NUCLEAR ENERGY UNIVERSITY PROGRAMS

Simulations of Failure via Three-Dimensional Cracking in Fuel Cladding for Advanced Nuclear Fuels

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Abstract

Enhancing performance of fuel cladding and duct alloys is a key means of increasing fuel burnup. This project will address the failure of fuel cladding via three-dimensional cracking models. Researchers will develop a simulation code for the failure of the fuel cladding and validate the code through experiments. The objective is to develop an algorithm to determine the failure of fuel cladding in the form of three-dimensional cracking due to prolonged exposure under varying conditions of pressure, temperature, chemical environment, and irradiation. This project encompasses the following tasks:

1. Simulate 3D crack initiation and growth under instantaneous and/or fatigue loads using a new variant of the material point method (MPM)
2. Simulate debonding of the materials in the crack path using cohesive elements, considering normal and shear traction separation laws.
3. Determine the crack propagation path, considering damage of the materials incorporated in the cohesive elements to allow the energy release rate to be minimized.
4. Simulate the three-dimensional fatigue crack growth as a function of loading histories.
5. Verify the simulation code by comparing results to theoretical and numerical studies available in the literature.
6. Conduct experiments to observe the crack path and surface profile in unused fuel cladding and validate against simulation results
7. Expand the adaptive mesh refinement infrastructure parallel processing environment to allow adaptive mesh refinement at the 3D crack fronts and adaptive mesh merging in the wake of cracks.

Fuel cladding is made of materials such as stainless steels and ferritic steels with added alloying elements, which increase stability and durability under irradiation. As fuel cladding is subjected to water, chemicals, fission gas, pressure, high temperatures, and irradiation while in service, understanding performance is essential. In the fast fuel used in advanced burner reactors, simulations of the nuclear fuels are critical to understand the burnup, and thus the fuel efficiency.