INVESTIGATE THE DELAY OF CRACK USING STOP DRILLED HOLES ON MILD STEEL

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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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Date: November 2009

STUDENT'S DECLARATION

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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I humbly dedicated this thesis to

my lovely mom and late father, Rosni Binti Jaafah and Razi Varathau Rajoo Bin Abdullah
my dearest brothers, Fadzli and Faidzal
my dearest sisters, Rosfazilah and Rosfazidah

who always trust me, love me and had been a great source of support and motivation.

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ABSTRACT

Many failures in engineering applications or machine components have been caused by a crack initiated from points at which stress was concentrated. As the stress concentration level is higher than a critical value, continuous crack-growth results in failure in the machine components. Crack initiation behavior has been evaluated to prevent an early failure of machine equipment. Delaying the crack initiation is important for the maintenance of machine elements as well as for the detection of crack initiation. Hence, the main objective of this study is to investigate the delay of crack using stop drilled holes. The investigation was based on the diameter of the stop drilled holes and the arrangement of the stop drilled holes. Both experiment and finite element analysis were done in order to validate the result. The experiment was carried out by using tensile test to obtain maximum applied load to the specimen while the finite element analysis was analyzed by using ALGOR V22 software to obtain the stress of the specimen. The experimental results and the finite element analysis results show that the crack initiation life of the specimen was longer when the diameter of the stop drilled holes increased. The further the location of the stop drilled holes with the slits location, the longer crack initiation life of the specimen. Thus, the influence of the stop drilled holes on the crack initiation life has been evaluated.

ABSTRAK

Kebanyakan kegagalan di dalam bidang kejuruteraan dan komponen mesin adalah disebabkan permulaan retak yang bermula dari titik di mana tekanan tertumpu. Apabila paras penumpuan tegasan adalah lebih tinggi daripada nilai kritikal, kesinambungan keretakan akan menyebabkan kegagalan dalam komponen mesin. Sifat permulaan retak telah dinilai bagi mencegah kegagalan awal dalam komponen mesin. Melambatkan permulaan retak adalah penting bagi tujuan penyeliaan elemen-elemen di dalam mesin. Maka, objektif utama kajian ini adalah untuk mengkaji kelambatan permulaan retak dengan menggunakan penahan lubang yang ditebuk ke atas besi lembut. Kajian adalah berdasarkan diameter dan susunan penahan lubang. Eksperimen dan juga analisis *finite element* telah dijalankan bagi tujuan mengesahkan keputusan ujikaji. Eksperimen telah dijalankan dengan menggunakan mesin tegangan untuk mendapatkan daya maksimum yang dikenakan ke atas specimen manakala analisis *finite element* dianalisis menggunakan perisian ALGOR V22 bagi mendapatkan nilai tekanan yang dikenakan ke atas specimen. Keputusan eksperimen dan juga fea menunjukkan hayat permulaan retak adalah lebih lama apabila saiz diameter penahan lubang meningkat. Semakin jauh lokasi penahan lubang dengan lokasi belahan, semakin lama hayat permulaan retak. Dengan demikian, pengaruhan penahan lubang terhadap hayat permulaan retak telah dibuktikan.

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LIST OF SYMBOLS

A	Cross Sectional Area
mm	Millimetre
s	Second
t	Thickness

l	Length
w	Width
d	Diameter
x	Horizontal distance
y	Vertical distance
N	Newton
σ_y	Yield Stress
P	Load
K_t	Stress concentration factor
δ	Ancillary hole
E	Modulus of Elasticity
σ	Stress
ε	Strain

LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
ASTM	American Society for Testing Materials
FE	Finite Element

FEA	Finite Element Analysis
FEM	Finite Element Model

CHAPTER 1

INTRODUCTION

1.1 Introduction

Crack initiation and propagation behavior has been evaluated to prevent an early failure of machine equipment. Delaying the crack initiation and propagation is important for the maintenance of machine elements as well as for the detection of crack initiation. Various methods for delaying crack initiation and propagation have been investigated. The stop-drilling technique is one of the methods for arresting further crack growth from cracks. The stop drilling technique involves drilling small circular hole near the crack tip. The main idea of the method is to reduce stress concentration at the edges of stop-drilled holes. In this study, the effects of drilling holes in the vicinity of crack tips on crack growth are to be determined.

