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Granular states and transitions

The behavior of particulate and granular matter – like sand, powder, suspended particles/colloids – is of considerable interest in a wide range of industries and research disciplines. Such materials are intrinsically disordered, often come with a wide distribution of particle sizes, shapes, or materials/mixtures. Granular matter can behave both solid- or fluid-like, including all the various transitions between these states. The related mechanisms/processes in particle systems are active at multiple scales (from nano-meters to meters, from micro-seconds to hours) and understanding them is an essential challenge for both science and application, i.e., finding the reasons for natural/industrial disasters like avalanches or silo-collapse. To understand the fundamental micro-mechanics one can use particle simulation methods, where often the fluid between the particles is important too, but neglected here. Large-scale applications (due to their enormous particle numbers) have to be addressed by coarse-grained models or by continuum theory. To bridge the gap between the scales, so-called micro-macro transition methods are necessary, which translate particle positions, velocities and forces into density-, stress-, and strain-fields. These macroscopic quantities must be compatible with the conservation equations for mass and momentum of continuum theory. Furthermore, some additional non-classical fields might be needed to describe the micro-structure or the statistical fluctuations, e.g., the fabric or the kinetic energy, before one can reach the ultimate goal of understanding and solving application problems. The granular transitions from fluid to solid, and back from solid to fluid, as well as the transient evolutions between those states are still not fully understood. We present a universal, nonlinear, visco-elasto-plastic material model for the mechanics related to the failure of solids (solid-fluid-transitions) and to the stagnation or jamming (fluid-solid transitions) that includes also the history of material structure and the dynamics as state variables, as based on DEM particle simulations.