

PROCEEDINGS

Damage Evolution and Failure of SiC/SiC Composites with Film-Cooling Holes Under Extreme Temperatures

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ABSTRACT

The service requirements of hot-section components in aero-engines operating in extreme high-temperature oxidizing environments (1200 °C) necessitate a comprehensive understanding of the high-temperature mechanical properties and failure mechanisms of SiC/SiC ceramic matrix composites (CMCs). Existing studies on the high-temperature behavior of CMCs have predominantly focused on ideal un-notched specimens. However, systematic investigations into the property evolution, damage mechanisms, and mechanical responses of CMCs featuring representative film-cooling holes under extreme temperatures remain insufficient. In this work, 2D woven SiC/SiC composites fabricated via chemical vapor infiltration (CVI) were investigated. Standard tensile specimens were designed, incorporating the inclination angles and staggered triangular arrays characteristic of film-cooling holes in realistic turbine blades. Systematic monotonic tensile tests were conducted at room temperature and an extreme high temperature of 1200 °C, complemented by ultra-depth-of-field 3D optical microscopy and fractography. The influence of the high-temperature environment on the tensile properties, damage evolution, and failure modes of the material was critically analyzed to elucidate the underlying physical mechanisms. The results demonstrate that at 1200 °C, the failure mode of the 2D woven SiC/SiC composites with cooling holes transitions from a fiber-dominated longitudinal tensile fracture—characterized by pseudo-ductile behavior and extensive fiber pull-out at room temperature—to a brittle fracture dominated by mixed-mode shear-compression sliding and short fiber pull-out. It is revealed that the degradation of the material's strength and fracture strain at elevated temperatures is primarily governed by high-temperature matrix softening, coupled with an altered crack propagation path. This alteration is driven by oxidation-induced interfacial embrittlement and the resulting strong fiber-matrix bonding. This study clarifies the property evolution trends and fundamental failure mechanisms of SiC/SiC composites with realistic film-cooling holes under extreme environments, providing essential experimental data and theoretical guidelines for the high-temperature strength design and structural reliability assessment of CMC hot-section components in aerospace propulsion systems.

KEYWORDS

Extreme high temperature; SiC/SiC ceramic matrix composites; high-temperature mechanical properties; film-cooling holes; failure mechanisms; tensile properties

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