Application of the Discrete Element Method to Finite Inelastic Strain in Multi-Materials

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Abstract: Forming of multiphase materials involves complex mechanisms linked with the rheology, morphology and topology of the phases. From a numerical point of view, modeling such phenomena by solving the partial differential equation (PDE) system accounting for the continuous behavior of the phases can be challenging. The description of the motion and the interaction of numerous discontinuities, associated with the phases, can be conceptually delicate and computationally costly. In this PhD, the discrete element method (DEM) is used to phenomenologically model finite inelastic strain in multi-materials. This framework, natively suited for discrete phenomena, allows a flexible handling of morphological and topological changes.

Ad hoc attractive-repulsive interaction laws are designed between fictitious particles, collectively rearranging to model irreversible strain in continuous media. The numerical behavior of a packing of particles can be tuned to mimic key features of isochoric perfect viscoplasticity: flow stress, strain rate sensitivity, volume conservation. The results for compression tests of simple bi-material configurations, simulated with the DEM, are compared to the finite element method (FEM) and show good agreement. The model is extended to cope with tensile loads. A method for the detection of contact and self-contact events of physical objects is proposed,
based on a local approximation of the free surfaces.

The potential of the methodology is tested on complex mesostructures obtained by X-ray tomography. The high temperature compression of a dense metallic composite is modeled. The co-deformation can be observed at the length scale of the phases. Two cases of ``porous'' materials are considered. Firstly, the simulation of the compression and the tension of aluminum alloys with pores is investigated. These pores stem from the casting of the material, their closure and re-opening is modeled, including the potential coalescence occurring at large strain. Secondly,the compression of a metallic foam, with low relative density, is modeled. The compression up to densification involves numerous interactions between the arms.