Towards Direct Numerical Simulation of Complex Particle Suspensions: Rheology and Phenomenology in Coupled LBM-DEM Modelling

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ABSTRACT

A computational model has been developed which facilitates the simulation of dense particle suspensions. The model employs the discrete element method (DEM) to represent a range of particle geometries, while the fluid phase is captured using the lattice Boltzmann method (LBM). Coupling of the LBM and DEM is achieved using an immersed moving boundary condition [1, 2]. The developed model has the ability to simulate Navier-Stokes hydrodynamics and a range of physical phenomena.

This paper presents progress on the development of the LBM-DEM model towards a robust framework for direct numerical simulation (DNS) of complex particle suspensions. In particular, focus is given to the incorporation of phenomenological models for lubrication and electromagnetic forces, and their subsequent impact on the rheology of already non-Newtonian suspensions.

Lubrication forces are incorporated via an explicit implementation of phenomenological models [3], which avoids the need for embedding implicit computations within the explicit LBM and DEM time integration. The stability of DEM contact resolution is maintained by the sub-cycling of individual contacts in adherence with the Courant-Friedrichs-Lewy criterion. The effects of electromagnetics are included as an additional set of DEM forces on charged particles calculated using the Lorentz equation and Coulomb's law (Biot-Savart interactions between particles are deemed negligible) [4]. With respect to fluid rheology, this work leverages previous research [5] on the numerical rheometry of non-Newtonian fluids and granular suspensions. Competing approaches for the inclusion of non-Newtonian behaviour in the LBM are contrasted, and progress towards an implementation based on modified equilibrium functions and a multiple-relaxation-time (MRT) collision operator is presented.

Numerical illustration and validation of the various aspects of the LBM-DEM model are presented via a range of single and multiple particle simulations. Outstanding areas of research required for the ultimate development of a DNS framework for complex particle suspensions are also discussed.

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