Modelling plasticity at the micron scale

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ABSTRACT

Experiments have consistently shown that metallic materials display strong size effects at the micron scale, with smaller being harder. As a result, a significant body of research has been devoted to model this size dependent plastic phenomenon (see [1] and references therein). At the continuum level, phenomenological strain gradient plasticity (SGP) formulations have been developed to extend plasticity theory to small scales. Grounded on the physical notion of geometrically necessary dislocations (GNDs, associated with non-uniform plastic deformation), SGP theories relate the plastic work to both strains and strain gradients, introducing a length scale in the constitutive equations. The numerical implementation of SGP formulations is however not free from challenges and numerical complexities have long hindered a comprehensive embrace of gradient plasticity models.

In this talk several *ad hoc* numerical basis for the main SGP formulations will be presented. Both lower and higher order gradient plasticity models will be considered and standard and enriched numerical solutions proposed. The robustness and efficiency of the numerical framework presented will be demonstrated by addressing engineering problems beyond micron-scale applications; namely, crack initiation and subsequent growth. GNDs are likely to impact fracture mechanics as, independently of the size of the specimen, the plastic zone adjacent to the crack is physically small and contains strong spatial gradients of deformation. The influence of GNDs will be then examined in a wide range of areas where they are expected to play a major role: crack tip fields characterization [2], cohesive zone modeling of crack propagation, hydrogen diffusion towards the fracture process zone [3] or environmentally assisted cracking [4].

REFERENCES

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