Nuclear Energy University Program
U.S. Department of Energy

Post-DNB Thermo-mechanical Behavior of Near-term ATF Designs in Simulated Transient Conditions

PI: Hwasung Yeom, University of Wisconsin, Madison

Collaborators: Michael Corradini and Kumar Sridharan (*University of Wisconsin, Madison*); David Kamerman and Robert Armstrong (*Idaho National Laboratory*); Raul Rebak and Andrew Hoffman (*General Electric Global Research*); Hangjin Jo (*Pohang University of Science and Technology*, South Korea)

Program: FC-2.1 (Fuel-to-Coolant Thermomechanical Transport Behaviors under Transient Conditions)

ABSTRACT:

Coated zirconium alloy (Zr-alloy) fuel cladding concepts are being actively considered as a near-term option for the development of Accident Tolerant Fuel (ATF) for light water reactors (LWR). The goals of the proposed research are to conduct experimental and modeling investigations of thermo-mechanical performance of these coated Zr-alloy ATF claddings with simulated burnup fuels under thermal transients (>1200 ˚C) to predict complex transient phenomena in accident conditions. The time-dependent thermal boundary condition at the interface between the coated claddings and the surrounding coolant in transient accident conditions will be evaluated. Conventional Zr-alloy cladding tubes with thin coatings such as cold spray (CS) Cr coating, physical vapor deposition (PVD) Cr coating, and GE-GNF's ARMOR™ coating (representing coating concepts developed by the three major reactor vendors) will be exposed to high temperature steam and subsequently subjected to water quenching to simulate loss of coolant accident (LOCA) scenarios to understand the transient boiling phenomenon. Fuel fragmentation relocation and dispersal (FFRD) and oxidation-induced embrittlement of cladding will be investigated using the coated claddings with pre-fabricated rupture, but filled with fragmented surrogate fuel pellets with and without addition of oxide dopants. The surrogate fuel pellets will be prepared using spark plasma sintering (SPS) with different thermal properties and fragment sizes to simulate high burnup microstructural and morphological effects. The experimental data obtained will be compared with calculated results from BISON fuel performance code and LWR transient analysis codes such as TRACE and RELAP5-3D to check the uncertainty of semi-empirical or empirical correlations in their heat transfer packages. Thermo-mechanical energetics of solid fragmented doped fuel or molten fuel/coated cladding injected into coolant will be predicted using TEXAS code.

Mechanical testing and materials characterization of the fuel-cladding system before and after the thermal transient tests will be cross-cutting themes throughout this research. Mechanical testing will be performed using ring compression tests and three-point bend tests to generate load-displacement curves of the cladding samples subjected to various test conditions. Adhesion and cohesion strength of the coatings will be estimated by measurement of a critical load in dynamically loaded scratch tests. Characterization methods including scanning electron microscpey in conjunction with energy dispersive spectroscopy (SEM-EDS), x-ray diffraction (XRD), and glow-discharge optical emission spectroscopy (GDOES) will be used to evaluate extent of oxidation at the inner and outer surfaces of cladding tubes, chemical interaction between coatings and Zr-alloy cladding, formation of any liquid phase, and secondary hydriding. Characterization of the surrogate fuel pellets will be conducted to evaluate the relationship between the initial microstructure (e.g., grain size, porosity level, dopant distribution), the extent of cracking, and framentation characteristics during thermal transient experiments.