"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in term of scope and quality for the reward of the Bachelor's degree of Mechanical Engineering (Structure and Materials)"

Signature :

Name of Supervisor : ENCIK OMAR BIN BAPOKUTTY

Date : MAY 2007

FATIGUE STUDY ON METAL BY USING TENSILE LOAD

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Thesis is submitted to Faculty of Mechanical Engineering in accordance with the partial requirements for the Bachelor of Mechanical Engineering (Structure & Materials)

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May 2007

"I hereby declare this thesis is the result of my own research except as cited in the references"

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Date : MAY 2007

DEDICATION

To my beloved mother and father

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ABSTRACT

Fatigue is a process at cumulative damage that is caused by repeated fluctuating loads. This is done by applying tensile test onto specimens to determine maximum yield point then followed by fatigue test. In this research, 10 specimens were used due to standard dimensional in American Standard Test Method. The purpose of this research was to investigate life cycles of low carbon steel. AISI 1020 type steel was chosen representing the low carbon steel for this study. To obtain specimens required, raw materials were cut into 10 piecess by Scantool Raspsaw Machine then followed by fabricate them using CNC Lathe Machine. Tensile test were run to obtain maximum yield stress. From the value, five mean stresses value were chosen to run fatigue test on the specimens. The fatigue test will result life cycles for each mean stresses and they were recorded into a table. Then S-N curve was plotted. From the S-N curve, we can determine the life cycle of a material corresponding to the load that applied. Hence, we can avoid any damages before it fails. The more benefits will be realized including safety and economic.

ABSTRAK

Kelesuan adalah satu proses di mana berlakuya kerosakan berganda yang disebabkan oleh ulangan daya yang berubah-ubah. Kajian ini dilaksanakan dengan menjalankan ujian ketegangan ke atas model-model untuk mendapatkan nilai alah maksimum dan diikuti dengan ujian kelesuan. Dalam kajian ini, 10 model telah digunakan berdasarkan ukuran piawai di dalam Kaedah Ujian Piawai Amerika. Kajian ini bertujuan untuk menyelidik jangka hayat pada besi yang rendah karbon. Besi AISI 1020 telah dipilih bagi mewakili besi yang rendah karbon untuk kajian ini. Untuk mendapatkan 10 model yang dikehendaki, bahan mentah besi yang rendah karbon telah dipotong kepada 10 batang dengan menggunakan Mesin Pemotong dan diikuti dengan membentuk mereka menggunakan Mesin Pelarik Komputer. Ujian ketegangan dijalankan untuk mendapatkan nilai alah maksimum. Daripada nilai itu, lima nilai tegasan purata dipilih untuk menjalankan ujian kelesuan ke atas model-model. Ujian kelesuan akan menghasilkan jangka hayat untuk setiap tegasan purata dan akan direkodkan di dalam jadual. Kemudian, graf Tegasan-Jangka Hayat dilukis. Daripada graf tersebut, kita boleh menentukan jangka hayat sesuatu bahan yang selari dengan daya yang dikenakan. Maka oleh itu, kita boleh mengelak apa-apa kerosakan sebelum ia gagal. Lebih banyak kelebihan akan didapati termasuk dari segi keselamatan dan ekonomi.

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LIST OF SYMBOLS

SYMBOL	DEFINITION
σ_{max}	Maximum Stress
σ_{min}	Minimum Stress
σ_{ys}	Yield Stress
σ_a	Stress Amplitude
σ_f	Fatigue Strength Coefficient
F	Load
F_m	Mean Load
F_{min}	Minimum Load
F_{max}	Maximum Load
S	Stress
S_m	Mean Stress
S_{max}	Maximum Stress
S_{min}	Minimum Stress
S_a	Stress Amplitude
ΔS	Stress Range
A	Alternating Stress Ratio
B	Height
L	Length
R	Stress Ratio
W	Width

G	Gage Length
D	Diameter
E	Modulus Young
mm	Milimeter
kN	Kilo Newton
K_{IC}	Critical Intensity Factor
K_{max}	Maximum Stress Intensity Factor
K_t	Stress Concentration Factor
N	Life Cycle
N_f	Cycles of Failure
N_i	Cycles to Initate a Crack
N_p	Cycles to Grow The Crack
LEFM	Linear Elastic Fracture Mechanics
MSC	Microsoft Corporation
CNC	Computer Numerical Control
MPa	Mega Pascal
Hz	Hertz
ε_e	Elastic Strain Amplitude

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CHAPTER 1

INTRODUCTION

1.1 Fatigue

Various structures and components in manufacturing operations such as tools, dies, gears, cams, shafts, and springs are subjected to rapidly fluctuating (cyclic or periodic) loads, in addition to static loads. Cyclic stresses may be caused by fluctuating mechanical loads (such as on gear teeth) or by thermal stresses (such as on a cool die coming into repeated contact with hot workpieces). Under these conditions, the part fails at a stress level below which failure would occur under static loading. Upon inspection, failure is found to be associated with cracks that grow with every stress cycle and propagate through the material until critical crack length is reached and the material fractures. This phenomenon is known as fatigue failure, and it is responsible for the majority of failures in mechanical components.

