Simulation of Wet Granular Materials

Progress Report of Sudeshna Roy

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1 Project Description

This report is based on the recent and ongoing activities related to the aforementioned project and provides a strategic understanding of the same for the users' committee. The main objective of this project is to determine the constitutive equations for the hydrodynamic stress-strain relations by simulation of wet granular materials. The numerical setup we use for simulation consists of a shear cell with annular geometry and a split in the bottom plate of the shear cell. We use this setup to study the quasi-static behavior of the materials and the transition to intermediate and fast flows. The inner cylinder is fixed and the outer cylinder is rotating with a constant angular velocity. The split in the bottom plate separates the stationary part from the moving one. The annular region is filled with polydisperse particles upto a certain filling height. This geometry results in the formation of a wide shear band originating from the split of the shear cell bottom plate. The interacting force for the wet granular materials in pendular regime is basically described by a combination of an elastic contact model and a non-linear liquid bridge model which acts irreversibly. Presently, we focus on understanding the characteristic adhesive parameters of the liquid model at the micro level that affects the macro properties of the system. Interestingly, we are now studying the rheology in the quasi-static regime where we assume the macroscopic friction coefficient to be constant.

2 Publications in 2014

1. Roy, S., Luding, S. Weinhart, T.,
   Towards hydrodynamic simulations of wet particle systems
   in: The 7th World Congress on Particle Technology, Beijing, China
   submitted to Procedia Engineering, 2014

3 Presentations in 2014

1. March 13, 2014,
   Simulation of Dry and Wet Granular Materials in Split Bottom Shear Cell
   Granular Day, University of Twente, Netherland

2. May 19, 2014,
   Simulation of Dry Cohesive to Wet Granular Materials in Split Bottom

Shear Cell
The 7th World Congress on Particle Technology, Beijing, China

3. July 15, 2014,
Simulation of Wet Granular Materials in Split Bottom Shear Cell
PiKo-Workshop "Liquid Bridges" in Paderborn

4 Ongoing Efforts

1. **Micro-macro transition for wet granular materials**

   - We have done a comparative study of the micro-macro behavior for the dry non-adhesive materials and wet materials. To reduce the computational time, we do simulation of a quarter of the shear cell with a periodic boundary condition in angular direction. The system consists of about 37000 particles. As observed from the results the yield shear stress of wet granular materials is higher than that of dry non-cohesive materials at the same pressure. This increase in shear stress is due to the acting cohesive force between the particles and so increases with increase in volume of liquid bridges. Also the shear band moves inwards towards the inner cylinder for wet cohesive materials.
   - Currently, we are investigating the key adhesive properties of wet granular materials at the micro level that affects the macro properties. To do so we replicate this model with an equivalent linear irreversible model and probe their micro-macro transition behavior for different adhesive strength. Further we intend to find out the critical adhesive strength and energy which is essentially constant for any volume of liquid bridge and is associated during contact of the particles and the additional variable energy required to separate the particles.
   - To improve computational efficiency further, we introduce smaller sector angle for simulation with a periodic boundary condition in angular direction. Apparently simulations with small sectors of shear cell give relative error and the results seem to be consistent for larger sector simulation. We run simulations for different sector angles under the same microscopic conditions and try to find out the optimum angle for the same. Presently, we study the effect of the reduced simulated volume on the stress-strain relations and the shear band location.

2. **Continuum model for Split Bottom Shear Cell**

   We are developing a two dimensional continuum model for the split bottom shear cell based on the continuity equation and momentum balance equations. We do this to study the effect of different constitutive models on the macroscopic shear behavior. Here we assume uniformity of properties along angular direction.