ENDURANCE LIMIT OF ALUMINUM, BRASS AND MILD STEEL ON DIFFERENT SURFACE FINISH OWING TO CYCLIC LOADS

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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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Dedicated to my parents, my supervisor, all my friends and Elianez Binti Abu Shuja

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ABSTRACT

The investigation is about the endurance limit of aluminum, brass and mild steel that has been done at the surface of the specimens on different surface roughness. The endurance limit of the specimens have been determined by testing under different loads on the fatigue testing machine and the life cycles of each specimens has been taken after crack occur on the specimen. Endurance limit is defined as the alternating stress that causes failures after some specified number of cycles. This study or investigation has the steps that is starting form the fabrication on different surface roughness, testing on the fatigue machine and gather all the data to compare the results.. The different surface roughness will give different life cycles. Then, comparison of the result needs to be done to get the best materials on different surface roughness to create a good choosing of materials in industry. Finally, studies of Endurance limit or fatigue strength can still be expanded and widened due to the other properties that can be tested such as curvature radii and elongation of the materials due to a break point.

ABSTRAK

Kajian ini mengenai had daya ketahanan aluminium, tembaga dan besi lembut dan kajian dijalankan diatas permukaan spesimen berdasarkan perbezaan kekasaran permukaan.Daya ketahanan setiap spesimen diuji dengan daya yang berbeza-beza di mesin ketahanan bahan.dan putaran hidup setiap bahan selepas keretakan berlaku.Daya ketahanan bermaksud bahan yang diuji tidak putus atau retak selepas dikenakan daya untuk beberapa putaran hidup. Pembelajaran dan kajian ini mempunyai beberapa tahap bermula dengan membina bahan untuk membolehkan ia dimasukkan didalam mesin, seterusnya diuji didalam mesin daya tahan dan seterusnya data diambil untuk membuat perbandingan untuk memilih bahan yang terbaik didalam industri.Yang terakhir, kajian mengenai had ketahanan setiap bahan boleh diperluaskan dengan kajian perbezaan melalui jejari setiap bahan dan kepanjangan bahan.

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 METHODOLOGY

CHAPTER 4 RESULTS AND DISCUSSION

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

APPENDICES

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOLS

r	radius
Rpm	radius per minute
N	Newton
$\boldsymbol{\Sigma}$	stress
N	Life cycles or endurance
$\mathbf{S}_f$	Fatigue strength
F	Friction of sut
Sut	tensile strength
$\mathbf{S'}_e$	rotary-beam yeast specimen endurance limit
$\mathbf{k}_a$	surface condition modification factor
$\mathbf{k}_b$	size modification factor
$\mathbf{k}_c$	Load modification factor
$\mathbf{k}_d$	temperature modification factor
$\mathbf{k}_e$	reliability factor
$\mathbf{k}_f$	miscellaneous-effects modification factor

LIST OF ABBREVIATIONS

S-N	Stress and Life Cycles
EL	Endurance Limit
UTS	Ultimate Tensile Strength

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

In the early part of the nineteenth century the failure of some mechanical components subjected to nominal stress well below the tensile strength of the material aroused some interesting among a few engineers of that time. The fact that puzzled these early engineers was that a component such as bolt or a shaft made from a ductile material such as mild steel could fracture suddenly in what appeared to be a brittle manner. There was no obvious defect in workmanship or material, and the only feature common to these failures was the fact that the stressed imposed were not steady in magnitude, but varied in a cyclical manner. This phenomenon of failure of a material when subjected to a number of varying stress cycles became known as fatigue, since it was thought that fracture occurred owing to the metal weakening or becoming ‘tired’.

Fatigue is a localized damage process of a component produced by cyclic loading. It is the result of the cumulative process consisting of crack initiation, propagation, and final fracture of a component. During cyclic loading, localized plastic deformation may occur at the highest stress site. This plastic deformation induces permanent damage to the component and crack develops. As the component experiences in increasing number of loading cycles, the length of the crack increases. After a certain number of cycles, the crack will cause the component to fail. The part fails at a stress level below that at which would occur under static loading. This phenomenon is known as fatigue failure, and it is responsible for the majority of failures in mechanical components.

The fatigue testing method involve testing specimen under various states of stress amplitude, the number of cycles it takes to cause total failure of the specimen or part is recorded. Stress amplitude is defined as the maximum stress, in tension and compression, to which specimen is subjected.

A typical plot known as S-N curves are based on complete reversal of the stress that is, maximum tension, the maximum compression, the maximum tension and so on. Then maximum stress to which the material can be subjected without fatigue failure, regardless the number of cycles, is known as the endurance limit or fatigue limit.

The preparation of the specimens must be done carefully especially when cutting the materials. Poor condition of cutting process can cause an error on the data.

The data from the experiment will be analyzed and comparison will be made. Some recommendation will be included in the conclusion.

1.2 PROBLEM STATEMENT

It has been estimated that at least 75% o all machine and structural failures have been caused by some form of fatigue (Richard G. Budynas, 1998). Fatigue failures occur most often in moving machinery parts, example shafts, axles, connecting rods, valves and spring. However, the wings and fuselage of an airplane or the hull of a submarine are also susceptible to fatigue failures because in service they are subjected to variations of stress. As it is not always possible to predict where and when fatigue failure will occur in service and because it is essential to avoid premature fractures in articles such as aircraft components, it is common to do full-scale testing on aircraft wings, fuselage, engine pods and others. This involve supporting the particular aircraft section or submarine hull or car chassis in jigs and applying cyclically varying stresses using hydraulic cylinders with specially controlled valves.

According to the problems stated above, there are two main problems related to this research which are:

1. When component breakdown down time is inevitable.
2. Unable to predict the time for preventive maintenance.

1.3 OBJECTIVE OF RESEARCH

The objective of this research is to determine the endurance limit of aluminum, brass and mild steel on different surface finish owing to cyclic loads.

1.4 SCOPES

In order to achieve the objectives notified earlier, the following scopes have been recognized:

1. Materials chosen for this research are aluminum, brass and mild steel.
2. Fatigue test machine is used for performing the test.
3. Lathe conventional machine is to be used for fabricating.
4. Gather all the data from the experimental and compare the result

.

CHAPTER 2

LITERATURE REVIEW

2.1 FATIGUE

In narrow sense, the term fatigue of materials and structural components means damage and damage due to cyclic, repeatedly applied stresses. In a wide sense, it includes a large number of phenomena of delayed damage and fracture under loads and environmental conditions.

It is expedient to distinguish between high-cycle (classic) and low-cycle fatigue. Plastic deformations are small and localized in the vicinity of the crack tip while the main part of the body is deformed elastically, then one has high-cycle fatigue. If the cyclic loading is accompanied by plastic deformation in the bulk of the body, then one has a low-cycle fatigue. Usually we say low-cycle fatigue if the cycle number up to the initiation of a visible crack or until final fracture is below 10^4 or 5.10^4 cycles.

In material science, fatigue is the progressive, localized, and permanent structural damage that occurs when a material is subjected to cyclic or fluctuating strains at nominal stresses that have maximum values less than (often much less than) the static yield strength of the material. The resulting stress may be below the ultimate tensile stress, or even the yield stress of the material, yet still cause catastrophic failure.

A practical example of low-cycle fatigue would be the bending of a paperclip. A metal paperclip can be bent past its yield point without breaking, but repeated bending in the same section of wire will cause material to fail.

2.2 FATIGUE STRENGTH

Fatigue strength is defined as the maximum stress that can be endured for a specified number of cycles without failure. Low cycle fatigue strength approaches the static strength. When the cycle number exceeds to one limit, the fatigue strength falls to fraction of the static strength.

The fatigue strength is the value of the alternating stress that results in failure by fracture a specific number of cycles of load application. It can also be the ordinate of the σ-n (stress versus number of cycles to failure) curve.

The fatigue behavior of a specific material, heat treated to a specific strength level is determined by a series of laboratory tests on a large number of apparently identical samples of those specific materials.

The specimens are machined with shape characteristics which maximize the fatigue life of a metal, and are highly polished to provide the surface characteristics which enable the best fatigue life. A single test consist of applying a known, constant bending stress to a round sample of the material, and rotating the sample around the bending stress axis until it fails. As the sample rotates, the stress applied to any fiber on the outside surface of the sample varies from maximum-tensile to zero to maximum-compressive and back. The test mechanism counts the number of rotations (cycles) until the specimen fails. A large number of tests is run at each stress level of interest, and the results are statistically massaged to determine the expected number of cycles to failure at that stress level.

The cyclic stress level of the first set of tests is some large percentage of the Ultimate Tensile stress (UTS), which produces failure in a relatively small number of cycles. Subsequent tests are run at lower cyclic stress values until a level is found at which the sample will survive 10 million cycles without failure. The cyclic stress level that the material can sustain for 10 million cycles is called the Endurance (EL).

2.3 FATIGUE STRENGTH TESTING

A failure that results from such cyclic loads is called a fatigue failure. Since many structural components are subjected to cyclic loads it is necessary for the design engineer to have some quantitative measure of the material's ability to withstand such repeated loads. Quantitative data for the fatigue properties of a given material are obtained by subjecting a number of standard specimens to cyclic loads until fracture occurs**.** (Joseph Datsko, 1997)

The objective of the fatigue strength or fatigue limit test is to estimate a statistical distribution of the fatigue strength at a specific high-cycle fatigue life. Among many fatigue strength tests methods, the staircase method (often referred as the up-and-down method) is the most popular one that has been adopted by many standards to asses statistical of a fatigue limit.

In this test, the mean fatigue limit has to first estimated, and a fatigue life test is the conducted at a stress level a little higher than the estimated mean. If the specimen fails prior to the life of interest, the next specimen has to be tested at a lower stress level. Therefore, each test is dependent on the previous test results, and the test continuous with a stress level increased or decreased.

2.4 FATIGUE DAMAGE PROCESS

Fatigue is gradual process of damage accumulation that proceeds on various levels beginning from the scale of the crystal lattice, dislocations and other objects of solid state physics up to the scales of the structural components. Three or four stages of fatigue damage are usually distinguishable. In the first stage, the damage accumulation occurs on the level of grains and intergranular layers. The damage is dispersed over the volume of a specimen or structural component, or at least, over the most stressed parts. At the end of this stage, nuclei of microscopic cracks originate, example, such aggregates of micro cracks that are strong stress concentrators and under the following loading, have a tendency to grow. Surface nuclei usually can be observed visually (at least with proper magnification). The second stage is the growth of cracks that depth is small compared with the size of cross section. At the same time, the sizes of these cracks whose depth is small compared with the size of the cross section. At the same time, the sizes of these cracks are equal to few characteristics scales of microstructure, say, to several grain sizes. Such cracks are called small cracks. Most of them stop growing upon meeting some obstacles, but one or several cracks transform into microscopic, “long” fatigue cracks that propagate in a direct way as strong stress concentrators. This process forms the third stage of fatigue damage. The fourth stage is rapid final fracture due to the sharp stress concentration at the crack front and/or the expenditure of the material’s resistance to fracture.

