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LINKING SCALES IN PLASTIC DEFORMATION AND FRACTURE

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Abstract. We investigate crack growth initiation and subsequent resistance in metallic materials by means of an implicit multi-scale approach. Strain gradient plasticity is employed to model the mechanical response of the solid so as to incorporate the role of geometrically necessary dislocations (GNDs) and accurately capture plasticity at the small scales involved in crack tip deformation. The response ahead of the crack is described by means of a traction-separation law, which is characterized by the cohesive strength and the fracture energy. Results reveal that large gradients of plastic strain accumulate in the vicinity of the crack, elevating the dislocation density and the local stress[1]. This stress elevation enhances crack propagation and significantly lowers the steady state fracture toughness with respect to conventional plasticity[2]. Important insight is gained into fracture phenomena that cannot be explained on the grounds of classic continuum theories. Namely, we show that strain gradient plasticity provides a rational basis for cleavage fracture in the presence of significant plastic flow, with the lattice cohesive strength being attained with meaningful values of the fracture energy and the length scale parameter. In addition, the investigation of short cracks in hydrogen-embrittled steels accounting for the GND-effect shows that failure takes place at low ductility levels, in agreement with experimental observations.

Keywords: Fracture, Cohesive zone model, Strain gradient plasticity, Cleavage.

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