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MODELLING SURFACE TENSION DOMINATED MULTIPHASE FLOWS USING THE VOF APPROACH

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Low-capillary number or surface tension dominated flows are found in a number applications, ranging from small scale microfluidics up to larger scale analysis of microgravity sloshing. This paper evaluates the possibility of modelling of surface tension dominated multiphase flows using an Eulerian volume-of-fluid (VOF) approach with high-resolution surface capturing. With the aim of improved stability and computational efficiency, a conservative formulation is employed that ensures the surface tension induced parasitic currents are negligibly small. This is achieved by utilising a smoothed volume fraction to obtain a more accurate representation of the curvature when computing the surface tension.

Level-set (LS) and VOF methods are extensively used in modelling multiphase flows as these approaches are easily extended to arbitrary unstructured three-dimensional meshes and allow for efficient scaling in parallel computation. When modelling surface tension dominated problems, LS methods allow for an accurate approximation of the curvature as it is based on a smooth, continuous approximation of the Heaviside equation. LS methods are, however, found to be non-conservative [1, 5] and require the reinitialisation of the distance function at regular time intervals to ensure a well maintained gradient [6]. It is noted that a number of studies suggested corrections to the LS approach to improve mass conservation, but it is argued that these tend to become over complex and computationally inefficient.

Conservative VOF schemes [4, 2] tend to provide an inaccurate approximation of the interface curvature due to the sharp change in the volume fraction gradient. This subsequently results in the formation of spurious or parasitic currents [3], which stems from an imbalance between the pressure and surface tension forces. It is, however, found that through careful treatment of the numerical discontinuities over the interface a more accurate approximation of the interface curvature can be achieved, which results in a reduction of the said parasitic currents.

Using the OpenFOAM® finite volume tool set a new VOF solver was developed which aims to improve on the following:

- Handling of numerical discontinuities in the pressure;
- the surface capturing formulation; and
- the approximation of the interface curvature.

By utilising the said open-source platform, it is furthermore possible to link to existing libraries such as those used for adaptive mesh refinement.

The proposed implementation is initially verified by evaluating a static micro droplet subjected to various capillary number ratios. Next, to evaluate the application of the numerical solver to model industrially relevant problems, various surface tension dominated test cases are considered. Were available the numerical results are validated against analytical and empirical correlations or experimental results. Permitting some adaptation to the VOF approach, it was found that this approach can provide a reasonable approximation of low capillary number flows while ensuring additional computational overheads are kept to a minimum.

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