FATIGUE CRACK GROWTH ANALYSIS OF STAINLESS STEEL UNDER MODE I

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FACULTY OF MECHANICAL ENGINEERING

We certify that the project entitled "*Fatigue Crack Growth Analysis of Stainless Steel under Mode I*" is written by *Ahmad Azam Azizan Bin Azlan*. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering.

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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LIST OF SYMBOLS

u	Displacement
f	Force
B	Thickness
W	Width
P	Pressure
a	Area
K_I	Stress Intensity Factor
N	Number of Cycles
σ	Stress
$\Delta\sigma$	Stress Range
$\frac{da}{dN}$	Crack Growth Rate

LIST OF ABBREVIATIONS

FCG	Fatigue Crack Growth
SAE	Society of Automotive Engineers
SIF	Stress Intensity Factor
CT	Compact Tension
FEA	Finite Element Analysis
CAD	Computer Aided Design
CPU	Central Processing Unit
TET	Tetrahedral
RAM	Random Access Memory
DOF	Degree-of-freedom

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ABSTRACT

Stainless steel is widely used in the industries nowadays due to their good properties of resistance to corrosion and rust. Due to its application in many industries, an analysis of fatigue crack growth was carried out to study the effect of stress ratio. The study of fatigue crack growth is important since fatigue has become a critical issue in industries that plague any structures that is subjected to cyclic and variable loading. A necessary analysis of fatigue crack growth need to be done to study the behaviour of fatigue crack growth. The effect of stress ratio on fatigue crack growth can affect the behavior of fatigue crack growth. In the project, three different stress ratios were used to investigate the effect of stress ratio towards crack growth. As the stress ratio increase, the stress intensity threshold and fracture toughness will decrease. This shows that an increasing stress ratio will lead to material failure. This happens when the stress intensity factor has entered the critical region where it exceeds the fracture toughness value. To remain the material unbroken or fail, the stress intensity factor value must not exceed the value of stress intensity threshold where below the stress intensity threshold value, the material remains stable. An analysis of fatigue crack growth was done using MSC software where the stress analysis is done using MSC PATRAN and MSC NASTRAN. After the results of stress analysis were obtained, the analysis of fatigue crack growth with different stress ratio was done using MSC FATIGUE software. Life prediction of the material is determined using Modified Paris Law equation of Fracture Mechanics. At certain level of stresses, below the endurance limit of the material, the effect of stress ratio does not affecting the life of the material. This is because the stress is not big enough to break the material.

ABSTRAK

Keluli tahan karat banyak digunakan dalam industri masa kini kerana ciri-ciri baik ia terhadap ketahanan kakisan dan karat. Disebabkan kegunaan ia dikebanyakan industri, ujikaji pertumbuhan retak lesu ini dilakukan untuk mempelajari pengaruh nisbah tegasan. Kajian tentang pertumbuhan retak lesu adalah penting kerana kelesuan telah menjadi isu penting dalam industri yang berlaku pada setiap struktur yang dibebani oleh beban sama berulang kali dan beban yang tidak menentu. Satu analisis penting daripada pertumbuhan retak lesu perlu dilakukan untuk mengkaji sifat pertumbuhan retak lesu. Kesan nisbah tegasan terhadap pertumbuhan retak lesu boleh mempengaruhi sifat pertumbuhan retak lesu. Didalam projek ini, tiga nisbah tegasan yang berbeza digunakan untuk mengetahui pengaruh nisbah tegasan terhadap pertumbuhan retak lesu. Apabila berlaku peningkatan nisbah tegasan, keamatan tegasan ambang dan kekuatan patah akan berkurangan. Hal ini menunjukkan bahawa nisbah tegasan meningkat dan akan mengakibatkan kegagalan bahan. Hal ini terjadi ketika faktor keamatan tegasan telah memasuki kawasan kritikal di mana ia melebihi nilai kekuatan patah. Untuk mengekalkan bahan itu tidak patah atau gagal, nilai faktor keamatan tegasan tidak boleh melebihi nilai keamatan tegasan ambang dimana ia berada dibawah nilai keamatan tegasan ambang dan bahan itu akan sentiasa stabil. Kajian pertumbuhan retak lesu dilakukan menggunakan perisian “MSC” di mana analisis tegangan dilakukan dengan menggunakan “MSC PATRAN” dan “MSC NASTRAN”. Setelah hasil analisis tegangan diperolehi, analisis pertumbuhan retak lesu dengan nisbah tegasan yang berbeza akan dilakukan dengan menggunakan perisian “MSC FATIGUE”. Jangka hayat bahan akan ditentukan menggunakan persamaan “Modified Paris Law” oleh Mekanik Patah. Pada peringkat tertentu tegasan, di bawah batasan daya tahan bahan, pengaruh nisbah tegasan tidak menjejaskan jangka hayat bahan. Hal ini kerana nilai tegasan tidak cukup besar untuk mematahkan bahan itu.

