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Study and Performance Evaluation of Thermal Barrier Coatings (TBCs) Using Infrared Thermography

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Abstract

Thermal barrier coatings (TBCs) are used in gas turbine engines to protect engine hot-section components in the harsh combustion environments, and extend component lifetimes. Infrared Thermography method has been selected for obtaining thermal images and studying the TBCs of Alumina, Zirconia and Alumina+Titanium oxide coated on the base plate of Titanium, by measuring the back wall temperatures. The results were analyzed in terms of different coating materials and of varying thicknesses. The salient features of Infrared Thermography for the measurement of temperature of TBCs have been brought out.

Keywords: *Infrared thermography, Thermal barrier coatings, Back-wall temperatures*

1. Introduction

Thermal Barrier Coatings (TBCs) perform the important function of insulating the components, such as gas turbine and aero engine parts, operating at high temperatures. TBCs are characterized by their very low thermal conductivity, the coating bearing a large temperature gradient when exposed to heat flow. Thus TBCs make possible the increase in operating temperatures and efficiency of the above parts. The thickness of TBCs range from a few hundreds microns up to 1 mm or more, depending on component and deposition technique mainly by Air plasma spray or electron beam physical vapor deposition.

Infrared Thermography is a Non destructive testing method used to measure the temperature differences by non-contact technique. This method has advantages of inspecting coated structures with wet and dry coatings and enabling to cover large coating areas at a time. Thermography detects both delaminations and thickness variations of these coatings on the substrates.

In the present work, TBCs of Alumina, Alumina+Titanium oxide and Zirconia have been coated on the base plate of Titanium, which are exposed to heat flow and their back wall temperatures are measured using Infrared camera. The performance of these TBCs is evaluated in terms of reduction in back wall temperatures to that of the base plate. The effect of varying coating thickness of TBCs materials is also studied. Further, the results are analyzed in terms of different coating materials and of varying thicknesses. Similar studies were carried out on TBCs using Infrared Thermography [1, 2]. P.G. Bison et.al. [1] studied on the detection performances of Non destructive evaluation techniques and reported the results on real and specifically manufactured components. M. Omar et.al. [2] studied the protective coating coverage on steel substrates by Infrared Thermography. The fast and area coverage attributes of Thermography, enabled the development of a real time thin paint detection system suitable for industrial production lines [2].

2. Experimental Details

TBCs of Alumina, Alumina+Titanium oxide and Zirconia have been coated on the base plate of Titanium using spray coating technique.

Infrared Thermography studies were carried out using Infrared camera of Focal plane array (320x240 pixels) having range of 8-9µm, with instantaneous field of view of 1.1 mrad, sensitivity of 0.03 ºC at 30 ºC and an accuracy of ±2 ºC of measured value. 2.5 mm thick Titanium base plates coated with TBCs were exposed to heat flow and their back wall temperatures were measured using Infrared camera. An uncoated base plate was also kept for reference temperature measurement. The performance of these TBCs is evaluated in terms of reduction in back wall temperatures to that of the base plate. The base plate and TBC coated plates were applied on with black chute for having the uniform emissivity for infrared measurements.

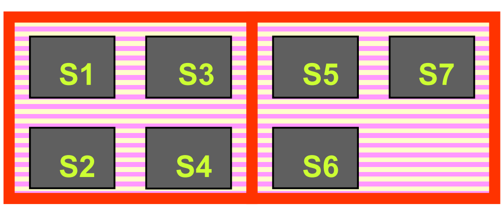

Fig.1: Experimental Setup

3. Results and Discussion

Fig.1 shows the experimental setup of Titanium base-plate and Titanium plates coated with Alumina, Alumina+Titanium and Zirconia as TBCs of varying thicknesses. Fig. 2 shows the thermal image obtained of the setup shown in fig.1. The back wall temperatures of these plates were measured and listed in Table-1. Fig.3 shows the temperature profiles of the base plate and TBCs coated plates.

