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Stress Distributions and Calving Rates at Antarctic Ice Shelves

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Ice shelves are the floating ice masses from which icebergs are calving off. The calving of large tabular icebergs are singular events and occur on timescales of years to decades. However small scale calving happens on more continuous periods and contribute to the mass balance of an ice shelf. For a better understanding of the influence of environmental parameters on calving mechanisms, a fracture mechanical approach examines the nature and frequency of calving events.

The ice shelf is modeled as a two, respectively three, dimensional rectangular body loaded by gravity and water pressure. There are two responses of ice to load: on long time scales ice reacts like a viscous fluid, and on short time scale like an elastic solid. In this study only the small scale calving events are analyzed, which usually occur on a rather short time scale.

The finite element software COMSOL is used to compute the deformations and stresses, where in a first approach a linear elastic analysis is performed. The stresses in the vicinity of the calving front are evaluated to estimate the position of a calving event. This leads to a bell shaped distribution of stresses on the surface and the location of the maximum tensile stress, which denotes the most likely position for a calving event, is located at the surface. The distance of the maximum stress at the surface is verified with a model of an elastically supported beam, loaded by a bending moment instead of the water pressure at the ice front.

Directly after a calving event the ice front is nearly vertical. After a certain time interval the exposure, due to waves and water flow, leads to an ice front, which is shaped like an under-water "nose". Therefore, the geometry is slightly modified and the added belly at the ice shelf front is modelled as half of an ellipse, where bouyancy forces affect this boundary. A crack originates, if the tensile stress at some point exceeds a critical stress bound.

The analysis of calving with a rate dependent material model leads to a calving rate incorporating the position of maximum stress, detachment time and flow velocity of the ice shelf. Different material models are implemented, where the results for the Kelvin solid and the 3-parameter solid point out the stress distribution over time after a calving event. Additionally the Maxwell fluid and the 3-parameter fluid contrast the effect of the strain distribution after a calving event. Therefore, the comparison of results for different viscoelastic material models are established and differences are demonstrated.