Dynamic Sintering of a High Temperature Granular Material: Experiments and Simulations

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ABSTRACT

Snow changes from a porous solid to a granular material during deformation with high strain rates. This transition occurs in many cases where snow is relevant to engineering problems (vehicle mobility, avalanche formation and prevention, skiing etc.). For the description of the fast deformation of snow the discrete element method (DEM) is a valuable tool, as it is able to account for both states and the transition between them: the interaction of the loose and bonded particles.

For the development of a physically relevant DEM snow model [1] we investigate experimentally along with simulations the basic processes of the granular behavior of snow. In the granular state, sintering plays an important role for the dynamics of the particles. Via sintering the high temperature ice particles (homologous temperature $T/T_m \approx 0.95$) bond together and change the structure and the physical properties of the material. This temperature dependent sintering process, which happens in the time range of milliseconds to hours, is in the focus of the present work.

The fast sintering of ice in the range of milliseconds has scarcely been investigated. However, from sintering studies with ice cones (radius of 3 mm) we know, that the sintering force is closely related to the contact area of the particles [2]. As the contact area changes considerably for complicated shapes, exhibited by natural snow crystals, we consider different snow types (grain shape and size), besides ice beads as spherical model snow. The latter one is used to exclude shape effects and to directly compare experiments to simulations with spherical particles.

To be able to take the effects of the grain shape into account and to examine sintering in the time range of interest (seconds), we perform angle of repose experiments and simulations. Snow is sieved to pile up on a flat base until an angle of equilibrium, the angle of repose, is formed. This angle increases with the sintering of the particles, but also with the inter-particle friction. To analyze the contribution of the friction and the grain shape without sintering, we perform the experiments at a low temperature $T = -31°\text{C}$ ($T/T_m \approx 0.87$), where sintering can be neglected; thus, the angle of repose is determined by inter-particle friction. With these measurements, we calibrate the simulations. At higher temperatures (up to $T = -1°\text{C}$) sintering changes the angle of repose, and a physically relevant sintering law for real snow is established in the simulations.

REFERENCES

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