A Review on Stress Intensity Factor

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Abstract - ***In this paper effort are taken to review on the Stress Analysis of cracked plate for the determination of stress intensity factor near the crack tip. Cracks in plates with different configurations often observed in both modern and classical aerospace, mechanical engineering structure. To understand effect of loading mode and crack configuration on load bearing capacity of such plate is very significant in designing of structure. There are number of Analytical, Numerical, and experimental technique available for stress analysis to determine the stress intensity factor near crack tip under different loading modes in an infinite and finite cracked plate made up of different material. These methods has been reported in this paper. An effort has been made in the present work to present an overview of various techniques developed for stress analysis & stress intensity factor.***

Key Words: *Stress intensity factor, Modes of fracture failure, Methods of stress analysis.*

1. INTRODUCTION

Propagation of cracks in materials are studied with Fracture mechanics. Methods of analytical solid mechanics are being used to calculate the driving force on a crack and those of experimental solid mechanics to characterize the material's resistance to fracture. Strength-of-material approach is generally used for Structural design concepts for designing a component. Due to the existence of cracks this approach does not anticipate the elevated stress levels. Stresses may results in the form of catastrophic failure of the structure under load. Fracture mechanics is an important tool in improving the Mechanical performance of mechanical components. Physics of stress and strain, in particular the theories of elasticity and plasticity is applied to the microscopic crystallographic defects found in real materials in order to guess the macroscopic mechanical failure of bodies. To understand the causes of failures and also verify the theoretical failure predictions with real life failures fractography is widely used with fracture mechanics. The prediction of crack growth is very important in damage tolerance discipline. The objective of fracture mechanics is to determine what conditions will create and drive a crack. Engineers can expertly design against this particular mode of failure by understanding the phenomena of fracture.

2. FRACTURE FAILURE

Consider a cracked plate on which a force is applied which might enable the crack to propagate. Irwin projected a classification matching to the three situations represented in Fig .1. Thus, three distinct modes are considered: mode I, mode II and mode III.

2.1 Modes of Fracture failure

Mode I: In this opening mode, the structure is loaded by tensile forces in such a way that the crack surfaces are pulled apart.

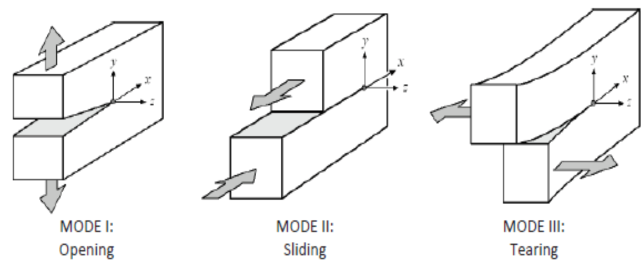

Fig -1: Failure modes of fracture [8]

Mode II: In this sliding mode (In plane shear), the structure is loaded by shear forces parallel to the crack surfaces that slide over each other.

Mode III: In this tearing mode (Out-of-plane shear), the structure is loaded by shear forces parallel to the crack front and the crack surfaces slide over each other.

2.2 Measure of Crack.

Four parameters have been well accepted to measure the potency of a crack.

I. Energy release rate (G)
II. Stress intensity factor (K)
III. J- integral (J)
IV. Crack tip opening displacement (CTOD)

Energy release rate is energy based and is applied to less ductile materials or brittle. The Stress intensity factor is developed for brittle or less ductile materials. J- Integral is developed to deal with ductile material. It formulation is quite common and can be applied to brittle materials also. The Crack tip opening displacement is displacement based which was basically developed for ductile materials.

2.3 Mixed mode crack initiation and crack growth

There is need to characterize the crack under mixed mode loading for conservative fracture based design estimates. In mixed mode condition studies has been carried out in finding crack extension direction, stability of crack path and critical load. To characterize the mixed mode crack many modes were suggested. Basically, the models are proposed based either on energy or stresses.