1.2 Problem Statement

Many failures in engineering applications or machine components have been caused by a crack initiated from points at which stress was concentrated. As the stress concentration level is higher than a critical value, continuous crack-growth results in failure in the machine components

1.3 Objective

Primary objective of this project is to investigate the delay of crack by using stop drilled hole on the mild steel plate. In order to support the main objective, the other objectives are identified as follows:

I. To investigate the effectiveness of stop drill holes in order to delay the crack initiation.
II. To simulate the testing by using Finite Element Analysis (FEA).

1.4 Project Scope

The project has two level of study about the delay of crack by using stop drilled hole technique. The first level of study will be the determination of maximum applied load and the time taken for the plate to fracture using a common tensile test.

The second level will be modeling and analysis of the test by using Finite Element Method (FEM). The model is validated by comparing the results from FEM with the results obtained from the tensile test.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

As a part of the project, the analysis of literature was done as it uses to have a further understanding the project. The materials that used for the literature review were from journals, books, and from the internet web pages. The review was to find out the relevance of the project and it must have a significant relation to the project.

2.2 Crack

The definition of crack initiation depends on the length scale being considered. Basically, crack initiation can be defined as the local overcoming of interatomic cohesive forces in combination with the formation of new surfaces (Ulrich Krupp, 2007). Once a crack is present in a material, it will tend to grow under the influence of cyclic loading. The crack may be initiated by pre-existing from manufacture, or may be caused by an impact, or similar event. The crack will grow to a critical length then fracture of the component will occur. The crack repair lies in retarding or arresting the crack propagation, which can be achieved by reducing crack-tip stress intensity, introducing residual compressive stresses, and reducing crack-tip stress concentrations.

2.3 Stop Drilling Technique

The stop-drilling technique, which involves drilling small circular hole near the crack tip, is one of the methods for arresting further crack growth from cracks. The main idea of the method is to reduce stress concentration at the edges of stop-drilled holes. The amount of life extension produced by the stop hole is critically dependent on the stress concentration associated with the stop hole. With the stop hole passing through the crack tip, the larger the stop hole, the more effective is the stop-drilling technique (Dyskin, A.V, Xiaozhi Hu, and Emad Sahouryeh, 2002).

A method of extending the fatigue life of a cracked plate after machining stop-drilled holes was proposed. In this method, to reduce the stress concentration factor at the edges of the stop-drilled holes, the ancillary holes were machined along with the stop-drilled holes as in the Figure 2.1.