In general, fatigue is a problem that affects any structural component or part that moves. Automobiles on roads, airplanes (principally the wings) in the air, ships on the high sea constantly battered by waves, nuclear reactors and turbines under cyclic temperature conditions (i.e., cyclic thermal stresses), and many other components in motion are examples in which the fatigue behavior of a material assumes a singular importance. It is estimated that 90% of service failures of metallic components that undergo movement of one form or another can be attributed to fatigue. Often, a fatigue fracture surfaces will show some easily identifiable macroscopic features, such as beach markings. Figure 1.1 shows a schematic of the fracture surface of, say, a steel shaft that failed in fatigue. The main features of this kind of failure are a fatigue crack initiation site, generally at the surface; a fatigue crack propagation region showing beach markings; and a fast-fracture region where the crack length exceeds a critical length. Typically, the failure under cyclic loading occurs at much lower stress levels than the strength under monotonic loading.

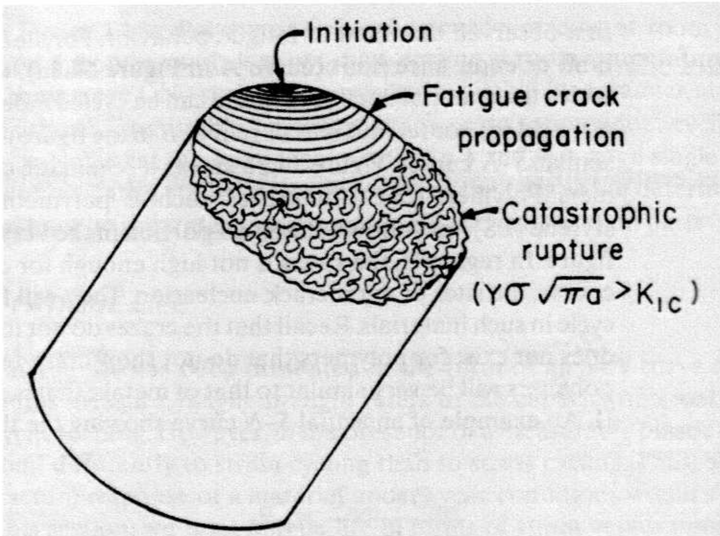

Figure 1.1: Fatigue fracture surface in a steel shaft, showing the initiation region (usually at the surface), the propagation of fatigue crack (evidenced by beach markings), and catastrophic rupture when the crack length exceeds a critical value at the applied stress.

1.1.1 Fatigue Parameter and S-N Curves

We first define some important parameters that will be useful in the subsequent discussion of fatigue.

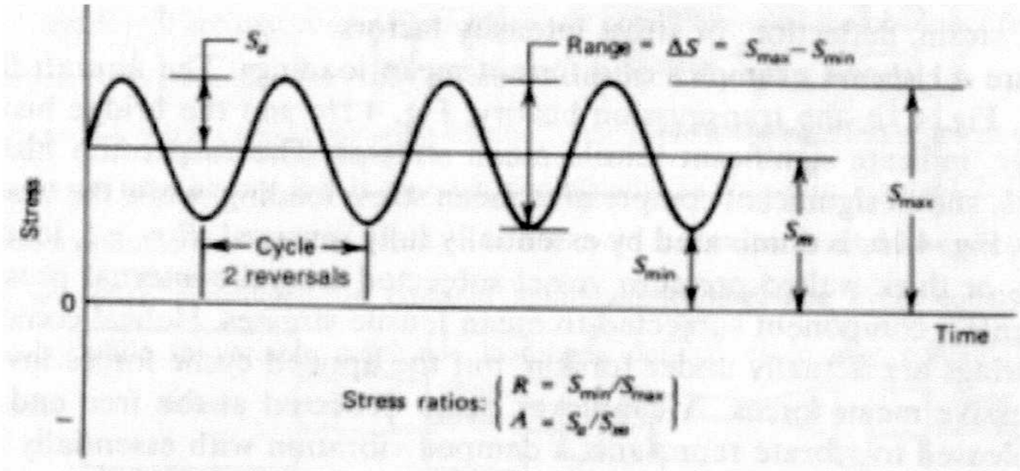

Figure 1.2: Nomenclature for constant amplitude cyclic loading

Mean, S_m, maximum, S_{max}, minimum, S_{min}, and range, ΔS of stress are indicated. The algebraic relationships among these terms are:

