A Lattice Boltzmann Scheme for Axisymmetric Multiphase Flows

Kannan N. Premnath and John Abraham
School of Mechanical Engineering
Purdue University, West Lafayette, IN 47907, U.S.A.
{nandha, jabraham}@ecn.purdue.edu

In this work, a lattice Boltzmann scheme is presented for axisymmetric multiphase flows. A number of multiphase flow applications can be considered to be axisymmetric in nature, such as liquid jets and head-on collisions of drops in sprays in engines. However, the formulation of the standard LBM is based on the Cartesian coordinate system and does not take advantage of possible axial symmetry in the multiphase flow. As a result, often fully three-dimensional (3D) calculations [1] need to be carried out, which limits the numerical resolution that could be employed. To improve the computational efficiency of the LBM for multiphase flow, we consider an approach whereby source terms are added into the 2D LBE so that the emergent dynamics of the multiphase flow can be transformed into the cylindrical polar system. This scheme is an extension of the idea proposed by Halliday et al. (2001) for single-phase flows [2] to multiphase flows. The source terms, which are temporally and spatially dependent, are treated appropriately in order to recover the correct hydrodynamics. This is done by taking into account the discrete lattice effects in the Chapman-Enksog technique so that the macroscopic axisymmetric mass and momentum equations are recovered self-consistently [3, 4]. We develop an axisymmetric multiphase scheme based on a LBM multiphase flow scheme applicable in the nearly incompressible limit due to He *et al.* (1999) [5]. The introduction of source terms makes it necessary to calculate additional gradients relative to the Cartesian LBM; but these can be readily computed since the full 3D multiphase flow already requires the evaluation of gradients to determine, for example, surface tension. We evaluate the accuracy of the axisymmetric multiphase flow scheme, by comparing the computed oscillations of axisymmetric spherical drops and breakup of axisymmetric liquid jets with analytical solutions.

References

[1] Premnath, K.N. and Abraham, J., *5th Int. Conf. Multiphase Flow*, Yokohama, Japan (2004).
[2] Halliday, I., *et al*., *Phys. Rev. E*: **64**, 011208-(1-8) (2001).
[3] Luo, X., *Phys. Rev. E*, **62**: 4982-4996 (2000).
[4] Guo, Z., Zheng, C. and Shi, B., Phys. Rev. E, **65**: 046308-(1-6) (2002).
[5] He, X., Chen, S. and Zhang, R., *J. Comp. Phys.*: **152**, 642-663 (1999).