work included the preparation of the surface first, followed by the deposition of the coating. Both these steps are detailed below:

2.1 Sample Preparation

Rectangular shaped specimens of mild steel and stainless steel were prepared followed by the shot blasting. Shot blasting was carried out by steel blasting media #29 [6] and roughness value of 9 µm was achieved to make the surface rough so that the coating can have good adhesion with the substrate. The roughness values were evaluated by using Surface Profilometer.

2.2 Deposition of the coating:

After shot blasting, coating was deposited by Thermal Spraying technique using air plasma gun in two steps. First the bond coat was deposited onto the substrate. For this purpose, nickel aluminum (NiAl) powder was used as the bond coat material. The deposition of top coat was carried out onto the bond coat surface. Yttria stabilized zirconia was used as the material for bond coat.

The power and current density in the torch was maintained at 50A Argon and hydrogen gases were used as the primary and secondary gases with pressures 50PSI. The feed rate of powder was adjusted at 6 pound/hour. The gun was kept at 6 inch away from the substrate at an angle of 90 degree. The speed of the spray was adjusted at 6 inch/hour. The substrate was first preheated at 150°C.

2.3 Characterization of the coating:

The coated surfaces were then characterized for its topographical and wear properties:

2.3.1 Surface roughness of the coating:

Surface roughness of the coating was evaluated using Surfcorder SE 1700 @ surface profilometer [7]. Tip radius of profilometer was 2 µm and maximum speed for scanning was set at 0.500 mm/sec. A length of 2.4 mm was scanned for each coated sample.

2.3.2 Wear Testing:

CSM Pin on Disc Tribometer [7] was used to evaluate the wear properties of the coating. Circular tracks of 3mm radius were produced using 100Cr6 [8] steel balls. Four tests were performed for each substrate using loads of 2N, 4N, 6N and 8N for each test. At each load, three tests were performed at temperatures of 28, 50 and 100 °C and carried out in lubricating environment using 50µl machine oil for each test. 3000 laps were produced for each test at a linear speed of 3.20 cm/sec. The volume of oil was measured using micro pipette.

2.3.4 Microscopic Analysis of Tracks and steel balls:

The wear tracks produced by Tribometer were analyzed at Image Analyzer advanced microscope. Zoom microscope was also used to analyze the tracks. The wear patterns developed at steel balls were analyzed using Image Analyzer microscope.

3. Results & Discussions:

The surface profiles and wear tracks have been discussed below:

3.1 Wear Testing:

Figures 1 and 2 show the micrographs of wear tracks at 2N load for both MS and SS substrates at room temperature (28°C), while figures 3 and 4 show the micrographs of wear tracks at 2N load for both MS and SS substrates at 100°C. Micrographs clearly depict that there is no appreciable wear on the surface of the coating.

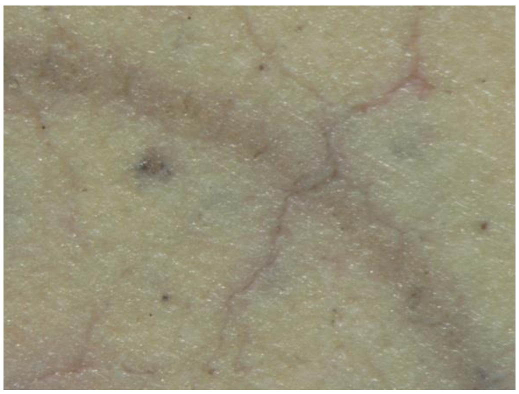

Fig.1 Wear track of coating on MS at 2N load at room temperature

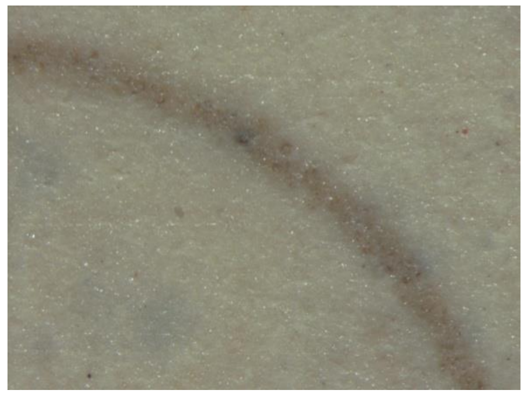

Fig.2 Wear track of coating on SS at 2N load at room temperature

Fig.3 Wear track of coating on MS at 2N load at 100°C

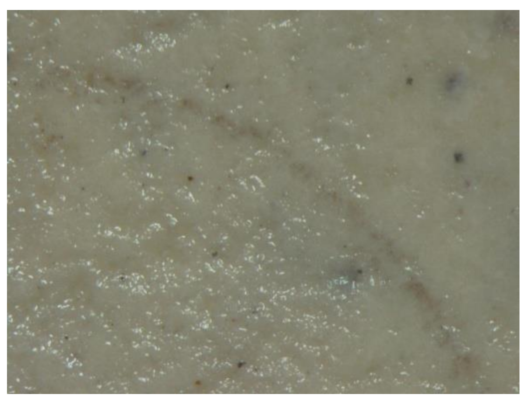

Fig.4 Wear track of coating on SS at 2N load at 100°C

The figures 5 and 6 show the wear tracks at 6N load on the surface of the coating on both SS and MS substrates at room temperature and the figures 7 and 8 show the wear tracks at 6N load on the surface of the coating on both SS and MS substrates at 100°C . Although tracks are much obvious at high load, but the coating still does not delaminate, which shows better adhesion of the coating with substrate.

