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PROCESS CONTROL OF THERMAL BARRIER COATING SYSTEM BY CURRENT VARIANT CHANGES TO ALTER THE MICROSTRUCTURAL AND MECHANICAL CHARACTERISTICS

A. Imran[1], S. Alam[1], M. Farooq[2], S.F. Shaukat[3]
[1]Pakistan Institute of Technology for Minerals & Advanced Engineering Materials (PITMAEM), PCSIR Labs. Complex, Lahore.
[2]Faculty of Engineering & Technology, University of the Punjab, Lahore.
[3]Head of Physics Department, COMSATS, Lahore.

ABSTRACT

Process development of thermal barrier coatings story begins when thermal barrier coatings are being developed, suitably, for air craft industry and processes being modified for effective and efficient insurance of the thermal barrier coated parts. As these coatings are being tested initially for use in diesel engine. Thermal barrier coatings functioned at higher temperature along with compressive loads and thermal shocks. An effort is being carried out for the optimizing the thermal barrier coating system by changing the current variable as it have other variants also. To optimize the current as a variant in process controlling, TBC was developed by Air plasma spraying system and characterized by using, image analyzer for porosity and microstructures & surface topography and Micro-Vickers hardness tester for hardness/mechanical effects on coatings. Significant results have been reported at 600 Amps for thermal barrier coatings.

Keywords: *current variant, Micro hardness, Porosity, Process controlling, Surface topography.*

1) INTRODUCTION

Among the different process for the development of thermal barrier coatings (TBC), thermal spraying is well renowned source. The air plasma spray (APS) process can be helpful in achieving variety of surface functionality like, abrasive, adhesive, fretting or sliding wear resistive and hot corrosion resistive coatings what's more for industries like, automotives, textile, metal processing, aerospace and power generation. And like the all other feedstock material/parameters of the air plasma spraying system have the flexibility regarding controlling of all these parameters. Among all energy for plasma spraying system is vital as its key role is to develop sufficient heat/energy to melt powder material (feed stock). The plasma gun utilize the chamber that is having cathode and anode, where this energy/heat is being produced by creating the plasma plume by the help of current importance of current variant can be seen by the concept that unstable plasma ions recombine back to the gaseous state while leaving the tremendous level of thermal energy, in the surrounding. And that energy is responsible for melting of feed-stock before propelled it to the substrate for coating purposes. In this study, a quality assurance attempt has been made to increase the vigilance on parameters control rather than rely on manpower. Yttria stabilized zircoina (YSZ) powders were selected because of its reported crystalline structural stability then other stabilizers and one application for YSZ for TBC is that is have less than 1 thermal coefficient value (< 1 W/mK) and is used to protect and insulate the hot section of metal components. YSZ with aluminide bond coat (Ni5%Al) were studied as a thermal barrier coatings system processed by APS at different current values and then coatings were characterized with the help of scanning electron microscope, image analyzer, micro-Vicker to evaluate the TBC behavior to optimized the process parameter of current variant.

2) EXPERIMENTAL WORK

In the present research work, Yttria Stabilized Zirconia (YSZ) TBCs coatings were produced on mild steel (AISI 1040) substrates using Air Plasma Spraying (APS) technique. TBCs Coatings were produced by varying process variable (current) to get optimum current value. Mild Steel (MS) 1040, coupons of size 24*12*5 mm were used for present experimentation. The Air Plasma Spraying (Sulzer Metco) was employed for thermal barrier coating on these coupons. NiAl 450 NS (Bond Coat) and 204 NSG ZrO2.Y2O3 (Top Coat) powders were used for TBC.

2.1) Surface Preparation

Surface preparation was carried out in 5 steps, as give below:

- Chemical Cleaning (solvent mixtures and aqueous washer solutions).
- Ultrasonic cleaning (cleaning solution at temperature of 60 °C).
- Drying (compressed air)

- Masking (Tape Mask)
- Dry Abrasive Grit Blasting

2.2) Holding and Fixturing

Within one hour of grit blasting, the coupons were arranged on a revolving fixture of Lath machine for coatings.

