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Coupled Mass and Heat Transfer in Multiscale Flows Using a Generalized Multiphase Modelling Approach

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Boiling flows play a pivotal role in a wide array of industrial processes, particularly in energy systems such as nuclear reactors, where efficient thermal management is essential to ensure system performance and safety. These flows exhibit complex behaviour due to the interaction of multiple phases, and they are characterized by a variety of flow regimes that depend on the local phase distribution pattern. Among the most challenging of these regimes is slug flow boiling, where large vapour structures form near heated surfaces, significantly influencing interfacial dynamics and heat transfer mechanisms. In recent years, the development of computational fluid dynamics (CFD) has greatly advanced the ability to simulate and analyse complex multiphase flows. However, conventional two-fluid models often struggle to accurately predict flow behaviour in regions with varying interfacial scales, particularly where the transition from dispersed bubbly flow to slug or annular flow occurs. To address these challenges, the Generalised Multifluid Modelling Approach (GEMMA), has been developed and implemented within the OpenFOAM code. This methodology enables dynamic selection between interface-resolving and Eulerian-Eulerian approaches within each computational cell, depending on the scale of interfacial structures present, improving the prediction of multiscale phenomena This study presents a significant extension to the GEMMA model by incorporating enhanced capabilities for simulating subcooled boiling flows across a wide range of vapour volume fractions. Specifically, the focus is on accurately capturing the transition from low void fraction nucleate boiling to high void fraction slug flow near heated walls, with emphasis on accurately predicting heat and mass transfer in the transition from nucleate boiling to vapour slug flow.

Technical Track

Nuclear Thermal-Hydraulics

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