DEM investigation of flow in silos: the effect of particle shape and rolling resistance

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ABSTRACT

The majority of particle scale studies using the Discrete Element Method (DEM) have assumed the particles to be perfect spheres. Despite prevalent acceptability of this assumption, it has been observed that the particle shape and the resulting geometric interlocking between particles is a primary contributor to the overall shearing resistance and is therefore critical for predicting the behaviour of a granular assembly [1]. Micro-scale irregularity, non-sphericity in shape and surface characteristics all affect the relative motion of particles, which leads to change in rheology at macro-scale. Additionally, asymmetric shape in grains, such as sands and cereals, induces a resisting moment at each contact that influences stress state over the bulk. Using idealized spherical particles in DEM simulations, studies have suggested an alternative approach to enable the shape effect to be captured by applying a resistance torque between contacts between spherical particles [2-6]. However it is not fully understood whether introducing a rolling resistance in spherical contact can adequately capture the granular friction in non-spherical particles. The present study focuses on this question by evaluating the capability of such rolling resistance as a shape effect parameter in capturing the macro-scale characteristics of dense granular system during silo discharge. In this regard, a series of DEM simulations are performed on a flat bottom silo as the main geometry with two types of particles; perfect sphere, having various values for the rolling friction parameter, and non-spherical particle which has the same mass as the perfect sphere. Consequently, the equivalency of computed macroscopic features through both systems are quantitatively investigated. A novel spatio-temporal averaging tool is used to quantify the mean and standard deviation over the temporal scale of the computation [7] and visualize the velocity profiles along the boundaries and also to monitor the discharge rate through the orifice of the silo. The force chains generation and distribution are monitored during the solids flow in the silo discharge to provide the insight into the particle scale phenomena. The comparison of the results highlights the impact of particle shape effect and also allows the recognition of deficiencies in the proposed rolling friction as a shape factor in predicting realistic flow behaviour of granular assemblies in silos.

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