Numerical Rheometry of Dense Particle Suspensions Using a Coupled Lattice Boltzmann and Discrete Element Method

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ABSTRACT

Transport of dense particle suspensions is of interest in a broad variety of industries from drug development to oil recovery. However the rheology of such suspensions is often characterised by semi-empirical models[1] which lack the flexibility required to accurately capture the relevant phenomena.

Previous work in this field has focused on development of constitutive equations to describe the effective viscosity of suspensions with a specific solid volume fraction[2]. The rheology specified by such expressions is then typically used to calibrate a power-law based rheological model[3]. However, work by Lyon & Leal has shown that even in a relatively simple poiseuille flow the distribution of solid particulates is not uniform across the aperture[4]. This spatially varying solid volume fraction brings into question the applicability of constitutive equations to fully describe suspension rheology.

Using a coupled lattice Boltzmann and discrete element method[5], we have developed a new tool for the numerical characterisation of dense suspension rheology. This approach has been implemented using a shared memory, multicore, parallel architecture which allows for rapid and inexpensive evaluation of model results. Where model capabilities include non-Newtonian rheology, turbulence, fluid-solid interactions, and lubricated solid-solid interactions. Through consideration of the fundamental phenomena of flow and contact mechanics this model is able to accurately capture the suspension rheology.

Using this coupled framework we have implemented a numerical couette flow rheometer, discrete element particles are packed into a cubic lattice Boltzmann domain which is periodic in the lateral directions. Using either stress or shear rate control, this model then simulates the shearing of the particulate suspension. The resultant hydrodynamic and mechanical forces on the shearing plane are recovered once the model has achieved a steady state, where these results are used to compute an effective suspension viscosity. The results from this analysis have been validated against existing semi-empirical expressions.

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