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DISCRETE ELEMENT SIMULATION OF GRANULAR MATERIAL BY ELONGATED MULTI-SPHERE PARTICLES

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ABSTRACT

The discrete element method (DEM) became recognized as a numerical tool for simulating granular material when the work by Cundall and Strack [1] was published. Representation of the particle shape is one of the key issues of DEM simulations. Diversity of real particle shapes requires, however, the development of more sophisticated particle models beyond the most popular sphere, while elongated ellipsoid-like particle is probably the most widely used non-spherical shape. The computation effort in the case of non-spherical particle shapes is increased, when integrating the equations of motion and calculating the contact forces.

The presentation deals with multi-sphere (MS) approach, the concept of which was described by Favier at. al. [2]. Contact detection efficiency by using sphere-to-sphere contact is the main advantage of the multi-sphere model.

The emphasis is placed on the development and validation of the non-smooth MS model composed of N spheres, where N is an odd number. The deviations of the MS model from the smooth shape at the particle level are regarded as real imperfections and are evaluated by the suggested microscopic factors.

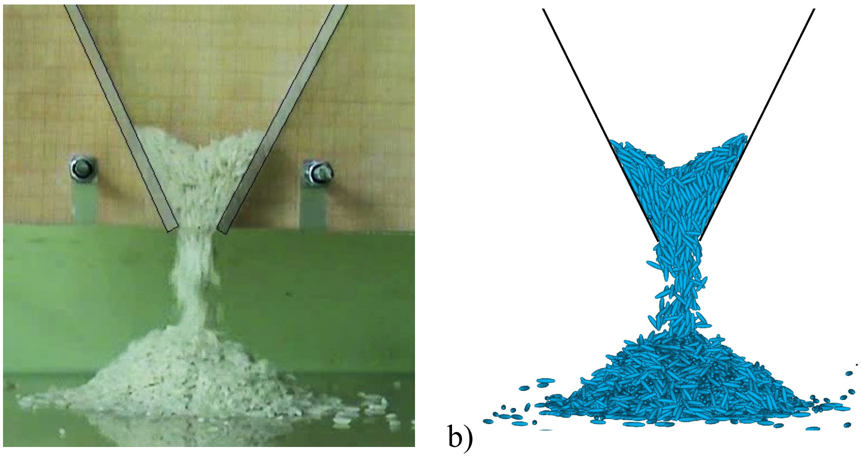
Non-cohesive frictional visco-elastic MS particle model was developed and implemented into the original code DEMMAT [3]. Here, the particle interaction is considered in terms of mutual contacts of particular spheres, while the particle motion is described by linear translations and non-linear rotations integrated explicitly. Euler equations describing rotations are finally expressed in terms of quarteronions.

The performance of the MS approach was illustrated by the case of the MS particle representing the perfect ellipse, while 2D piling and compacting by rigid wall problems were examined for evaluation purposes. The influence of non-smoothness was examined by increasing the number of spheres. The tendency of convergence towards a perfect shape illustrated by the direct comparison of microscopic and macroscopic parameters as well as the increase of computational expenses was considered in detail.

The 3D models of the non-smooth elongated particles were validated by comparison

with experiment by considering the hopper discharge. A small hopper model with the orifice of 15×21 mm in size made from Plexiglas was used. Granular material containing 5000 rice grains was presented by MS particles, each of them composed of 11 spheres. The shape of the elongated non-ellipsoidal axis-symmetric particle with aspects ratio 3.50 was taken from the measurement. Poly-dispersed composition with longer size, ranging from 6.4 mm to 7.6 mm was used in simulations.

The numerically and experimentally obtained time for the hopper discharge and the resulting repose angle of pile were compared and good agreement was found. A snapshot of the discharged material after 1.7 s is presented in Fig. 1. The experiment was filmed by video camera.



a) b)

Fig. 1. Illustration of discharge and piling: a) experimental view, b) results of DEM simulation

Generally, it could be stated, that MS approach is able to model elongated particles. Rather than developing models for the real particle shape, the unified MS model may be used, while the particular shape may be implemented by relatively simple data generators dealing with spheres. It was indicated that numerically evaluated macroscopic parameters of the non-smooth particle, such as repose angle, packing density and coordination number, asymptotically converge towards the smooth shape with the increasing number of spheres, while the increase of computational expenses is practically linear. The number of spheres depends, finally, on the aspects ratio of the particle, while its rational value would be obtained on the basis of a bi-criterion compromise.

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