Measurement of Thermal Barrier Coating (TBCs) Topcoat Thickness by Pulsed Thermography Method

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Abstract In this work, we focused on the possibilities of measuring non-uniform topcoat of thermal barrier coating using pulsed thermography method. A comparative study of simulation and experimental result is presented. In an experimental investigation, a short and high energy light pulse impinged on the sample surface, and an infrared camera was used for the monitoring of the surface temperature of a thermal wave propagated into the sample. For simulation, the ThermoCalc™-3D software based on the FDM was used for the replication of the physical phenomena that were present in the experiment. The response of thermally excited surface was recorded, and data processing with Fourier transform was carried out to obtain the phase angle. The calculated phase angle was correlated with the coating thickness. The method demonstrated potential in the evaluation of coating thickness and was successfully applied to measure the non-uniform top layers ranging from 0.1 mm to 0.6 mm

Keywords: Thermal barrier coating (TBCs), Pulse thermography, Fourier transform, Phase angle

1. Introduction

Thermal barrier coatings (TBCs) refer to a refractory-oxide ceramic coating deposited on the metal surface. TBC provides insulation to the base part and is widely used in aviation, power generation and automotive industries to improve the service life of components being exposed to high-temperatures. The topcoat thickness is an important parameter which determines the thermal insulation characteristics and is important for performance evaluation. Therefore, there is a need for nondestructive testing (NDT) techniques to evaluate the coating thickness for uniformity. Pulse thermography is one of the most popular thermal excitation methods in infrared thermography (IRT) due to the quickness of the test relying on a short and high power thermal excitation pulse to the sample surface [1-3]. This paper presents the simulation and experimental study of pulsed thermography in reflection mode for the evaluation of TBC thickness deposited on Ni-based superalloy.

2. Materials and methods

In the present study, a square shaped sample with dimension 180 × 180 mm was modeled in ThermoCalc™-3D. The model consisted of nickel based superalloy substrate with intermetallic material, MCrAlY as a bond coat and Zirconia (ZrO2) as the topcoat. The substrate and the bond coat thickness were kept at 4 mm and 0.1 mm respectively whereas the top coating thickness was varied from 0.1 mm to 0.6 mm. In simulation, a single square pulse heating of 9 KJ was considered for the duration of 5 milliseconds. The time step was set to 0.01 s for duration of 5 second.
Fig. 1 shows a detail configuration of the test sample considered in this study. The experimental pulse thermography system consisted of an Universal BALCAR (France), Power: 6400 W-s as a heat source; BALCAR Light System, Nexus A 6400 (France) to synchronize the input and output signals; an IR camera (SC645, FLIR Systems, Sweden) with a 640 × 480 pixel resolution and a wavelength of 7.5–13 μm to record the thermal response of the sample and a system controller (Computer).

Results and Discussions

Phase angle was computed by the processing of pulsed thermal data with Fourier transform in MATLAB and ThermoFit Pro software. As shown in Fig. 2, phase angle increased with the increasing coating thickness in both the simulation and experimental investigation. Although there appeared some difference in the magnitude of phase angle with the simulation and experimental result, it is worth noting that both the experimental and the simulation results follow the same trend that phase angle increased with the increasing coating thickness.

Fig.2 Results (a) Simulated phase angle image, (b) Experimental phase angle image and (c) Comparison of simulation and experimental results
The results can also be influenced by the material properties of the sample, the emissivity, the heating power, the IR camera thermal sensitivity, the image processing methods, and the number of raw images considered for processing. Furthermore, comparing the experimental results with simulation, the experiment result was limited owing to structural and apparatus noise.

4. Conclusions

In this work, coating thickness measurement method was developed by using pulse thermography. The experimental verification of the simulated PT technique was done to measure the non-uniform top layer of TBC. The method demonstrated potential in the evaluation of coating thickness and was successfully applied to measure the non-uniform coating thickness ranging from 0.1 mm to 0.6 mm.

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