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Modeling Creep Effects within SiC/SiC Turbine Components

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Summary

Anticipating the implementation of advanced SiC/SiC ceramic composites into the hot section components of future gas turbine engines, the primary objective of this on-going study is to develop physics-based analytical and finite-element modeling tools to predict the effects of constituent creep on SiC/SiC component service life. A second objective is to understand how to possibly select and manipulate constituent materials, processes, and geometries in order to minimize these effects. In initial studies aimed at SiC/SiC components experiencing through-thickness stress gradients, creep models were developed that allowed an understanding of detrimental residual stress effects that can develop globally within the component walls. It was assumed that the SiC/SiC composites behaved as isotropic visco-elastic materials with temperature-dependent creep behavior as experimentally measured in-plane in the fiber direction of advanced thin-walled 2D SiC/SiC panels. The creep models and their key results are discussed assuming state-of-the-art SiC/SiC materials within a simple cylindrical thin-walled tubular structure, which is currently being employed to model creep-related effects for turbine airfoil leading edges subjected to through-thickness thermal stress gradients. Key findings include: (1) thermal gradients through all current SiC/SiC composite systems should be kept below 300oF at high temperatures to avoid life-limiting cracking on the inner wall; (2) at temperatures near the maximum operating temperatures of advanced SiC/SiC systems, thermal stresses induced by the thermal gradients will beneficially relax with time due to creep; (3) although stress relaxation occurs, the maximum gradient should still not exceed 300oF because of residual tensile stress build-up on the airfoil outer wall during cool-down; and (4) without film cooling and mechanical stresses, the NASA-developed N26 SiC/SiC system with thru-thickness fiber reinforcement and a typical environmental barrier coating (EBC) has the potential of offering a long-term steady-state operating temperature of 3100oF at the EBC surface.