International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE) ISSN: 2349-7947
Volume: 3 Issue: 10 01 - 03

Investigation of the Effect of Change in Center Crack Width on Stress Intensity Factor of Finite Plate

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Abstract—In fracture mechanics, theoretical solutions are presented for idealized cases such as Infinite flat plate with edge crack, central crack and so on. Limitation of these theoretical solutions is that they are very restrictive and lot of assumptions are needed. Finite Element Analysis is widely used tool to determine Stress Intensity Factor (SIF). Mostly cracks initiate at geometric discontinuities (such as weld toes, voids, notches, holes, etc.) that induce large stress. Generally the stress intensity factors depend on the geometry of the workpiece and on loading condition. In this study investigation is carried on central cracked plate of a finite length to investigate effect of different values of crack on stress intensity factor. This paper highlight the effect of crack width on stress intensity factor.

Keywords- *Stress Intensity Factor (SIF), ANSYS, crack width*

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I. Introduction

During the lifecycle of mechanical structures, they subject to unfavorable changes in their structural properties mostly caused due to errors in design and construction, environmental degradation, fatigue, wear and overloads. Metal plates are extensively used in industrial applications. In case of Plate structures, Crack formation and crack growth are highly sensitive and the outcome of this can affect the reliability as well as performance. A stress concentration zone which initiates the crack formation may be notches, holes, and other mechanical defects. Fracture mechanics deals with the study of the propagation of cracks. Various methods of analytical solid mechanics are used to estimate the driving force on a crack and to characterize the material's resistance to fracture. Structural design concepts generally use a strength of material approach for designing a component that does not consider the elevated stress levels because of the existence of cracks. The presence of such stresses can lead to catastrophic failure of the structure. Now a days in materials science, to ensure improvement in the mechanical performance of components fracture mechanics is important. In order to predict the macroscopic mechanical failure of bodies the physics of stress and strain is applied to the microscopic crystallographic defects found in real materials.

II. Literature Review

In recent years, for the estimation of crack fatigue life and propagation, researchers have been made extensive efforts by the development of analytical as well as numerical models. Objective for the researchers is to develop structures with high reliability and crack resistant.

M.H. Gozin, M. et al. discussed plasticity induced crack closure theory. Generally three dimensional finite element method were used by researchers to study the effect of compressive residual stress field on the fatigue crack growth [1]. A. Boulenouar et al. carried out research on a numerical modeling of crack propagation under mixed mode loading conditions. Researcher's implemented the Displacement Extrapolation Method and the strain energy density theory. [2]. Gustavo V. Guinea et al. drawn some considerations related to the influence of arrangement of mesh element size, and shape on numerical values of stress intensity factor by the displacement method [3]. Mxolisi L. Mbandezi et al. investigated the effect of crack geometry on the stress intensity factor in a Thin Plate of finite length. [4]. A.B. de Morais demonstrated that the shear foundation can be rejected, thus permitting a much simpler model implementation of cohesive zone model [5]. De Xiea and Sherrill B. Bigger used an interface element under mixed-mode loading to solve 2D progressive crack growth problems and estimated the strain energy release rates based on the virtual crack closure technique [6].

Crack free materials do not exist in real world. Crack initiate and propagate from the locations of stress and strain concentration. The intensity of the stress field in the crack tip region is given by Stress Intensity Factor. For a center-cracked plate of finite thickness, very few authors contributed to obtain the stress distribution close to the edge of central crack.

III. PROBLEM DEFINATION

Generally cracks develop in the corners of a structural member due to high stress concentration. If rate of stress intensity factor for change in crack width is known to an engineer, he can schedule inspection accordingly and repair or replace the part before sudden failure. Furthermore, predicting the path of a crack helps a designer to incorporate sufficient geometric tolerance in design to increase the part life. In this work, Finite Element Analysis of a finite plate with a central crack by changing the crack width is carried out. Finite square plate with tension on both sides and a center crack is considered. Structural steel is used as material for analysis and is assumed to be linear elastic and isotropic in nature. The material properties for structural steel are given in table 1.properties of structural steel

Material Properties	value
Coefficient of thermal expansion	$\alpha = 12 \times 10^{-6}$/°C
Shear modulus	G= 81,000 N/mm²
Modulus of elasticity	E = 210,000 N/mm²
Poisson's ratio	$\nu = 0.3$

IV. PREPARE ANALYSIS OF CRACK PLATE

The objectives for this FEA is to investigate effect of crack width variation on Stress Intensity Factors for center crack on finite square plate. In this FEA number of elements are maximum at the crack region as compared to non- crack region. Total number of elements are 6511 and total number of nodes are 14109. Fig. 2 shows nodes and elements in crack plate.

