Small Scale Yielding Model for Fracture Mechanics

K. C. Koppenhoefer[1], J. Thomas[1], J. S. Crompton[1]

[1]AltaSim Technologies, LLC., Columbus, OH, USA

Abstract

Computational fracture mechanics has been used to develop solutions to complex nonlinear fracture mechanics problems that scale between laboratory specimens and full-size structures. As engineers and scientists use COMSOL Multiphysics® simulations to develop solutions to nonlinear fracture mechanics problems, the need for accurate solutions to these complex problems grows. The COMSOL Model Gallery gives a model of an edge crack [1] where calculated stress intensity factors are compared with the classic linear elastic fracture mechanics (LEFM) solution. This model shows the capability to accurately calculate the KI to determine brittle fracture for materials with low fracture toughness. For materials with sufficiently high fracture toughness, limit load analysis is used to determine failure governed by the plastic flow characteristics of the material.

The field of non-linear fracture mechanics, specifically elastic-plastic fracture mechanics (EPFM), has developed equations and models for describing the stress singularity of a cracked bodies where plasticity effects cannot be neglected but at the same time are confined locally to the crack tip [2]. This "small-scale yielding" modeling assumption has given rise to a number of analytical solutions including those developed by Irwin [3] and later by Rice and Rosengren [4] and Hutchinson [5].

The current study compares published EPFM solutions to solutions developed using the small- and large-strain plasticity models available with the COMSOL software. The analyses use a plane strain formulation with a Ramberg-Osgood power-law material model. The primary metric for comparison is the normal stress on the remaining ligament. Results include finite-element analysis with large-strain theory that include crack blunting effects. The solutions developed using COMSOL are compared with other commercial finite element analyses.

Reference

[1] COMSOL Multiphysics Model Gallery, Single Edge Crack, Model ID: 988.
[2] Fracture Mechanics: Fundamentals and applications, D. T. Anderson. CRC Press, 1991.
[3] Irwin, G.R., “Analysis of Stresses and Strains near the End of a Crack Traversing a Plate.” Journal of Applied Mechanics, Vol. 24, 1957, pp. 361-364.
[4] Rice, J.R. and Rosengren, G.F., “Plane Strain Deformation near a Crack Tip in a Power-Law Hardening Material.” Journal of the Mechanics and Physics of Solids, Vol. 16, 1968, pp. 1-12.
[5] Hutchinson, J.W., “Singular Behavior at the End of a Tensile Crack Tip in a Hardening Material.” Journal of the Mechanics and Physics of Solids, Vol. 16, 1968, pp. 13-31.