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DETERMINATION OF INTERFACIAL PROPERTIES BETWEEN CERAMIC MATRIX COMPOSITE AND ITS ENVIRONMENTAL BARRIER COATING

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ABSTRACT

Ceramic Matrix Composites (CMCs) are considered as a promising alternative to metallic materials for the design of hot section components of aircraft engines [1]. Their high temperature thermomechanical and physical properties as well as their low density allow for high performances in extreme environments. In particular, silicon carbide (SiC) fiber reinforced SiC matrix CMCs are suitable for structures subjected to temperatures up to 1300°C. Yet, this kind of material is very sensitive to water vapor that causes recession [2]. To avoid this degradation mechanism, an Environmental Barrier Coating (EBC) is applied to the CMC surface to protect it and extend the life of CMC structures. The adhesion between the CMC and the EBC must be strong enough to withstand the temperatures and the oxidizing environment experienced by CMC components. To ensure this good adhesion, it is necessary to characterize the stress threshold and the fracture energy of the interface up to high temperatures. The aim of this work is to present several tests carried out at room and high temperatures to characterize these interfacial properties.

Each test presented below was realized on CMC samples. The top surface of the CMC substrate was covered with a thin layer of silicon (Si) bond coat and a thick layer of Yttrium Disilicate (YDS) top coat. On the one hand, the stress threshold was determined by a thermal test using a laser setup. A high power (3kW) heat flux was generated by a CO_2 laser heating locally the coating of the sample, allowing 3D thermal gradients to be generated close to a corner. The experiments were instrumented with an infrared (IR) camera and a monochromatic pyrometer to measure the surface temperature of the coating (Figure 1). Another IR camera was used to measure temperature fields on the CMC (back) surface. Last, an acoustic emission (AE) sensor was attached to the backside of the sample to detect acoustic events. Thanks to this sensor, damage was detected during some of the tests. Scanning Electron Microscopy (SEM) observations revealed a crack that started at the CMC/EBC interface and then branched into the EBC layer.

On the other hand, the interfacial fracture energy was characterized using a three-point end-notched flexure test, four-point flexural tests performed at room temperature [3] and in a furnace at 1000°C [4]. Each room temperature test was instrumented with two visible light cameras at an angle of 25° to measure 3D displacement fields. Furthermore, AE sensors were used to detect damage during loading.

At 1000°C, only a single visible light camera was used due to the space taken up by the furnace (Figure 2-a.). For all tests, SEM observations of the samples showed transverse cracks through the EBC layer propagating along the CMC/EBC interface (Figure 2-b.). The displacement fields and the lengths of the interfacial cracks were determined using global finite element based digital image correlation (DIC) analyses at room temperature. At high temperatures, heat haze effects caused optical artifacts. A spatiotemporal regularization of the DIC technique was utilized to achieve the same measurement accuracy at high temperature (Figure 2-c.).

Laser and flexural tests were modelled to determine the stress threshold and the interfacial fracture energy. The experimentally measured fields (temperatures or displacements) were used as input data to update the various finite element models. Measurement uncertainty will be discussed in relation to the characterization of interfacial properties.

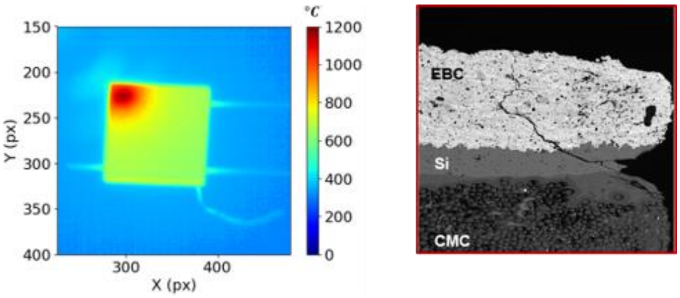

Figure 1: Temperature field measured by an infrared camera of an EBC surface and the damage mechanism observed via SEM.

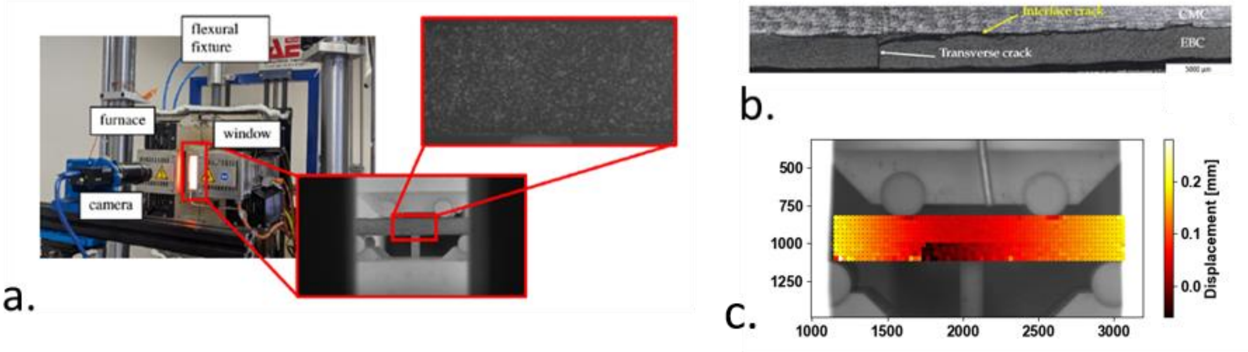

Figure 2: Illustrations of (a.) the four-point flexural test at 1000°C instrumented with a single visible light camera, (b.) cracks observed by optical microscopy, and (c.) vertical displacement field (expressed in mm) determined by spatiotemporal DIC.

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