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A Finite Element Analysis of Notch Effect of Stress Intensity Factor of Mode SE Cracked Specimen

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Abstract

The stress intensity factor is the parameter widely used for quantifying crack growth behavior. This parameter depends on the loads and geometry. A finite element analysis is used to find the effect of notch on the stress intensity factor of a crack in mode I of propagation. The results are compared with the no-notch specimen.

Nomenclature

a	Crack length	H	Specimen height
W	Specimen width	K_I	First mode stress intensity factor
P	Load	σ	Applied stress in far field
β	Non-dimensional geometric parameter		

1. Introduction

A major problem in components with experience cyclic loading during their operation is the fatigue crack nucleation and propagation. In general, the cracks are initiated in the places where the equivalent maximum stress takes place. This is critically important to understand the fatigue crack and its behavior in respect with the loading in order to predict the life of components.

Conventionally, crack propagation rate has been related to stress intensity factor [1, 2]. The bases of Paris law which determines the propagation speed is on the stress intensity factor in the second stage of growth. The are several methods of testing of fatigue crack growth. Fig.1 shows these tests. The specimen which are prepared for crack propagation tests are put in fatigue machines and are subjected to a cyclic load with a defined load ratio. One can track the tip of the moving crack and measure the speed of propagation by derivative of crack tip location in respect with time.

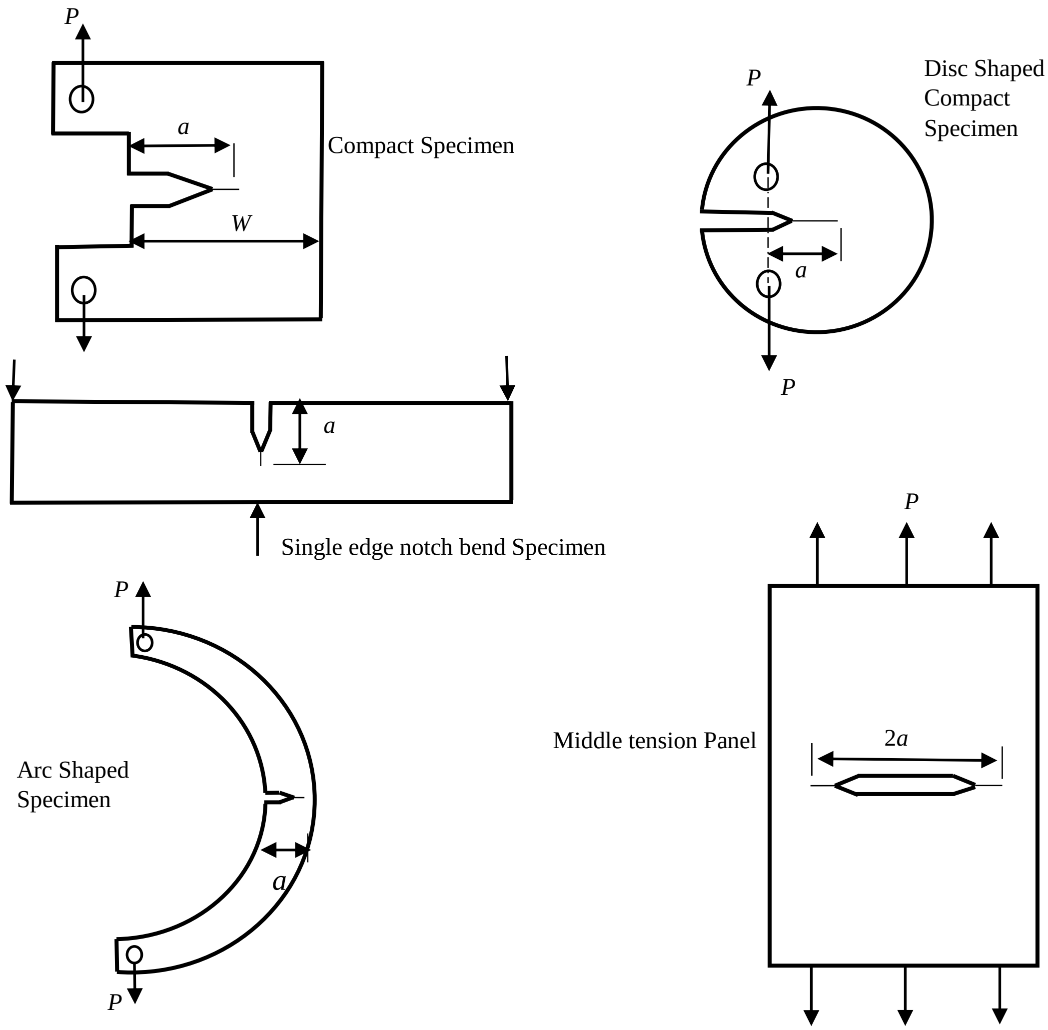

Figure 1. Different types of specimen for crack growth tests.

