A semi-smooth Newton method for orthotropic plasticity and frictional contact at finite strains

Abstract:
A new approach for the unified treatment of frictional contact and orthotropic plasticity at finite strains using semismooth Newton methods is presented. The contact discretization is based on the well-known mortar finite element method using dual Lagrange multipliers to facilitate the handling of the additional Lagrange multiplier degrees of freedom. Exploiting the similarity of the typical inequality constraints of plasticity and friction, all involved discrete inequalities are reformulated as nonlinear non-smooth equations using complementarity functions. The resulting set of discrete semi-smooth equations can be solved efficiently by a variant of Newton’s method, where all additionally introduced variables are condensed from the global system so that a linear system only consisting of the displacement degrees of freedom has to be solved in each iteration step. In contrast to classical radial return mapping methods for computational plasticity, the plastic constraints are not required to hold at every iterate in the nonlinear solution procedure, but only at convergence. This relaxation in the pre-asymptotic behavior results in a significant gain in robustness compared to radial return mapping algorithms. The
presented elasto-plasticity algorithm includes arbitrary isotropic hyperelasticity, an anisotropic Hill-type yield function with isotropic and kinematic hardening, plastic spin and appropriate finite element technology for nearly incompressible materials. Therefore, it is well suited for the modeling of sheet metal forming and similar processes. Several numerical examples underline the superior robustness of the proposed plasticity algorithm and the efficient treatment of elasto-plastic contact problems.

Stichworte:
Finite strain plasticity, Anisotropic Hill model, Frictional contact, Mortar finite element methods, Semi-smooth Newton methods, Nonlinear complementarity functions

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