Development of a Comprehensive Two-phase Flow Database for the Validation of NEK-2P

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Program: NEAMS 1.4 – Thermal Hydraulics

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ABSTRACT:

Two-phase Computational Fluid Dynamics (CFD) codes are emerging as a powerful and potentially practical tool for applications in which detailed local flow information is needed. However, two-phase flow models and associated closure relations are not well established for CFD applications, which is partly due to the lack of high-quality validation data. Most of the existing two-phase flow data that are currently being used for CFD code development are not designed by following strict validation experiment guidelines, and have relatively low Validation Experiment Completeness (VEC) level. These data either do not contain complete flow information of both phases, and/or involve large measurement uncertainties.

The objective of this research is to develop three high-quality, high-resolution databases with accurately quantified uncertainties for the validation of NEK-2P code, the two-phase CFD code in the NEAMS toolkit. This objective will be achieved by first integrating four advanced local measurement systems, including Particle Image Velocimetry and Planar Laser-Induced Fluorescence (PIV-PLIF), high-speed imaging, X-ray densitometry, and multi-sensor conductivity probe technique. The integration will enable us to carry out complete measurements for both the gas and liquid phases, and will facilitate the uncertainty quantification of the obtained experimental data. Tests will be first performed in two existing air-water flow loops in PI's and university co-PI's laboratories: the first one consisting of a test section of a 30 mm × 10 mm rectangular channel and the second a 50-mm inner diameter round pipe test section. Both facilities are specifically designed for high-fidelity optical measurements. The data obtained will contain not only a complete set of time-averaged parameters necessary for the validation of the overall code performance of NEK-2P, but also the information of each individual bubbles, which are valuable to validate various closure models including the bubble induced turbulence, lift force, wall lubrication force, and turbulent dispersion force. The third validation experiment will be performed in a 3×3 heated rod bundle test facility that will be designed and constructed under this project. The test facility will be designed such that the advanced instrumentation systems can be implemented to perform high-resolution measurements. One focus of the tests will be on the wall nucleation phenomenon in subcooled boiling condition. Selected saturated boiling conditions will also be tested with a focus on the phase distribution in the rod bundle geometry.

In the proposed work, detailed test plan will be developed based on the NEK-2P needs and the guidelines for performing validation experiments. The ANL collaborators will interact closely with the university experimental teams to ensure that the data collected address the validation needs for the NEK-2P code. Simulations will be performed to validate the two-phase flow models implemented in the code using the experimental data obtained during the project. The WEC partner will design and fabricate the spacer grids that will be used in the rod bundle boiling experiment and also provide industrial perspectives on the experimental and modeling studies to be performed in this work scope.