

Boiling Flows: Thermomechanical Theory, Algorithm, and Simulations

Ju Liu¹, Hector Gomez², Thomas J.R. Hughes¹ and Chad M. Landis³

¹ Institute for Computational Engineering and Sciences, The University of Texas at Austin

² Department of Mathematical Methods, University of A Coruña

³ Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin

Boiling flows are widely used as an energy transfer mechanism in practice. However, due to its disparity of spatiotemporal scales and elusive nature of many sub-processes, a complete theory of boiling is still lacking. Phase-field type multiphase flow models are considered well-suited for describing liquid-vapor phase transitions. However, the current study on these models mainly focuses on bubble dynamics and free surface problems. The full capability of phase-field type multiphase models has not been fully realized by the multiphase flow community.

In this work, we first systematically derive a new modeling framework for multiphase and multicomponent flows, using the celebrated microforce theory developed by Gurtin [2]. This modeling framework guarantees entropy production intrinsically. We will show that the thermomechanical theory derived by Dunn and Serrin [1] is a special case in this framework by choosing an appropriate thermodynamic potential function.

A new fully discrete scheme is constructed to solve the aforementioned thermomechanical theory, i.e., the Navier-Stokes-Korteweg equations [3]. In particular, the spatial discretization is designed based on the notion of functional entropy variables. A new time integration scheme is constructed based on a pair of special quadrature rules. The resulting fully discrete scheme is provably entropy dissipative and second-order accurate in time.

The pool boiling problem is numerically investigated by making proper assumptions on transport parameters and boundary conditions. Compared with traditional multiphase solvers, the dependency on empirical data is significantly reduced for boiling simulations. It will be demonstrated that this modeling approach provides a unified predictive tool for both nucleate and film boiling. Both two and three-dimensional simulation results will be provided and discussed.

References

- [1] J.E. Dunn and J. Serrin. On the thermomechanics of interstitial working. *Archive for Rational Mechanics and Analysis*, 88:95–133, 1985.
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