A ghost fluid method for the modeling of contact discontinuities in two-phase flow with capillary effects

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The numerical simulation of two-phase flow using a single set of equations involves a multitude of jumps (discontinuities) of fluid properties across the interface separating the fluids. Simulations involving an under-resolved velocity shear along the interface should moreover result in a contact discontinuity at the interface, hence also yielding a jump in the tangential velocity component. Neglecting such a contact discontinuity may result in the unphysical liquid entrainment by a much lighter gas due to significant smearing of the velocity components at the interface.

When considering the Navier-Stokes equations in jump form we find that a nonzero jump in the tangential component of velocity yields a nonzero jump of the normal component of the material derivative. The resulting jump of the material derivative may be interpreted as a centrifugal force and is balanced by a jump in the normal derivative of the pressure.

We use a Finite Volume model in which the interface is sharply tracked using the Moment-of-Fluid method [1]. The proposed numerical model sharply takes into account density jumps, surface tension via a pressure jump condition and contact discontinuities via a jump condition on the normal derivative of the pressure. The model is based on the Ghost Fluid Method [2] and results from modifications near the interface of discrete differential operators present in the Navier-Stokes equations. The entire model results in the solution of a modified pressure Poisson equation, which still involves a definite and self-adjoint linear operator.

We show the efficacy of the proposed numerical model in numerous test-cases involving the development of free surface instabilities such as the Kelvin-Helmholtz instability.

References

[1] Dyadechko, V. and Shashkov, M. (2005). Moment-of-fluid interface reconstruction. *Mathematical Modeling And Analysis*, 836:1–41.

[2] Fedkiw, R. P., Aslam, T., Merriman, B., and Osher, S. (1999). A Non-oscillatory Eulerian Approach to Interfaces in Multimaterial Flows (the Ghost Fluid Method). *Journal of Computational Physics*, 152(2):457–492.