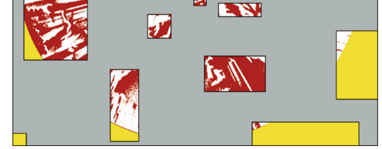

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Generalization of Mixed Mode Crack Behaviour by the Plastic Stress Intensity Factor

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Abstract

An elastic–plastic finite element analysis is performed for cruciform specimens of two configurations and a compact tension–shear specimen subjected to mixed Mode I/II loading. A Ramberg–Osgood stress–strain relation is used to characterise the properties of two types of steel and titanium and aluminium alloys. For the specified geometry of the specimen considered, the governing parameter of the elastic–plastic crack-tip stress field I_n factor, the stress triaxiality, and the plastic stress intensity factor are determined as a function of mode mixity and elastic–plastic material properties. Special emphasis is put on the analysis of the effect of specimen geometry. Analytical and numerical results are compared for the complete range of mixed-mode loading. A correlation between the plastic stress intensity factor and the constraint parameter based on the numerical analysis is found. Coupling between mode mixity and material nonlinearity is indicated. The applicability of the plastic stress intensity factor approach to large-scale yielding analysis is also discussed.

Keywords: mixed mode, stress triaxiality, strain energy density, plastic stress intensity factor.

1. Introduction

According to Hutchinson's analytical solution [1], the near-tip field at a stationary Mode I crack in an elastic–plastic power hardening material is governed by the amplitude of the dominant singularity. This amplitude of the plastic singular solution is called the plastic stress intensity factor (SIF) to indicate that it plays a role analogous to that of elastic stress intensity factor and is directly related to the J integral by a simple equation for small-scale yielding conditions. Shih [2] later extended this solution for the case of small-scale yielding mixed-mode fracture and showed that an important feature of such analysis is the formulation of the additional parameter governing singular stress fields for an elastic–plastic material. Shih [2] assumed that the amplitude of the first term in the form of the plastic SIF can be expressed in terms of corresponding elastic SIFs K_1 and K_2, but the expression depends implicitly on the additional mode mixity parameter M_P. Shlyannikov and Tumanov [3] reconsidered the Hutchinson [1] and Shih [2] solutions for both pure Mode I and mixed-mode conditions, respectively. They proposed a new method for the analytical solution of plane mixed-mode problems by introducing an additional boundary condition for the governing compatibility equation of the reference crack-tip fields in the form of a crack deviation angle criterion.

Hilton and Hutchinson [4], Hilton and Sih [5], and Hilton [6] investigated the behaviour of the dominant singularity at the crack tip, the plastic stress or strain intensity factor, for both the small- and large-scale yielding ranges. Goldman and Hutchinson [7] continued a nonlinear analysis to solve fully plastic crack problems and found approximate dependencies between the J integral and the plastic stress (strain) intensity factors. Hilton [6] and Lee and Liebowitz [8] studied biaxial loading effects on plastic stress and strain intensity factor behaviour for pure Mode I cracked-plate problems. The authors of these works have concluded that biaxial effects on