STRESS INTENSITY FACTOR INVESTIGATION ON CRACK SIMPLE I-BEAM USING FINITE ELEMENT ANALYSIS

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B091910326

BACHELOR OF MECHANICAL ENGINEERING (MAINTENANCE TECHNOLOGY) (BMMM) WITH HONOURS

2022

Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering (Maintenance Technology) (Bmmm) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this Choose an item. entitled “ Stress Intensity Factor Investigation On Crack Simple I-Beam Using Finite Element Analysis ” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering (Maintenance Technology) (Bmmm) with Honours.

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DEDICATION

This thesis is dedicated to those who have helped me during my academic career. Thank you for forcing me to complete this adventure.

ABSTRACT

Stress intensity factor value has become a most essential value in engineering aspect and also in our daily life because of its contribution in a lot of industries. Crack is a very common phenomena and it can be observed in our daily life. In order to get a sound understanding of the crack that has occurred on a plate or a beam in any industry, the mode of fracture causing the crack and also the stress intensity factor value of the crack need to be obtained. In this thesis, a specimen has been selected and the crack on the specimen has been studied. Simple I-beam specimen made up of mild steel has been selected as the specimen in this research. Simple I-beam has been selected because it is widely used in many industries because of its application that can reduce the manufacturing and shipping costs in a significant way. Mild steel has been selected as the type of material of the simple I-beam because steel is a commonly used as ductile known for its versatility and its strength.Calculation on the selected specimen according to its own dimension has been carried out because every simple I-beam will have its very own dimension.Therefore, calculation of certain values of the specimen prior to the stress intensity factor value estimation need to be done. There are several methods of estimating the stress intensity factor value of a crack and finite element analysis is chosen because it gives a better accuracy and a better visualization of the crack that has occured. Stress intensity factor value estimation for different sizes of crack subject to bending on the simple I-beam specimen has been identified through the finite element analysis of calculation using the Finite Element software. The values obtained are then tabulated to compare and analyse. SIF values against the different sizes of crack subject to bending has been plotted and compared against the SIF value graphs obtained in the engineering books or articles.

ABSTRAK

Nilai faktor intensiti tekanan telah menjadi nilai yang paling penting dalam aspek kejuruteraan dan juga dalam kehidupan seharian kerana sumbangannya dalam banyak industri. Retak adalah fenomena yang sangat biasa dan ia boleh diperhatikan dalam kehidupan seharian kita. Bagi mendapatkan kefahaman yang kukuh tentang rekahan yang telah berlaku pada plat atau rasuk dalam mana-mana industri, mod keretakan yang menyebabkan rekahan dan juga nilai faktor keamatan tegasan retak itu perlu diperolehi. Dalam tesis ini, satu spesimen telah dipilih dan rekahan pada spesimen telah dikaji. Spesimen rasuk I ringkas yang diperbuat daripada keluli lembut telah dipilih sebagai spesimen dalam penyelidikan ini. I-beam telah dipilih kerana ia digunakan secara meluas dalam banyak industri kerana aplikasinya yang boleh mengurangkan kos pembuatan dan penghantaran dengan ketara. Keluli lembut telah dipilih sebagai jenis bahan rasuk I ringkas kerana keluli biasa digunakan sebagai mulur yang terkenal dengan fleksibiliti dan kekuatannya. Pengiraan ke atas spesimen yang dipilih mengikut dimensinya sendiri telah dijalankan kerana setiap I mudah -rasuk akan mempunyai dimensinya yang tersendiri.Oleh itu, pengiraan nilai tertentu spesimen sebelum anggaran nilai faktor intensiti tegasan perlu dilakukan. Terdapat beberapa kaedah untuk menganggar nilai faktor keamatan tegasan retakan dan analisis unsur terhingga dipilih kerana ia memberikan ketepatan yang lebih baik dan visualisasi yang lebih baik bagi retakan yang telah berlaku. Anggaran nilai faktor keamatan tegasan untuk saiz retak yang berbeza tertakluk kepada lenturan pada spesimen rasuk-I ringkas telah dikenal pasti melalui analisis unsur terhingga pengiraan menggunakan perisian Elemen Terhingga. Nilai yang diperoleh kemudiannya dijadualkan untuk membandingkan dan menganalisis. Nilai SIF terhadap saiz retak yang berbeza tertakluk kepada lenturan telah diplot dan dibandingkan dengan graf nilai SIF yang diperoleh dalam buku atau artikel kejuruteraan.

ACKNOWLEDGEMENTS

The Most Gracious, the Most Merciful

First of all, I would like to thank my Creator and my supporter, Allah Almighty, for everything I have received from the beginning of my life. Second, I thank my beloved mother Nagaratinam A / P Veerappan Chettiar and my father Sangar Raj A / L Many Chettiar for their endless support, love, and prayer.

