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Microstructure-based simulations of the tensile strength of snow

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The mechanical behavior of snow is essential to understand the formation of snow avalanches. In particular, the failure properties of snow are determinant in snow slab avalanche release.

Direct experiments on snow are difficult to conduct and to interpret. First, seasonal snow is often a very fragile material which can be easily damaged before a mechanical test is finished. Second, natural snow is generally not homogenous, but consists of many thin layers. Thus, a direct mechanical test is in this case very difficult to interpret. This motivated us to implement a numerical simulation that uses the full 3D-structure of snow.

The microstructure of snow samples was captured with a micro-computer tomograph and the tensile strength of the same samples was measured. A subvolume (about 30 mm^3) of the zone where the fracture occurred in the mechanical test was numerically simulated. To this purpose, the mechanical properties of monocrystalline ice were considered to model the constitutive material of snow. Because the orientation of ice grains cannot be determined in adsorption tomography, orientation-averaged properties were used as a first approximation.

The results show that the average simulated tensile strength is in good agreement with the measurements for the tested snow, rounded grains at a density of about 350 kg m^{-3}. In a second approach, a geometrical grain selection algorithm was used to associate to each ice grain a specific c-axis and the corresponding oriented anisotropic stiffness and strength. This artificial orientation of ice grains does not modify significantly the elastic stress distribution in the snow sample but decreases slightly the effective tensile strength of snow compared to the simulation using orientation-averaged properties of ice.

As a conclusion, even if the size of the simulated volume remains relatively small (about 30 mm^3), the direct numerical simulation of the tensile strength of snow is possible and enables the investigation of the failure behavior of snow at a microscopic scale.