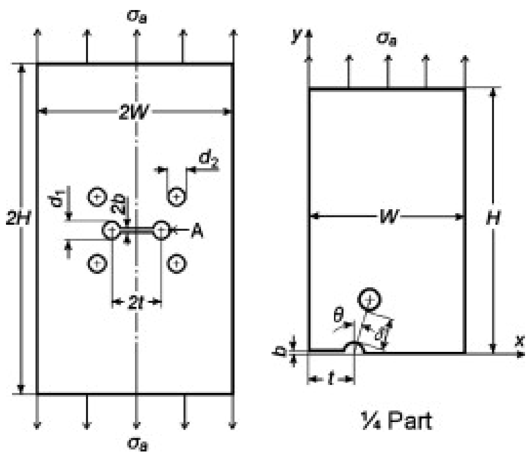

Figure 2.1: Position of the Ancillary Holes

Source: Dyskin, A.V, Xiaozhi Hu, and Emad Sahouryeh, 2002

The results that obtained in this study are the values of the stress concentration factor K_t at the edges of stop-drilled holes were influenced by the distance between the edge of stop-drilled hole and ancillary hole δ. Within the calculation results of the present study, the distance $\delta = 0.8$ mm resulted in lower stress concentration than $\delta = 1.6$ mm. The fatigue initiation lives for the specimens were affected not only by the addition of the ancillary holes, but also by the diameter of the ancillary holes d_2. In the present experimental cases where $d_1 = 3.2$ mm and $\theta = 0°$, the fatigue lives of the specimen with the diameters ancillary holes $d_2 = 3.2$ mm and 4.8 mm were, respectively, four and more than six times longer than that of the base type (Murdani, A., Makabe, C., Saimoto Akihide and Kondou Ryouji, 2007).

From the other research, the paper of investigated how the stop drilling procedure improved the crack initiation life and the total fatigue life in specimens of 6061-T651 aluminum alloy and AISI 304 stainless steel was proposed. The crack initiation life was the number of fatigue cycles initiating a 0.2 mm crack at a stop hole edge. The larger the stop hole diameter, the longer the crack initiation and total fatigue lives. The specimen was prepared as in the Figure 2.2.

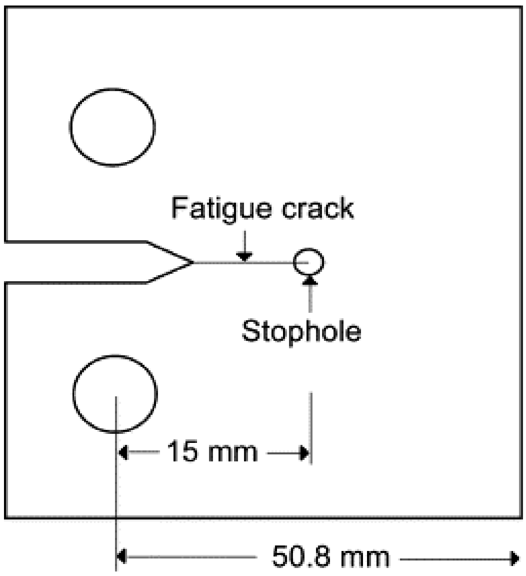

Figure 2.2: The Dimension of Specimen

Source: P. S. Song and Y. L. Shieh, 2004

The results that obtained in this paper were show in Table 2.1.

Table 2.1: Result Obtained

Material	Stophole diameter D (mm)	Crack initiation life N_i (cycles)	Total fatigue life N_t (cycles)	Improvement[a] (%)
6061-T651	Nonstop-drilled	–	76,530	–
	2	163,790	219,450	187
	2.5	265,960	322,480	321
	3	358,500	415,200	443
AISI 304	Nonstop-drilled	–	132,160	–
	2	113,720	227,120	72
	2.5	177,690	292,580	121
	3	255,870	362,260	174

Source: P. S. Song and Y. L. Shieh (2004)

From the Table 1, the larger the stop hole, the longer the 6061-T651 and AISI 304 crack initiation lives, which resulted from the larger stop hole lowering the stress gradients and the stress concentrations (P. S. Song and Y. L. Shieh, 2004).

In this study, the effects of drilling holes in the vicinity of crack tips on crack growth are to be determined. The effects which to be determined are the direction of the crack, time taken for the specimen to fracture, and the breaking load of the specimen. If the crack propagation direction is forced to change by drilling holes and applying compressive residual stress that distributed on crack growth route, crack growth can be delayed and the life of material will be longer.