Thanks to Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform. A big thank you to my main supervisor, Dr. Setyamartana Parman, Universiti Teknikal Malaysia Melaka (UTeM), all his support, advice and inspiration. His lasting patience for leadership and the provision of valuable insights will be remembered forever.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
h	-	Height, mm
t_{Max}	-	Maximum Thickness, mm
r	-	Stress intensity domain
i	-	Stress x Length
K	-	Stress intensity factor
$\sigma\infty$ and α	-	The severity of the stress state at the crack tip
σ	-	Far-field stress
a	-	Half length of the crack
W	-	Width
M	-	Bending moment
d	-	Web thickness
t	-	Flange thickness
B	-	Flange width
M_a	-	Additional bending moment
Ac	-	Area of un-cracked surface
I_C	-	Moment of inertia for I-beam
P	-	Load

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

The stress intensity factor (SIF) plays an important role in the practical application of the principles of linear elastic fracture mechanics (LEFM). Very useful for assessing the security and reliability of cracked machines and parts. This principle allows you to calculate the crack length rate of components under fatigue loads and stress corrosion. There are several ways to determine the value of the stress intensity factor: B. Numerical method 1 or analytical method. Analytical methods for analyzing stress intensity factors are also available, including complex stress functions, equivalent stress, total deformation (Sneddon and Lowengrub 1969; Sneddon 1973), Green's function methods, and weighting function-based approaches. Numerical methods are very widely used because of their versatility and ease of use because they can handle complex shapes. The three most important numerical methods are the finite element analysis (Wilson 1973; Atluri 1986), the finite element analysis (Aliabadi, Rooke and Cartwright 1987; Cruse 1996; Mukhopadhyay, Maiti and Kakodkar 2000; Rabczuk 2013), and the gridless method (Aliabadi, Rooke and Cartwright 1987; Cruse 1996; Cruse 1996; Rabczuk 2013). Belytschkoetal .1996; Atluri and Zhu 1998). Experimental methods include strain gauge-based methods (Dally and Sanford 1987), photoelasticity (Kobayashi 1975; Dally and Riley 1991; Ramesh 2000), and caustic methods (Theocaris and Gdoutos 1976; Theocaris 1981; Rosakis and Zehnder 1985). included. In addition, the stress field near the crack tip of the elastic body can be specified by the stress intensity factor, which is closely related to the stress specificity generated by the crack tip.

Meanwhile, the use of special finite elements, including the exact pattern of stress specificity at the crack tip, was proposed by Byskov Rao and his colleagues and Pian and his colleagues. The work of the author's last group is based on the concept of hybrids. In this study, we propose a new method based on superposition of analytical and finite element solutions as an efficient tool for analyzing stress around cracks. Assuming linear elasticity, the stress in the domain can be represented by the sum of the two parts, the first part is called the "analytical part", which has a stress singularity at the crack tip and can be specified in the analytical form. .. The second part, called the "residual part", on the other hand, is regular over the range and can be calculated with sufficient accuracy using the traditional finite element method. The singularity of the stress field at the crack tip can be determined from the analytical part of the solution that provides the stress intensity factor. The analysis part can be determined within some constants that can be obtained using the simple formulas presented in this paper. For simplicity, body force is ignored and the so-called out-of-plane shear mode of the singularity is not considered in this task. In most cases, obtaining an accurate solution for estimating the stress intensity factor of a cracked object is very difficult, if not almost impossible. Therefore, to calculate the intensity, you need to use the approximate numerical method. In this paper, we show that the finite element method is one of the numerical methods that can be used to estimate the stress intensity factor value of a cracked body. The specific approach used in this paper is an extension of the previously presented method for calculating the Mode I stress intensity factor K1 for planes under in-plane load. Only the bending strength factor KB is considered here. In other words, expanding the shear strength factor requires only minor changes.

The software of the I-beam shape can drastically lessen production and transportation costs. This is due to the fact I-beams have a selected cross-sectional profile. This approach that simple I-beams require much less cloth withinside the production system than strong beams. In addition, simple I-beams have extra capability for bending pressure, however are especially lighter than different beams. The foremost benefits of the usage of the I-beam shape are its awesome power and stiffness-to-weight ratio (Camotim et al., 2010; Keykha et al., 2015; Sudhirsastry et al., 2015; Lanc et al., 2015. Huang and Zhang, 2018). The I-beam is fabricated from a completely skinny plate and has a cross-sectional profile much like the letter "I". In the article, Kuangetal (1984) concluded that I-beams with a height-to-thickness ratio of fifty or extra may be described as simple beams.Simple I-beam could be very clean to fabricate and alter in step with purchaser requirements. Simple I-beams are normally crafted from sheet steel beams with a skinny profile. Thin plates may be shaped into an I-fashioned thin beam the usage of a welding system. Therefore, Simple I-beams have awesome layout flexibility to maximise load bearing and production cloth benefits, and this observe analyzes the pressure depth element values of cracked I-beams used as a probe for bending and axial anxiety are the principle body.