The endurance limit of 1045 steel, 2014-T6 Aluminum and the approximation of S-N Curves shown in figure 2.1 and figure 2.2. The local stress concentrations domains as well as near the damaged or weakest grains. The initial slip planes and micro cracks in grains are oriented mostly along the planes with maximal shear stresses. Small cracks are inclined, at least approximately, in the small directions. There is example of S-N Curves and the approximation of Endurance limit.

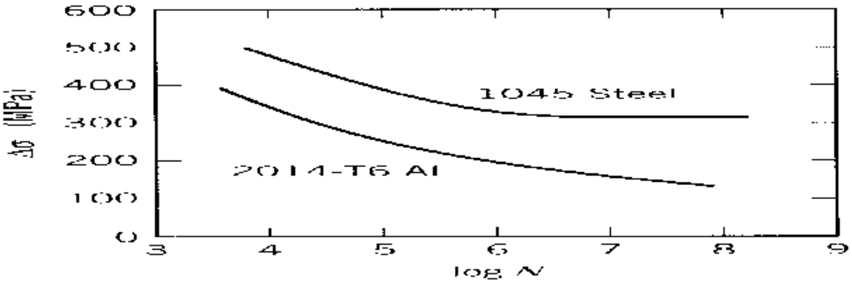
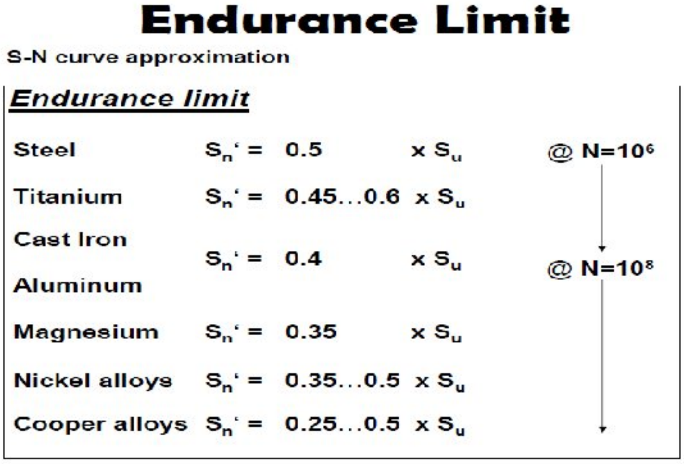


Figure 2.1: Life Cycle of 1045 Steel and 2014-T6 Al

Source: A David Roylance, 2001



Endurance Limit

S-N curve approximation

Endurance limit

Steel	$S_n' =$	0.5	$\times S_u$	@ $N=10^6$
Titanium	$S_n' =$	0.45...0.6	$\times S_u$	
Cast Iron Aluminum	$S_n' =$	0.4	$\times S_u$	@ $N=10^8$
Magnesium	$S_n' =$	0.35	$\times S_u$	
Nickel alloys	$S_n' =$	0.35...0.5	$\times S_u$	
Cooper alloys	$S_n' =$	0.25...0.5	$\times S_u$	

Figure 2.2: S-N Curve Approximation

Source: Poncelet (France) 1983

2.5 FATIGUE FAILURE

Failure is one of most important aspects of material behavior because it is directly influent the selection of material for certain application, the method of manufacturing and service life of component.

The majority of engineering failures are caused by fatigue. Fatigue failure is defined as the tendency of a material to fracture by means of progressive brittle cracking under repeated alternating or cyclic stresses of intensity considerably below the normal strength. Although the fracture is of a brittle type, it may take some time to propagate, depending on both the intensity and frequency of the stress cycles. Nevertheless, there is very little, if any, warning below failure if the crack is not noticed. The number of cycles required to cause fatigue failure at a particular peak stress is generally quiet large, but it decreases as the stress is increased. For some mild steels, cyclical stresses can be continued indefinitely provided the peak stress (sometimes called fatigue strength) is below the endurance limit value.

A good example of fatigue failure is breaking a thin steel rod or wire with your hands after bending it back and forth several times in the same place. Another example is an unbalanced pump impeller resulting in vibrations that can cause fatigue failure.

The type of fatigue of most concern in circuit cards, gasoline, diesel, gas turbine engines and many industrial applications is thermal fatigue. Thermal fatigue can arise from thermal stresses produced by cyclic changes in temperature.

Fundamental requirements during design and manufacturing for avoiding fatigue failure are different for different cases and should be considered during design phase. Fatigue failures almost always begin at the surface of a material. The reasons are:

1. The most highly-stresses fibers are located at the surface (bending fatigue)
2. The intergranular flaws which precipitate tension failure are most frequently found at the surface.

Suppose that a particular specimen is being fatigue tested. Now suppose the fatigue test is halted after 20% to 25% of the expected life of the specimen, and the surface condition is restored to its original state. Now the fatigue test is resumed at the same stress level as before. The life of the part will be considerably longer than expected. If that process is repeated several times, the life of the part may be extended by several hundred percent, limited only by the available cross section of the specimen. That proves fatigue failures originate at the surface of a component.

Fatigue failure is also due to crack formation and propagation. A fatigue crack will typically initiate at a discontinuity in the material where the cyclic stress is a maximum. Discontinuities can arise because of:

1. Design of rapid changes in cross-section, keyways, holes, etc. where the cyclic stress concentrations occur.
2. Element that roll and/or slide each other (bearings, gears, cams) under high contact pressure, developing concentrated subsurface contact surfaces that can cause pitting from after many cycles of the load.
3. Carelessness in locations of stamp marks, tool marks, scratches, and burrs; poor joint design; improper assembly; and other fabrications faults.
4. Compositions of the material itself as processed by rolling, forging, casting, extrusion, drawing and heat treatment. Microscopic and submicroscopic

surface and subsurface discontinuities arise. (Joseph E Shigley, Charles R. Mischke, Richard G. Budynas, 2004)

Fatigue fracture typically occurs in material of basically brittle nature. External or internal cracks develop at pre-existing flaws or fault of defects in the material; these cracks then propagate and eventually they lead to total failure of part. The fracture surface in fatigue is generally characterized by the term "beach marks". Examples of fatigue failure can be shown as the following figures:

Figure 2.3: Fatigue failures on crankshaft

Source: Serope Kalpakjian, Steven R. Schmid. 2000

Figure 2.4: Fracture of a bolt

Source: Serope Kalpakjian, Steven R. Schmid. 2000

2.6 ENDURANCE LIMIT

The fatigue limit or endurance is the largest value of alternating stress that that will not result in fracture, regardless of the number of cycles of applied load. It is the value of alternating stress corresponding to the horizontal portion of the sigma-N curve. In this case, the endurance limit is defined as the alternating stress that causes failures after some specified number of cycles. (Joseph Datsko, 1997)

It is important to remember that the endurance limit of a material is not an absolute or fully repeatable number. In fact, several apparently identical samples, cut from adjacent sections in one bar of steel, will produce different EL values (as well as different UTS and YS) when tested, as illustrated by the S-N diagram below. Each of those three properties (UTS, YSL, and EL) is determined statistically, calculated from the (varying) results of a large number of apparently identical tests done on a population of apparently identical samples. Example of endurance limit of steel & aluminum can be shown in the graph below:

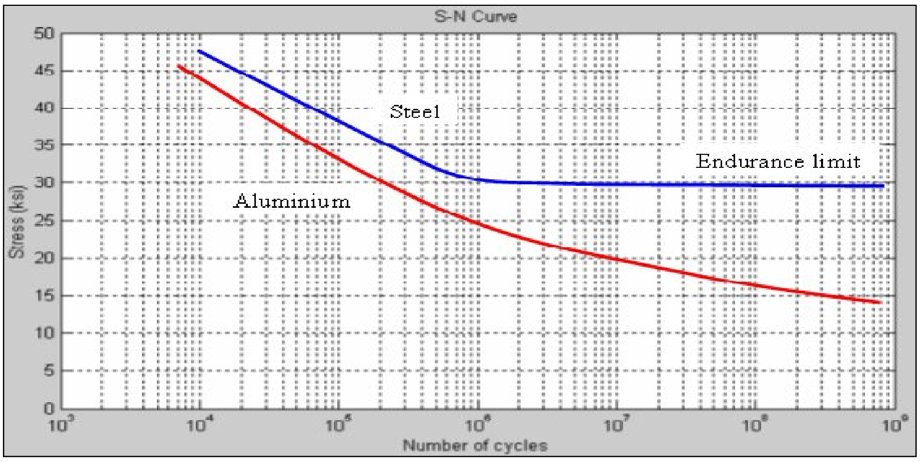


Figure 2.5: stress versus number of cycles for steel (in blue and showing an endurance limit) and aluminum (in red and showing no such limit)

Source: Joseph Datsko, 1997

2.7 FACTORS INFLUENCING FATIGUE LIFE

The resistance against fatigue depends essentially on a number of factors. Among them are: stress concentration, surface roughness, frequency of loading, loading history, residual stress-strain fields, temperature, environmental conditions, etc. Manufacturing process features such as heat treatment and cold deformation also affect fatigue life. (Dr. Yung-Li Lee, Jwo Pan, Richard Hathaway, Mark Barkey, 2005)

Magnitude of stress including stress concentrations caused by part geometry. Quality of the surface; surface roughness, scratches, etc. cause stress concentrations or provide crack nucleation sites which can lower fatigue life depending on how the stress is applied. For example, shot penning puts the surface in a state of compressive stress which inhibits surface crack formation thus improving fatigue life. Other surface treatments, such as laser penning, can also introduce surface compressive stress and could increase the fatigue life of the component. This improvement is normally observed only for high-cycle fatigue. Little improvement is obtained in the low-cycle fatigue regime.

The most recent development in the field of surface treatments utilizes ultrasonic energy to create residual compressive stresses that surpass those achieved by shot penning, laser penning, and other legacy methods. Ultrasonic Impact operates within the harmonic frequency range of metals, allowing energy to be delivered deep into the material. Low amplitudes ensure the metal is not overworked.