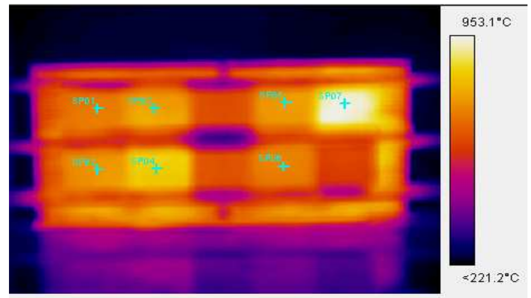

Fig. 2: Thermal image of experimental setup

Table-1 lists the samples of different TBC coating materials with varying thicknesses along with base plate, their corresponding back wall temperatures measured and temperature difference of coated plate to that of the base plate. It is clear from the Table-1 that as the thickness of the coating material increases the reduction in back wall temperature is increased. Further, the performance of these TBCs is evaluated in terms of the reduction in back wall temperatures to that of the base plate, which is clear from Table-1. Alumina and Zirconia of 600µm performed better as thermal barrier coatings over the materials and the thicknesses studied, listed in Table-1. The salient features of Infrared Thermography for the measurement of temperature of TBCs are as follows. Thermography is highly useful in obtaining the thermal signatures of the whole-plate and also allows the data for further processing and analysis, which is not possible with thermocouples. Thermography being a non-contact measurement, which is advantageous, where as thermocouple is a contact measurement, which may peel-off during measurements. Thermography being the non-invasive and whole-field technique, covers a large area of the object under test, allows the flexibility of choosing area of interest, which is not possible with thermocouple and other type of measurement techniques.

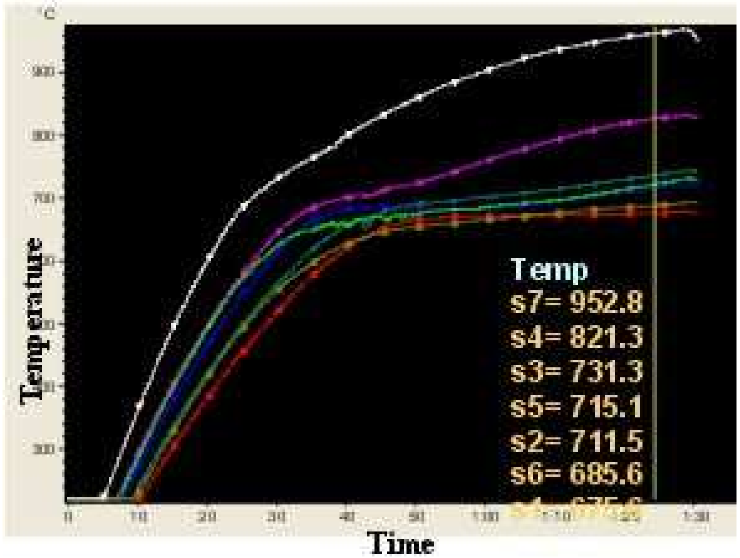

Fig. 3: Temperature profiles of the base plate and TBCs coated plates

Table 1: Samples of different coating materials with varying thicknesses, temperatures measured and their temperature differences to coated base plate

Sample	Coating Material	Thickness (μ)	Temp (^oC)	Temp.Diff (^oC)
S1	Al_2O_3	600	675.6	277.2
S2	Al_2O_3	300	711.5	241.3
S3	$Al_2O_3+TiO_2$	600	731.3	221.5
S4	$Al_2O_3+ TiO_2$	300	821.3	131.5
S5	Zr_2O_3	300	715.1	237.7
S6	Zr_2O_3	600	685.6	267.2
S7	Base Plate	No Coating	952.8	--

4. Conclusion

Infrared Thermography has been successfully used, studied and evaluated the performance of Thermal Barrier Coatings (TBCs). Thermography is proved to be flexible, non-contact, non-invasive and whole-field technique.

5. References

1. Paolo G. Bison, et al. ''Inspecting thermal barrier coatings by IR thermography'' Thermosense XXV, Proc of SPIE, vol. 5073, Apr 2003, pp.318-327.
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