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Adaptive spectral refinement for accurate simulations of turbulent multiphase flows

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Abstract

Simulating turbulent multiphase flows, which are found in engineering applications such as fuel injection for combustion systems, remains a daunting task. Robust handling of large density ratios, precise modeling of surface tension forces, and accurate tracking of the phase-interface are but a few of the design objectives of a successful numerical scheme for turbulent two-phase flows. This work presents an extension of the spectrally refined interface (SRI) approach introduced in [J. Comp. Phys. 228 (2009) 1658–1677] for simulating turbulent multiphase flows. Based on pseudo-spectral sub-grid refinement of a level set function using quadrature points in each computational cell, the SRI methodology was shown to combine excellent accuracy with good numerical robustness. The increased resolution obtained from the introduction of quadrature points makes SRI a method of choice for tracking small-scale liquid structures. Several improvements to this method are presented in this paper. First, a standard signed distance level set function is used instead of a hyperbolic tangent function, which is found to improve significantly the accuracy of curvature computation. Then, the communication pattern between refined cells is simplified, leading to a straightforward implementation. Finally, the number of quadrature points is allowed to vary from cell to cell, enabling the sub-cell resolution to be adapted to the interface topology. Two strategies for adaptive refinement are combined, namely refinement based on the distance from the phase-interface, and refinement based on the local front curvature. The new adaptive SRI scheme (ASRI) is easier to implement, and is shown to be more accurate and computationally efficient than the original SRI approach.

Key words: Multiphase flow, level set method, spectral method, sub-cell resolution, adaptive refinement.

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