Material type: Certain materials, such as steel, will never fail due to fatigue if the stresses remain below a certain level. Other materials, such as aluminum, will eventually fail due to fatigue regardless of the stresses the material sees. Surface defect geometry and location: The size, shape, and location of surface defects such as scratches, gouges and dents can have a significant impact on fatigue life. Significantly uneven cooling, leading to a heterogeneous distribution of material properties such as hardness and ductility and, in the case of alloys, structural composition.

Size, frequency and location of internal defects: Casting defects such as gas porosity and shrinkage voids, for example, can significantly impact fatigue life. In metals where strain-rate sensitivity is observed (ferrous metals, copper, titanium, etc.) strain rate also affects fatigue life in low-cycle fatigue situations. For non-isotropic materials, the direction of the applied stress can affect fatigue life. For most metals, fine-grained parts exhibit a longer fatigue life than coarse-grained parts.

Environmental conditions and exposure time can cause erosion, corrosion, or gas-phase embrittlements, which all affect fatigue life. The operating temperature over which the part is exposed to affect fatigue life.

2.8 IMPROVING FATIGUE STRENGTH

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

1. Inducing compressive residual stresses on surface for example, by shot penning or by roller burnishing.
2. Surface (case) hardening by various means.
3. Producing a fine surface finish and thereby reducing the effects of notches and other surface imperfection.
4. Selecting appropriate materials and ensuring that they are free from significant amounts of inclusions voids and impurities.
5. Eliminate or reduce stress raisers by streamlining the part
6. Avoid sharp surface tears resulting from punching, stamping, shearing, or other processes.
7. Prevent the development of surface discontinuities during processing
8. Reduce or eliminate tensile residual stresses caused by manufacturing.
9. Improve the details of fabrication and fastening procedures

Following factors and process can reduce fatigue strength:

1. Decarburization
2. Surface pits (due to corrosion) that act as stress raisers

3. Hydrogen embrittlement
4. Galvanizing
5. Electroplating (Serope Kalpakjian, Steven R. Schmid. 2000)

2.9 DESIGN AGAINST FATIGUE

Dependable design against fatigue-failure requires thorough education and supervised experience in structural engineering, mechanical engineering, or materials science. There are three principles approaches to life assurance of mechanicals parts that display increasing degrees of sophistication:

1. Design to keep stress below threshold of fatigue limit
2. Design (conservatively) for a fixed life after which the user is instructed to replace the with a new one (a so-called life part, finite lifetime concept, or “safe-life” design practice);
3. Instruct the user to inspect the part periodically for cracks and to replace the part once a crack exceeds a critical length.

2.10 S-N CURVES

Between 1852 and 1870, August Wohler, a German railway engineer, conducted the first systematic fatigue investigations and tests. These tests are most common type of fatigue testing. From these tests, it is possible to develop S-N curves that represent the fatigue life behavior of a component or of a material test specimen. S-N fatigue tests provide valuable information to an engineer during the design process.

An S-N curve is a very useful way to visualize time to failure for a specific material is with the S-N curves. The “S-N” means stress verse cycles to failure, which when plotted use the stress amplitude, sigma a plotted on the vertical axis and the logarithm of the number of cycles to failure.

The significance of the fatigue limit is that if the material is loaded below this stress, then it will not fail, regardless of the number of times it is loaded. Material such as aluminum, copper and magnesium do not show a fatigue limit, therefore they will fail at any stress and number of cycles. Other important terms are fatigue strength and fatigue life. The stress at which failures occurs for a given number of cycles is the fatigue strength. The number of cycles required for a material to fail at a certain stress in fatigue life.

Fatigue life data exhibit widely scattered results because of inherent micro structural in homogeneity in the materials properties, differences in the surface and the test conditions of each specimen and other factors. In general, the variance of log life increases as the as the stress level decreases. It has been observed that once grains nucleate cracks in a material at high stress levels, these cracks have better chance of overcoming the surrounding microstructure. As a result of unavoidable variation in fatigue data, median S-N fatigue life curves are not sufficient for fatigue analysis and design. The statistical nature of fatigue must be considered. There is a need for statistical S-N testing to predict fatigue life at various stress amplitude and mean stress combinations. (Dr**.** Yung-Li Lee, Dimler Chrysler, 2005)

Since the mid-1800s, a standard method of fatigue analysis and design has been the stress-based approach. This method is also referred to the as stress-life or S-N approach and is distinguished from other fatigue analysis and design techniques by several features:

1. Cyclic stress is the governing parameter for fatigue failure.
2. High-cycle fatigue conditions are present in high number of cycle to failure and little plastic deformation due to cyclic loading.

During fatigue testing, the test specimen is subjected to alternating loads until failure. The load applied to specimen are defined by either a constant stress range (S_r) or a constant stress amplitude (S_a). The stress range is defined as the algebraic difference between the maximum stress S max and minimum stress S min in a cycle. Equation represent as follows:

$$S_f = \sigma'f\,(2N)^{b}$$

S_f = Fatigue strength

f = Friction of sut

Sut= tensile strength

S= aN^b

a= (f Sut) 2/ **S_e**

b= -1/3 log (f Sut / **S_e**)

2.10.1 CALCULATION OF STRESS

P= Load in N

L= Length of specimen in mm

r / y = Radius of specimen in mm

I= Moment of inertia

$$\sigma = \frac{M_y}{I} \quad (2.1)$$

$$\sigma = \frac{4PL}{\Pi r^3} \quad (2.2)$$

2.10.2 CALCULATION OF THE SPECIMEN

The specimen is loaded with a known weight W and cycled until the specimen fractures, and the number o cycles N to fracture is recorded. The value of σ_{max} corresponding to fracture at a specific number of cycles is referred to as S_f the fatigue strength.

As S-N curves can be generated for standard smooth material specimens, for individual manufactured structural components for subassemblies, or for complete structures. The material S-N curves provides the base line fatigue data on a given geometry, loading condition and material process for use in subsequent fatigue life and strength analysis. The baseline data can be adjusted to account for realistic component conditions such as notches, size, surface finish, surface treatments, temperature, and various type of loading. The S-N curve for real components, subassemblies, or structures represents the true fatigue behavior of productions parts or structures. (Darryl Taylor, 2005)

In high-cycle fatigue situations, materials performance is commonly characterized by an S-N curve, also known as a Wohler curve. This is a graph of the magnitude of a cyclic stress (S) against the cycles to failure (N).

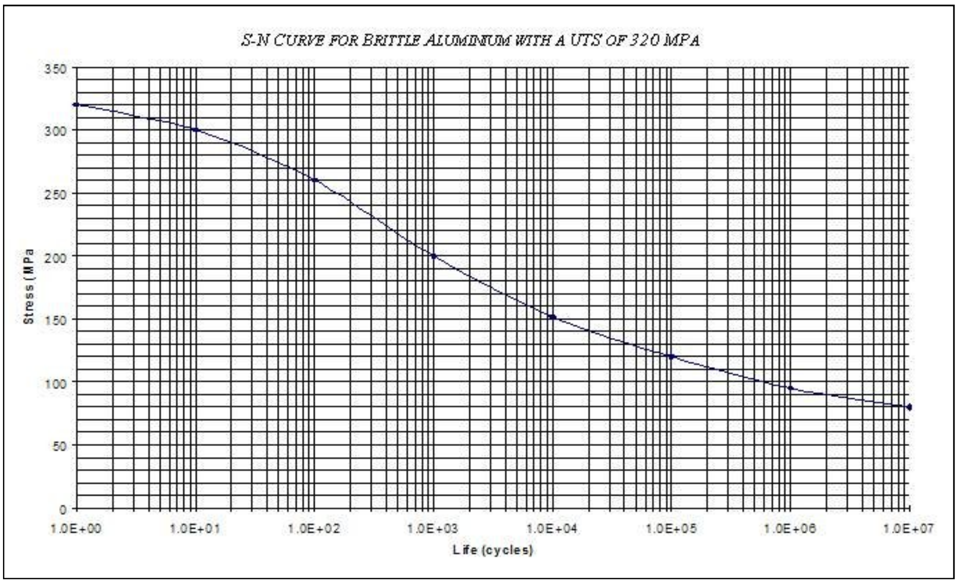


Figure 2.6: Example of Brittle Aluminum S-N Curves

Source: J. McEvily, 2002

S-N curves are derived from tests on samples of the materials to be characterized (often called coupons) where a regular sinusoidal stress is applied by a testing machine which also counts the number of cycles to failure. (J. McEvily, 2002)

2.11 PREVIOUS RESEARCH STUDY

Most steels and ferrous alloy exhibit the former types of curve, and the stress range at which the curve becomes horizontal is termed the fatigue limit. Below this value it appears that the metal cannot be fractured by fatigue. In general, non-ferrous metals such as aluminum do not show a fatigue limit but fractures can still be obtained after several cycles of stress usually 50.10^6. (PP Benham, RJ Crawford & CG Armstrong, 1998)

The S-N curves for a low-carbon steels show an abrupt break, or knee, at which point the curve tends to approach a horizontal line. In other words, with any stress below the fatigue or endurance limit, low-carbon steel can be cycled continuously without fracturing. Aluminum and other nonferrous materials fracture at relatively low stresses after many cycles. For many ferrous alloys the endurance limit is about one-half the tensile strength of the metal. Furthermore, they exhibit no fatigue limit, which means that there is no stress below which they will not fracture. (James A. Jacobs & Thomas F. Kilduff, 2003)

Differences between the actual part and the test specimen in size, surface finish, geometry, temperature, the presence of residual stresses, corrosion, and surface treatment reducing the fatigue strength of the part. (Richard G. Budynas, 1998)

The rougher the surface finishes the easier for material to crack. (SW Walmsley, 1998)

Cyclic fatigue tests were conducted on recycled polycrystalline metals and alloys at room and elevated temperatures to determine the fatigue strength, endurance limit and endurance ratio. Annealed and polished stainless steel (Fe-18Cr-8Ni), mild steel (Fe-0.25Cr), aluminum (Al), alpha-brass (Cu-30 % Zn) and copper (Cu) specimens of respective grain size of 45.0, 63.5, 72.5, 150.0, and 341.2 μm were tested. Fatigue damage assessment obeyed Paris law, fatigue limit was inversely proportional to grain size, fatigue strength decreased as temperature increased, while fatigue life cycles increased with temperature decrease. The fatigue failure resulted from residual stresses which caused crack opening and propagation leading to cup and cone fracture. The fatigue properties of recycled metals and alloys compared satisfactory with primary materials, and could be used to fabricate engineering components in Ghana. (A Ayensu and O Owusu-Korkor, 2008)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Since different materials are used for fabrication in industry will differs the properties of the materials, this project will find the failure mode of various specimens will fails through an experimental fatigue testing. Different types of specimens' data are used to assess the durability of structural components subjected to cyclic loading. With the use of different strength and cross-section of specimens being used, we can know the fatigue performance of a specimen.