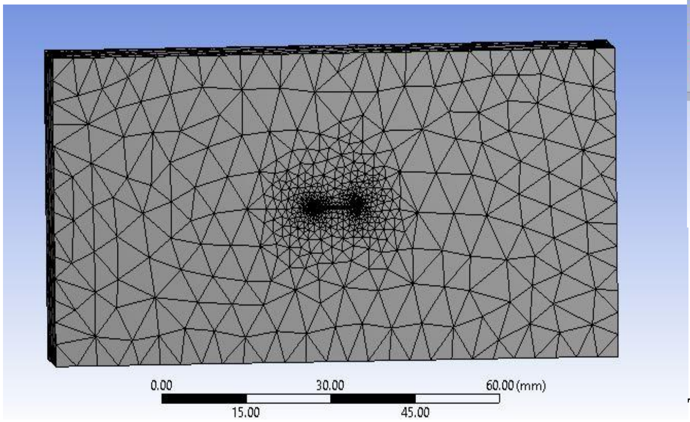

Figure 1. Meshing

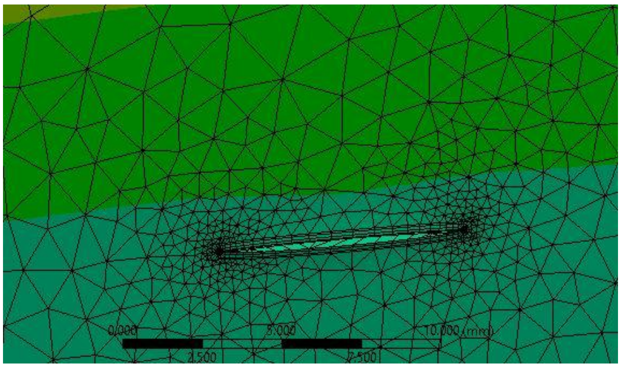

Figure 2. Crack shape after applied load

Pressure of 1000 MPa is applied in vertical direction by maintaining symmetry. Analysis was carried out with variation in width and fixed crack length (4mm) as shown in table 2.

TABLE I. SIF WITH VARIATION IN CRACK WIDTH

Sr. No.	Crack width (mm)	Minimum SIF	Maximum SIF
1	0.5	325.19	1322.2
2	1	944.19	1778.4
3	1.5	1415.6	2032.9
4	2	1705.9	2170.5
5	2.5	1945.2	2248.2
6	3	2120.6	2285.2
7	3.5	2250.2	2376.1
8	4	2287.9	2536.8

Fig 3 shows that stress Intensity Factor is minimum at the center while maximum at the open ends.

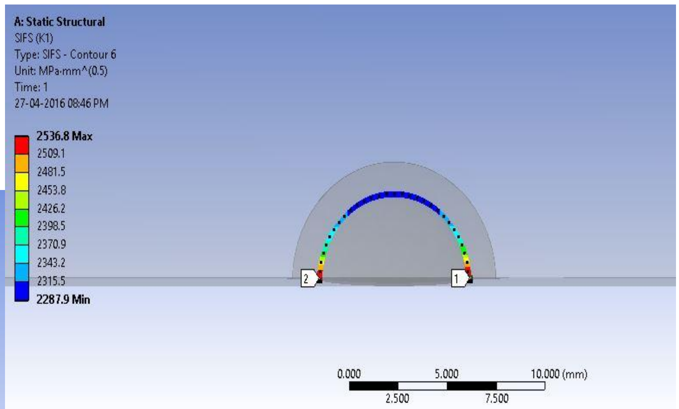

Figure 3. Stress Intensity Factor at various areas of crack

V. RESULT AND DISSCUSSION

Table 2 shows the variation of stress intensity factor. Both maximum and minimum values of Stress intensity factor KI are compared with variation in crack width. Fig 4 shows that with increase in crack width, SIF value increases but at width 3.5

mm both maximum and minimum values are close to each other.

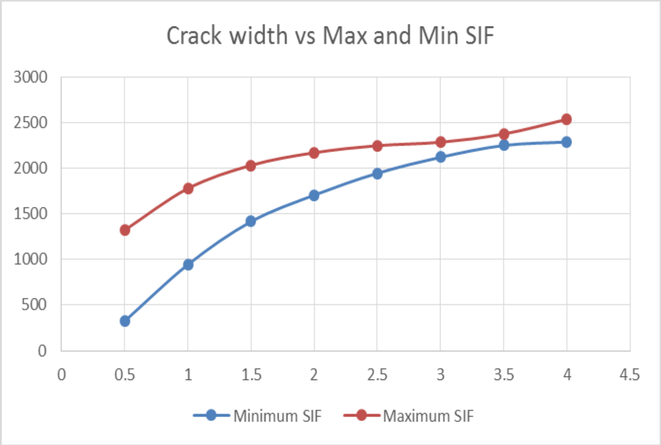

Figure 4. Crack width versus maximum and minimum SIF

VI. CONCLUSION

In this work the ANSYS 16 used for the analysis of static fracture mechanics problem. Stress Intensity Factor was estimated under different crack width conditions. It was found that stress intensity factor increases with increase in crack width. Stress intensity factor is minimum at the center while maximum at the open ends.

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