An Improvement on the Coupling of Particle Suspensions using the Lattice Boltzmann and Discrete Element Methods with Immersed Moving Boundaries

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ABSTRACT

Past studies have shown that the drag predictions of the lattice Boltzmann method (LBM) exhibit viscosity-dependence when used with certain boundary conditions such as the bounce-back and interpolated bounce-back schemes. This is most pronounced when the single-relaxation-time (SRT), Bhatnagar-Gross-Krook (BGK) form of the LBM collision operator is employed. The work of Pan et al. [1] showed that, when flow through a porous medium was simulated, the predicted permeability was found to change with the computational viscosity (which is calculated solely from the BGK relaxation parameter, τ). This viscosity-dependence presents an issue for a range of coupled fluid-solid models based on the LBM, in particular particle suspensions.

The problem of viscosity-dependence in the BGK-LBM can be addressed in a number of ways. Using a relaxation parameter of unity, which results in a computational viscosity of 1/6, eliminates the error [2] but places an undesirable constraint on the LBM timestep. The use of a two- (TRT) or multiple-relaxation-time (MRT) collision operator, in conjunction with higher-order boundary conditions such as quadratically-interpolated or multi-reflection bounce-back, can significantly reduce the error [1]. However, this introduces non-local computations.

In this work, the MRT-LBM is implemented in conjunction with an immersed moving boundary (IMB) method [3] for hydrodynamic coupling in an attempt to address the viscosity dependence problem. A range of formulations of the IMB are tested, and a number of improvements to the solid weighting function, β, are investigated and discussed. By reducing viscosity-dependence, without constraining the relaxation parameter, τ, an important degree of flexibility surrounding the coupling of the LBM and DEM timesteps is maintained [4].

Results for single and multiple particle test cases are presented, highlighting the improvement of the developed coupling strategy over BGK-LBM results. Performance of the model in the numerical rheometry of dense particle suspensions is also discussed.

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