NUCLEAR ENERGY RESEARCH INITIATIVE

Improving the Integrity of Coated Fuel Particles: Measurement of Constituent Properties of SiC and ZrC, Effects of Irradiation, and Modeling

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Collaborators: CEGA Corporation, Idaho National Engineering & Environmental Laboratory; Massachusetts Institute of Technology; General Atomics; Argonne National Laboratory

The silicon carbide (SiC) layer integrity in the TRISO-coated gas-reactor fuel particle is critical to the performance, allowed burn-up, and hence, the intrinsic efficiency of high-temperature gas cooled reactors. While there has been significant developmental work on manufacturing the fuel particles, the effects of the complex in-service stress state combined with realistic materials property data under irradiation has on fuel particle survival are not adequately understood. Furthermore, there is virtually no experimental data on the effects of irradiation on the thermo-mechanical properties of zirconium carbide, which has been proposed as a higher-temperature replacement for SiC. The basic assertion behind this proposal is that a significant need exists for detailed fuel particle modeling including realistic, experimentally derived data on fuel particle constituent materials in the non-irradiated and irradiated condition. To perform this work will require advances in modeling, along with development of techniques for measuring materials properties at the small scale of the fuel particle.

Four elements are proposed for this work:

(1) Modeling Work: In recent years, a collaboration has been established between Idaho National Engineering and Environmental Laboratory (INEEL) and the Massachusetts Institute of Technology (MIT) to look into finite-element and other methods of modeling the stress state of fuel pellets. This work has been carried to the point where it is being limited by the lack of realistic material property input. Specific information on the statistical distribution of strength, creep, and swelling for SiC is poorly described in the literature. Data on the thermomechanical properties of pyrolytic ZrC is also very limited. This new data will be generated and applied in spherical and cylindrical model geometry. The objective of this work is to use the new data to better describe the stress state of the TRISO particle under irradiation and to give a direct comparison of the integrity of SiC-v-ZrC for this application. Potential failure during pellet processing will also be addressed.

(2) Technique Development for Measuring Constituent Properties: To this point, techniques to study the integrity of fuel particles have been relatively rudimentary, consisting of compression tests (crush or c-ring) of the particle or bare SiC overcoat. The objective of this element is to apply state-of-the-art techniques and to develop new techniques specifically for application to the TRISO system to generate realistic data for the modeling. These techniques would then become available for the community developing gas-cooled-reactor fuels. Specific tools will be developed to measure strength through internal pressurization, elastic moulus on the scale of the TRISO particle, creep relaxation, and PyC/SiC interfacial properties.

(3) Irradiated Materials Property Information: An irradiation program will be coupled with the technique-development program to generate information on mechanical properties needed for modeling input. The irradiation program will include the model, non-fueled cylindrical and spherical TRISO structures, and spherical TRISO-containing, helium-producing boron carbide.

(4) Updated Materials Data Handbook for TRISO Fuels: As part of this effort, a materials property

handbook will be developed. This handbook will include pertinent physical property information on all constituent materials of coated particle fuel. Sources of information will be the open literature on nuclear materials, reports dealing with HTGRs (e.g., CEGA-002820, Rev 1), and information developed as part of this proposal. This material will then be available to the larger fuels community.