The preparation of the specimens must be done carefully especially when cutting the materials. Poor condition of cutting process can cause an error on the data. Then the data is compared with analytical data before conclusion made. Some recommendation will be included in the conclusion.

3.2 PROCESSING FLOW

The processing flow can be described as the figure below:

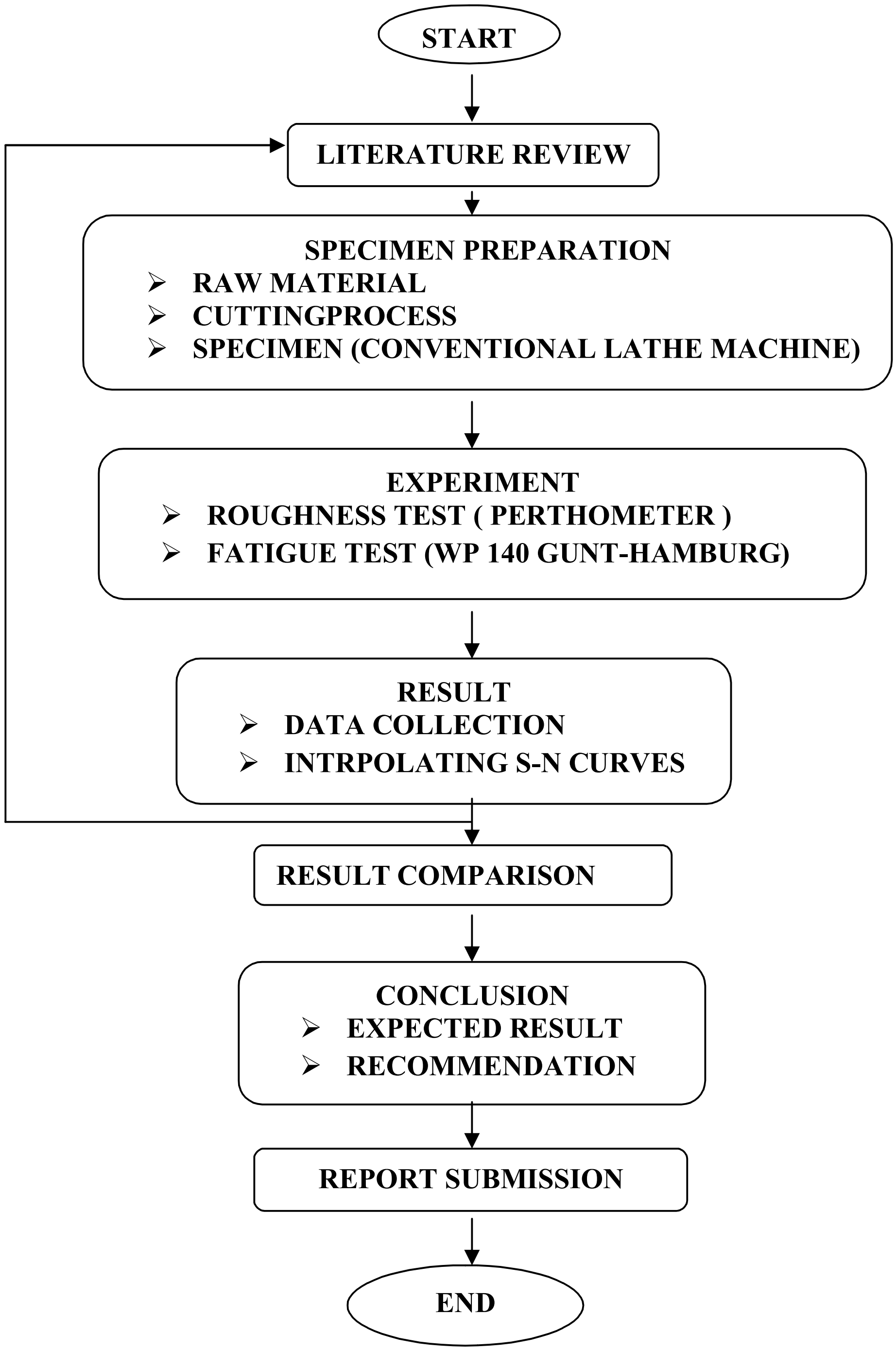


Figure 3.1: Processing Flow

3.3 SPECIMEN PREPARATION

The test bar that will be used to conduct the testing is test bar where the curvature

Radius, r = 0.5mm.

Type of specimens: 1. Aluminum, 2. Brass 3.Mild Steel

Table 3.1: Numbers of specimen

No.	**Materials**	**Length**	**Diameter**	**Unit**
1	Aluminum	146mm	12mm	9
2	Stainless Steel	146mm	12mm	9
3	Mild Steel	146mm	12mm	9

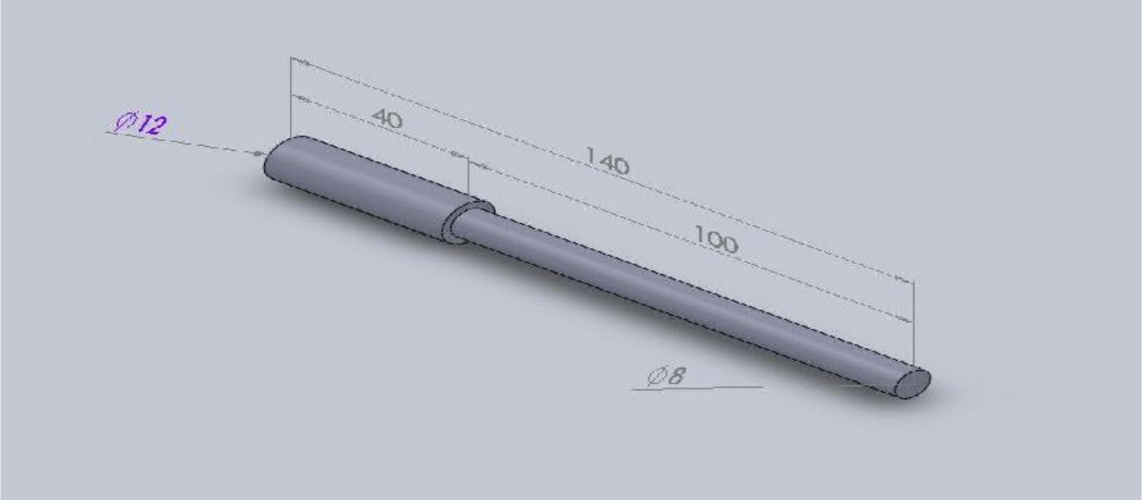


Figure 3.2: Dimension of the Specimen

3.4 CUTTING SPECIMEN

Because the specimens that being ordered have an offset to prevent it from have an error or it is skew, a cutting process must be conduct. The machine that is being use to fabricate and cutting the specimen is CNC lathe machine or conventional lathe machine.

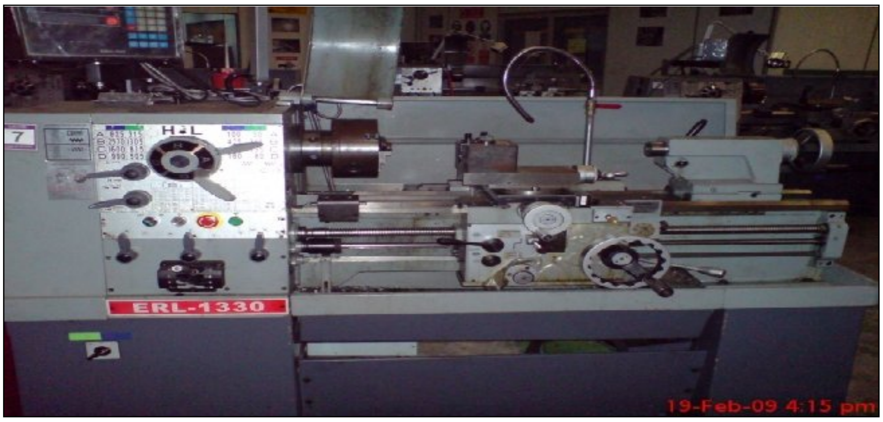


Figure 3.3: Conventional Lathe Machine

3.5 EXPERIMENT METHOD

Machine: Conventional Lathe Machine

Material: Aluminum, Brass and Mild steel.

1. The cutting tools are fit according to the dimension that we need.
2. Next, the material that we need to cut is placed at the clamp.
3. Then, the specimen is ready to be cut according to the step and parameters as the table below:

Table 3.2: Parameters for cutting material

Machining Parameters	LOW	MEDIUM	HIGH
Spindle speed (rpm)	100	990	2570
Depth of cut (mm)	0.5	0.5	0.5
Feed rate (mm/min)	21.0	21.0	21.0

4. Each spindle speed, we need to cut 3 specimens each.

5. Step 1 to 3 is repeated using another material that is brass and mild steel.
6. So, as a conclusion, there are 27 specimens to be cut**.**

3.6 SURFACE ROUGHNESS MEASUREMENT

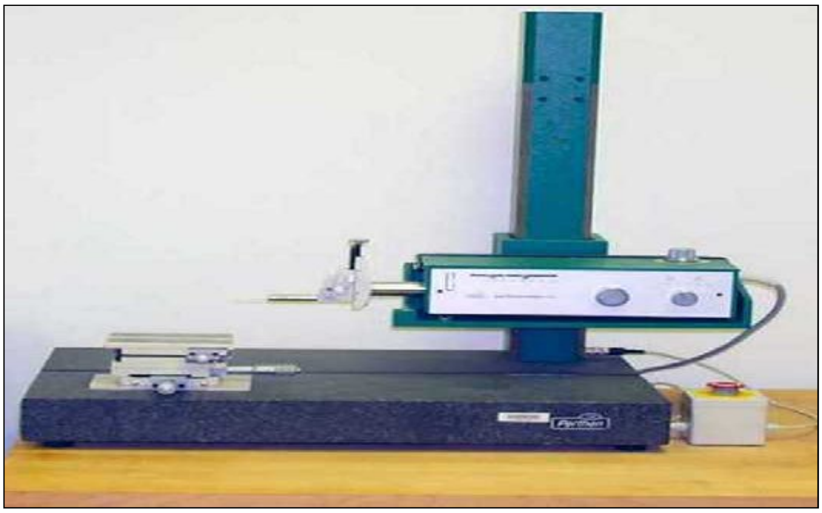


Figure 3.4: Perthometer

Every machining operation leaves characteristic evidence on the machined surface. This evidence in the form of finely spaced micro irregularities left by the cutting tool. Each type of cutting tool leaves its own individual pattern which therefore can be identified. This pattern is known as surface finish or surface roughness.

