General Atomics
Partnered with
Oak Ridge National Laboratory

NE-23-31249: Post-Irradiation Examination to Quantify Irradiation-Induced Bowing of SiGA® Silicon Carbide Composite Structures

YEAR AWARDED: 2023

TOTAL PROJECT VALUE: $288K (General Atomics, $72k; DOE $216k)

STATUS: Completed

PRINCIPAL LAB INVESTIGATORS: Christian Deck (General Atomics), Takaaki Koyanagi (ORNL)

DESCRIPTION: General Atomics (GA), located in San Diego, Calif., specializes in bringing new nuclear materials and designs to market. Accurate material behavior models are required for the licensing and implementation of silicon carbide composite (SiC/SiC) structures in nuclear reactors. This project addressed first-of-a-kind experimental post-irradiation examination (PIE) of irradiation-induced bowing response in SiC/SiC structures. GA engaged with Oak Ridge National Laboratory (ORNL) to perform PIE on previously irradiated SiC/SiC specimens. ORNL has decades of SiC irradiation and PIE experience and developed a custom profilometry rig that works with the specimen geometries to accurately quantify post-irradiation deformation.

BENEFIT: The PIE results of this project help GA in commercialization and licensing of their SiGA® nuclear fuel cladding technology. SiGA is an engineered, multilayer SiC/SiC composite cladding structure offering high temperature performance and other operational benefits for current and future nuclear reactors.

IMPACT: The irradiation experiment was designed to accommodate a single square SiC/SiC composite channel specimen (miniaturized version of a boiling water reactor channel box), as well as two SiC/SiC cladding tube specimens (with typical pressurized water reactor cladding diameters). The experiment was located in a large vertical experiment facility within HFIR's permanent reflector directly exposed to the reactor coolant. This configuration enabled a simplified separate-effects test to allow unconstrained swelling with minimal temperature variations to induce irradiation-induced bowing in the specimens. This GAIN project facilitated metrology using novel methods to experimentally measure this bowing.

SIGNIFICANT CONCLUSIONS: The measurement tools provided the necessary accuracy to capture the effects of irradiation and the resulting bowing induced by differential flux across the specimens. Although minor uncertainties arose from specimen surface roughness and the challenge of comparing identical locations before and after irradiation, both the light curtain and surface-normal height measurements yielded bowing values of about 0.8 mm. These outcomes show a reasonable consistency with the predicted value of roughly 1 mm, underscoring the robustness and reliability of the results.

NEXT STEPS: Modeling work was outside the scope of this CRADA, but additional work could be performed to incorporate the as-irradiated neutronics results into the FEA models and see if the small (~0.2 mm) discrepancy in measured vs. calculated bowing can be explained. Alternatively, it may be that irradiation creep, or other phenomena may need to be incorporated into the models.