Analysis of strain localization near a blunting crack tip using a higher-order gradient crystal plasticity theory

Mitsutoshi Kuroda

Graduate School of Science and Engineering, Yamagata University,
Yonezawa, Yamagata 992-8510, Japan
e-mail: kuroda@yz.yamagata-u.ac.jp

ABSTRACT

Nonuniform and localized deformation near a blunting crack tip in FCC single crystals under pure Mode I loading conditions is investigated using finite element method. To model a cracked specimen subjected to Mode I loading, a large semi-circular region of radius R_0 with a notch of radius a_0 ($R_0 >> a_0$) is considered so that conditions of small scale yielding are satisfied. A size-dependent higher-order gradient crystal plasticity theory accounting for finite strains [1] is adopted to characterize the material. A conventional crystal plasticity model [2] is also employed for comparison purposes. Idealized plane strain deformation is considered utilizing a planar *3-effective* slip model in which any out of plane action from one crystallographic slip system is assumed to be cancelled by geometrically symmetric other slip systems [3].

In case of employing the conventional crystal plasticity model without any length scale effect, severely localized deformation accompanying shear band development appears near the blunting crack tip. With introduction of an intrinsic material length scale effect that is related to higher-order slip gradients, formation of severely localized shear bands inside the material near the crack tip is suppressed, but at the crack tip surface a peculiar nonuniform deformation still remains, which might suggest crack propagation. It is observed that the crack tip opening displacement (CTOD) is not significantly affected by the length scale effect.

REFERENCES

[1] M. Kuroda and V. Tvergaard, "A finite deformation theory of higher-order gradient crystal plasticity". *J. Mech. Phys. Solids*, **56**, 2573-2584 (2008).

[2] D. Peirce, R.J. Asaro and A. Needleman, "Material rate dependence and localized deformation in crystalline solids", *Acta Metall.*, **31**, 1951-1976 (1983).

[3] J.R. Rice, "Tensile crack tip fields in elastic-ideally plastic crystals", *Mech. Mater.*, **6**, 317-335 (1987).