SIMULATION ASSISTED STUDY ON STRUCTURAL DEGRADATION IN ADVANCED SiC/SiC CMC COMPONENT DURING HIGH-TEMPERATURE FATIGUE

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Testing of SiC/SiC CMCs is a matter of concern in terms of material cost and experimental time. To solve these issues, various simulation techniques have been used. One standout technique is extended finite element method (XFEM), which is an important tool to stimulate crack propagation, especially during quasi-static loading. XFEM does not require a pre-defined crack path and has the advantage of unnecessity of mesh refinement at crack-tip. From the past few years, the XFEM technique was applied to micro-scale and macro-scale modeling of CFRP, but its application to CMC is limited to only micro-scale modeling since macro-scale modeling involves various damage modes occurring simultaneously. Therefore, the aim of this study was to simulate the fracture behavior during bending-fatigue at the high-stress concentrated region of the SiC/SiC CMC component at the macroscopic scale.

The SiC/SiC CMC component was modeled using Abaqus/CAE software. The load was applied at the particular node to simulate the bending behavior in the high-stress region. XFEM was utilized to predict fracture behavior during and post fatigue loading. A few cycles of fatigue loading were applied and then retained strength was measured. The 3D component was modeled with an 8-node brick element type (C3D8R) with 1376 elements. All the anisotropic properties of SiC/SiC CMC were added as a bulk material input. Damage criteria have been applied for the XFEM method. For damage initiation criterion, maximum principal stress (MAXPS) was applied, while experimental fracture energy was used as damage evolution. Finally, XFEM crack was added via the interaction module in the Abaqus.

Figure 1 shows Mode I and mode II fracture simulation via XFEM with CE and comparison with experimental damage observations. Since the maximum tensile stress was concentrated only at the upper surface of the sample, the matrix-cracking occurred and was considered as mode I failure (Figs. 1 (a) and (c)); the stresses were also redistributed simultaneously. Since the cracking was already initiated from the sample surface and propagated towards the thickness direction, crossing the CEs, high stress was concentrated along the CEs rather than the upper surface of the sample. When the critical strength of CE was reached, they revealed damage (Figs. 1 (b) and (d)); some of the CEs were deleted, which suggests damage due to delamination (mode II). Since the simulation was carried out at a macroscopic scale, delamination was represented only at the fiber tow interface. It is mentioned that experimental observation showed that delamination occurred, microscopically, in a stepwise way at fiber/matrix interface within a fiber-tow.

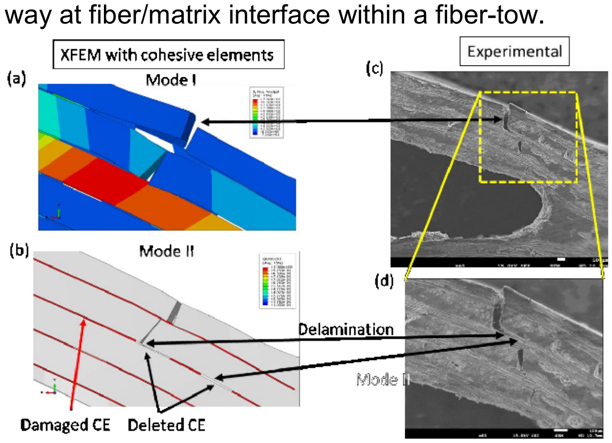

Figure 1 – (a) Mode I and (b) mode II fracture simulation via XFEM with CE, and (c,d) comparison with experimental results.