3.6.1 EXPERIMENT PROCEDURE

The experiment procedure describe as the following:

1. Set the perthometer to the fix reading
2. Put the specimen on the weighing scale on the perthometer.
3. Take the roughness reading on the screen.
4. Do it the steps 1-3 for the next 26 specimens.

3.7 FATIGUE TESTING

3.7.1 Fatigue Tester

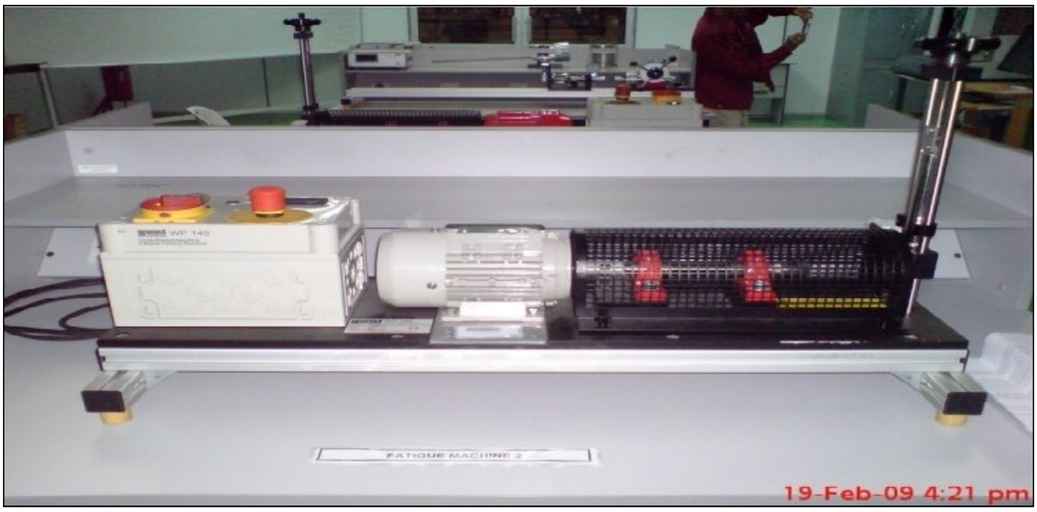


Figure 3.5: Fatigue Tester Machine

Figure 3.5 is a fatigue tester machine. With this machine, it is possible to demonstrate the basic principle of fatigue strength testing, including the production of a stress-number diagram. The sample is subjected to a pure reversed bending stress in the machine. Via different sample shapes, it is possible to show the notch effect and the influence of surface quality on fatigue strength. The amplitude of the reversed stress is infinitely adjustable. The machine switches off automatically if the sample ruptures. The number of load cycle is displayed via digital counter.

3.7.2 TEST INSTRUCTION

3.7.2 Procedure to operate the Fatigue Testing Machine.

Procedure to execute fatigue testing is as follows:

1. Firstly, erect the revolving fatigue testing machine and connect to the power supply.
2. Secondly, Remove the protective hood (unhook the fasteners by rotating the knobs to the left).
3. Thirdly, relieve the load device using the hand wheel (move the floating bearing down to the bottom).
4. Fourthly, remove any sample which may be in position and lightly tighten the union nut on the collets chuck. Finally, mount the protective hood and lock with all four knobs.
5. Please do ensure that the following things are properly checked:

    a. EMERGENCY OFF switch is released (pulled out)
    b. Switch on the machine using the master switch.
    c. Reset the counter using the RST button and counter must display zero.
    d. Starting up the motor using the motor control switch.
    e. Check the spindle is running smoothly and true.
    f. Check the counter is counting correctly.
    g. Check the automatic stop device is functioning.

3.8 INTERPOLATING S-N CURVES

Stress at which the material fails below the load cycle limit of 10^6 are termed fatigue limit. The corresponding number of load cycles N until rupture should be given in bracket. Stress-number (S-N) diagram for two different materials N: number of load cycles, s: stress load on the specimen with an increasing number of load cycles, the permitted loading on a material approaches the fatigue strength asymptotically. The stress-number diagram (S-N Diagram) portrays the correlation between the number of load cycles until rupture and the corresponding load stress in graph form. This clearly shows that as the number of load cycles increases, the permissible load asymptotically approaches the fatigue strength. When plotting a stress-number curve, it is important that with alternating stress, the mean stress is kept constant for the various loads.

CHAPTER 4

RESULT AND DISCUSSION

4.1 ENDURANCE LIMIT ANALYSIS

Metal fatigue is a significant problem because it can occur due to repeating loads below the static yield strength. This can result in an unexpected and catastrophic failure in use.

Because most engineering materials contain discontinuities, most metal fatigue cracks initiate from discontinuities in highly stressed regions of the component. The failure may be due the discontinuity, design, improper maintenance or other causes. A failure analysis can determine the cause of the failure.

The number of loading cycles required to cause the failure of a specimen through repeated successive loadings and reverse loadings may be determined experimentally for any given maximum stress level.

We note that, if the applied maximum stress is high, relatively few cycles are required to cause rupture. As the magnitude of maximum stress is reduced, the number of cycles required to cause rupture increases, until a stress known as endurance limit is reached.

4.2 TESTING RESULT

Figure 4.1 : Pictures of specimen before experiment

Figure 4.2: Pictures of specimen after experiment

4.3 TESTING UNDER DIFFERENT SURFACE ROUGHNESS

Table of Life cycle number of Aluminum, Brass and Mild Steel on different Surface Roughness:

Table 4.1: Data of stress and life cycle of Aluminum (2570 rpm)

No.	Surface Roughness (µm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	1.421	100	200	9092
2.	1.382	75	150	88342
3.	1.321	50	100	3291140

Table 4.2: Data of stress and life cycle of Aluminum (990 rpm)

No.	Surface Roughness (µm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	1.763	100	200	8546
2.	1.825	75	150	69881
3.	1.975	50	100	2891006

Table 4.3: Data of stress and life cycle of Aluminum (100 rpm)

No.	Surface Roughness (µm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	2.50	100	200	8004
2.	2.41	75	150	62792
3.	2.44	50	100	2455180

Table 4.4: Data of stress and life cycle of Brass (2570 rpm)

No.	Surface Roughness (µm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	1.082	100	200	13544
2.	1.197	75	150	979126
3.	0.941	50	100	4823351

Table 4.5: Data of stress and life cycle of Brass (990 rpm)

No.	Surface Roughness (μm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	1.281	100	200	11670
2.	1.302	75	150	783155
3.	1.250	50	100	3508867

Table 4.6: Data of stress and life cycle of Brass (100 rpm)

No.	Surface Roughness (μm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	1.693	100	200	9949
2.	1.681	75	150	726331
3.	1.529	50	100	2966479

Table 4.7: Data of stress and life cycle of Mild Steel (2570 rpm)

No.	Surface Roughness (μm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	0.387	150	300	25734
2.	0.371	100	200	589446
3.	0.382	75	150	2835545

Table 4.8: Data of stress and life cycle of Mild Steel (990 rpm)

No.	Surface Roughness (μm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	0.484	150	300	20678
2.	0.424	100	200	464321
3.	0.295	75	150	2389347

Table 4.9: Data of stress and life cycle of Mild Steel (100 rpm)

No.	Surface Roughness (μm)Ra	Load in N	Stress in σ =N/mm2	Endurance (N)
1.	0.832	150	300	19291
2.	0.942	100	200	426742
3.	0.861	75	150	2168322

4.4: DISCUSSION OF COMPARISON ON LIFE CYCLE OF MATERIALS

From the experiments have been done to compare endurance limit of selected materials, the characteristics and properties is influencing the number of cycles.The bending force applied to those materials is set to be different with 50 N, 100 N, and 150 N.

From the table above, mild steel has the highest fatigue limit and the highest cutting speed has the longest cycles. This steel that also called low-carbon steel has less than 0.3% because and it's normally has higher strength than others.

Then, it follows with brass. Brass is any alloy of copper and zinc, the proportions of zinc and copper can be varied to create a range of brasses, each of which has unique properties. Brass has higher malleability than copper or zinc. The relatively low melting point (900-940^{o}C depending on composition) of brass and its flow characteristics make it a relatively easy material to cast. By varying the proportions of copper and zinc, the properties of the brass can be changed, allowing hard and soft brasses.

Aluminum is a ductile member of non-ferrous metals unless it is being alloyed. Aluminum is a soft, light weight, malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. Relatively pure aluminum is encountered only when corrosion resistance and/or workability is more important than strength or hardness. Pure Aluminum has a low tensile strength. The yield strength of pure aluminum is 7-11 Mpa, while aluminum alloys. Aluminum has about one-third the density and stiffness of steel. It is ductile, and easily machined, cast, and extruded. One important structural limitation of aluminum alloys is their fatigue strength. Unlike steels, aluminum alloys have no well defined fatigue limit, meaning that fatigue failure will eventually occur under even very small cyclic loading.