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Fatigue crack growth (FCG) analyses of stainless steel under mode I or under axial loading with different stress ratio, R were carried out using MSC FATIGUE. Stainless steel is widely used in medical equipment, sculptures, building facades, building structures and some automotive manufacturers due to their good properties and mostly it does not stain, corrode, and rust easily as ordinary steel.

An analysis of fatigue crack growth was conducted on compact tension specimen, using MSC FATIGUE interface. A necessary solution parameter is being measured to define the condition of the analysis. Stress intensity threshold and fracture toughness are to be determine for different stress ratio, R. Stress analysis were carried out using MSC PATRAN and solved by solver MSC NASTRAN.

Stress is a parameter need to be measured in this project. Stress allows this project to get a fair comparison of the effects of a force on different samples of a material. A tensile force will stretch and, possibly, break the sample. However, the force needed to break a sample will depend on the cross sectional area of the sample. If the cross sectional area is bigger, the breaking force will be bigger. However, the breaking stress will always be the same because the stress is the force per unit area. For fatigue analysis, a different load is applied to the specimen that will give different results of life cycles before the specimen fails. Meanwhile, further analyses on FCG are required to study the crack growth behavior of stainless steel.

Different R ratio gives the different results of crack growth and stress intensity threshold and fracture toughness to be determined. As if the value nearer to the original fracture toughness of steel, it is the better or we can simply say that our analysis is rectify. When conducting the analysis, the mesh density is an important parameter that needs to be manipulated. By giving different mesh density to the boundary condition area, the higher mesh density, the accurate the results will be. The mesh density indicates the size of the elements in relation to the size of the body being analyzed. The mesh density need not be uniform all over the body. There can be areas of mesh refinement (more dense meshes) in some parts of the body. Making the mesh finer is generally referred to as h-refinement. Making the element order higher is referred to as p-refinement.

1.2 PROJECT OBJECTIVES

The main objective of this project is to analyze the fatigue crack growth of stainless steel under an axial loading with different stress ratio, R. A load is applied to the model to investigate the propagation of the crack and its behavior and the necessary parameter are to be defining the fatigue growth of steel. The second objective is to predict the life cycle of the model for stainless steel using Modified Paris Law equation of Fracture Mechanics analysis.

1.3 PROBLEM STATEMENT

Fatigue is the biggest issue in industry that cause failure in civil structure such as bridge trusses, building structures and trusses, and railway for train in city. It is still new to the industries where they facing the problem in structure failure. The studies of fatigue are still on the beginning where many factors are to be considered in designing and constructing structure such as stress ratio, stress range and mean stress. Fatigue failure also has been a critical issue in automotive industry that occur in many mechanical parts motion for example, connecting rod, crank shaft, gearing system, and mechanical tools. The study of fatigue crack growth is important in engineering sector to overcome the problem that has occurred for over a century. This is important because many engineers did not consider the fatigue failure in designing any engineering

structure. The study of fatigue crack growth will helps in engineering sector to maintain the structure for a long period of time before it fails. Therefore, it also can reduce the cost of maintenance for structure. Fatigue crack growth also leads to development of new materials that has high fracture toughness that can be used in many industries and also important to the country developments.

1.4 SCOPES OF PROJECT

The scopes of the project are:

(i) Fatigue analysis under mode I loading.
(ii) Stress analysis using MSC PATRAN and solver MSC NASTRAN.
(iii) Three different stress ratios.
(iv) The model used is standard Compact Tension (CT) specimen.
(v) Fatigue analysis using MSC FATIGUE.

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