$$\text{Stress Amplitude, } S_a = \Delta S/2 = \frac{S_{max} - S_{min}}{2}$$

$$S_m = \frac{S_{max} + S_{min}}{2}$$

$$S_{max} = S_m + S_a$$

$$S_{min} = S_m - S_a$$

The stress range, ΔS is twice the alternating stress. Tensile or compressive stresses are taken algebraically as positive and negative, respectively. Alternating stress is an absolute value. The stress ratio, R, and the alternating stress ratio, A, are used frequently in fatigue literature, where

$$R = \frac{S_{min}}{S_{max}} \text{ and } A = \frac{S_a}{S_m}$$

R = -1 and R = 0 are two common reference test conditions used for obtaining fatigue properties. R = -1 is called the "fully reversed" condition since S_{min} is equal to $-S_{max}$; R = 0 where $S_{min} = 0$ is called "pulsating tension." One cycle is the smallest segment of the stress versus time history that is repeated periodically, as shown in Figure 1.2. Under variable amplitude loading, the definition of one cycle is not clear and hence reversals of stress are often considered. In constant amplitude loading, one cycle equals two reversals, while in variable amplitude loading a defined cycle may contain many reversals.

A typical plot, known as S-N curves is shown in Figure 1.3. These curves are based on complete reversal of the stress- that is, maximum tension, then maximum compression, then maximum tension, and so on- such as that imposed by bending an eraser or a piece of wire alternately in one direction and then the other. The test can also be performed on a rotating shaft with a constant downward load. With some materials, the S-N curve becomes horizontal at low stresses, indicating that the material will not fail at stresses below this limit. The maximum stress to which the material can be subjected without fatigue failure (regardless of the number of cycles) is known as the endurance limit or fatigue limit.

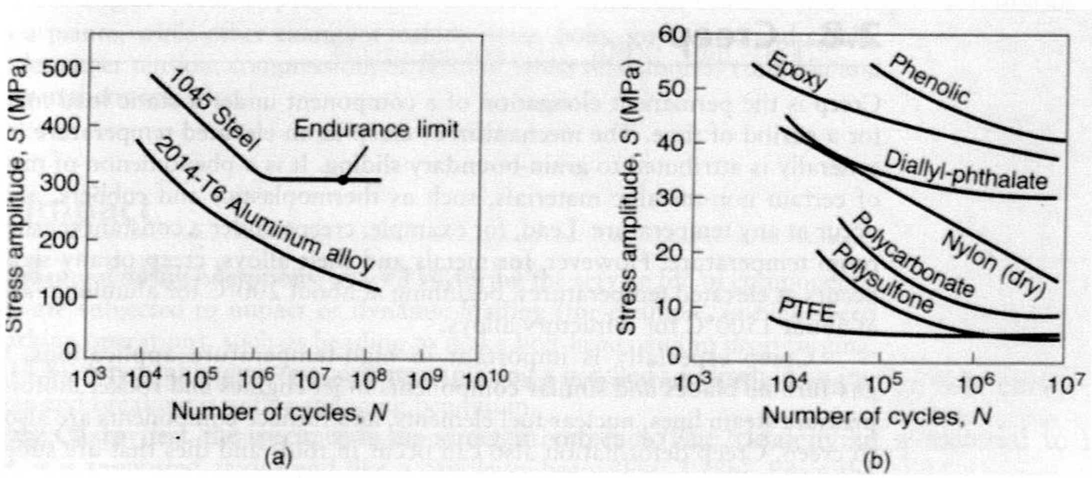

Figure 1.3: (a) Typical S-N curves for two metals. Note that, unlike steel, aluminium does not have an endurance limit.

(b) S-N curves for common polymers

1.1.2 Fatigue Fracture

Fatigue fracture typically occurs in a basically brittle nature. Minute external or internal cracks develop at pre-existing flaws or defects in the material; these cracks then propagate over a period of time, and eventually they lead to total and sudden failure of the part. The fracture surface in fatigue is generally characterized by the term beach marks, because of its appearance (Figure 1.4). Under high magnification (typically more than 1000X), a series of striations can be seen on fracture surfaces, each beach mark consisting of several striations.

