Identification of the damage mechanism in a ceramic matrix composite / protection {CMC-EBC} system under tensile test.

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Abstract

Ceramic matrix composites (CMC) are used in the aeronautic field for extreme thermomechanical conditions. Their low density and high refractory properties make them relevant materials for critical parts such as turbine blades. To prevent the CMC degradation for long life duration in an oxidizing atmosphere at high temperature into the engine, the material has to be coated with an environmental barrier coating (EBC). The EBC is a two-layer material composed of a silicon bond coat and a rare earth disilicate top coat. CMC and EBC are well-identified components: elaboration and deposition method, main failure mechanisms under various environment. However, only little researches deal with the synergic effect of the EBC and the CMC (1).
The {CMC-EBC} system performance in the engine is leaned on chemical compatibility, effectiveness of the EBC and mechanical resistance. Moreover, the initiation and the propagation of cracks between the CMC and the EBC are key information to predict the lifetime of the system in the engine environment. Indeed, under thermomechanical loadings, several factors have to be investigated to predict the stress distribution and damage evolution of {CMC-EBC}: interfaces, morphologies of the EBC and of the CMC, thermal properties and the part geometry. First works were carried out with tensile test at room temperature (2). These authors highlight the dissimilar behavior between CMC and {CMC-EBC}, especially depending on the substrate condition (degree of surface roughness).

This work focuses on the understanding of the cracking of a SiCf/SiCm CMC coated with an ytterbium disilicate (DSYb) top coat for turbine blade application. The different thermomechanical parameters are identified and considered separately in order to quantify their impact on the system in the engine. Furthermore, owing to damage closure phenomenon, a direct in-situ analysis is required to characterize the initiation and the propagation of first cracks through the CMC and the EBC. Specific instrumentations are set up for each test: image correlation, direct microscopy, acoustic emission.

Before the introduction of thermomechanical factors, an initial behavior has to be established. Tensile tests on {CMC-EBC} are performed at room temperature to determine the original crack path. The effect of different surface states of the substrate is also explored.

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Such a test allows direct observation of the surface by microscopy. A digital microscope maps a polished surface at several level of strain. Coupled with Digital Image Correlation (DIC) on other faces, a comprehension of the cracking between the CMC and the EBC is permitted. Elsewhere, these experiments are supported by tomographic test campaigns. Experiments are reproduced directly in the micro-computed tomography device. These acquisitions are challenging because of the low SiC/SiC contrast and the high absorbance of the top coat. It is necessary to work at high energy with phase contrast. Thereby, the crack behavior in the {CMC-EBC} at room temperature will be described in the volume.

This work paves the way for a full understanding of the behavior under thermomechanical loadings of a {CMC-EBC} system and for determining whether the EBC can enhance the lifetime of the aeronautical part if its damage threshold is greater than that of the CMC.

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