2.3) Coating

The Sulzer Metco Air Plasma spraying system was used consisting of 80kVA power supply, computer controlled powder feeder, plasma spraying gun, heat exchanger, air compressor and control unit to control the various coating parameters. Two layers coatings, i.e., Nickel 5% Aluminum (Ni5Al) as bond coat with thickness of 0.05 mm and Zirconia 8% Yttria (ZrO2.Y2O3) with coating thickness of 0.10 mm, were produced on coupons.

All parameters were remained same but only current varies from 445A to 600A (Table: 1).

2.4) Synchronization of Equipment

The following setup procedures were made before starting the system:

- Supply gases, air, and water turned on.
- Switch on electrical power to all units.
- Switch on exhaust system.
- Set power feed parameters.
- Ensure eye, ear, and skin protection for all participants.

Table 1: Current Parameter of Plasma Sprayed for TOP Coat Samples

Samples	Arc Current
A	445A
B	500A
C	550A
D	600A

Microstructures, morphology and defects were also studied using optical microscopy. Standard metallographic sample preparation techniques were used to obtain samples with scratch free and polished surfaces. Some samples were etched in order to observe the microstructure while others were examined without etching to reveal the porosity distribution. The hardness of selected samples was also measured using Micro Vickers Hardness Testing Machine 402 MVD. Each specimen was indented 3 to 5 times and average hardness values were calculated.

3) RESULTS AND DISCUSSION

The main objective of the present research work was to develop an insulating ceramic coating (TBCs) and studying effects of current variation on micro structural and mechanical behaviour of coatings.

3.1) Micro Structural Characterization

A few representative Optical micrographs of TBCs coated at different current values (table 1) are presented in Figures 1, 2, 3 and 4. The micrographs show the typical microstructure of the plasma sprayed thermal barrier coatings, however, effects of current variant on morphology are observed. The figure 1 shows the microstructure of topcoat of sample A coated at 475A. Microstructure reveals large size voids, oxidized, peeling off coating and non-melted particles but there is adequate adhesion between top and bond coats.

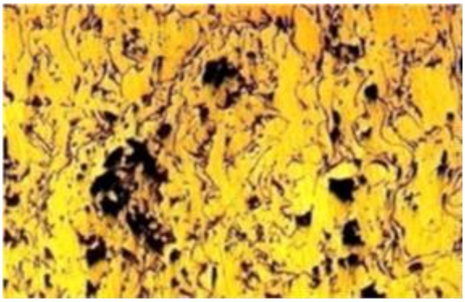

Figure 1: Photomicrograph of Sample A, 50X

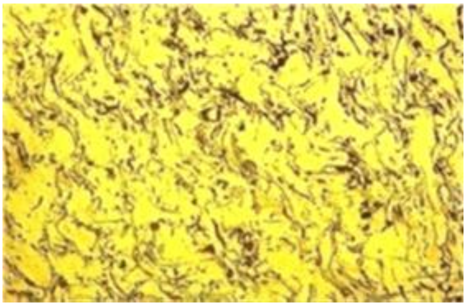

Figure 2: Photomicrograph of Sample B, 50X

The microstructure of sample B, TBCs deposited at 500 A which shows small sized voids, less non-melted grains and small areas of peeling off coating as compare to sample A (Fig.1). The figure 3 of TBCs sample C coated at 550 ampere, illustrates the microstructure of topcoat having very small voids and few uncoated areas. There is an adequate amount of inter lamellar contacts and continuity of adhesion as converse to sample A (475 A) and B (500 A) respectively (Fig. 1, 2). Optical photomicrograph of sample D coated at 600A shows the characteristic microstructure of TBCs with voids and uncoated areas. There is satisfactory amount of inter lamellar contacts present fig. 4. The microstructure of sample D coated at 600A is more or less identical to sample C (Fig. 3), but different to sample A and B (Fig. 1, 2) coated at 475 A and 500 A respectively.