4.5 GRAPS FOR ALUMINUM, BRASS AND MILD STEEL ON DIFFERENT SURFACE ROUGHNESS

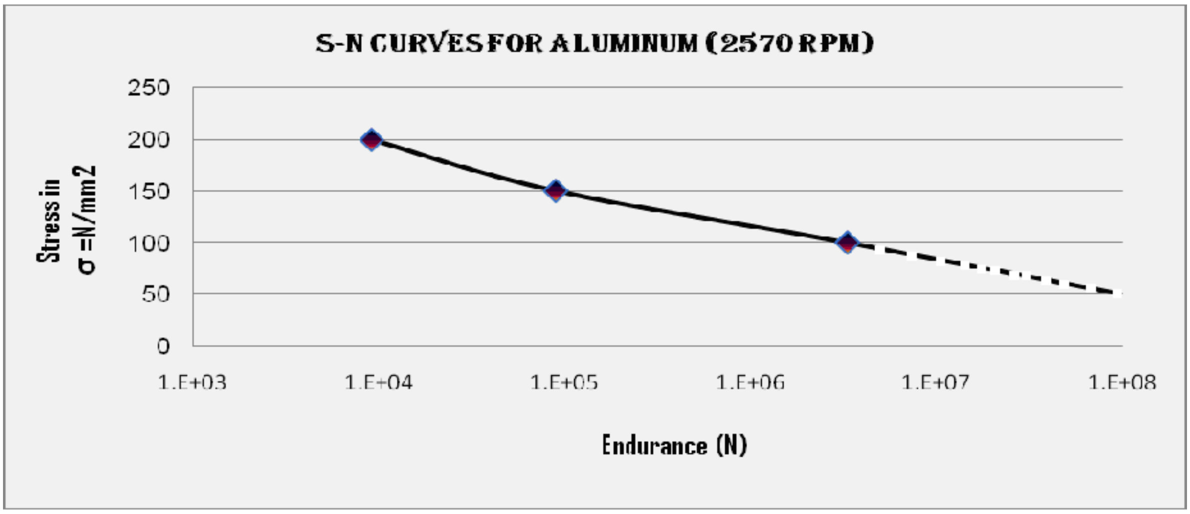


Figure 4.3: S-N Curves For Aluminum (2570 RPM of spindle speed lathe machine)

Figure 4.3 shows the effect of aluminum to the life cycles when the surface roughness of aluminum is cutting on 2570 RPM using the conventional lathe machine. The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 200, 150 and 100 N/mm2. At 200 N/mm2 the life cycle is 9092 cycles and the life cycle increased 88342 cycles when the stress is 150 N/mm2. At 100 N/mm2 the life cycle is 3291140. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The extrapolation lines continue according to the literature research that stated the aluminum still has fracture if the stress is continuously. It means, if the stress is given on the specimen when the fatigue testing is running, the failure is still occur. the In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

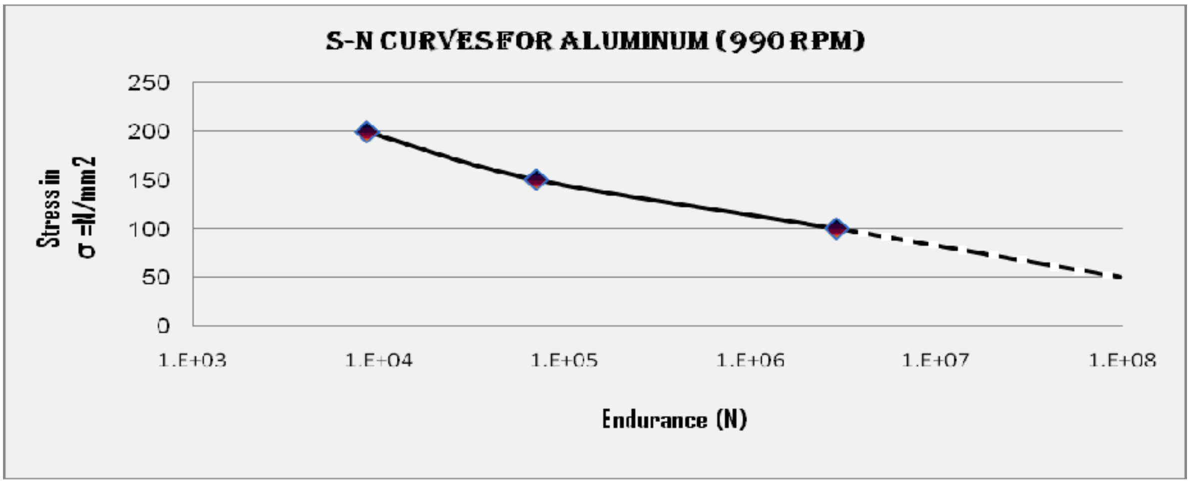


Figure 4.4: S-N Curves For Aluminum (990 RPM spindle speed lathe machine)

Figure 4.4 shows the effect of aluminum to the life cycles when the surface roughness of aluminum is cutting on 990 RPM. The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 200, 150 and 100 N/mm2. At 200 N/mm2 the life cycle is 8546 cycles and the life cycle increased 69881 cycles when the stress is 150 N/mm2. At 100 N/mm2 the life cycle is 2891006 cycle. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The extrapolation lines continue according to the literature research that stated the aluminum still has fracture if the stress is continuously. It means, if the stress is given on the specimen when the fatigue testing is running, the failure is still occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

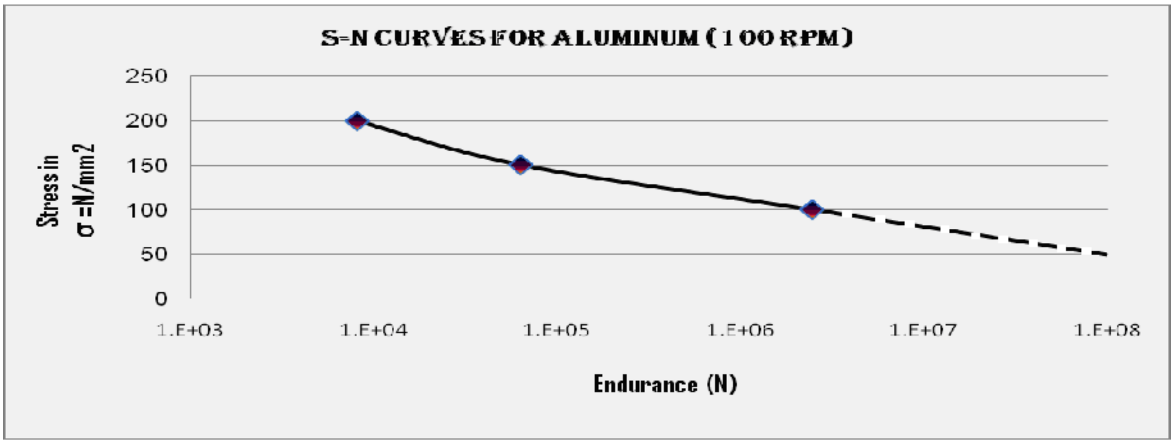


Figure 4.5:S-N Curves For Aluminum (100 RPM spindle speed lathe machine)

Figure 4.5 shows the effect of aluminum to the life cycles when the surface roughness of aluminum is cutting on 100 RPM. The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 200, 150 and 100 N/mm2. At 200 N/mm2 the life cycle is 8004 cycles and the life cycle increased 62792 cycles when the stress is 150 N/mm2. At 100 N/mm2 the life cycle is 2455180 cycles. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The extrapolation lines continue according to the literature research that stated the aluminum still has fracture if the stress is continuously. It means, if the stress is given on the specimen when the fatigue testing is running, the failure is still occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

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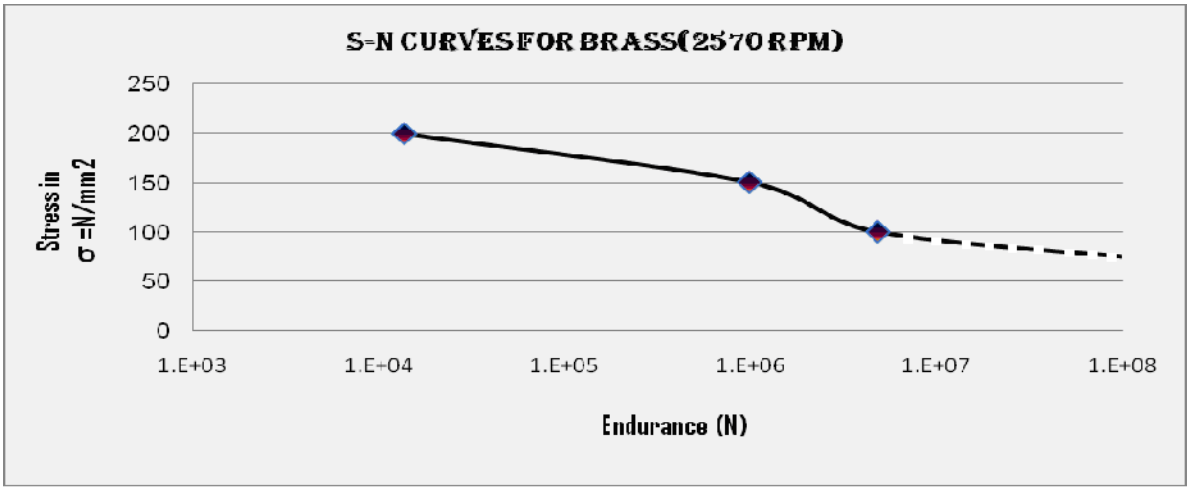

Figure 4.6: S-N Curves For Brass (2570 RPM spindle speed lathe machine)

Figure 4.6 shows the effect of Brass to the life cycles when the surface roughness of Brass is cutting on 2570 RPM. . The y axis is represented by stress while the x axis is for endurance. The material was subjected on three Stresses that were 200, 150 and 100 N/mm2. At 200 N/mm2 the endurance is 13544 cycles and the endurance increased 979126 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 4823351. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The extrapolation lines continue according to the literature research that stated the brass still has fracture if the stress is continuously. It means, if the stress is given on the specimen when the fatigue testing is running, the failure is still occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

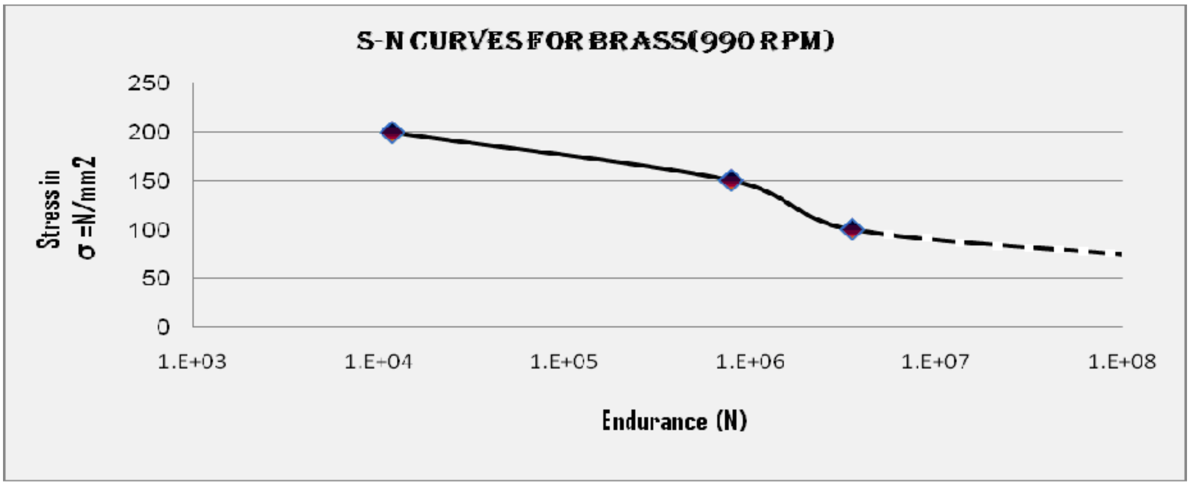

Figure 4.7: S-N Curves For Brass (990 RPM spindle speed lathe machine)