The Mixed mode crack propagation criteria:

I. Modified Griffith criterion
II. Maximum tangential stress (MTS) criterion
III. Strain energy density (SED) criterion

In the modified Griffith criterion, the theory of energy balance is being extended to include energy release rates related with all the modes. For a crack in a plate exposed to mode I and mode II loading, total energy release rate is given as, ($G=G_I+G_{II}$). As per this Criterion, crack extension occurs in the direction where energy release rate will be maximum and the extension will take place when the maximum energy release rate touches a critical value. It depends on the material considered. Erdogan and sih suggested the maximum tangential stress criterion (MTS) based on a criterion component of stress state reaching a critical condition. As per the SED criterion, crack extension occurs in the direction of minimum strain energy density S (θ) and the extension will occur when the S (θ) reaches a critical value S_C which is a material dependent parameter.

3. METHODS FOR STRESS ANALYSIS

Different approaches used for stress analysis are Analytical, Numerical and Experimental.

3.1 Analytical Approach

Distribution of stresses in a structure with boundary conditions, i.e. displacements and forces on the boundary can be determined by using either the closed form analytical methods or by approximate numerical methods. Boundary value problems can be solved analytically by using constitutive equations based on the elastic or plastic behavior of the material under load. Analytical or close-form solutions can be obtained for simple geometries, constitutive relations and boundary conditions. [1, 2, 3, 4, 5, 6]

Some popular analytical methods:

I. Interaction Energy Integral Method
II. Critical Plane-Based Multi axial Fatigue Theory
III. Element Free Galerkin Method
IV. Non-linear Regression Analysis

3.2 Numerical Approach

In Numerical Approach Following Method are important

I. Boundary Collection
II. Finite difference
III. Finite Element

Finite Element method is based upon discretization of material surface into several solid elements. Displacements at boundaries of adjacent element are matched to define the shape of deformed body by assuming distribution of stress over the element. Stiffness matrix is used to calculate the stresses. In recent years, with the advent of advanced software's, the FEA based software like ANSYS, have been very useful for stress analysis. These software's are chosen by users according to the type of elements to be analyzed, type of stress analysis, and the depth of accuracy required.

3.3 Experimental Approach

Among the experimental method three have gain popularity, these methods are

1. Photo elasticity:

Photo elasticity involves the use of light (photo) and elastically stresses model. This method was earlier used for plane bodies of complicated shape and geometries, mostly for the reason that such geometrical shapes were not amenable to mathematical analysis. It is an experimental method for measurement of stress and strain in which light is either reflected from the surface of loaded body or passed through a model. Model made by Photo elastically preferred in situation where and strain information is required over extended region, therefore whole field method. For measuring the magnitude and direction of principal stresses Stress analysis is an important technique. When polarized light is passed through a stressed transparent model, interference patterns in the form of fringes are formed. Qualitative information can be gathered about the general distribution of stress, locations of stress concentrations and of areas of low stress using referring the principals of stress optic law. [5]

2. Brittle Coating:

A brittle coating is a material forming a thin layer on a base material, brittle in nature mainly with respect to base material. The coating may crack when the body is subjected to certain minimum stress due to the brittle nature. It is a Non-destructive technique applicable on machine part to be analyzed in actual situation. Many types of coating material like Glass-Lacquer, Strained, and Stress coat are available for this application. Coating is generally air sprayed onto the part. Thickness of coating is maintained uniform in the range of 0.05 to 0.2 mm. Most of the time the coating is often dried at room temperature [8]

3. Electrical Strain Gauges:

The electrical resistance strain gauges is reliable of all the tools of experimental stress analysis. It works on the principle electrical resistance of a conductor changes proportionally to any strain applied to it. Short length of wire bonded to the structure in such a way that it experiences the same deformation as the structure, then strain can be obtained by measuring the change in resistance [9]

4. CONCLUSIONS

In the recent past, many researchers have been used analytical solutions for the determination of stress intensity factor with some Numerical and experimental validations. An analytical solution used by researchers includes Interaction energy integral method, Critical plane-based multiaxial fatigue theory, Muskhelishvili's complex potentials formalism and conformal mapping, Element Free Galerkin Method those give solutions for mode-I and mode-II loading.

In this paper an effort is taken to review the stress analysis of cracked plate with different crack configurations. An effort has been made in the article to present an overview of various techniques developed for stress analysis of infinite and finite cracked plate.

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