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June 28, 2021

MEMORANDUM TO: Christopher N. Van Wert, Acting Chief
Advanced Reactor Technical Branch
Division of Advanced Reactors and Non-Power Production and Utilization Facilities
Office of Nuclear Reactor Regulation

FROM: Hossein Esmaili, Chief
Fuel and Source Term Code Development Branch
Division of Systems Analysis
Office of Nuclear Regulatory Research

Signed by Esmaili, Hossein on 06/28/21

SUBJECT: FAST CODE ASSESSMENT FOR TRISO FUELS

In accordance with the Advanced Reactor Program – Summary of Integrated Schedule and Regulatory Activities (US NRC, 2021) (ML21083A140), technical reports have been prepared for completing the identified task, “FAST code assessment for TRISO fuel” milestone, in the integrated schedule (Geelhood, Wells, & Phillips, 2021; Wells, Phillips, & Geelhood, 2021). This memorandum identifies the overall conclusions from the initial FAST-TRISO code development, material property development, and assessment work.

In NRC’s Non-LWR Vision and Strategy, Volume 2 report (ML20030A177), it was found that NRC’s fuel performance code FAST had limited functionality for the treatment of spherical-shaped fuel (i.e., TRISO fuel particles). This preliminary assessment concluded that FAST was not, at the time, equipped with sufficient heat transfer, radionuclide diffusion, and solid mechanics solvers for spherical geometries. In FY21, FAST-TRISO had been developed addressing the above-mentioned gaps and adding to the NRC’s capability of modeling 1-D TRISO fuel particles.

The phenomena included in FAST-TRISO-1.0 (Geelhood, Wells, & Phillips, 2021) include:

- 1-D spherical heat conduction through the TRISO fuel particle,
- Deformation within the various layers, including thermal expansion and irradiation-induced swelling,
- Stress distribution through the outer layers of a TRISO fuel particle,
- Fission gas release, internal pressure, and void volume calculations,
- Failure probability of the outer layers of a TRISO fuel particle,
- Production and release of radioactive fission products from the particle.

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In addition to developing 1-D thermo-mechanical solvers, FAST-TRISO has been implemented with material property correlations for performing analyses for UCO-fueled TRISO particles. Material properties associated with the fuel performance of TRISO particles include the fuel kernel (e.g., UCO and UO_2), outer layers (e.g., buffer carbon, pyrolytic carbon (PyC), and silicon carbide), and graphite matrix. TRISO particle failure mechanisms have also been identified (Wells, Phillips, & Geelhood, 2021), which are informed by previous work such as the TRISO-coated particle fuel PIRT for fission product transport (Morris, Petti, Powers, & Boyack, 2004). The work described herein, was performed by Pacific Northwest National Laboratory under NRC direction.

An assessment of the code was performed. Verification tests were added to FAST-TRISO. One type of verification test added are material property tests, which indicate that the material property correlations have been implemented correctly and working as designed.

FAST-TRISO results (i.e., release fractions) have been compared against a series of high temperature annealing TRISO fuel tests (IAEA, 2012). These benchmarks compared results against other fuel performance codes. In general, FAST-TRISO performed similar to the other fuel performance codes (IAEA, 2012). Most fuel performance codes were not in good agreement with the experimental data provided in (IAEA, 2012). These data sets may not be ideal to perform FAST-TRISO validation as these high temperature annealing tests are not considered to be prototypic in-reactor conditions. During the literature survey, it was also found that there is lack of well characterized TRISO particle irradiation data with post-irradiation measurements. Efforts to validate the particle failure models are ongoing; however, the lack of detailed post-irradiation measurements will complicate this validation work.

Future Work

This FAST-TRISO work had identified key improvements that should be addressed to prepare the NRC for confirmatory calculations. Near-term improvements include further investigation of the treatment of PyC irradiation-induced shrinkage/creep. This phenomenon may induce a compressive stress on the SiC layer. A compressive stress in the SiC layer may offer an additional protection from failure due to internal overpressure. Additional work to confirm this interaction is needed, as the pyrolytic carbon data used to develop creep and swelling models are from un-restrained samples. It is believed that the swelling behavior of un-restrained and restrained pyrolytic carbon differ. Additional future work will also include expanding the validation of FAST-TRISO as more irradiation data becomes available (e.g., DOE's AGR program). Lastly, an additional planned task is to add the capability to determine particle failure and releases from a batch of TRISO fuel particles. This memorandum will complete the Strategy 2 Volume 2 (US NRC, 2020) "FAST code assessment for TRISO fuel" milestone (US NRC, 2021).

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