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NUMERICAL CHALLENGES IN MULTIPHASE FLOW SIMULATIONS

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ABSTRACT

Multiphase flows arise in a wide range of fields, including mechanical engineering, chemical engineering, ocean engineering, civil engineering, and biomedical engineering, and appear in various forms such as droplets, bubbles, films, sprays, free-surface flows, and flows in porous media. Numerical simulation is one of the primary tools for understanding and predicting these phenomena. However, accurately capturing interfaces undergoing complex topological changes in space and time, while handling sharp variations of material properties across interfaces, remains nontrivial. In addition, there is an increasing need to resolve interfacial transport processes, such as those involving surfactants. When phase change is involved, such as evaporation and condensation, the treatment of mass and energy transfer at interfaces also becomes necessary.

In practice, a variety of interface-capturing and tracking methods have been proposed for multiphase flow simulations, including Volume of Fluid, Level Set, Phase Field, and Front Tracking. These methods exhibit different characteristics, and the treatment of interface evolution remains one of the central issues. From the perspective of flow solvers, accurately resolving the transport of sharply varying physical quantities near interfaces is also required. This includes the treatment of surface tension effects (e.g., suppression of spurious currents), as well as considerations of mass, momentum, and energy conservation, and entropy-related properties in compressible flows.

Furthermore, the use of high-performance computing (HPC) has become essential for high-resolution simulations. In multiphase flows, the distribution of phases directly affects the flow field, and therefore resolving the location and shape of interfaces is critical. To address this, large-scale parallel computing, GPU-based simulations, and adaptive mesh refinement (AMR) techniques that concentrate grid resolution near interfaces are widely employed.

This minisymposium aims to provide a forum for discussing recent advances and open challenges in multiphase flow simulations. Contributions are invited on interface-capturing methods, numerical schemes, high-resolution computations, surfactant transport, phase-change phenomena, extensions to complex fluids, and emerging approaches such as machine learning for accelerating multiphase simulations.