VICI 10828: Bridging the gap between particulate systems and continuum theory

Progress report of Thomas Weinhart, May 2014

Project description

This report briefly describes the ongoing activities related to the aforementioned project and provides a road map of the same for the users' committee. The project is mainly concerned with the *micro-macro transition* required to obtain the bulk properties of a system of granular particles directly from the particle properties. This requires a description of a discrete granular system (the positions and velocities of and forces acting on each particle) in terms of density, velocity, and stress. In particular, we focus on the definition of the macroscopic stress near external boundaries and in multiphase flows as they appear in most granular systems but still lack a proper definition. Shallow steady granular flow down an incline over a rough bottom is chosen as an industry-relevant reference system.

Publications in 2014:

1. Windows-Yule, K.; Weinhart, T.; Parker, D.J.; Thornton, A.R.,
   The influence of thermal convection on density segregation in a vibrated binary granular system,
   Physics Review E (2014).
2. Windows-Yule, K.; Weinhart, T.; Parker, D.J.; Thornton, A.R.
   Effects of system packing on the segregation behaviours of granular systems,
   Physics Review Letters (2014).
3. R. Fuchs, T. Weinhart, J. Meyer, H. Zhuang, T. Staedler, X. Jiang and S. Luding
   Rolling, sliding & torsion of micron-sized silica particles - Experimental, numerical and theoretical analysis,
   Granular Matter (2014)

Presentations in 2014:

1. February 28, 2014,
   From discrete particles to continuum fields,
   Seminar of Hydraulic Engineering Department, Politecnico di Milano
2. March 3, 2014,
   Rolling, sliding and torsion of micron sized silica particles,
   PiKo Workshop "Dialog Experiment - Modell (II)" in Magdeburg
3. April 18, 2014,
   Coarse-grained local and objective continuum description of 3D granular flows

down an inclined surface,
Annual European Rheology Conference in Karlsruhe, Germany

4. April 28, 2014,
From discrete particles to continuum fields in the bulk, at boundaries, and in mixtures,
European Geosciences UnionGeneral Assembly in Vienna, Austria

Ongoing Efforts:

A) Micro-Macro transition:

Currently, we are investigating how to choose the proper time-averaging window to obtain accurate macroscopic fields in dynamic situations.

B) Validation of closure relations with medium-scale experiments & simulations

Three projects are currently in progress to validate the measured closure rules for granular flows by comparing continuum simulations of medium scale experiments/ simulations: (i) the flow through a contraction, (ii) the flow impacting an inclined plane, and (iii) the flow front of a granular avalanche.

C) Segregation in multiphase granular flows

Granular flows often consist of multiple phases that differ in size, shape or material properties such as density. Such polydispersed granular flows tend to segregate when sheared or shaken. Segregation in vibrated granular systems was studied in (Windows-Yule, Weinhart et al. 2014, Windows-Yule, Weinhart et al. 2014b). Shear segregation was studied in Thornton, Weinhart et al. (2012), where we measured the segregation rate of polydispersed steady flows as a function of polydispersity. Several continuum theories (Gray and Thornton 2005, Fan and Hill 2011) exist to model segregation in mixtures. In (Weinhart, Luding et al. 2013), we applied the mixture coarse-graining formulation to confirm some assumptions on the segregation dynamics in particle simulations of bi-dispersed chute flows. This work is currently extended to take into account both density and size segregation in dense, sheared granular flows, which will further serve to validate (or invalidate) the existing continuum theories.

D) Development of an open-source code for particle simulations, MercuryDPM

The micro-macro transition methods described in the previous chapters are implemented in MercuryDPM (Thornton, Krijgsman et al. 2013, Thornton, Weinhart et al. 2013). MercuryDPM is an open-source code for particle simulations developed within the Multi Scale Mechanics group and is actively developed by Thomas Weinhart, Anthony Thornton and Dinant Krijgsman. MercuryDPM is a very versatile, easily understandable code. Thus, it enables the transition of scientific knowledge to users in industry and academia. The code continues to be developed and the micro-macro transition methods discussed above are all made available within MercuryDPM.