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Crack propagation modeling on the interfaces of thermal barrier coating system with different thickness of the oxide layer and different interface morphologies

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ABSTRACT

A finite element model (FEM) is developed to simulate the crack development in a typical plasma sprayed thermal barrier coatings system in consequence of the stresses induced by thermal cycling, the growth of the oxide layer and different interface morphologies. The thermo-mechanical model is designed to takes into account a non-homogenous temperature distribution and the effects of the residual stress generated during coating process.

Crack propagation at the top-coat/oxide and oxide/bond-coat interfaces is simulated thanks to the contact tool "*Debond*" present in the ABAQUS finite element code. Simulations are performed with a geometry corresponding to identical or dissimilar amplitude of asperity and for different thickness of oxide layer.

The results show a significant difference between the case with and without presence of crack propagation and an important damage on the interfaces due to the growth of the oxide layer very close to the height of the interface asperities.

1. Introduction

Thermal barrier coatings system (TBCs) is found very efficient for the turbine components at high temperatures. The major weakness of TBCs is located at the interface between the metallic bond-coat (BC) and the plasma sprayed thermal barrier coating (TBC). At this interface, an in-service degradation is usually observed leading to a macroscopic spallation of the ceramic layer [1]. The interface regions undergo high stresses due to the mismatch of thermal expansion between BC and TBC. Additionally, the growth stresses due to the development of thermally grown oxide (TGO) at the interface and stresses due to the interface roughness are superimposed. Stress relaxation leads generally to reduce stress level at high temperature, but can give rise to enhanced stress accumulation after thermal cycle resulting in early crack initiation at the TBC/TGO and TGO/BC interfaces and spallation failure after-wards [2].

Several finite element simulations have been performed in previous studies [3,4]. In [3], the temperature distribution on whole TBCs system was considered as homogenous. The effects of the shape and height of the interface asperity, plastic, creep deformation and oxidation at the bond-coat/top-coat interface on the residual thermal stresses in thermal barrier coatings have been numerically simulated. It was demonstrated that the stresses in the TBCs, during the high temperature, are strongly influenced by creep properties of the TBC, BC and TGO layers.

In the previous work [4], an additional model that considers the thermal conduction in the whole system and the convection with the surrounding environment leading to a non-homogenous temperature distribution has been proposed to improve the thermo-mechanical behavior prediction of the thermal barrier coatings system. This model was used to describe the residual stress resulting from the plasma spraying process of a zirconia based thermal barrier coating. Moreover, this model was used to study the stress distribution in the system at the end of the thermal loading cycle while the residual stresses in the top-coat (due to the coating process) were considered as initial conditions. Therefore, this model can be considered as sufficiently reliable to be developed with the objective to model the crack propagation. The increase of the TGO layer induces an important tensile zone on the TBC, BC layer and TGO itself. These zones may lead to the crack initiation and propagation in the interfaces, within the TBC and the TGO layers. Cracks observed at the "peak" of TGO/BC interface was named "mechanism I" and at the "middle" of TBC/TGO interface was named "mechanism II". Linking of the micro-cracks at the ceramic/metal interface, through the TBC and TGO layers could lead to ultimate spallation failure of the TBC (mechanism III). These three failures mechanisms that correspond to different scenarios of

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