A Computational Study of Rising Plane Taylor Bubbles

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Received April 5, 1999

The problem of a plane bubble rising in a 2-D tube is revisited using Birkhoff's formulation developed in 1957. The equations in this formulation have a one parameter (Froude number F) family of solutions which are divided into three regimes characterized by distinct topologies at the apex. These equations are solved numerically using a conventional series representation method and Newton's iterations. This numerical method fails for values of F in a range which contains the transition points. In this paper, it is demonstrated through careful numerical computations how and why this method fails. We also analyze the series and provide estimates of the transition points. This strategy of estimating the transition points can be used for some problems where the conventional series representation method fails because it does not adequately account for changes in the nature of the singularity that takes place as these transition points are approached in the parameter space. Furthermore, existence of two new critical Froude numbers is demonstrated numerically. We further show that the previous results on this problem have been incomplete by leaving out the characterization of the topology at the apex of the bubbles for values of F in the regime $0.234 < F < 0.3578$. We also resolve this issue in this paper.

Appeared: *J. Comp. Phys.*, 157(1), pp. 120-142, 2000.