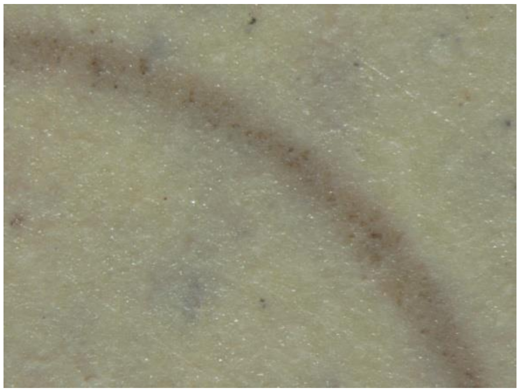

Fig.5 Wear track of coating on MS at 6N load at room temperature

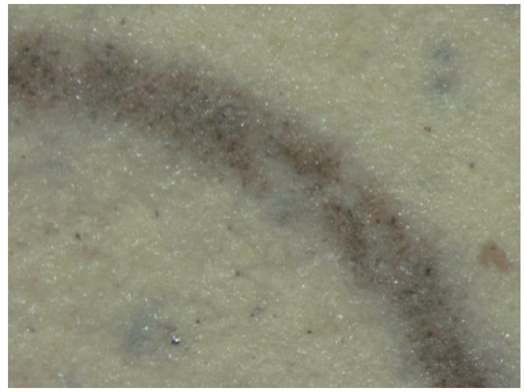

Fig.6 Wear track of coating on MS at 6N load at room temperature

Fig.7 Wear track of coating on MS at 6N load at 100°C

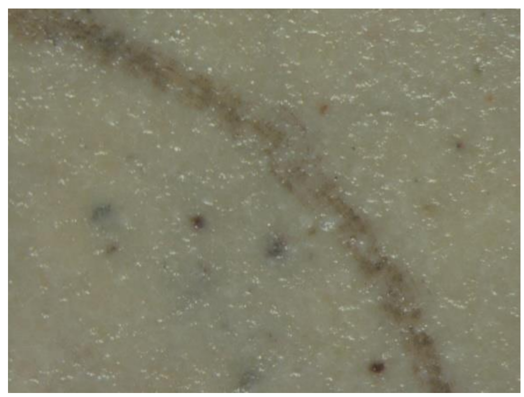

Fig.8 Wear track of coating on MS at 6N load at 100°C

The figures 9 and 10 below shows the wear on the balls used during wear testing against both MS and SS substrates respectively. It is quite obvious that the wear is more prominent and dense when the steel ball is slided against MS substrate. The wear patterns also show that the ball material is likely to be deposited on the coating surface, leaving a dark impression on the wear track, rather than delaminating the surface.

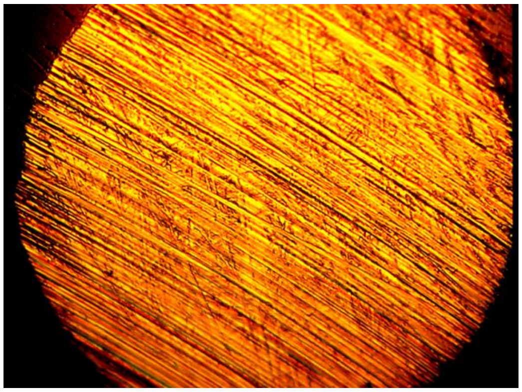

Fig.9 Micrograph showing wear on steel ball against MS substrate

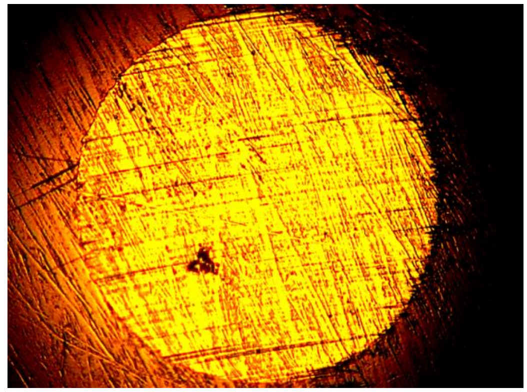

Fig.10 Micrograph showing wear on steel ball at against SS substrate

Conclusions:

- Both substrates show very good wear resistance with the coating. But stainless steel substrate shows better wear resistance as indicated by the wear patterns on steel ball.
- Even at higher temperatures, there is no significant change in the wear resistance of the coating.
- The wear on the steel balls is the clear indication of the fact that coating is more wear resistant.
- The coating did not delaminate even at the maximum load, showing better characteristics of the coating in lubricating environment.

References:

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[8] **Steel OCR4ES (Mat.No. 1.3505, DIN 100Cr6, AISI 5210)**