Figure 4.7 shows the effect of Brass to the life cycles when the surface roughness of brass is cutting on 990 RPM. . The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 200, 150 and 100 N/mm2. At 200 N/mm2 the endurance is 11670 cycles and the endurance increased 783155 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 3508867. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The extrapolation lines continue according to the literature research that stated the brass still has fracture if the stress is continuously. It means, if the stress is given on the specimen when the fatigue testing is running, the failure is still occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

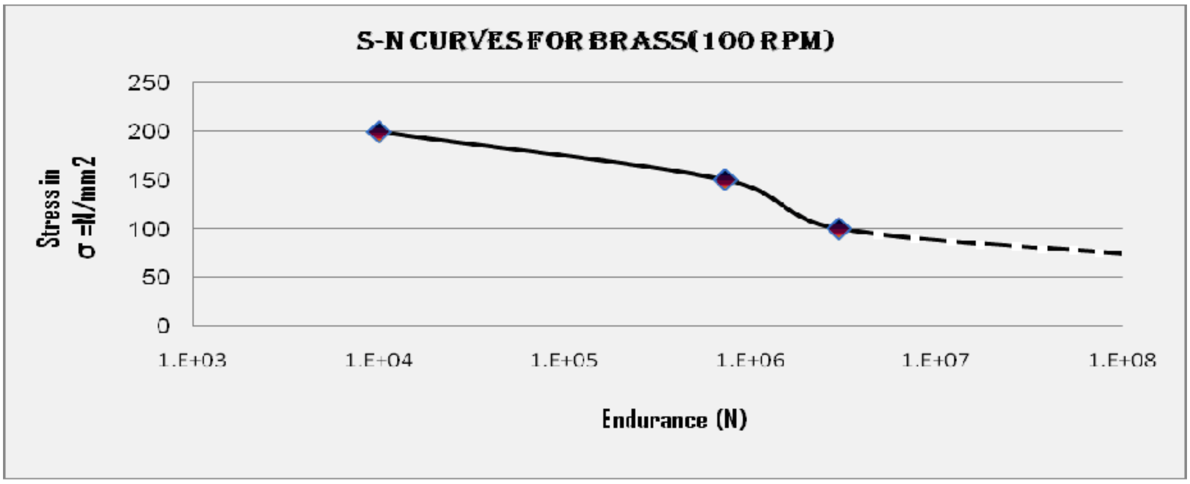

Figure 4.8:S-N Curves For Brass (100 RPM spindle speed lathe machine)

Figure 4.8 shows the effect of brass to the life cycles when the surface roughness of brass is cutting on 100 RPM. The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 200, 150 and 100 N/mm2. At 200 N/mm2 the endurance is 9949 cycles and the endurance increased 726331 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 2966479. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The extrapolation lines continue according to the literature research that stated the brass still has fracture if the stress is continuously. It means, if the stress is given on the specimen when the fatigue testing is running, the failure is still occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

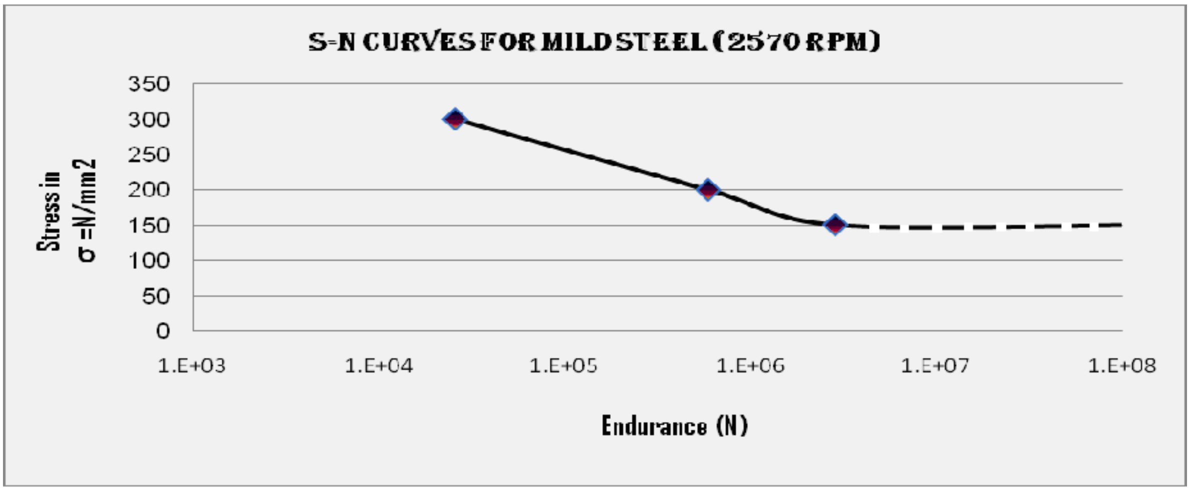

Figure 4.9 : S-N Curves For Mild Steel (2570 RPM spindle speed lathe machine)

Figure 4.9 shows the effect of Mild Steel to the life cycles when the surface roughness of Mild Steel is cutting on 2570 RPM. The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 300, 200 and 150 N/mm2. At 300 N/mm2 the endurance is 25734 cycles and the endurance increased 589446 cycles when the stress is 200 N/mm2. At 150 N/mm2 the endurance is 2835545. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The line continues according to the literature research that stated the Mild Steel stop fracture until 50^6 cycles. It means, if the stress is given on the specimen when the fatigue testing is running, the failure will not occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

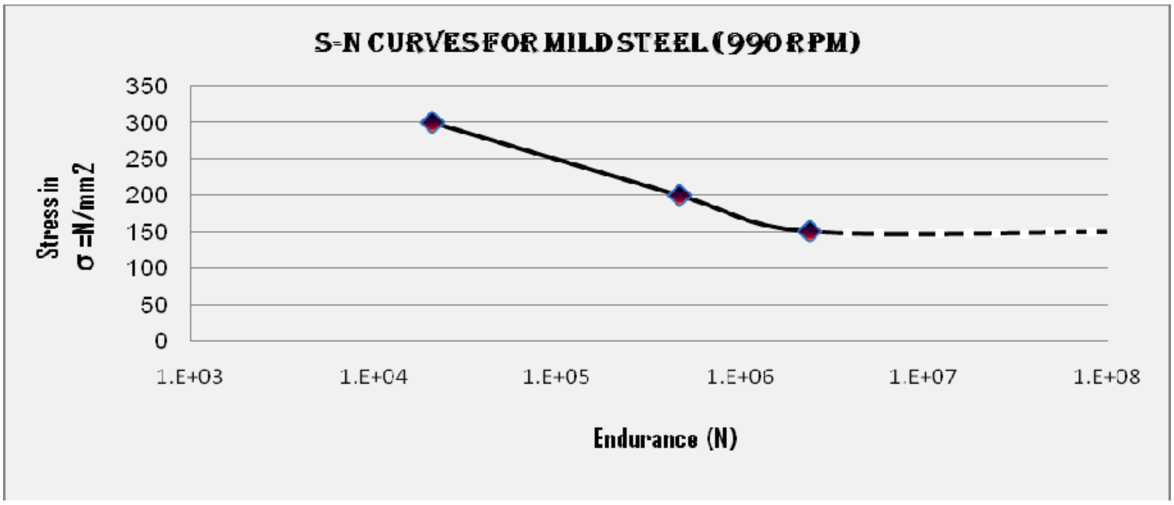

Figure 4.10 : S-N Curves For Mild Steel (990 RPM spindle speed lathe machine)

Figure 4.10 shows the effect of Mild Steel to the life cycles when the surface roughness of Mild Steel is cutting on 990 RPM. The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 300, 200 and 150 N/mm2. At 300 N/mm2 the endurance is 20678 cycles and the endurance increased 464321 cycles when the stress is 200 N/mm2. At 150 N/mm2 the endurance is 2389347. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The line continues according to the literature research that stated the Mild Steel stop fracture until 50^6 cycles. It means, if the stress is given on the specimen when the fatigue testing is running, the failure will not occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

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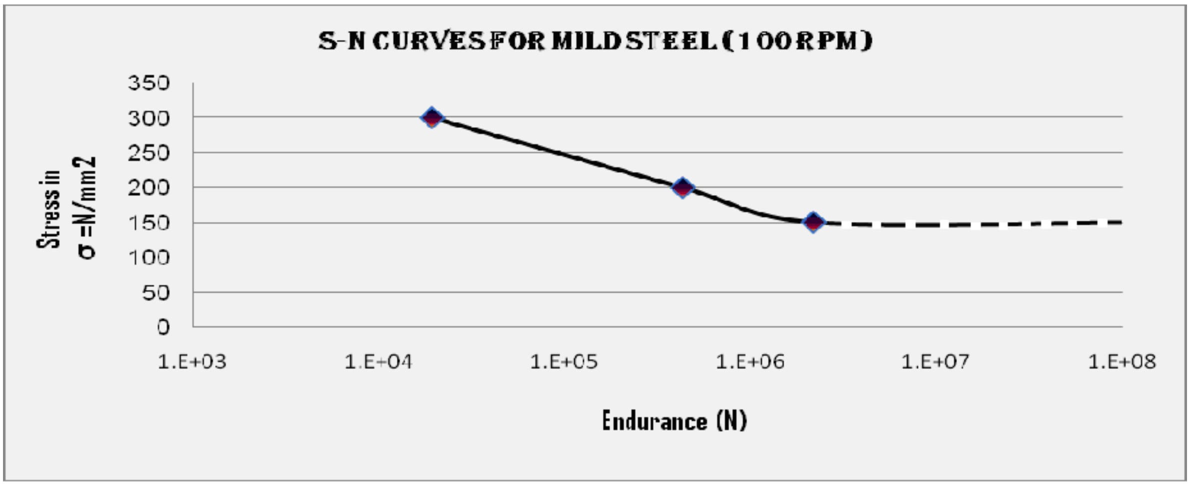

Figure 4.11 : S-N Curves For Mild Steel (100 RPM spindle speed lathe machine)

Figure 4.11 shows the effect of Mild Steel to the life cycles when the surface roughness of Mild Steel is cutting on 100 RPM. The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 300, 200 and 150 N/mm2. At 300 N/mm2 the endurance is 19291 cycles and the endurance increased 426742 cycles when the stress is 200 N/mm2. At 150 N/mm2 the endurance is 1108322. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The lines continue according to the literature research that stated the Mild Steel stop fracture until 50^6 cycles. It means, if the stress is given on the specimen when the fatigue testing is running, the failure will not occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

