Crack growth resistance in gradient plasticity solids

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ABSTRACT

While micron-scale tests motivated at first the investigation of size effects in metal plasticity, the influence of geometrically necessary dislocations extends beyond micro-technology applications, as plastic strains vary over microns in a wide range of engineering designs. Particularly, strain gradient plasticity modelling of fracture and damage appears imperative (independently of the size of the specimen) as the plastic zone adjacent to the crack tip is physically small and contains strong spatial gradients of deformation (see, e.g., [1-2] and references therein).

In this work, crack initiation and subsequent growth is examined for a strain gradient plasticity solid with a cohesive zone formulation characterizing the fracture process zone. Computations predict a finite fracture toughness for a critical cohesive stress of 8 to 10 times the yield stress, as a consequence of the increased dislocation density associated with large plastic strains in the fracture process zone [3]. These results are obtained for meaningful values of the length scale parameters and could rationalize cleavage fracture in the presence of significant plastic flow. For a given critical cohesive stress, a very strong reduction of the steady state fracture toughness is observed (relative to conventional plasticity predictions), revealing the need to consider gradient effects in fracture and damage models. The influence of short and large cracks is also investigated and the implications of the results on hydrogen assisted environmental cracking [4-5] thoroughly discussed.

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