DEM-LBM studies of electro-rheology of particle suspension

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ABSTRACT

Suspensions of micron size particles form a large class of multi-physics problems and find applications in, e.g., microfluidic devices [1], additive manufacturing [2] and pharmaceutical industry [3]. In this work, we study such suspensions using the discrete element method (DEM) coupled with a kinetic theory based lattice Boltzmann method (LBM) [4] to resolve particle dynamics and multiple fields, e.g., fluid or electric-field, respectively. Position updates of each particle computed in DEM at a given time are communicated to the LBM algorithm through a DEM-LBM interface. Here, we use sophisticated extrapolation methods to transfer the particle-centric information of DEM to the computational grid-level information for the LBM and vice versa. Coupling of DEM and LBM has only very recently been examined [5,6]. The design of this interface is important to obtain time accurate results.

The present work details on the analysis of particle suspension in viscous fluid (such as dielectric fluids) under the externally applied electrical voltage across the confining domain boundaries (a scenario common in electrical discharge machining or electrical discharge coating [2]). The electrical-field is computed using the Ohm's law, which is transformed as a variable coefficient Poisson equation. The first set of the LB distribution functions is used to solve this time-invariant PDE. Thus, an instantaneously converged electrical field information on the computational grid (composed of multiple levels [7]) is used to estimate the dielectrophoretic forces on the particles. Further, electric-field could generate electro-osmotic flow locally in addition to the imposed background flow-field and variations in fluid velocities are important due to the particle-fluid interactions. The second set of distribution functions are used to solve for the fluid-flow velocities at lattice grid-points. The novelty of the work lies in the coupling of two LB methods, one using multiple grids and the other on regular grid, with the DEM approach. The computational challenges arising from the coupling, such as time-scaling and convergence, are discussed.

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