phaseFieldFoam - A framework for multiphase flows using the phase field method

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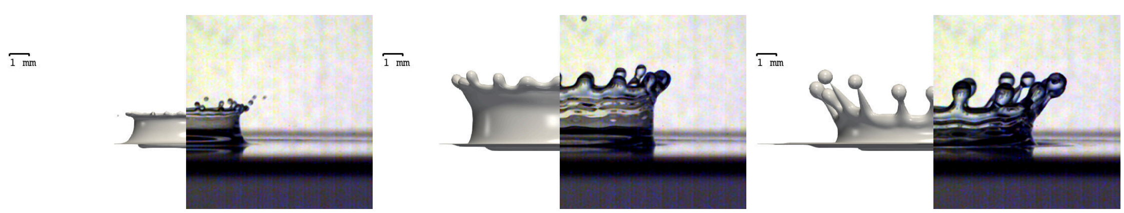
The Phase Field Method (PFM) is a numerical approach widely employed in Computational Multiphase Flows (CMF) to model and simulate the dynamics of multiple interacting phases within a single computational framework. Unlike traditional sharp-interface methods, PFM represents phase boundaries as diffuse regions, allowing for smooth transitions between different phases. This diffuse interface approach simplifies the handling of complex interfacial phenomena, such as phase transitions, coalescence, and breakup.

The PFM introduces a phase field variable that varies continuously across the computational domain, indicating the local phase of the material. The evolution of this phase field is governed by a set of partial differential equations derived from a free energy functional [6]. This mathematical formulation enables the simulation of complex fluid phenomena involving multiple phases, including liquid-gas, solid-liquid, and other multiphase interactions [1, 13].

Applications of the Phase Field Method span a wide range of scientific and engineering disciplines. In fluid dynamics, PFM finds use in simulating phenomena such as droplet coalescence [7], drop film interactions [3] (Figure 1), bubble dynamics [12], and wetting dynamics [4]. Materials science applications include the modeling of solidification processes [5], grain growth [8], crack propagation [11], phase separation in alloys [10] and additive manufacturing processes [9].

This contribution introduces a framework, called phaseFieldFoam, for solving multiphase problems within OpenFOAM (FOAM-extend) utilizing the Phase Field Method [2]. The unified methodology followed in the development of this framework integrates diverse multiphase phenomena into a cohesive computational platform, streamlining the simulation of complex interactions and enhancing predictive capabilities. The presented framework aims to become a unified phase field framework facilitating a seamless representation of various multiphase scenarios, ranging from fluid dynamics and material science to biological systems. By employing a common mathematical foundation, researchers should be enabled to efficiently model disparate phenomena, reducing the need for specialized methods tailored to specific applications. This not only simplifies code development but also fosters interdisciplinary collaboration, as researchers across domains can share a common language and computational infrastructure. A unified framework also promotes code interoperability and knowledge transfer. Researchers can leverage existing models and methodologies across different domains, accelerating the development and dissemination of advanced phase field modeling techniques.



(a) $t = 1\,\mathrm{ms}$ (b) $t = 4\,\mathrm{ms}$ (c) $t = 7\,\mathrm{ms}$

Figure 1: Comparison of a droplet impact on a wall film (simulated with phaseFieldFoam) (left) with the corresponding experiment (right)

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