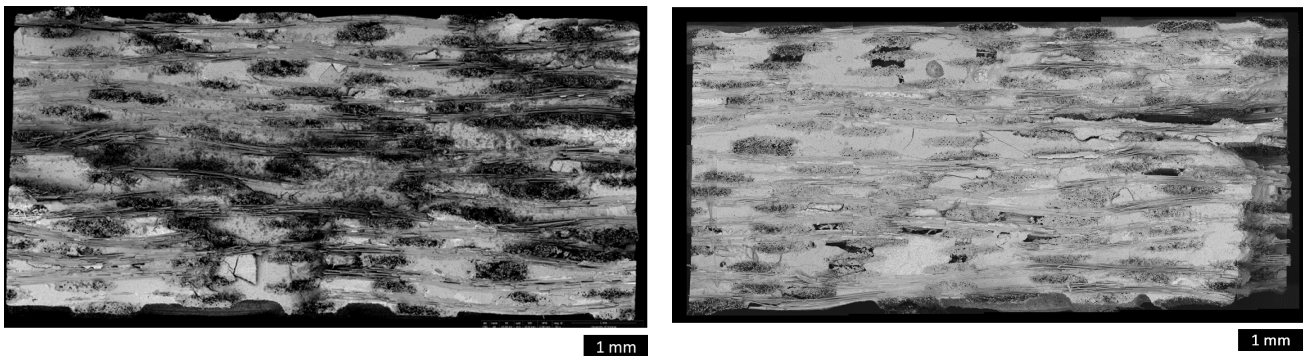


## SYNERGISTIC DEGRADATION MECHANISMS OF SiC/BN/SiC IN OXIDIZING ENVIRONMENTS AT INTERMEDIATE TEMPERATURES UNDER LOAD

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SiC-based ceramic matrix composites (CMCs) are subject to degradation in load-bearing, high-temperature, water vapor-containing combustion environments. In this presentation, mechanisms for degradation of SiC/BN/SiC composites from Rolls-Royce HTC CMCs were studied at three levels of applied load, intermediate temperatures (600 or 800°C), and three different oxidizing (air, dry oxygen, wet oxygen) conditions to explore synergies between load and thermochemical environment. The intent of the study was to hold the CMCs in these stressed high temperature oxidizing conditions and study crack formation and oxidation via microscopy methods, without stress rupture, to track the kinetics of cracking and oxidation degradation. Three stress levels were chosen based on room temperature fast fracture results, where the CMC exhibited i) first matrix cracking (150 MPa), ii) increased crack density (180 MPa), and iii) matrix saturated with cracks (200 MPa), wide crack opening displacements, and initiation of fiber failure. One key observation for CMC degradation without applied load is that at 600°C in 50 v% water vapor/50 v% O<sub>2</sub> environments, SiO<sub>2</sub> growth is slow and BN oxidation/volatilization is rapid resulting in annular voids forming around each fiber. Under other conditions studied, protective surface oxidation was observed that preserved the BN interphase. The 600°C, 50 v% water vapor/50 v% O<sub>2</sub> temperature test condition resulted in a unique failure mechanism when CMCs were under applied load. The figure below compares the fracture surface for specimens that failed at 800°C 200 MPa in lab air (left) vs. a failure observed after exposure at 600°C 150 MPa in 50 v% water vapor/50 v% O<sub>2</sub> (right). Dark regions indicate the desired fiber pullout, essential for CMC toughening, and bright regions indicate brittle fracture. Note the 800°C lab air failure tends to have the expected fracture morphology of smooth regions around the edges of the coupon indicating oxidation embrittlement where oxidant is able to penetrate into the composite through cracks. In contrast, the 600°C failure has a smooth fracture surface throughout most of the fracture section with some fiber pullout around the edges. High magnification microscopy shows that the fibers with pull-out for the right-hand sample have no boron nitride interphase material remaining. This fracture morphology observed after exposures at 600°C in 50 vol% water vapor/50 v% O<sub>2</sub> suggests there are numerous gas phase diffusion paths into the interior of the composite due to rapid loss of BN without significant SiO<sub>2</sub> growth. To summarize, the CMC degradation mechanism for the 600°C, 150 MPa, 50 v% H<sub>2</sub>O/50 v% O<sub>2</sub> exposure is BN oxidation/volatilization first, followed by matrix cracking and fracture. The 800°C, 200 MPa, lab air CMC failure is suggestive of local surface cracking damage first, allowing oxidant transport inwards followed by local embrittlement and fracture.



SiC/BN/SiC fracture surfaces after exposures. Left: 800°C, 200 MPa, lab air failure at 49h vs. Right: 600°C, 150 MPa, 50 v% H<sub>2</sub>O/50 v% O<sub>2</sub> failure at 26h.

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