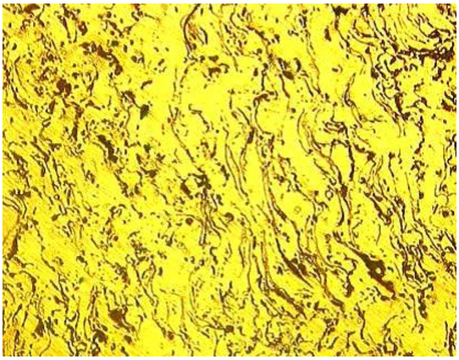

Figure 3: Photomicrograph of sample C, 50X

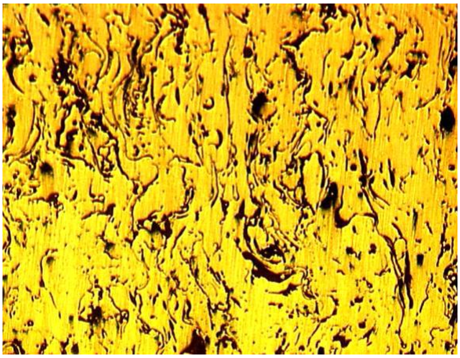

Figure 4: Photomicrograph of Sample D, 50X

3.2) Mechanical Properties

The sprayed layer adheres to the substrate mainly because of the combined action of mechanical anchoring, valence forces and Vander Walls forces. The sprayed coatings are more brittle then their corresponding compact materials, they are brittle in fracture. [ref 2.4.3 page 48]. Results for tensile strength are summarized in Table 2. The sample C has highest value of tensile strength, while sample D coated at 600 A close to it. Both samples A and B coated at 475 and 500 amperes have lower values then samples C and D. It shows that values of tensile strength increase with increasing current amperes. This result suggests that the cohesion of splats boundary becomes stronger at higher current because of complete melting and densely packing of melted particles.

Table 2: Tensile Bond Strength of TBCs Coatings

Sr. No.	Sample	Tensile Bond Strength [MPa]
1)	A (445A)	25
2)	B (500A)	32
3)	C (550A)	40
4)	D (600A)	38

3.3) Micro-Hardness Testing

Hardness of the coatings was also studied using micro hardness tester (HV0.1) from the coating cross section, including topcoat, bond coat and coating interface. Results are presented as mean values of five separate measurements.

It can be seen in table 3 that the maximum value of hardness is achieved at 550 A while at 500 A the lowest hardness value is obtained. Hardness values of sample A and D are in between samples C and D.

Table 3: Hardness Profile of Topcoat, Bond Coat and interface of TBCs

Sample	Current (A)	Hardness $HV_{0.1}$		
		Top Coat	Inter Face	Bond Coat
A	475	765	147	117
B	500	718	241	125
C	550	785	123	110
D	600	765	138	107

Micro hardness has corresponding relationship with the microstructure of TBCs. The lower the percentages value of porosity higher the micro hardness value because during the process, a complex elastic-plastic field is formed under the indentation and Porosity tries to reduce the load bearing area, which is harmful to strength.

4) CONCLUSION

- From the present literature review and experimental work it may be concluded that; 550 A was found an optimum current value for better micro structural properties of TBCs, i.e. low porosity, less non-coated areas, smaller voids and good adhesion between top and bond coats.

- Altering the current has influence on the carrier gas properties (such as the carrier gas speed (12 FMR), the carrier gas density and the vapour species composition) which relates to coating properties.
- Mechanical evaluation proves that superior coatings bond strength value (40 MPa) was attained at 550 A.
- The micro hardness values gradually increased with increasing current up to 550 amperes (785 HV0.1) and then decreased.

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