

Modeling soft granular media

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Soft-particle materials such as colloidal pastes, vesicles and microgel suspensions, are composed of individual elementary particles, which can undergo large deformations without rupture. In this respect, they are different from rigid-particle materials in which the plastic behavior is essentially dictated by particle rearrangements. Particle shape change under loading in soft materials leads to enhanced space filling and thus specific assembly properties. The compaction, shear behavior and other rheological properties of soft-particle assemblies beyond the "jamming" limit remain unexplored due to the lack of proper numerical and experimental tools.

The molecular dynamics method is widely used for the simulation of particle assemblies due to its ability to account for particle interactions and complex loading conditions. However, since this approach is based on the rigid-body assumption, it cannot be used with large particle deformations. To model the mechanical properties of soft particles as well as their mutual interactions, a new methodology is proposed. It is based on an implicit formulation of the Material Point Method (MPM) for modeling large particle deformations coupled with the Contact Dynamics (CD) method for the treatment of frictional and cohesive contacts between particles. In this approach, each particle is discretized into a set of material points. At each time step, the information carried by these points is projected onto a background mesh, where equations of motion are solved by taking into account frictional contacts between particles. This solution is then used to update the information associated with material points. This implicit MPM-CD model is implemented in a manner that the contact variables (velocity, force...) can be computed simultaneously with bulk variables.

We used this model to analyze the compaction process of 2D soft-particle packings. The packing can reach high solid fractions by particle shape change and still flow plastically. The compaction is a nonlinear process in which new contacts are formed between particles and the contact areas increase. We find that the evolution of the packing fraction is a slow logarithmic function of the driving stress as a consequence of increasing contact area. We also evidence the effect of friction, which favors strong stress chains and thus the elongation of particles, leading to a larger packing fraction at a given level of compressive stress as compared to frictionless particle packing.

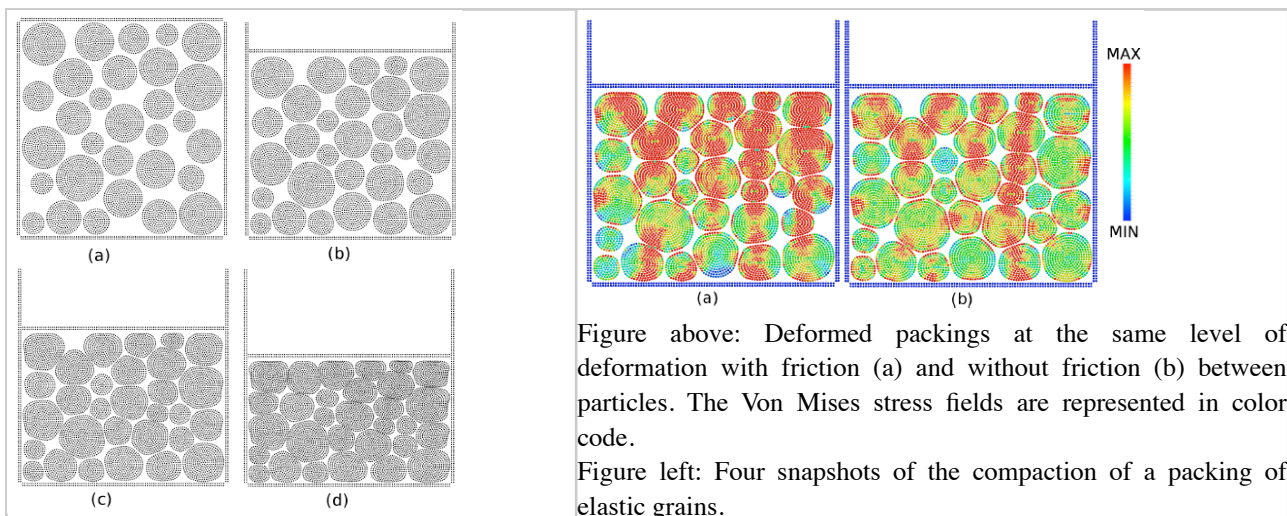


Figure above: Deformed packings at the same level of deformation with friction (a) and without friction (b) between particles. The Von Mises stress fields are represented in color code.

Figure left: Four snapshots of the compaction of a packing of elastic grains.