Strain gradient plasticity based on saturating internal variables

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ABSTRACT

The micromorphic approach to gradient plasticity is an efficient method to enhance classical plasticity models and account for size effects in the nonlinear behaviour of materials [1]. It can also be used to regularize plastic strain localization phenomena such as shear banding in metallic components [4]. It contains the Aifantis strain gradient plasticity theory as a limit case. The latter relies on the introduction of the gradient of cumulative plastic strain in the free energy potential, as a quadratic contribution. However, the approach suffers from several shortcomings such as ever-increasing isotropic hardening during cycling loading, broadening of localization bands after saturation of hardening after initial softening, and possible vanishing of the yield stress for significant positive values of the Laplacian of cumulative plastic strain. Some of these shortcomings can be overcome by introducing the gradient of saturating internal variables instead of the ever-increasing cumulative plastic strain variable. The approach is first illustrated for an exponentially saturating internal variable. In this case, the method is shown to be equivalent to considering a varying length scale in the Aifantis model [3]. A second example deals with the introduction of the gradient of the total dislocation density following Kocks-Mecking celebrated evolution equation. Finite element results for constrained cyclic shearing, bending and torsion are provided within the framework of finite deformation plasticity [2, 5].

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