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Stress intensity factors of various size single edge-cracked tension specimens: A review and new solutions

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ABSTRACT

Non-dimensional geometric correction factor, ß, data for stress intensity factor, K, calculations are generated through finite element analyses and collected from the literature for axially loaded single-edge cracked plates with rotationally free and constrained loaded edges typically used in fatigue crack growth experiments. The solutions are valid for crack length-to-width ratio, a/W, in the range of $0.01 \leqslant a/W \leqslant 0.975$ and plate height-to-width ratio, H/W, in the range of $0.8 \leqslant H/W \leqslant 10.0$. Comparisons are made between the literature reported data and the present effort's results with generally satisfactory correlation. However, differences as large as 12.7% exist for short cracks in small H/W valued plates.

1. Introduction

The use of fatigue crack growth simulations is fundamental in the modern assessment of a structural component's serviceable life. Generation of this vital crack growth rate data falls to the many researchers and labs that have been able to provide tremendous amounts of data for use by analysts. However, the connection between crack growth rate measurements and a fracture mechanics parameter, such as the stress intensity range, ΔK, is undertaken by several different methods [1]. The use of single edge-cracked specimens subjected to tensile loading is commonly desired for use in experimental testing due to its ease of use and minimal amount of material needed in specimen fabrication. Furthermore, there is an additional benefit of having a single crack tip where only the front to back symmetry is of concern. As such, the relationship between pertinent geometric features (e.g. height-to-width (aspect) ratio, H/W), applied loading, and the stress intensity factor, K, at the crack tip is essential.

The aim of the present paper is to collate data from various researchers and present some comparisons and discussion about the applicability of the available data with regards to single edge-cracked monolithic specimens subjected to tensile loading. Numerical results, generated by the author, obtained through an *hp*-version finite element analysis (FEA) program [2] are also presented with comparisons to available solutions.

The primary loading, or boundary condition (BC), investigated here is the Clamped-End scenario. This BC precludes the rotation and lateral contraction of the specimen along the upper and lower edges, which idealizes a uniaxial loading apparatus with friction grips, as shown in Fig. 1. This specimen and loading scenario is referred to as the Modified Single Edge-Crack specimen, MSE(T), as opposed to the SE(T) designation which is commonly used to refer to a similarly designed specimen with uniform applied remote tensile stress and tested in a Pinned-End load fixture. SE(T) solutions for the non-dimensional geometric correction factor, *ß*(a/W), are readily available in the literature [3,4]. The eccentrically-loaded

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Nomenclature

a	crack length
B	plate thickness
CMOD	crack mouth opening displacement
E	Young's (elastic) modulus
H	plate height
K	mode-I stress intensity factor
ΔK	mode-I stress intensity factor range
MSE(T)	modified single edge-cracked specimen under tensile loading
P	remote axial tensile load
SE(T)	single edge-cracked specimen under tensile loading
u	x-direction (transverse/horizontal) displacement
v	y-direction (axial/vertical) displacement
W	plate width
$ß$	non-dimensional geometric correction factor
ν	Poisson ratio
σ	average far-field axial stress

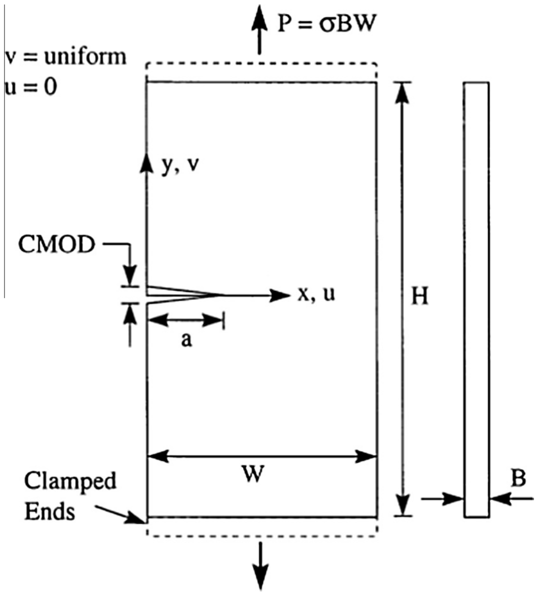

Fig. 1. Schematic and geometric definitions for the MSE(T) specimen.

single edge-crack tension, ESE(T), is another commonly used experimental configuration [1]. The MSE(T) prevents rotation of the specimen, which precludes significant compression at the un-cracked edge and is thus ideally suited for thin specimens.

The total applied tensile force, along the y-direction, P, is used in conjunction with the plate cross-sectional dimensions of width, W, and thickness, B, to determine the average "far-field" axial stress, σ, shown in Eq. (1). Note that the stress distribution can be highly non-uniform for small aspect ratio plates and/or large crack lengths.

This far-field stress, along with $ß$ and the crack length, a, is commonly used to calculate the stress intensity factor, K, through Eq. (2). Here, K refers to the mode-I opening mode, or K_I, stress intensity factor.

$$\sigma = P/BW \tag{1}$$