DTU Library

Crack Tip Mechanics in Distortion Gradient Plasticity

Fuentes-Alonso, Sandra; Martínez Pañeda, Emilio

Published in:
Proceedings M2D2017 - 7th International Conference on Mechanics and Materials in Design

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Fuentes-Alonso, S., & Martínez Pañeda, E. (2017). Crack Tip Mechanics in Distortion Gradient Plasticity. In J. F. Silva Gomes, & S. A. Meguid (Eds.), *Proceedings M2D2017 - 7th International Conference on Mechanics and Materials in Design* (pp. 509-510). Article 6770 INEGI - Instituto De Ciência E Inovação Em Engenharia Mecânica E Engenharia Industrial.

Proceedings of the 7th International Conference on Mechanics and Materials in Design
Albufeira/Portugal 11-15 June 2017. Editors J.F. Silva Gomes and S.A. Meguid.
Publ. INEGI/FEUP (2017)

PAPER REF: 6770

CRACK TIP MECHANICS IN DISTORTION GRADIENT PLASTICITY

Sandra Fuentes-Alonso[1(*)], Emilio Martínez-Pañeda[2]
[1]Department of Construction and Manufacturing Engineering, University of Oviedo, Gijón, Spain
[2]Department of Mechanical Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark
[(*)]*Email:* uo233571@uniovi.es

ABSTRACT

The important role of geometrically necessary dislocations in structural integrity assessment has encouraged an extensive use of strain gradient plasticity theories to characterize the behavior at the small scales involved in crack tip deformation. However, despite the popularity of Distortion Gradient Plasticity (DGP), the influence on crack tip mechanics of DGP's distinguishing features that entail superior modelling capabilities has not been investigated yet. In this work crack tip fields are thoroughly examined by implementing the higher order theory of DGP in an implicit finite element framework. The implications on fracture and damage modeling are extensively discussed.

Keywords: distortion gradient plasticity, fracture mechanics, finite element method.

INTRODUCTION

Experiments have consistently shown that metals display strong size effects at the micron scale - *smaller is stronger*, and much research has been devoted to model this size dependent plastic phenomenon. At the continuum level, phenomenological strain gradient plasticity formulations have been employed to extend plasticity theory to small scales. Grounded on the physical notion of geometrically necessary dislocations (GNDs, associated with non-uniform plastic deformation), gradient theories relate the plastic work to both strains and strain gradients, introducing a length scale in the constitutive equations.

In recent years, increased attention has been focused on the need to account for the plastic spin, as proposed by Gurtin (2004), to properly describe the plastic flow incompatibility and associated dislocation densities. It has been consistently shown that the use of phenomenological higher order models that involve the whole plastic distortion (generally referred to as Distortion Gradient Plasticity, DGP) leads to superior modeling capabilities; see (Martínez-Pañeda et al., 2016) and references therein.

While growing interest in micro-technology motivated the development of gradient plasticity models at first, the influence of GNDs extends beyond micron-scale applications, as strains vary over microns in a wide range of engineering designs. Particularly, gradient enhanced modeling 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.

In this work Gurtin (2004) model is numerically implemented and subsequently employed to investigate the role of large dislocation densities associated with gradients of plastic strains in the fracture process zone.

RESULTS AND CONCLUSIONS

Results show a very strong influence of GNDs, revealing the need to incorporate gradient effects to adequately characterize behavior at the small scales involved in crack tip deformation. As shown in Fig. 1, far from the crack both conventional J2 plasticity and DGP estimations agree but differences arise within micros to the crack tip. Moreover, the stress elevation intrinsic to gradient plasticity theories shows sensitivity to the weighting of energetic or dissipative length scales.

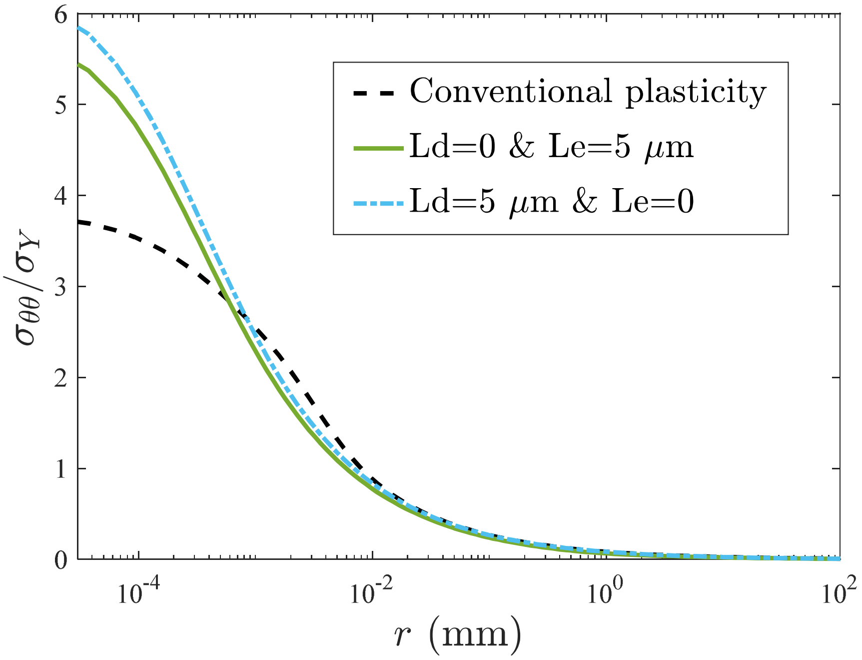

Fig. 1 - Representative results. Normalized opening stress distribution ahead of the crack tip for conventional plasticity and DGP with different weighting of energetic and dissipative gradient effects. The figure shows results along the extended crack plane with the distance to the crack tip in logarithmic scale.

ACKNOWLEDGMENTS

E. Martínez-Pañeda acknowledges financial support from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013) under REA grant agreement nº 609405 (COFUNDPostdocDTU).

REFERENCES

[1]-Gurtin ME. A gradient theory of small-deformation isotropic plasticity that accounts for the Burgers vector and for dissipation due to plastic spin. Journal of the Mechanics and Physics of Solids, 2004, 52, p. 2545-2568.

[2]-Martínez-Pañeda E, Niordson CF, Bardella L. A finite element framework for distortion gradient plasticity with applications to bending of thin foils. International Journal of Solids and Structures, 2016, 96, p. 288-299.