THERMAL OXIDATION CYCLING STUDIES OF APS AND EB-PVD COMPOSITE TBC MICROSTRUCTURED COATINGS

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Introduction

Thermal barrier coatings (TBCs) are used in gas turbine engines to achieve higher working temperatures, and thus better efficiencies. Yttria-Stabilized-Zirconia (YSZ) is often used as the top coat layer to provide thermal protection due to its low thermal conductivity. The primary objective of this effort is to study the effects of lamellar (standard) and vertically cracked (VC) air plasma spray (APS) TBC microstructures and compare these to electron beam physical vapor deposition (EB-PVD) columnar structured TBCs for advanced gas turbine applications at elevated temperatures. Effects of pre-treatment of bond coats and thermally grown oxide (TGO) for increasing performance of TBC systems [1-3] have been investigated. The pre-oxidation and TGO growth behavior, oxidation, and TBC degradation [4-5] have been evaluated using thermogravimetric analysis (TGA) to understand the effects of pre-oxidation treatments in low pressure oxygen environments to suppress the formation of detrimental oxides and form a stable alpha aluminum oxide layer. Similar TGA studies are planned to evaluate the tailored microstructures produced in these studies.

In the present study, TBC systems were investigated using NiCoCrAlYHf bond coats with YSZ TBC top coatings of 300 µm and 600 µm for both standard and VC APS TBC and 300 µm thick EB-PVD YSZ top coatings to determine the effect of coating thickness and tailored microstructure in dry and wet thermal cyclic oxidation studies at elevated temperatures. In addition, thermal conductivity measurements were carried out up to 1300^{o}C and will be presented. The microstructural, porosity, and TGO growth for the various tailored microstructures are currently being modeled and will be presented at a later date.

Experimental

Materials
IN 738 superalloy from Howmet Castings was EDM machined to 12.54 mm dia. x 3 mm thick disc specimens to which 125 µm MCrAlYHf bond coat was applied by APS prior to depositing the EB-PVD, standard and vertically cracked APS test specimens. The bond coat chemical composition (wt.%) was Ni-22Co-17Cr-12.5Al-0.25Hf-0.4Si-0.6Y, and was considered to provide better performance and spalling resistance of the TBCs for higher temperature applications. The top coat thickness was 300 µm and 600 µm 7.65 % ytrria stabilized zirconia YSZ for the standard and vertically cracked APS test specimens, and 300 µm for EB-PVD coated specimens. The standard and the vertically cracked APS TBC specimens were produced by Materials Solution International, MSI, TX.

Apparatus and Procedures
The spalling resistance testing was carried out in a CM 1700 bottom loaded furnace using a 6 hour thermal cycle with ramping from 25^{o}C to 1200^{o}C in 30 minutes, soaked at 1200^{o}C mode for 300 minutes, followed by cooling down from 1200^{o}C to 25^{o}C in 30 minutes.

In addition, wet and dry thermal oxidation cycling studies were carried out at the Applied Research Laboratory, the Pennsylvania State University at 1125^{o}C with a 1 hour cycle time in which the samples were held at temperature (1125^{o}C) for 55 minutes followed by forced air cooling to room temperature. The thermal cycling tests for wet oxidation used the same 1 hr cycle but incorporated saturated water vapor to investigate oxidation behavior in moist environments.

Results and Discussion

The preliminary spalling resistance test results at 1200^{o}C are shown in Figure 1.

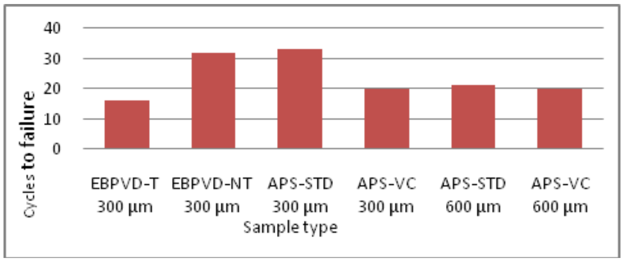
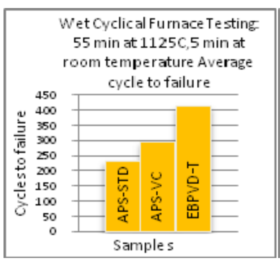


Fig.1 Thermal Cycling Spalling Resistance using 6- hour thermal cycles at 1200 ^{o} C.

The spalling resistance results show that average cycles to failure range between 16-33 cycles for all specimens as shown in Figure 1.



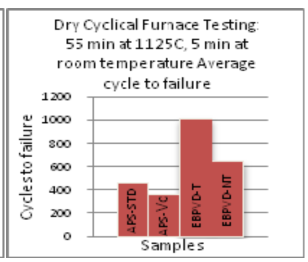


Fig 2. Wet Cyclical Furnace Test Results. Fig 3. Dry Cyclical Furnace Test Results.

Fig.2-3. Thermal cyclic oxidation results of various YSZ TBC under wet (left) and dry cyclic conditions evaluated at 1125^{o}C.

The results of the wet and dry thermal cyclic furnace testing at 1125^{o}C are reported in Figure 2 and 3. As shown in Figure 2 the average number of cycles to failure for the standard plasma spray APS-STD, vertically cracked plasma spray APS-VC, and EB-PVD tumbled EBPVD-T TBC coatings was 232, 297 and 417 respectively for the wet thermal cyclic testing. There was a slight improvement in the average number of cycles to failure for the vertically cracked samples as compared to the standard plasma spray APS coatings. In Figure 3 the average number of cycles to failure for the standard plasma spray APS-STD, vertically cracked plasma spray APS-VC, EB-PVD tumbled EBPVD-T and EB-PVD non-tumbled EBPVD-NT TBC coatings was 463, 360, 1012 and 642 respectively for the dry thermal cyclic testing. All of these results will be presented and discussed.

Conclusion

The spalling resistance at 1200^{o}C of the standard and vertically cracked APS and EB-PVD 300 µm top coat thickness showed better life for EB-PVD specimens in the non-tumbled condition and standard APS test specimens. The 600 µm top coat thickness of the standard and vertically cracked APS test specimens had lower spalling resistance life compared to 300 µm top coat thickness specimens. These results are being correlated to thermal properties and porosity measurements in a parallel study which will be reported in a future publication.

For high temperature turbine operating conditions, extended wet and dry thermal oxidation cyclic testing data at 1125^{o}C showed that the wet oxidation testing samples, in general, failed earlier than the dry oxidation testing, for similar coated samples.

Acknowledgements

This work was supported by DOE Grant DE-FG-26-08NT001471 and Louisiana Clean Power and Energy Research Consortium (CPERC).

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