Deformation Behavior of SiC-SiC Channel Box in Boiling Water Reactor Environment

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Silicon carbide fiber-reinforced silicon carbide matrix (SiC-SiC) composites are being considered for channel boxes in boiling water reactors. In the nuclear reactor environment, the channel box will be exposed to neutron and other radiation damage and temperature gradients. To ensure reliable and safe operation of a SiC-SiC channel box, it is necessary to assess its deformation behavior and stress development under in-reactor conditions including the expected neutron flux and temperature distributions. In this work, the effect of non-uniform dimensional changes caused by spatially varying neutron flux and temperatures on the deformation behavior and the stresses that will develop in the channel box have been evaluated. These analyses have been performed using the fuel performance modeling code BISON and the commercial finite element analysis code Abaqus, based on the fast flux and temperature boundary conditions that have been calculated using the neutronics and thermal-hydraulics codes MPACT and CTF, respectively. Three different positions of control blade in the channel box assembly have been considered in the analyses. The dependence of dimensions and thermophysical properties on fast flux and temperature has been incorporated into the material models. These initial results indicate significant bowing of the channel box which raises concerns regarding the smooth insertion of the control blade in the assembly. The channel box bowing behavior is time dependent and driven by the temperature-dependent, irradiation-induced swelling of SiC and the neutron flux/fluence gradients. The bowing behavior is found to be significantly different for the three positions of the control blade. The stresses are found to exceed the proportional limit stress of the material which may lead to generation of microcracks in the channel box.