The crack front experience concentrated filed of stress when loads are applied to the faces of crack (Fig. 1).

The Clamped –End condition where boundary condition precludes the rotation and eliminate the lateral contraction of the specimen between the lower and upper edge. This type of specimen with the discussed boundary condition is called modified single edge crack specimen (MSE(T)). This specimen is illustrated in Fig. 2. which is used for many fatigue crack growth studies [3, 4]

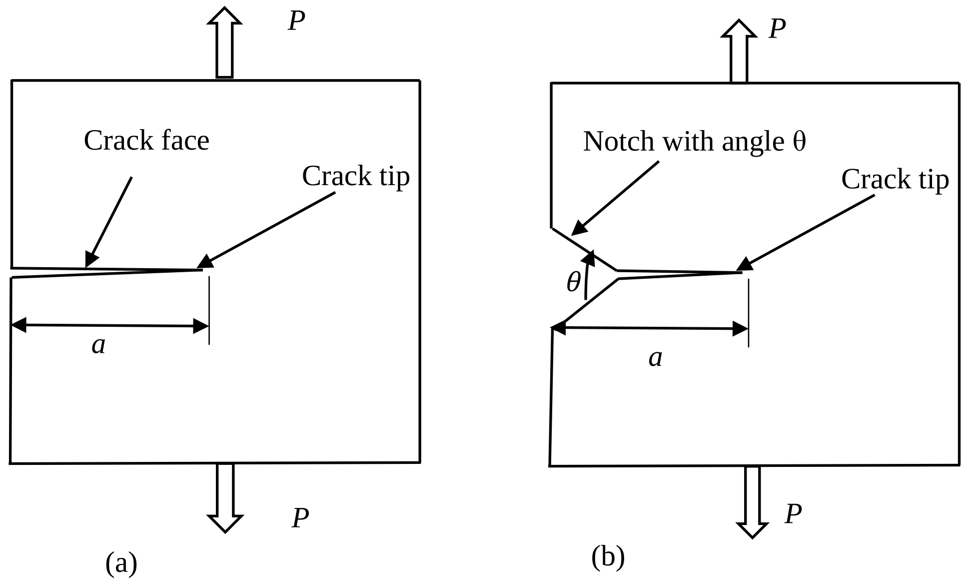

Figure 2. Crack faces loaded in the first mode of crack propagation for MSE(T) (a) without and (b) with notch.

To initiate the crack in the specimen, it is common to cut a notch in center side of the specimen. The stress concentration in the area around the crack is the driving force of the initiation of the crack. As it was mentioned, the geometry and load decides the value of stress intensity factor. This is clear that if the notch changes the geometry and consequently the stress intensity factor (SIF). There are analytical and numerical relation that give SIF as a function of load and geometric parameters. In this study, it is tried to find the notch effect on SIF for a MSE(T) utilizing finite element method. For this purpose, the results are compared with the case where no notch contributes to stress concentration.

If the stress intensity factor is defined by the following relation.

$$K_I = \sigma\beta\sqrt{\pi a} \tag{1}$$

where K_I is the first mode SIF and β is a non-dimensional geometric parameter and a is crack length. The load effect on SIF is reflected through σ which is the stress far away from the crack.

2. Previous studies

There have been several studies concerned the MSE(T) specimen SIF. Marchant *et al.* [5] and Jones [6] where the pioneers in this area. More recently Bassindale *et. al.[7]* and Hammond *et. al.* used the theoretical and numerical methods for determining the KI stress intensity solution. John and Rigling [8] studied height to width ratio on SIF and CMOD of single edge crack. Narasimhachary *et. al.* [9] described a SES for fatigue and creep-fatigue.

2.1. Finite Element Method

Numerical model simulations can be used in variety of researches including material science [10], heat transfer [11], fluid dynamics [12]. In the current research a finite element scheme in ABAQUS is used for determining the stress intensity factor. The mesh used is CPS4R 4-node bilinear plane stress quadrilateral. To minimize the time needed for the calculation, reduced integration method is implemented and deformation of the elements are controlled with hourglass approach.

