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A new analytical method for stress intensity factors based on *in situ* measurement of crack deformation under biaxial tension

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ABSTRACT

A new approach for the calculation of stress intensity factors (SIF) for isotropic and orthotropic materials under biaxial tension loading was proposed in this paper. In order to determine SIF from the full-field displacement data, an asymptotic expansion of the crack tip displacement field was performed. The deforming shape and surface residual stress of the crack tip was obtained at the early extended stage of the loading process by using optical microscope and X-ray diffraction measurement. During this stage, a modified Dugdale Model, which takes into account the coupled effect at the crack tip, was proposed for the open displacement of the crack tip. In this paper, the SIFs of two types of silicon steel sheet with isotropic and orthotropic properties were calculated using the modified Dugdale Model based on the biaxial tension experimental data. From the results, it was found that analysis using the modified Dugdale Model is an effective way to evaluate SIF under biaxial stress.

1. Introduction

Fracture is a local phenomenon, and methods of conventional fracture mechanics have been successfully used in the assessment of engineering structures for a long time. Some of them have already been applied in industries, whereas others are rather novel [1,2]. However, even the applicative methods need to be re-evaluated when new design principles are introduced, especially for new materials.

The fracture of isotropic elastic–plastic materials with crack is described well enough by the crack tip opening displacement (CTOD) and the Dugdale Model [3] in a broad range of variation of the plastic zone size near the crack tip. Wells used the CTOD method to systematically study the early extension of linear elastic fracture mechanics (LEFM) in materials [4]. Through this method, Wells found that significant plastic yielding occurs. Wells supposed that the CTOD is proportional to the overall tensile strain even after the general yield was reached, and this hypothesis was later confirmed. Since then, CTOD has been widely used in various elastic–plastic assessments.

Although various methods of elastic–plastic analysis were available, the need for an explicit expression for CTOD was satisfied only after Dugdale developed the "strip yield model" for a sheet containing a crack. In this model, the sheet is subjected to tension at infinity, giving rise to a Mode-I type deformation at the rims of the crack, which is consequently opened to form the plastic zone at the head of the crack tips. The opening is then arrested by applying closing normal tractions, equal to the yield point stress, to the rims of the plastic zones. Since its development, the Dugdale model has been widely used to determine CTOD at the crack tip [5]. In addition, the Dugdale Model has been modified by Harrop [6] for cases where plastic zones are closed by a cohesive normal parabolic stress distribution. Numerical studies of crack tip plasticity in glassy polymers have been carried out by Lai and Van der Giessen [7]. Viola discussed the case of two interacting equal collinear straight cracks in an isotropic elastic unbounded plate [8]. The Dugdale Model was further extended by Theocaris [9] for when two unequal collinear straight cracks, which the plastic zones might develop at the four tips, are separated. Theocaris considered the case in which an infinite plate contains two equal cracks with coalesced plastic zones. Recently, Lu and Chow [10] also modified the Dugdale strip yield model to take into account the influence of a biaxial stress field on the yield condition of the material, such that the role played by the loads applied in a direction parallel to the crack plane is no longer taken as incidental.

In addition, the wide use of structural members made of anisotropic materials necessitates studying their behavior under nearly critical loads. Fracture characteristics of orthotropic plates with a crack are researched in [11,12] using a modified Dugdale Model under biaxial loading. In this paper, a new method is provided for evaluating data which are based on stable crack extension in

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