Discrete to continuum fields in bidisperse granular mixtures

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(Received 2 February 2015)

In recent years, fully three dimensional discrete particle simulations (DPMs) have proved to be a very efficient and powerful tool for understanding particle dynamics. Applications range from emulations of small scale experiments to in-depth analysis of large scale natural or industrial scenarios. However, due to limited computational power and time, DPMs can tend to be expensive depending on the scale of the problem; even when parallelised. Although experiments appear to be ideal in any case, the existing modern day post-processing techniques still cannot provide the plethora of information which DPMs can offer. It is this information, from DPMs, that has become a vital ingredient for our analysis.

With the available DPMs data, several studies have lead to a variety of averaging techniques which project the discrete particle data onto a continuum field. Examples including binning micro-scale fields into small volumes, averaging along planes or coarse graining (CG) spatially and temporally (e.g. Weinhart *et al.* 2013). We present an extension to the CG based method of Weinhart *et al.* (2012) to extract continuum fields (density, velocity, stress, fabric, etc.) from discrete particle systems that is applicable to mixtures as well as boundaries and interfaces. The particle data is coarse grained in a way that is by construction compatible with the continuum equations of mass-, momentum-, and energy balance. Boundary interaction forces are taken into account in a self- consistent way and thus allow the construction of continuous stress field even within one particle radius of the boundaries. Similarly, stress and drag forces can also be determined for individual constituents/components of a mixture, which is critical for the application of mixture theory based segregation models (e.g. Gray & Thornton 2005). The method does not require temporal averaging and thus can be used to investigate time-dependent flows as well as static and steady situations. This coarse-graining method is available from the open-source code MercuryDPM (Thornton *et al.* 2013, http://MercuryDPM.org) and can be run either as a post-processing tool or in real time. In real-time mode, it not only reduces the data which has to be stored but also allows boundary conditions etc. to be coupled to the current macroscopic state of the system, e.g. allowing the creation of a pressure-release wall.

As an example, the formulated CG expressions are applied to bidisperse granular mixtures flowing over inclined channels (Tunuguntla *et al.* 2014). For steady flows, we show the existence of coarse graining scales for which the macroscopic fields are invariant. Furthermore, applications of CG techniques for unsteady flows are investigated. Thereby, illustrating a suitable coarse graining scale and time window required to construct macroscopic fields for unsteady flows.

† Will present at the conference

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