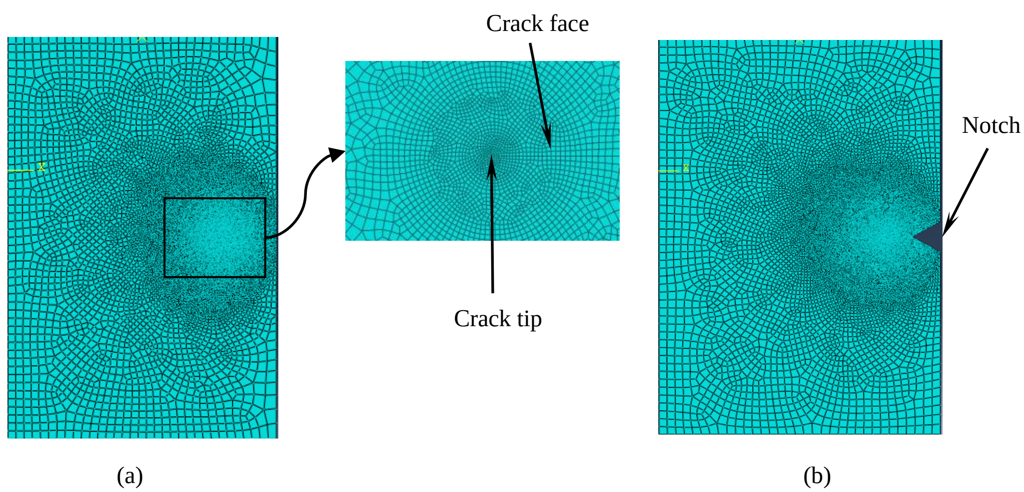

Figure 3. FE mesh of crack MSE(T) (a) without and (b) with notch.

Boundary condition is applied by considering the lower edge pinned. The movement of all nodes in the lower edge are restricted in horizontal and vertical direction. The upper edge where load is applied, is confined to move in the y direction. In order to eliminate the rotation of the upper edge, Multi Point Constraint is applied on the center point of the upper edge.

2.2. Results and discussion

The SIF geometric parameter, β, is shown as a non-dimensional crack length function in Fig. 4. The results are given for three different notch angle $\theta = \frac{\pi}{6}, \frac{\pi}{2}$ and $\frac{3\pi}{2}$. It is seen that in higher values of notch angle, β deviates from the value for no-notch specimen. In all of the cases, β become close to no-notch specimen value as a/w gets larger.

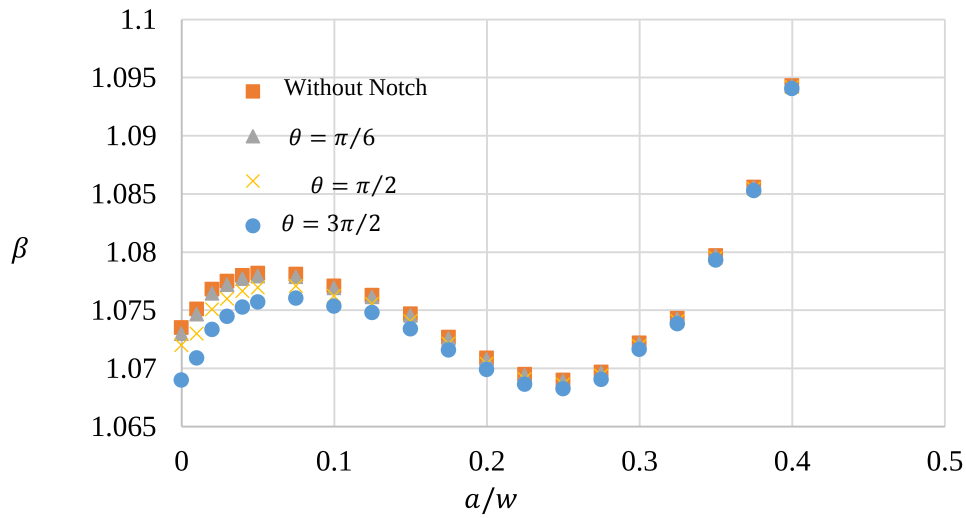

Figure 4. Non-dimensional geometric parameter β as a function of crack length divided by width $\frac{a}{w}$

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