Fluid-Structure Interaction Modeling of High-Aspect Ratio Nuclear Fuel Plates Using COMSOL Multiphysics®

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Abstract

The High Flux Isotope Reactor (HFIR) at Oak Ridge National Lab (ORNL) is in the design stage of converting its fuel. Due to different physical properties of the new fuel and changes to the fuel plate design, a rigorous reevaluation of the current safety basis is required. One of the areas being explored is the fluid-structure interaction (FSI) between the thin fuel plates (50 mils thickness) and the cooling water between each plate. A schematic of the HFIR is provided in Figure 1.

Detailed CFD and FSI simulations have only recently become feasible due to advancements in computing technology. Because of its flexibility and the CFD Module, COMSOL Multiphysics® was chosen to evaluate this complex problem. COMSOL's ability to solve multiphysics problems using a fully-coupled analysis is crucial in obtaining a stable, accurate solution.

Using modern techniques, experiments are being setup and performed at the Oregon State University (OSU) and University of Missouri (MU). These experiments will support the LEU conversion process and will help develop a deeper understanding of complex FSI phenomena. Recently, data obtained by Kennedy et al. at Missouri [1] has been used to validate our FSI model using COMSOL. The tests at MU consisted of two different plate thicknesses (40 mils and 32 mils) and were performed for a single plate using a laser that was used to measure plate deflections accurately. The experimental setup was modeled in COMSOL using its fluid-structure interaction (FSI) capabilities and the results for two of the tests are provided in Figures 2 and 3 for the 40 and 32 mil plates, respectively. As can be seen, the COMSOL model matches the experimental data quite well.

Using available experimental data as code validation helps us establish confidence in COMSOL. After such validation studies, the new fuel plate designs can be quickly evaluated for their effect on the performance and safety of the reactor. COMSOL's multiphysics capabilities will enable the analysis of FSI in conjunction with thermal hydraulics, thermal-structure interaction, and reactor physics; this multiphysics tool will allow the simulation of the entire HFIR core in the future.

Reference

[1] J. C. Kennedy et al., "Fluid-Structure Interaction Modeling and Experimental Benchmarking," Colombia, MO, 2012.

Figures used in the abstract

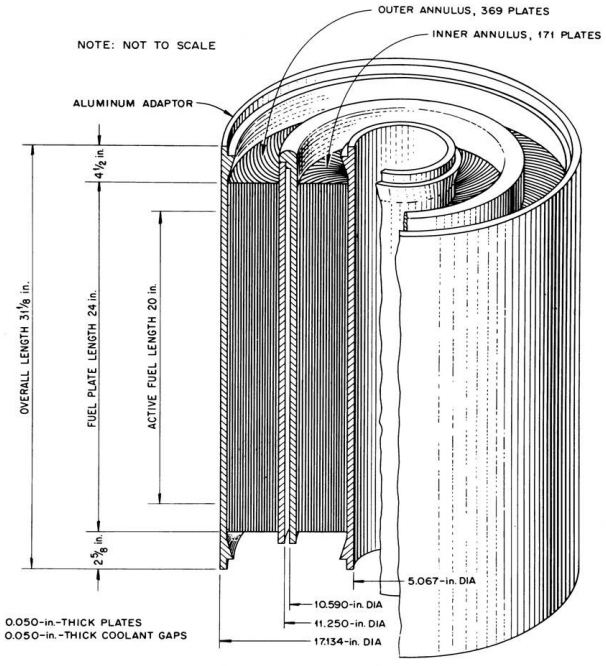

Figure 1

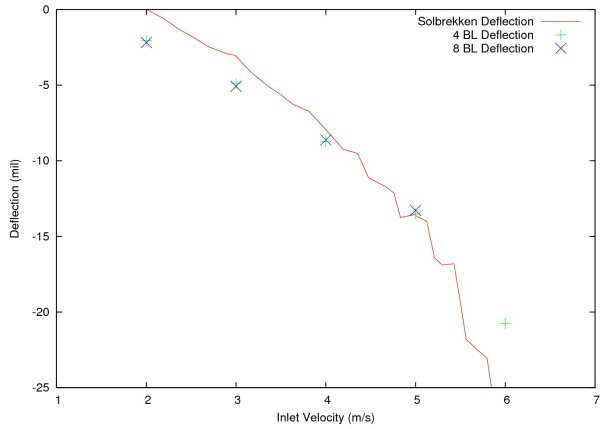

Figure 2

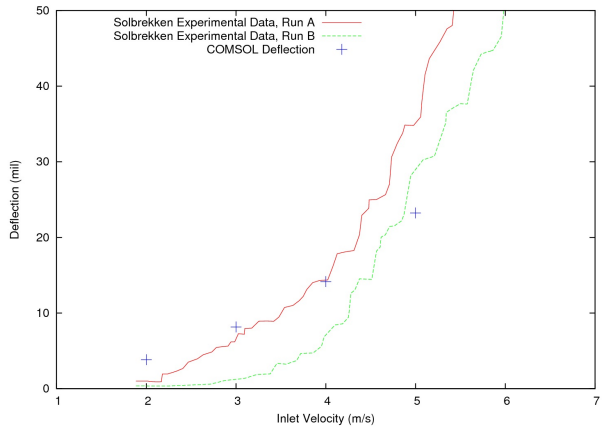

Figure 3