1.2 Problem Statement

Previously, the available method to identify the stress intensity factor on a simple I-beam is a long numerical method or mathematical calculation which takes up a lot of our time and energy. The mathematical calculation might not give us the accurate reading because we might make mistakes while doing the manual calculation.

Therefore, an economical approach and online method to identify the stress intensity factor on a simple I-beam is required. This simulation approach or computational method should be used because it will be able to decrease the time and energy spent in order to calculate the SIF value on a cracked body. Each mode of fracture on a simple I-Beam will have an associated stress intensity factor values and by using this online method, we will be able to identify the SIF values by just interpreting the data and graphs we obtain instead of doing a long numerical calculation using the formulae and coming up with a graph manually depending on its mode of fracture and type of crack on the specimen.

1.3 Research Objectives

a) To evaluate the Stress Intensity Factor (SIF) of the cracked I-beam under four point bending using finite element analysis.

b) To compare the Stress Intensity Factor (SIF) result with other research work.

1.4 Scope of Research

The scope of this research are as follows:

1. Identification and calculation of stress intensity factor values on a simple I-beam specimen made up of steel through finite element analysis method of calculation using Finite Element software.

2. Study on single edge crack through mode 1 fracture on a simple I-beam specimen made up of steel will be carried out.

3. Development of SIF graphs using Finite Element software to compare and analyses against the graphs obtained from the ones published in engineering books.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Stress intensity factor (SIF) plays a vital role in the practical application of the principles of linear elastic fracture mechanics (LEFM). It is very useful in assessing the safety and reliability of cracked machines and parts. This principle allows us to calculate the crack length rate of components under fatigue loads and stress corrosion. Safety assessment requires two things which are SIF that corresponds to the stress of the part, and also crack of the material. There are several ways in identfying the stress intensity factor values such as numerical 1 method or experimental technique. There are also analytical methods available in order to analyse the stress intensity factor that includes complex stress functions, limit selection methods, integral transform methods (Sneddon and Lowengrub 1969; Sneddon 1973), Green's function methods, and weight function-based approaches. Numerical methods are very widely used because of their versatility and easy to use which they can handle complex shapes. The three main numerical methods are the finite element method (Wilson 1973; Atluri 1986), the boundary element method (Aliabadi, Rooke, and Cartwright 1987; Cruse 1996; Mukhopadhyay, Maiti, and Kakodkar 2000; Rabczuk 2013), and the gridless method (Belytschkoetal. 1996; Atluri and Zhu 1998). Experimental methods include strain gauge-based methods (Dally and Sanford 1987), photoelasticity (Kobayashi 1975; Dally and Riley 1991; Ramesh 2000), and caustic methods (Theocaris and Gdoutos 1976; Theocaris 1981; Rosakis and Zehnder 1985).

Besides, the stress field near the crack tip of an elastic body can be specified by the stress intensity factor, which is closely related to the stress specificity generated from the crack tip. However, these singularities cannot be accurately represented by traditional finite element models.

This task proposes a new method for analyzing stress around cracks based on the superposition of analytical and finite element solutions. This method has been applied to some 2D problems where the solution is analytically obtained, and its numerical results have been shown to be very consistent with the analysis results. Sufficiently accurate results can be obtained by the conventional finite element analysis with rather coarse mesh subdivision.

However, computational efforts are then considerably reduced compared with other methods due to its digital value in the method which may sound very complicated to use but it is rather one very easy and simple way in analysing the stress intensity factor value on a cracked body. Many papers have dealt with the application of the finite element method for evaluating the stress intensity factors. In these papers finer mesh subdivision or the use of higher order elements are commonly adopted near crack tips in order to approximate the stress singularities, but it does not seem to be effective in comparison with necessary efforts. The displacement method, which is based on the comparison of the displacement value of the crack opening and the theoretical value of will not give accurate results unless the tip of the crack is covered with a fine mesh compared to the length of the crack. The energy method, which is based on the relationship between the energy release factor and the stress intensity factor, can be used to subdivide relatively coarse meshes, but it can be applied to a limited number of problems. The traditional finite element method is used for both methods. Meanwhile, the use of special finite elements, including the exact pattern of stress specificity at the crack tip, was proposed by Byskov Rao and his colleagues and Pian and his colleagues. The work of the author's last group is based on the concept of hybrids. In this study, we propose a new method based on superposition of analytical and finite element solutions as an efficient tool for analyzing stress around cracks. Assuming linear elasticity, the stress in the domain can be represented by the sum of the two parts, the first part is called the "analytical part", which has a stress singularity at the crack tip and can be specified in the analytical form. The second part, called the "residual part", on the other hand, is regular over the range and can be calculated with