HOT CORROSION AND THERMAL OXIDATION STUDIES OF EB-PVD AND APS THERMAL BARRIER COATINGS

Ravinder M. Diwan[1], Patrick F. Mensah[1], Naresh Polasa[1] and Douglas E. Wolfe[2]

[1]Department of Mechanical Engineering, Southern University, Baton Rouge, LA 70813
[2]Department of Materials Science and Engineering, Pennsylvania State University, PA 16802

Introduction

Thermal Barrier Coatings (TBCs) are used in gas turbines to increase the turbine life, reduce the temperature and to achieve higher efficiency. These TBCs generally consist of metallic bond coat (MCrAlY, M=Ni or Co) with Yttria Stabilized Zirconia (YSZ) as topcoat which provides thermal insulation for the substrate. Thermally Grown Oxide (TGO) is formed between the interface of the bond coat and the topcoat during the ceramic deposition. TGO generally consists of aluminum oxide. For NiCoCrAlY bond coats minor amount of spinels (Ni, Co)$(Al,Cr)_2O_4$ and occasionally NiO are also found particularly in the region closer to the bond coat [1-3]. The characteristics of the hot corrosion under Type I and Type II conditions have been of interest for applications of thermal barrier coatings in high temperature and gas turbine components [4-5].

In this work, bond coats are prepared using Air Plasma Spray (APS) and High Velocity Oxy Fuel (HVOF) process. The bond coats in the TBCs are expected to provide protection to substrate superalloys and resistance to highly corrosive and high temperature environments.

The oxidation kinetics for TGO growth are observed with measurements of weight gain using thermogravimetric analysis (TGA) experiments performed for isothermal conditions at 1000°C and 1200°C. Hot corrosion testing studies have been performed on selected APS and EBPVD samples using Dean Rig test apparatus for hot corrosion Type I (900°C) and Type II (705°C) testing with sodium sulfate contents. Results of these evaluations for hot corrosion and thermal oxidation studies will be presented.

Experimental

The TBC specimens for the study of resistance to hot corrosion Type I (900°C) and Type II (705°C) were processed using IN 738 substrate EDM machined pin specimens (3/16 inch diameter x 3 inch long), tumbled, and prepared with special bond coats containing Hf with chemical composition (wt.%) Ni-22Co-17Cr-12.5Al-0.25Hf-0.4Si-0.6Y bond coats of about 125 µm and top coats of about 7.65 % ytrria stabilized zirconia YSZ. In these hot corrosion tests, the top coat thickness was 300 µm and 600 µm YSZ for the standard and vertically cracked APS test pin specimens and 300 µm YSZ for EB-PVD coated pin specimens investigated for Type I and Type II hot corrosion conditions for durations from 20 to 100 hrs. The apparatus used for this testing was the Dean Rig test equipment consisting of a multi-temperature zone furnace, alumina tube, molten sodium sulfate salt, and an O_2-O.1%SO_2 gas mixture.

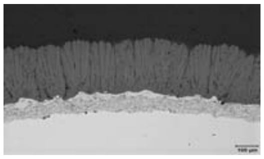
For the oxidation studies, two spray systems were utilized to deposit bond coat formulations with bond coat compositions as given in Table 1.

Table 1: Composition of bond coat samples for TGO studies:

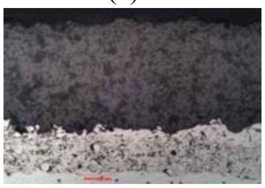
	Ni	Co	Cr	Al	Y
APS	Bal	-	22.50	10.60	1.10
HVOF	Bal	23	17	12.5	0.5

Results and Discussion

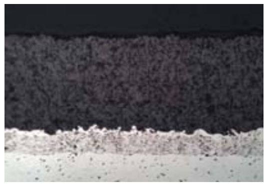
Typical microstructures of the coated TBC specimens of the columnar EB-PVD structure and of the standard and vertically cracked VC air plasma sprayed APS TBC coatings are shown in Figure 1.



(a)



(b)

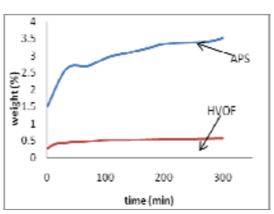


(c)

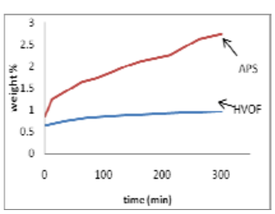
Fig.1 (a) EB-PVD and (b) standard APS and (c) vertically cracked VC APS coated TBC specimens microstructural images.

The results of the hot corrosion testing of the uncoated and the coated TBC samples were analyzed for periods up to 100 hrs under Type I (900°C) and Type II (705°C) test conditions. The several samples tested indicate the best resistance to hot corrosion in case of the EB-PVD and columnar structures. However, specimens with higher coating thickness in case of the APS specimens appear to have higher hot corrosion resistance for Type I and Type II test conditions. Other factors could also be impacting on the hot corrosion effects. Rough surface finish will tend to facilitate better mechanical adhesion and processing of columnar structure appears to help in achieving more strain tolerant microstructural top ceramic coatings of these TBC specimens.

The oxidation kinetics of APS (NiCrAlY) and HVOF (NiCoCrAlY) bond coats are studied under oxygen environment at 1000°C for 5 hrs and then at 1200°C. The weight gain is observed during the isothermal oxidation of the TGA samples. The growth of weight is higher with the increase of temperature from 1000°C to 1200°C.



(a) Percentage weight gain vs time at 1000°C



(b) Percentage weight gain vs time at 1200°C

Figure 2 Results of TGA oxidation studies at 1000 °C and 1200 °C.

Conclusion

The studies of the hot corrosion of the TBC specimens and of the bond coats of the selected processed conditions indicate the role of different contributing factors towards the oxidation kinetics of the TGO on the bond coats and of the effects of TBCs of processed microstructures under Type I and Type II hot corrosion test conditions. The EB-PVD and the vertically cracked VC or columnar structures in general appear to exhibit better tolerance to hot corrosion effects. In case of the bond coat TGA studies, the rate of weight gain is higher for the APS specimens in comparison to the HVOF processed samples due to microstructural processing effects.

Acknowledgements

This work has been supported by DOE Grant DE-FG-26-08NT001471, NASA EPSCoR Grant and funding from Louisiana Clean Power and Energy Research Consortium (CPERC). The authors are also grateful for support of Mr. Sean Kohl of TA instruments for support in preliminary testing work in weight gain oxidation work and Dr. Purush Sahoo of MSI International in processing of the APS coatings of supplied IN 738 samples.

References

1. S.Y. Park, J.H. Kim, M.C. Kim, H.S. Song, C.G. Park, Microscopic observation of degradation behavior in yttria and ceria stabilized zirconia thermal barrier coatings under hot corrosion *Surface and Coatings Technology*, 190, 2005, 357-365.

2. Saremi Mohsen, Afrasiabi Abbas, Kobayashi Akira, Bond coat oxidation and hot corrosion behavior of plasma sprayed YSZ coating on Ni superalloy, *Transactions of JWRI*, Vol. 36, 2007, No. 1.

3. Sudhangshu Bose, High Temperature Coatings, Butterworth-Heinmann, Elsevier Inc. 2007.

4. R. L. Jones, Some aspects of the hot corrosion of thermal barrier coatings, *Journal of Thermal Spray Coatings*, Volume 6 (1), March 1997, 77-84.

5. N. Eliaz, G. Shemesh R. M. Latanision, Hot corrosion in gas turbine components, Engineering Failure Analysis (2002), 31-43.