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A phase-field approach to structured plastic deformations

A variational approach to determine the deformation of an ideally plastic substance is proposed by solving a sequence of energy minimization problems under proper conditions to account for the irreversible character of plasticity. The flow is driven by the local transformation of elastic strain energy into plastic work; remarkably the plastic part of the deformation localizes on slip surfaces, once that a certain energetic barrier for slip activation has been overcome. The resulting deformation is "structured" because it is associated with supplementary kinematical variables (the plastic slips), governed by an evolution law. This is a "phase field approach" because the matching condition at the slip interfaces are substituted by the evolution of an auxiliary phase field that, similarly to damage theory, is unitary on the elastic phase and null on the yielded phase.

The slip lines diffuse in bands, whose width depends upon a material length-scale parameter. The distinction of the elastic strain energy into spherical and deviatoric parts can also be used to incorporate in the model the idea of von Mises plasticity and isochoric plastic strain. Numerical experiments on representative problems in plane strain provide solutions with striking similarities with the results from classical Prandtl slip-line field theory of plasticity. However, whereas such a theory considers a rigid-plastic material, so that small boundary data provoke plastic glide in the whole body, the proposed model is much richer because, accounting for elastic deformations, it can describe the formation of slip bands at the local level, which can nucleate, propagate, widen and gradually diffuse by varying the boundary conditions.

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