
Benchmark Evaluation of Transient Multi-Physics Experimental Data for Pellet Cladding Mechanical Interactions

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ABSTRACT:

The goal of the proposed project is to develop an integral benchmark evaluation based on available experimental data from cold ramp tests performed at the Studsvik testing R2 reactor. Such transient multi-physics benchmark evaluations are needed to support the U.S. DOE Nuclear Energy (NE) such as Fuel Cycle Technologies (FCT), LWR Sustainability (LWRS), and Advanced Modeling and Simulation (AMS) programs for validation of the NEAMS ToolKit and the VERA suite. Evaluation of transient multi-physics experimental data for LWR systems is a growing area of interest for U.S. DOE. Analyses of reactivity-initiated accidents such as design basis accidents as well as the slower and less severe anticipated operating occurrences (AOOs) are important in determining the overall safety of the current fleet and future nuclear power plants. Industry challenge problems, as the pellet cladding interaction (PCI) and the pellet cladding mechanical interaction (PCMI), are associated with those events. PCI and PCMI are based on multi-physics and multi-scale phenomena requiring accurate and realistic modeling and simulation. Three-dimensional fuel performance models coupled with reactor physics and thermal-hydraulics models are needed to assess the complex coupled physics and irregular geometries responsible for PCI/PCMI fuel failures. At present time, there is a need for adequate high-quality experimental data for PCI/PCMI industry challenge problems to properly validate both the existing multi-physics tools and as well as the high-fidelity multi-physics code systems being developed. The proposed project will address this need by evaluating test reactor data from controlled experimentation. The selected cold ramp tests were performed in 2005 and were experimental simulations of an uncontrolled withdrawal of a control rod group in a cold critical LWR which is a reactivity transient representative of AOOs. These special cold ramp tests were selected to: (1) develop a case problem based on measurements that involve two or more physical phenomena; and (2) investigate PCMI phenomenon in fuel rods. The selected dynamic/transient tests are multi-physics by nature: involve transient changes and interactions between reactor physics, thermal-hydraulics, and fuel performance. Multi-physics benchmark specifications will be developed to provide the data necessary to construct calculation models. The IRPhEP guidelines will be extended to make the evaluation process applicable for multi-physics transients. All available R2 reactor information, related to the initial conditions and transient tests, will be utilized. The information will constitute the Benchmark Experiment Data. This data will be subjected to Benchmark Evaluation Process. Based on the lessons learnt during the preparation of the benchmark specifications and its execution, a proposal for developing a multi-physics and transient evaluation protocol will be prepared using similar review pathway and similar evaluation format as the one established in IRPhEP: collecting benchmark experimental data, follow-up benchmark evaluation process, and peer review.