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NURBS plasticity: yield surface evolution and implicit stress integration for isotropic hardening

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Abstract

This paper extends the non-uniform rational basis spline (NURBS) plasticity framework of Coombs et al. [8] to include isotropic hardening of the yield surfaces. The approach allows any smooth isotropic yield envelope to be represented by a NURBS surface. The key extension provided by this paper is that the yield surface can expand or contract through the movement of control points linked to the level of inelastic straining experienced by the material. The model is integrated using a fully implicit backward Euler algorithm that constrains the return path to the yield surface and allows the derivation of the algorithmic consistent tangent to ensure optimum convergence of the global equilibrium equations. This provides a powerful framework for elasto-plastic constitutive models where, unlike the majority of models presented in the literature, the underlying numerical algorithm (and implemented code) remains unchanged for different yield surfaces. The performance of the algorithm is demonstrated, and validated, using both material point and boundary values simulations including plane stress, plane strain and three-dimensional examples for different yield criteria.

Keywords:
elasto-plasticity, constitutive modelling, non-uniform rational basis spline (NURBS), stress integration, finite-element analysis, isotropic hardening

1. Introduction

Robust and efficient constitutive models are at the heart of every boundary value stress analysis problem, providing the essential link between stress and strain for the material that they represent. Elasto-plasticity is one class of inelastic material behaviour that allows these models to predict yield and capture post-yield behaviour. Central to these models is the concept of a yield surface that provides the boundary between elastic (inside the surface) and elasto-plastic behaviour (on the surface). However, such models are typically developed in rate form, providing a rate relationship between stress and stain that