Exceptional Radiation Stability of Advanced SiC/SiC Composites

Composite materials consisting of a silicon carbide matrix reinforced with silicon carbide fibers (SiC/SiC) are relatively new structural materials which are rapidly being industrialized. For fusion energy, SiC/SiC composites are considered particularly attractive for blanket components due to their outstanding thermo-mechanical / thermo-chemical performance and the inherent low activation/low decay heat properties. However, tolerance of these materials to harsh neutron irradiation environment has been demonstrated only to relatively low fluence levels. In a recent study performed at ORNL, advanced near-stoichiometric SiC/SiC composite specimens were irradiated in the High Flux Isotope Reactor to a neutron exposure in excess of 40 displacement-per-atom (dpa). Post-irradiation testing did not reveal any hint of degradation in either the proportional limit or ultimate failure stresses (Figure 1), indicating the absence of any apparent irradiation effects on strength of the matrix, fiber reinforcement, and the fiber-matrix interface. Moreover, it was found that the other known effects of irradiation on SiC, including swelling, thermal conductivity decrease, and reduction in Young's modulus, appear to saturate after an exposure of a few dpa and do not undergo further degradation. Thus, this study demonstrated a general lack of irradiation effects on mechanical properties and swelling following neutron exposure to at least 40 dpa at 800°C. The advanced SiC/SiC composite proved to be an exceptionally radiation-stable structural material (Figure 2). Note that 40 dpa approximately corresponds to the lifetime fluence of the mid-blanket sections in typical fusion power reactor designs and the maximum lifetime fluence in the core of graphite-moderated thermal spectrum fission reactors.

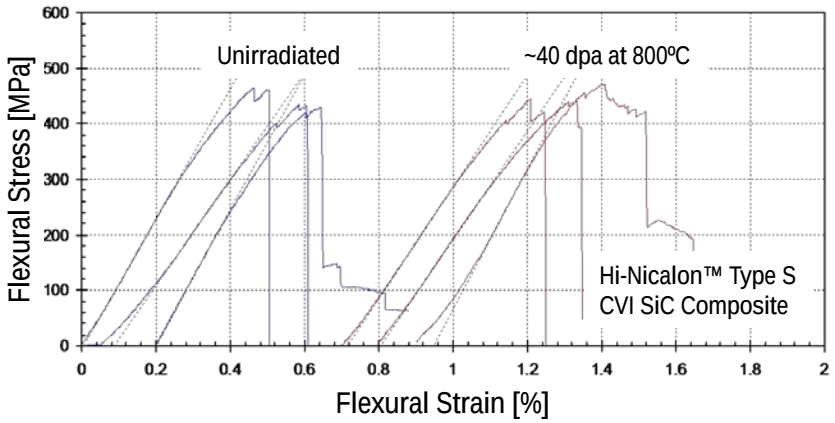

Figure 1 – Flexural stress-strain relationship for 2D Hi-Nicalon™ Type S, chemically vapor-infiltrated SiC matrix composite before and after neutron irradiation to 40 dpa at 800°C, indicating lack of irradiation effects.

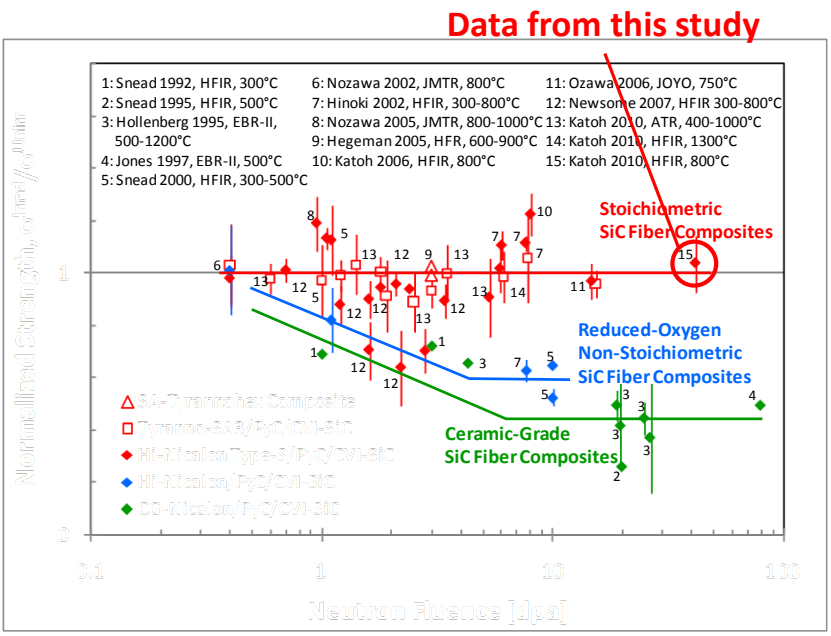

Figure 2 - Effect of neutron irradiation on strength of conventional and advanced SiC/SiC composites for irradiation temperatures 300 - 1300°C.