Multiple relaxation time, two-phase lattice Boltzmann methods and applications

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One significant advantage of the lattice Boltzmann method (LBM) over traditional Navier-Stokes computational methods is its ability to model multiphase flows based upon physics at a mesoscopic level [1]. Traditional front capturing methods such as level sets and Volume of Fluid (VOF) require interface reconstruction in order to determine the curvature of the interface and in turn the influence of surface tension on the fluid momentum [2]. Front tracking methods also use the curvature of the interface to add a surface force between liquids and gases [3]. The use of surface forces is a particular problem when trying to determine the curvature at a singular point on an interface as often occurs in liquid breakup. One limitation to current LBM models is the use of the BGK collision operator, which has a single relaxation time. When only one relaxation time is employed it is impossible to adjust several physical parameters independently. For example, the shear viscosity cannot be changed independently from the bulk viscosity [4].

In this paper, a multiple relaxation time (MRT) lattice Boltzmann model for multiphase flow is developed. Previous authors have suggested using a collision operator based upon multiple relaxation times and have shown increased numerical stability for single-phase flows [4]. The use of MRT models for these flows allows for independent adjustment of bulk and shear viscosities and for non-unity Lewis numbers [4]. The two-phase MRT model uses a forcing term to account for intermolecular attraction. The MRT model is evaluated for accuracy on several test problems including oscillating liquid cylinders and capillary waves. The oscillation frequency of the liquid cylinder computations is within 4% of the analytical solution of Lamb [5]. The capillary wave computations show that the MRT model is able to achieve numerically stable results at lower viscosities relative to the corresponding BGK model. The model is then employed to study breakup in liquid jets.

References:

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