Influence of inter-particle properties on the elastic moduli of granular materials

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ABSTRACT

In our daily life, we are surrounded by granular materials like soil, coffee, sand, nuts, etc. These constitute over 75% of raw materials feedstock in industry, including pharmaceutical, mining, agriculture, chemical, biotechnological, textile. Many industrial systems display unpredictable behaviour during processing, storage and transport. This gives rise to considerable challenges for the design and operation of unit-processes and plants. Due to the wide application, granular media have received a lot of attention in many fields, such as soil mechanics, material science and physics. Because of their discreteness and disorder at the microscopic scale, it is necessary to employ a multi scale approach which can link the discrete nature of granular systems to the continuum description. The Discrete Element Method (DEM) is a new, powerful tool to help us to get a better understanding, by modelling the motion line of every single particles and translate this information to the continuum macro level.

DEM simulations are very slow when large-scale phenomena and industrial applications of granular materials are taken into account. Even with the most advanced computational techniques of today, it is not possible to simulate realistic numbers of particles with complex geometries. Thus, continuum models are more desirable where a granular medium is assumed as a continuum and principles of continuum mechanics are applied to obtain macroscopic field variables. However, besides an advantage of continuum approach, many features of granular materials at microscopic scale has to be neglected, such as restructuring, geometric non-linearity due to discreteness, explicit control over particle properties. The mechanical behaviour of the materials is presented as a constitutive relation, then the constitutive model has to be defined based on the relation between stress and strain extracted from continuum models..

In this study, assemblies of polydisperse, linearly elastic frictionless, frictional and cohesive spheres are isotropically prepared using DEM . In a second stage, several static, relaxed configurations at various volume fractions above jamming are generated and tested. We investigate the effects of inter-particle contact properties on the elastic bulk and shear modulus by applying isotropic and deviatoric perturbations. The amplitude of the applied perturbations has to be small enough to avoid particle rearrangement and to get the elastic response, whereas large amplitudes develop plasticity in the sample due to contact and structure rearrangements between particles. As expected, both the bulk and shear modulus increase with volume fraction. Interestingly, we observe that both the bulk and shear modulus decrease by increasing the friction coefficient and cohesion between particles [1].

Finally, the evolution of macroscopic quantities (stress and fabric tensors) are studied as a functions of friction, volume fraction ,cohesion and strain rate at different deformation modes. The obtained results and the elastic moduli are used to develop and calibrate a simplified constitutive model. Further work will focus on predicting the plastic response of a granular assembly under large deformation.

REFERENCES

[1] K. Taghizadeh, et al, in IOP Conference Series: Earth and Environmental Science (IOP Publishing,2015), Vol. 26, p. 012008.