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Three-dimensional Explicit Finite Element Formulation with Embedded Weak Discontinuities for Continuous Shear Band Propagation via a Global Tracking Strategy

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Adiabatic shear localization is characterized as the concentration of ductile plastic deformation within thin bands of material, which is often observed as a precursor to failure in metals. In this work, we present an explicit finite element formulation in three dimensions (3D) using embedded weak discontinuities to treat shear localization under highly dynamic loading conditions. The onset of shear localization is detected via a material stability analysis suitable for viscoplasticity, and the continuous propagation of shear band is ensured via a global tracking strategy [1,2]. This strategy involves solving a heat-conduction type boundary value problem (BVP) for a scalar level set function in the global domain. The thickness of the shear band is treated as a constant parameter across the entire domain of interest to regularize the finite element formulation. A modified quadrature rule involving the shear band volume and the distances between each integration point and the shear band surface is proposed to consider the influence of the shear band location inside individual finite elements. We show that the proposed quadrature rule is consistent with the modified quadrature rule in [3]. The mechanical threshold stress (MTS) model, modified to account for dynamic recrystallization (DRX), is adopted as the constitutive model for rate- and temperature-sensitive metallic materials. The constitutive equations are formulated in a rotation-neutralized (corotational) framework. The algorithmic setup used to integrate the global tracking strategy within the explicit finite element simulation is described in detail. Numerical results are compared with split-Hopkinson pressure bar experiments to demonstrate the capability of the proposed computational framework.

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