THE ANALYSIS OF STRESS INTENSITY FACTOR IN A PLATE WITH DIFFERENT TYPES OF CRACKS USING BOUNDARY ELEMENT METHOD

By

Osama Elsayed Gamea Abdlsamea

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Engineering Mechanics

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

The analysis of stress intensity factor in a plate with different types of cracks using boundary element method

Key Words:

Boundary element method; Stress intensity factor; Singular stress element;

Summary:

In this thesis we use the multidomain boundary element method to study the stress intensity factor around an inclined crack in a plate under uniform static tension. We study the variation of the stress intensity factor with two parameters; the inclination angle of the crack, and the crack width. A singular stress element is used beside the crack to represent the singularity of stress at the crack tip.

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Nomenclature

u,v	The displacement components in x and y directions
ε	Strain component
σ	Stress component
λ,μ	Lame constants
G	Modulus of rigidity
τ	Shear stress component
ʒ,η	Orthogonal coordinates
K_I	Stress intensity factor mode I crack
T	Stress fundamental solution
Γ	Boundary of the problem
Ω	Domain of the problem
r	Vector connecting source and influence points
U	Displacement fundamental solution
b	Body forces
δ	Dirac delta function
N	Shape function
E	Modulus of elasticity
ν	Poisson ratio
β	The inclination angle of a crack between the crack and loading directoin
ϕ,ψ	Components of the Galerkin vector ($\underline{G}$)

Abstract

In this thesis we are going to use the boundary element method to analyze the stress intensity factor, deformation and stress distribution in a plate with an inclined crack of linear homogenous media. First we derive the equations used in the boundary element method. The approach depends on the reciprocal identity of work of Betti.

In this approach we reach the famous identity of reciprocity. This identity relates the displacement at a point with the values of tractions and displacements on the whole domain.

The domain can be discretized into sub regions. This case is forced in some situations. One is in crack problems to avoid the double definition at the same point that causes singularity.

Constant, linear, quadratic and higher order elements can be used to discretize the boundary. For good results quadratic elements are used. We present the quadratic element used in discretizing the boundary to apply the boundary integral equations on it.

Normal quadratic elements can be used to solve elastostatic problems with good accuracy. But in the case of crack presence the normal quadratic elements fail to fully present the variation of stresses and displacements in the line with cracks. A special singular element is used. The midpoint of the element is relocated in the quarter length of the element. Using this element at the crack tip provides a good representation of the stress distribution.

A brief introduction of linear elastic fracture mechanics is also presented. The definition and the evaluation of stress intensity factor are presented. The analytical solution of fracture elastostatic problems is very consuming.

After discretizing the boundary, a system of algebraic equations is generated. Boundary conditions are then introduced. The solution of this system using gauss

elimination method gives the unknown values of tractions and displacements on the boundary.

A program was written to solve both single and multidomain problems. To verify its results a number of problems were solved and accurate results were obtained compared to the exact solution.

The stress intensity factor was evaluated by using extrapolation method for different types of cracks and different loading types. Satisfying results are obtained compared to linear elastic fracture solution.

Chapter 1: Introduction

The failure of mechanical structure is considered a field of great importance. The failure of bridges, steel structures, tunnels, airplanes and others took a lot of research to avoid such catastrophes [1]. These accidents may cause a big number of deaths and have a disastrous effect on the companies' names related. Many theories appeared to explain the possible reasons that caused failure in structures. The most common causes for such failures fall onto the following categories:

1- Faults during design, construction or operation of structures.
2- New materials and modern designs which are tried recently.

The first cause greatly depends on humans and can be neglected by good practicing. Although modern designs and materials can have great advantages they can also hide catastrophic behavior. So, any new design or material should be put under sever and various testing conditions to be approved in any application.

A common result of using new designs and materials is the occurrence of brittle fracture in structures. Great efforts were exerted to save lives and damage to property that resulted from failures of such fractures. Fracture mechanics helps to prevent both causes of structure failures.

A great progress was achieved in the 1960s when the fundamentals of linear elastic fracture mechanics (LEFM) appeared and researchers focused on the stress concentration at the crack-tip. Researches started to deal with this stress concentration issue. In the past when a material is selected for a certain design, the material was assumed suitable if its strength is greater than the expected applied stress. This approach could resist brittle failure with the use of safety factor on stress. In fracture mechanics two factors are considered to avoid brittle fracture. These factors are flaw size and fracture toughness which replaces material strength.

There are two approaches to fracture analysis, the energy criterion and the stress intensity approach. The energy approach says the failure happens when the available energy for crack growth is enough to overcome the material strengths (surface energy, plastic work, etc...). Griffith and Irwin developed the present version of this approach.