LBM-DEM Modelling of Particles in Viscoplastic Fluids without Regularisation

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ABSTRACT

The simulation of particle suspensions using coupled lattice Boltzmann (LBM) and discrete element (DEM) methods [1,2] has been well documented in the literature. This approach has the advantage of being able to simultaneously capture many of the phenomena relevant to suspension flows, including two-way mass and momentum transfer, inertia and transience, friction and lubrication effects, non-Newtonian rheology [3], electromagnetic interactions [4], and more.

This paper presents the recent development and testing of an LBM-DEM model of fluid-particle systems which can capture the rheology of viscoplastic fluids such as the Bingham model without regularisation of the stress-strain rate discontinuity. The process of regularisation, either via the Papanastasiou model [5] or bilinear viscosity, is widely implemented in computational modelling of viscoplastic fluids in spite of its inherent inaccuracies. In this work, this shortcoming is addressed by the adaptation of a locally-implicit formulation of the LBM [6] which, when coupled to particles, shows greatly improved performance.

Following a description of the model, aspects related to the choice of lattice stencil, spurious currents and stresses, and hydrodynamic coupling are discussed. The convergence of the model in pure-fluid duct flows and synthetic porous media is presented, followed by a selection of two- and three-dimensional test cases. These demonstrate the improved performance of the locally-implicit formulation over existing techniques, particularly for transient flows, inertial flows, and for increasingly large Bingham number. In closing, the path towards large-scale implementation of the model is then discussed.

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