U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Evaluation of Metal Fuel for use in Light Water Reactors utilizing the BISON code

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Pathway:
3 Regulatory Assistance Grants

Abstract

The nuclear industry wants to enhance the accident tolerance and to improve fuel utilization of Light Water Reactors (LWRs). This could be achieved by innovative fuel designs. One proposed fuel concept is the use of metallic fuel (uranium zirconium alloy) in LWRs. The desired characteristics of high flow rate, low operating temperature, and less modification to power plants make this attractive for the near-term deployment. However, it may take decades to generate data from experimental irradiation programs to qualify the use of metal fuel, and even longer to find out performance issues from operation. Therefore, it is of interest to develop analytical tools for the utility customers and the nuclear regulators to perform quantitative evaluations to foresee potential problems, which in turn may improve the fuel designs.

This project would leverage the modeling and simulation capabilities developed from U.S. DOE's NEAMS and CASL programs to assist fuel qualification and licensing activities. In particular, the BISON fuel performance code developed at INL, with participation from participants in this FOA proposal, will be used as an analytical simulation of metal fuel behavior in LWR environment. New material and behavior models will be developed and implemented in BISON to provide the needed capabilities for high-fidelity performance evaluation of metal fuel under normal operations, anticipated operational occurrences and accident conditions. The models and general methodology will be documented in a detailed report.

The proposed work will be divided into following sub-tasks:

A. Development and Implementation of material and behavior models for metal fuel in BISON code

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- Open literature data on fuel and clad materials will be collected, and material models will be developed and implemented in BISON code for the metal fuel evaluation.
- To deal with special designs with helical geometry, efficient modeling methodology will be developed to capture the essence of fuel performance issues as well as optimizing computation cost.
- An in-house finite element tool will be used to compare to BISON code for verification.

B. Fuel performance evaluation under operation and accident conditions

- Performance metrics of interests for licensing application will be evaluated which includes material failure limits, fuel swelling and creep, power to melt, water-side corrosion, etc.
- Based on the strengths/limitations from the performance evaluation, simulations of a few idealized accident scenarios in the current LWR conditions will be performed.
- Comparison will be made to conventional ceramic oxide fuels with emphasis on discerning the limiting conditions for the application of metallic fuel.

Deliverables:

Material models implemented in BISON code.

Final report on the evaluation of metal fuel in Light Water Reactors.

Collaborators: SIA (Primary applicant), UTK (Sub-contractor)