Numerical Rheometry of Non-Newtonian Particle Suspensions using Coupled Lattice Boltzmann-Discrete Element Methods

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ABSTRACT

A computational model has been developed which facilitates the simulation of particle suspensions in non-Newtonian fluids. The model employs the discrete element method (DEM) to represent a range of particle geometries. The fluid phase is captured using a non-Newtonian formulation of the lattice Boltzmann method (LBM) and full hydrodynamic 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, turbulence, a range of rheological models (e.g. power law) as well as varying fluid viscosities and densities.

This paper outlines the extension and application of the non-Newtonian LBM-DEM model to simulate numerical rheometry experiments [3] and channel-flow analyses [4] using particle suspensions in power law fluids. The numerical rheometry procedure employs a three-dimensional periodic shear cell geometry, which is an extension of previous work that studied the behaviour of granular media in a cylindrical Couette rheometer [5]. Currently, the periodic shear cell is utilised in a displacement-controlled arrangement. Future work will investigate the feasibility of a stress-controlled arrangement which would facilitate the simulation of drained rheometry experiments under varying consolidation. This will require the development of a porous immersed moving boundary which can apply both normal and shear stresses to the cell geometry without affecting the fluid pressure. The channel-flow analyses utilise a three-dimensional periodic aperture geometry to study the development length of steady-state, pressure driven particle suspensions.

By directly capturing the physical phenomena which dominate the interaction of particles suspended in confined geometries, the developed LBM-DEM model can be employed to investigate a range of physical phenomena in the oil, gas and mining industries. Examples include sanding in oil reservoirs, proppant transport in hydraulic fractures, and fines migration and mud rush in block cave mines.

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