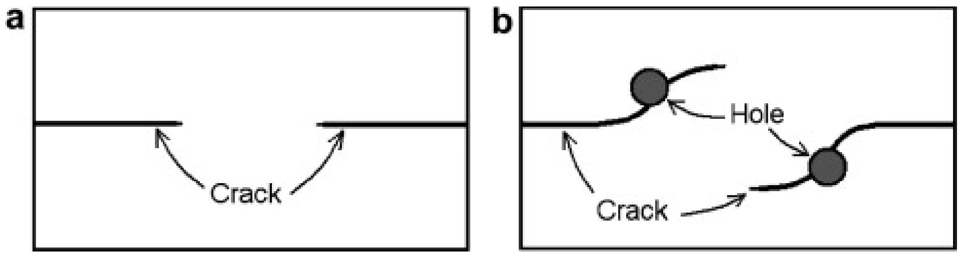

Figure 2.3: Schematic Representation of Crack Growth

Figure 2.3 shows a schematic representation of crack growth. Figure 2.3(a) represents the expectation of reorientation of crack growth without holes and Figure 2.3(b) represents expectation of reorientation of crack growth with holes. Retardation of crack growth is expected due to reorientation of the crack growth direction, which is dependent on the drilling method.

2.4 Mechanical Properties

The developments of science in material analysis have given some method to measure certain properties of materials. Technology in material science allows the determination of materials properties even before it has manufactured (Gedney Richard T, 2007). Mechanical properties that are taken into account are such as Yield strength, Young Modulus, Elasticity, Stress, Strain and many others. These properties are important to ensure further understanding and help in the analysis of material.

2.4.1 Stress

Consider a material is subjected to an external load such as in a tensile test. The force will tend to fail the material by breaking the internal bonds. Stress is the internal resistance to oppose the breaking of materials (Meyers, Marc A., and Chawla, Krishan Kumar, 1999). Basically a uniaxial stress is defined as the force (F in Newton) acting on area (A in m^2) or simply denoted by a symbol σ (Benham, P.P., Crawford, R.J., and Armstrong, C.G., 1996). Stresses can be exerted as three states which are Tensile Stress, Compressive Stress and Shear Stress. Tensile stress happen when a material is subjected to pulling force. Compressive stress usually happen when a material is subjected to pushing or compressing force. Meanwhile, when a material fails along a plane parallel to the force applied it will experienced shear stress.

2.4.2 Strain

Strain is related the deformation of material. It is measured by dividing the difference of length by the original length. Strain does not have any specific unit and it can be calculated not only in the elongation of material but also any other geometrical chance such as thermal expansion.

2.4.3 Modulus of Elasticity

Generally, the Modulus of elasticity or Young Modulus is the value obtain when stress is divided by strain.

$$= -$$

The unit of Young Modulus is N/mm². This property can be used to determine the stress and strain relationships.

2.4.4 Elasticity

Elasticity can be defined as the ability of the material to return to its original shape after the stress on it released. Elastic region is always the straight line a stress-strain relationship plot. Thus, it is a directly proportional quantity.

2.4.5 Yield Strength

Yield strength is the value of the stress where the material begins to deform plastically.

2.5 Mechanical Testing

Basically, there are many mechanical testing available to find the properties and behavior of the material. The types of test that are common or standard are such as tensile test, compression, impact, torsion, fatigue, hardness, creep, bending and few other specific material tests. Each test has its own particular property to be determined. In order to investigate the delay of crack by using stop drilled hole on mild steel, we rather do a simple tensile test to find the maximum applied loads and the time taken for the material to fracture.

2.6 Finite Element Method

The finite element method or FEM also referred to as finite element analysis is numerical technique for finding approximate solutions of partial differential equations as well as of integral equations. Or simply, finite element analysis is a computerized method for predicting how a real world object will react to forces, heat, vibration, and so on, in terms of where it will fails. (Wikipedia/FEM)

The finite element method works by breaking real object down into a large number of elements, such as little cubes. The behavior of each little element, which is regular in shape, is readily predicted by set mathematical equations. The computer then adds up all of the individual behaviors to predict the behavior of the actual object. The finite in finite element analysis comes from the idea that there are a finite number of elements in a finite element model. finite element method is employed to predict behavior of things with respect to virtually all physical phenomena such as Mechanical stress, Mechanical vibration, Heat Transfer, Fluid, Various electrical and magnetic phenomena and Acoustics. (Algor Help File, Algor Corp)