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Validation data and model development for fuel assembly response to seismic loads

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ABSTRACT

All commercial nuclear power plants are designed to shut down safely during an earthquake. During an earthquake, the fuel assembly spacer grids can collide, which may, during an unexpectedly large (or Beyond Design Basis) event, result in buckling of guide tubes - preventing control rods insertion- and in bending of the fuel rods - creating contacts between cladding and fuel pellets, and hot spots. The main objective of the present work is to provide comprehensive data characterizing the dynamics of the fluid and the structure in PWR fuel assemblies under seismic loads. The data will enable validating the US DOE SHARP virtual reactor simulation suite on this important multi-physics problem.

To achieve this objective an international "contributory" approach will be used: a series of experiments will be conducted in parallel at the George Washington University (GW) and at the Commisséria à l'Energie Atomique (CEA) in France. The data obtained in these experiments will be used to develop and validate computational models of various levels of fidelity at GW, Argonne National Lab (ANL), and the CEA. Under simulated seismic and operating plant conditions, GW will develop new instruments and conduct high resolution, spatio-temporal channel velocity and fuel rod displacement measurements in a 6x6 fuel rod bundle. The CEA experiments on the other hand, will focus on the interaction of multiple reduced fuel assemblies (i.e. 2x2 matrix) at lower resolution. At ANL and GW, the fuel bundle data will be used to develop and validate high-fidelity multi-physics numerical tools for fully-coupled fluid-structure models as implemented in the ANL Reactor Integrated Performance and Safety Code (IPSC) component of the U.S. Department of Energy's Nuclear Energy Advanced Modeling and Simulation Program (NEAMS).

Successful completion of the project will benefit existing and future nuclear reactors by: i) introducing new experimental techniques to the field of flow induced vibrations, and providing an extensive database of high-dimensional experimental data suitable for validating computational approaches of various levels of fidelity, preserved in NE-KAMS; ii) gaining new insights of the multi-scale, multi-physics phenomena governing the response of fuel assemblies to seismic loading; iii) developing predictive tools on core response to transients encountered during earthquakes. This will permit refining design margins on seismic loads in current and future reactors. These developments will also be beneficial to nuclear fuel reliability, such as grid-to-rod fretting, which is responsible for a type of operational fuel rod failure; this aspect will also benefit CASL and EPRI.