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On the implementation of hyperplastic models without establishing a yield surface

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ABSTRACT

The integration of constitutive relations to determine stress increments is a cornerstone of nonlinear finite element analysis. Conventional elastoplastic approaches rely on predefined yield criteria and plastic potential functions to distinguish between elastic and elastic-plastic responses, and to govern the flow direction, respectively. In recent decades, the hyperplasticity framework, grounded on Ziegler's thermodynamic principles, has emerged as an alternative. This framework constructs thermodynamically consistent constitutive models by specifying a free energy potential, a dissipation function, and kinematic constraints, with key elements such as the yield function and flow rule derived through mathematical transformations like the degenerate Legendre transformation or Fenchel's duality theorem.

Despite its promise, the hyperplasticity framework faces challenges in handling the mathematical complexities of these transformations, particularly with complex dissipation functions and realistic kinematic constraints. In this talk, I will introduce a simplified and flexible numerical integration scheme that bypasses these complexities by leveraging the direct use of the free energy potential, dissipation function, and kinematic constraints. This method allows for efficient computation of elastic-plastic responses and the visualization of yield surfaces.

The proposed scheme is validated using a family of sand models based on the Matsuoka-Nakai (MN) failure criterion with varying kinematic constraints and friction mobilization, as well as clay models derived from the Modified Cam-Clay (MCC) model and its hybrid formulations with MN. Numerical simulations and generated yield surfaces will illustrate the method's robustness. Finally, I will demonstrate the scheme’s implementation into a finite element program solveing boundary value problems, showcasing its practical applicability and potential to advance constitutive modeling in geomechanics.