Public Abstract

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Title: A Parametric Study of a Curved Nuclear Fuel Plate in a Narrow Channel Using Numeric Fluid Structure Interaction Modeling

In 2004 the Global Threat Reduction Initiative (GTRI) was established by the National Nuclear Security Administration (NNSA) to quickly identify, secure, remove and/or closely monitor nuclear and radiological materials that pose a high-risk threat to the United States and the international community. Part of GTRI's mission is to convert high performance research reactors and isotope production facilities from their current High Enriched Uranium (HEU) fuel to Low Enriched Uranium (LEU) foil based fuel. In compliance with the conversion portion of the GTRI's mission, the University of Missouri Research Reactor (MURR) is currently trying to convert its reactor fuel.

The proposed fuel uses a monolithic U-10Mo foil meat with a zirconium barrier between the aluminum cladding. This is different than the current HEU fuel meat which is comprised of Uranium dispersed in an aluminum matrix in an aluminum cladding. In addition to a change in the physical structure of the fuel, the fuel plate thickness has been significantly decreased. The fuel plates in the MURR reactor are subject to high velocity coolant (water) flow. A decreased thickness in the fuel plate suggests that the rigidity of the fuel plate will decrease as well. With concerns about the hydro-mechanical stability of the newly designed fuel plate being exposed to the high velocity flows in the reactor, there is a need to characterize the structural response of a very thin plate in presence of a velocity flow.

Fluid structure interaction (FSI) simulations have been developed to analyze all of the characteristics of a thin fuel plate as the velocity of the water increases across the fuel plate. These models are developed by coupling CFD software, STAR CCM+, with Finite Element Analysis (FEA) software, ABAQUS, to determine the magnitude, location and direction of the deflection of the fuel plate along with other useful metrics to characterize attributes of the flow and movement of the plate.

The FSI simulations were designed to replicate the plate thickness, fluid channel geometry and velocities of the experimental set up. The experimental set up consists of a flow loop and curved test section have been constructed for studying plate deflection and channel pressure drop under a variety of fluid flow velocities. The test section consists of two concentric steel cylinders bolted together with spacers between the two to form a fluid channel. The fuel plate inside the test section is clamped at the edges to maintain the axial location of the plate in the fluid channel. The aluminum fuel plate in the test section is 25.5 inches long, 16 mils (0.016 inches) thick and has an arc of 45 degrees. The outer cylinder of the test section has five plexi-glass windows that allow deflection data to be collected at various locations by the laser measurement system. The laser measurement system was fixed at the leading edge of the fuel plate because that is where the maximum deflection has been shown to occur. Since the focus of this study is on the maximum deflection of the fuel plate, the laser measurement system was fixed at that point.

The FSI simulations were based on seven different geometries. The first consideration was an ideal geometry that the test section was designed to reflect. This consisted of a 130 mils thick inner fluid channel and a 78 mils thick outer fluid channel. Because the test section was assembled at Argonne National Laboratory (ANL) and then shipped to the University of Missouri, the dimensions of the test section fluid channel geometry was altered during transit. This change in the shape of the fluid channels lead to the

need to characterize the shape of the fuel plate and fluid channels again.

Since it is physically impossible to characterize the geometry of the entire fuel plate and the azimuthal geometry of the fluid channels of the test section without disassembling it, several geometric options were considered. Three geometries for the shape of the fuel plate were considered. The three fuel plate shapes were based on the distance of the plate based on the distance between the inner radius of the outer cylinder and the location of the fuel plate in the fluid channel. These measurements were obtained by measuring the outer channel gap thickness with a depth micrometer at the pressure tap locations that coincide with the location of the plate. Although this was helpful, it only helped to characterize the shape of the plate between the leading and trailing edges of the plate. This left about eight inches of the fuel plate (4 inches at each end) uncharacterized, leading to the three geometric considerations.

The three geometric considerations were combined with two geometric considerations for the fluid channels. An azimuthally constant and varied geometry was considered. This was prompted by the inability to measure the distance of the fluid channels in the azimuthal direction due to the design of the test section. This lead to developing a geometry for the fluid channels that was constant along the azimuthal direction of the fuel plate and another where the fluid channel decreased in thickness as the azimuthal location progressed from the middle of the test section to the edges where the spacers are located.

The FSI simulations and the experiments produced deflection results for the 16 mils (0.016 inches) thick fuel plate at velocities ranging from approximately 2 m/s to 4 m/s. Because the fuel plate is so thin, it has been decided that the velocity in the FSI simulations and experiments should be kept relatively low to avoid permanently damaging the aluminum plate in the test section.

The As-Built numeric models have been shown to compare well with the experimental results. The As-Built numeric model results also show that the constant azimuthal fluid channel geometry produces a smaller magnitude of deflection for all three fuel plate shapes considered when compared to the models with a varying azimuthal geometry. the FSI simulations “crashed” for all models ran with a velocity beyond 4 m/s. The experimental results showed that maximum deflection results can be obtained beyond 4 m/s. This provides the opportunity to investigate the differences between the experimental and modeling geometries and recalibrate the model to obtain maximum deflection results through the FSI simulations.