Validation of pressure relaxation coefficients in RELAP-7 Seven-Equation model

PI: Philippe M Bardet George Washington University

Collaborators: Eric Johnsen, University of Michigan

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ABSTRACT:

The RELAP-7 code is the next-generation nuclear reactor system safety analysis code being developed by DOE. In this code, the comprehensive Seven-Equation multiphase model is used to represent quasi-one-dimensional gas-liquid flows for problems with varying cross-sectional areas. For fast transients (such as water hammer or steam explosion) in water, this model takes into account non-equilibrium processes through relaxation rate terms. The validation of this model requires to measure the dynamic evolution of velocity and pressure in each phase and at the interface.

Due to the complex nature of the H_2O molecules, there is significant empiricism and knowledge gap in the evaluation of the relaxation terms, which limits the application domain of the model for fast transients. *This project aims to acquire validation data of non-equilibrium processes to validate the Seven-Equation model in RELAP-7* by:

(1) Measuring velocity and pressure in each phase and the interface as well as return to equilibrium in fast transients with high-speed non-intrusive laser diagnostics in canonical experiments;
(2) Complementing experimental data with a multiscale computational approach, including a 3D proprietary direct numerical solver;
(3) Validating RELAP-7 with a combination of experimental data and first-principle simulations.

All the dynamical quantities in the Seven-Equation model will be measured, enabling direct estimation of the relaxation coefficients entering this model. This will be accomplished thanks to a suite of demonstrated molecular-based non-intrusive optical diagnostics. Additionally, a laser absorption spectroscopic technique will be further advanced to measure pressure in the gas phase. The pressure in the liquid will be measured with a demonstrated approach. From the data, the pressure and velocity at the interface will be deduced. All measurements will be conducted with repetition rates > 1 MHz and, therefore, will be time-resolved even in these challenging fast transients. Additionally, the new laser spectroscopy technique enables very fine measurements that directly resolve relaxation rates to equilibrium providing a second estimate (first-principle based) of the relaxation terms! To complement the experiment and help alleviate experimental limitations (such as three dimensionalities) a multi-scale numerical approach will be followed from molecular dynamics to 3D direct simulations of the flows of interest. The combination of experiment and simulations will provide unique and complete datasets to validate RELAP-7 with high confidence. It will also bring a new class of experimental and numerical tools to the thermalhydraulics multiphase community.