Anisotropic Azimuthal Power and Temperature Distribution on Fuel Rod: Impact on Hydride Distribution

PI: Arthur Motta – Pennsylvania State University

Collaborators: Kostadin Ivanov – Pennsylvania State University, Maria Avramova – Pennsylvania State University

Program: Fuel Cycle R&D

ABSTRACT

The challenges to achieve extended burnups include developing a modeling capability and performing investigations to understand and predict key aspects of fuel and cladding performance. One of the mechanisms of degradation of cladding is the degradation of mechanical properties associated with hydrogen ingress and hydride formation during corrosion, forming hydrides which can degrade cladding ductility. For a given overall hydrogen content the hydrogen *distribution* is crucial to determining cladding ductility. Because hydrogen is quite mobile in Zr alloy cladding, and because it is responsive to temperature and stress gradients the hydride distribution is not homogeneous, tending to concentrate in the colder regions and in regions of higher stress concentration. This greater local hydrogen concentration, can reduce the ductility of the cladding, and potentially degrade its performance in extended dry storage.

A research program is proposed to perform systematic studies of the influence of azimuthal flux and heat transfer variations on the distribution of hydrogen in the cladding tube. The proposed study will be performed by an integrated high-fidelity reactor core simulation system, for modeling of neutronics, thermal-hydraulics, thermo-mechanics, and fuel behavior – all with feedback effects, and determine radial, axial and azimuthal flux distribution, energy deposition, coolant and fuel temperature distributions for different pin cells/sub channels (fuel rod with surrounding coolant) at different core locations. The calculated flux and cladding temperature distributions result in a concentration of hydrogen in excess of the average; such a concentration will be calculated using existing models. Using a gas-charging procedure hydrogen will be introduced onto cladding to reproduce the calculated concentration enhancements. Samples will be tested using a ring compression test to correlate ductility with hydrogen distribution. It will thus be possible to explore the range of hydrogen distribution present in discharged fuel and its effects on ductility.

The proposed work directly addresses the question of the used high-burnup fuel disposition by providing data relevant to the assessment of risk involved in storage and transportation of such fuel. Since interim storage depends on dry storage, ensuring that such material is safe is essential to the objectives of **FC-6**. This work will create a unified framework to help assess the issue of variability in hydrogen distribution driven by flux and temperature variations in high burnup cladding and evaluate the bounds of such variation. It will thus create unique data and a modeling framework for understanding aging and degradation effects of hydrogen uptake and reorientation on fuel cladding, for long term storage and transportation. The calculations conducted, tests performed and the microstructure examinations will be summarized in a final report and published in the open literature.