A MODEL STRESS ANALYSIS OF SWELLING IN SIC/SIC COMPOSITES AS A FUNCTION OF FIBER TYPE AND CARBON INTERPHASE STRUCTURE—C. H. Henager, Jr. (Pacific Northwest National Laboratory), E. A. Le (University of Washington), and R. H. Jones (Pacific Northwest National Laboratory)*

OBJECTIVE

The objective of this task is to develop and validate a numerical model of swelling-induced stresses in SiC composites with Hi-Nicalon and Type-S ceramic fibers and having a pyrocarbon interphase to determine which pyrocarbon interphase results in the lowest stresses due to irradiation.

EXTENDED ABSTRACT

A continuous fiber composite was simulated by four concentric cylinders (consisting of fiber, fiber/matrix interphase coating, matrix, and surrounding composite) to explore composite stresses when irradiation swelling of the various components is included as a function of neutron dose. SiC Type-S and Hi-Nicalon fibers and three types of transversely isotropic carbons for the fiber coating were considered. Radiation swelling terms were added by using parametric fits to strain (swelling) as a function of dose for the various materials. The swelling of β-SiC and Type-S fibers for different temperatures [1, 2] was fit using linear swelling versus time and the swelling is assumed to be linearly dependent on dose up to a critical dose, which then saturates at constant swelling; the saturation dose being temperature dependent. For Hi-Nicalon fibers, fiber density as a function of neutron dose was converted to fiber strain. The data of Kaae [3] were used for the swelling of three pyrolytic carbons, denoted as high-density isotropic carbon (HDIC), low-density isotropic carbon, and high-density slightly anisotropic carbon.

Six different cases were studied under simulated neutron irradiation at 1000˚C using a dose rate of 0.44 dpa/year. Values of the model domain radii were chosen to match microstructural information for CVI SiC/SiC composites. The fiber coating thickness was 0.15 μm which is representative of pyrocarbon coating thicknesses. One case considered a 1-μm thick HDIC fiber coating on Type-S fiber. The stresses were computed out to 8 dpa. Composites containing Hi-Nicalon fibers reach 1 GPa radial tensile stresses at the fiber-coating interface at 1 dpa, large enough to cause interfacial debonding due to differential swelling between the Hi-Nicalon fiber and the SiC matrix. These large stresses occur at the interface regardless of the type of pyrocarbon coating. The observation of interfacial debonding in irradiated Hi-Nicalon fiber composites validates this finding of the model. Composites containing Type-S fiber have no differential swelling stresses developing between the fiber and matrix. Differential swelling of the various carbon coatings causes small values of radial stresses (ranging from 65 to 280 MPa) at the fiber/coating interface, allowing retention of fiber/matrix bonding up to significant neutron doses. In particular, the HDIC pyrocarbon interphase shows excellent irradiation stability and results in low interfacial stresses in the simulation. Although no detailed study of the pyrocarbon interphase of irradiated SiC/SiC with Type-S fiber has been conducted, the lack of debonding after irradiation has been observed. Since the carbon interphase swelling determines the radial debonding stresses for the Type-S fiber materials, interphase tailoring can be explored to control composite properties by controlling the coating deposition process. Changing the coating thickness from 0.15 μm to 1 μm increases radial stresses at the fiber-coating interface. This result suggests that thinner coatings can lead to improved radiation resistance.

References

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