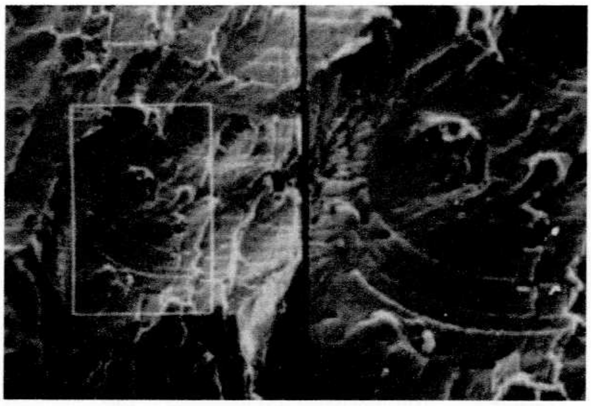

Figure 1.4: Typical fatigue-fracture surface on metals, showing beach marks. Magnification: left, 500X; right, 1000X

1.1.3 Fatigue Strength or Fatigue Life

Traditionally, fatigue life has been presented in the form of an S-N curve. With regard to this measure, fatigue strength refers to the capacity of a material to resist conditions of cyclic loading.

1.1.4 Improving Fatigue Strength

Fatigue life is influenced greatly by the method of preparation of the surfaces of the part or specimen (Figure 1.5). The fatigue strength of manufactured products can be improved overall by the following methods:

a. Inducing compressive residual stresses on surfaces – for example, by shot peening or by roller burnishing.
b. Case hardening (surface hardening) by various means.
c. Providing a fine surface finish and thereby reducing the effects of notches and other surface imperfections.
d. Selecting appropriate materials and ensuring that they are free from significant amounts of inclusions, voids, and impurities.

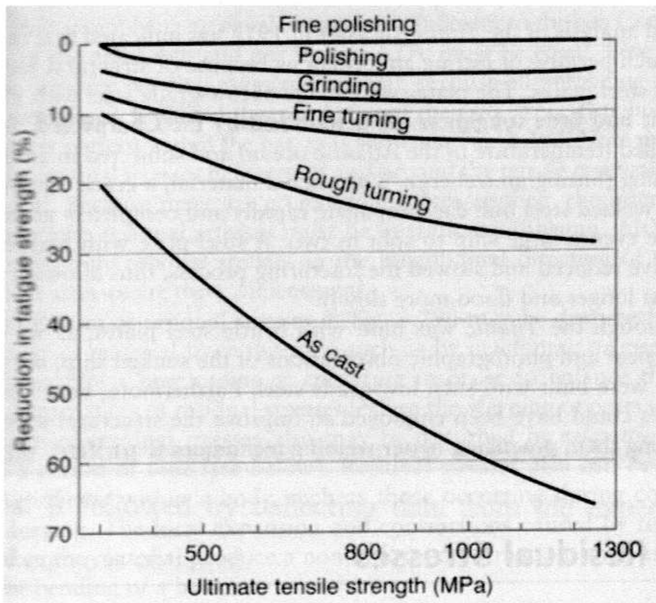

Figure 1.5: Reductions in the fatigue strength of cast steels subjected to various surface-finishing operations. Note that the reduction becomes greater as the surface roughness and the strength of the steel increase.

1.2 Objective

The objective of the fatigue test is to produce a Stress versus Cycle (S-N curve) of a metal using tensile load and specific mean load.

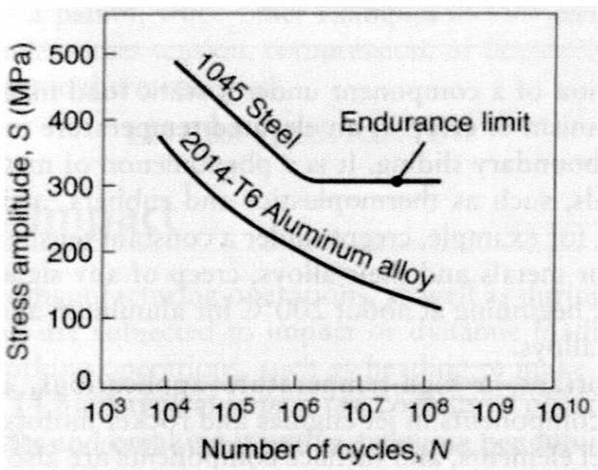

Figure 1.6: Typical S-N curves for two metals

1.3 Scope

These fatigue testing covers the literatures research, develop and design the experiment methods. It followed by collecting data from the experiment, analyze the data and finally S-N curve is obtained.