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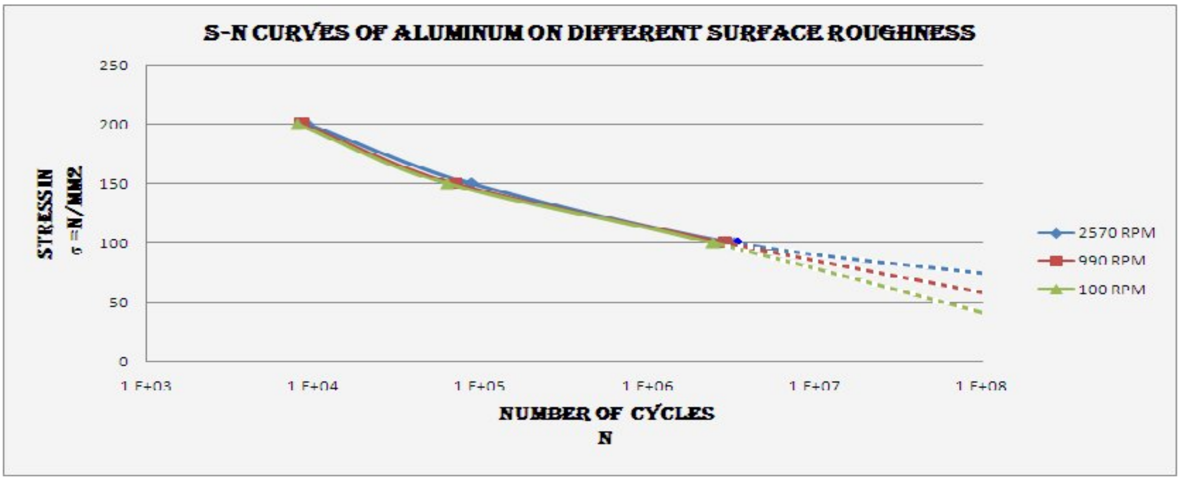

Figure 4.12: S-N Curves For Aluminum on Different Surface Roughness

Figure 4.12 shows the effect of aluminum on different surface roughness to the life cycles. The y axis is represented by stress while the x axis is for endurance. The material was subjected on three stresses that were 200, 150 and 100 N/mm2.Firstly, The 2570 RPM. The material was subjected on three stresses that were 200, 150 and 100 N/mm2. At 200 N/mm2 the endurance is 9092 cycles and the endurance increased 88342 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 3291140 .Then, the cutting speed of 990RPM, At 200 N/mm2 the endurance is 8546 cycles and the endurance increased 69881 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 2891006.Lastly, the cutting speed of 100RPM. At 200 N/mm2 the endurance is 8004 cycles and the endurance increased 62792 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 2455180. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The extrapolation lines continue according to the literature research that stated the aluminum still has fracture if the stress is continuously. It means, if the stress is given on the specimen when the fatigue testing is running, the failure is still occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

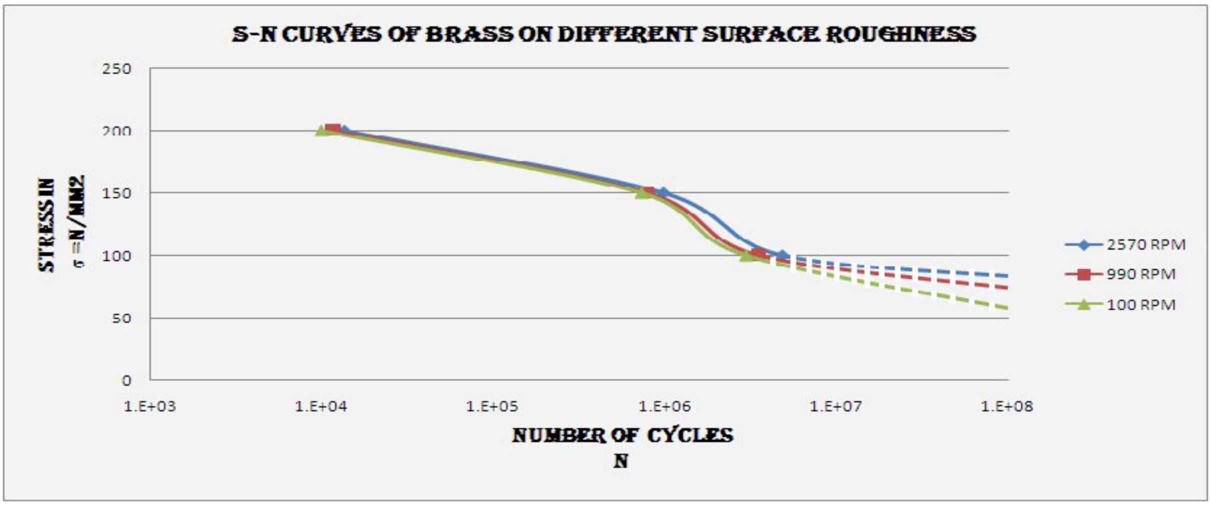

Figure 4.13 : S-N Curves For Brass on Different Surface Roughness

Figure 4.13 shows the effect of brass on different surface roughness to the life cycles. The y axis is represented by stress while the x axis is for endurance. The materials was subjected on three stresses that were 200, 150 and 100 N/mm2.Firstly, we look at 2570 RPM. The material was subjected on three stresses that were 200, 150 and 100 N/mm2. At 200 N/mm2 the endurance is 13544 cycles and the endurance increased 979126 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 4823351 .Then, the cutting speed of 990RPM, At 200 N/mm2 the endurance is 11670 cycles and the endurance increased 783155 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 3508867.Lastly, the cutting speed of 100RPM. At 200 N/mm2 the endurance is 8004 cycles and the endurance increased 62792 cycles when the stress is 150 N/mm2. At 100 N/mm2 the endurance is 2966479. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The extrapolation lines continue according to the literature research that stated the brass still has fracture if the stress is continuously. It means, if the stress is given on the specimen when the fatigue testing is running, the failure is still occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

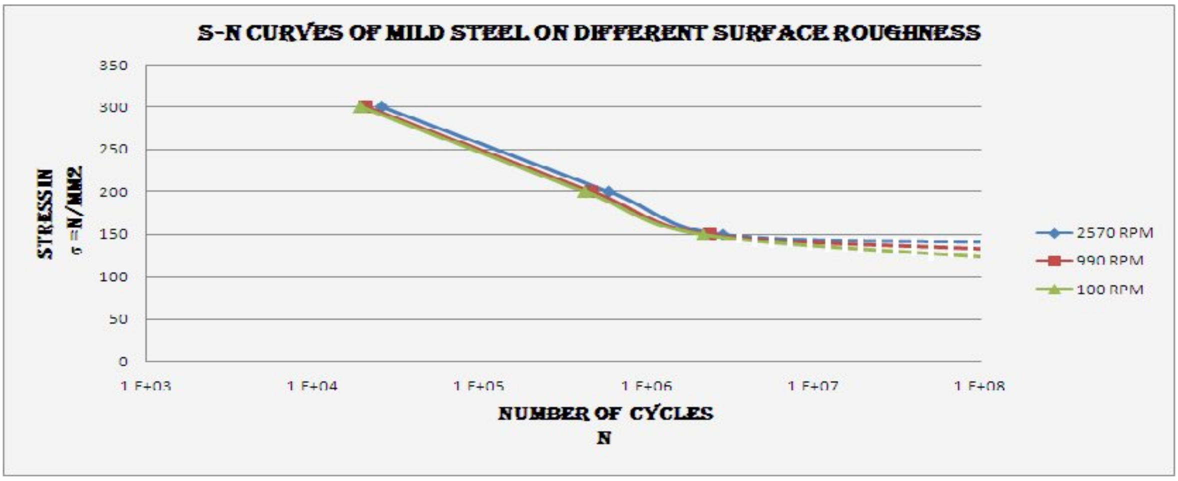

Figure 4.15 : S-N Curves For Mild Steel on Different Surface Roughness

Figure 4.15 shows the effect of mild steel on different surface roughness to the life cycles. The y axis is represented by stress while the x axis is for endurance. The materials was subjected on three stress that were 300, 200 and 150 N/mm2.Firstly, we look at 2570 RPM. The material was subjected on three stresses that were 300, 200 and 150 N/mm2. At 300 N/mm2 the endurance is 25734 cycles and the endurance increased 589446 cycles when the stress is 200 N/mm2. At 150 N/mm2 the endurance is 2835545 .Then, the cutting speed of 990RPM, At 300 N/mm2 the endurance is 19291 cycles and the endurance increased 426742 cycles when the stress is 200 N/mm2. At 150 N/mm2 the endurance is 2168322.Lastly, the cutting speed of 100RPM. At 300 N/mm2 the endurance is 20678 cycles and the endurance increased 62792 cycles when the stress is 200 N/mm2. 464321 cycles. At 150 N/mm2 the endurance is 2389347. This figure shows that the line is increasing horizontally if the stress is decreasing. The unit of stress in N/mm2 means it same with Mpa while the endurance is same with life cycle. The lines continue according to the literature research that stated the Mild Steel stop fracture until 50^6 cycles. It means, if the stress is given on the specimen when the fatigue testing is running, the failure will not occur. In this figure, we can conclude that the life cycle is increasing if the lower stress is decreasing.

4.6 DISCUSSION FROM THE GRAPH

From all graph of material above, the life cycle of all materials is decrease when the spindle speed of cutting material is decrease. This is because if the lowest cutting speed is subjected to the materials the rougher the surface of the materials. So, if the surface of the materials is rougher the easier materials to crack.
Why rougher surface is easy to crack:

1. The dimension of the rougher surface is more depth and its mean if we do the fatigue test, it will more easy to crack.
2. Notch will occur when we use the low cutting speed while fabricate the specimen.

In designing a product like drive shaft, it is a must to consider this thing because the rougher of the surface materials, it will easy to fracture.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The main objective of this study is to determine the endurance limit of materials on different surface finish owing to cyclic loads. The materials that being tested were aluminum, brass and mild steel. After the fatigue strength test has been performed and the data has been made, the data is being analyze and being compared to each other.

The objective was achieved. This study shows that, selection of materials to manufacture a product is very important because it will influence the products properties and strength. Each type of materials has their own characteristics.

Endurance limit of each material is different. The endurance of each material before fracture was being measured through experiment. From that, the highest and lowest one was known. Mild steel is the highest endurance and most strength compare with an endurance average is. Then it been followed with brass with and the lowest is aluminum with.

The specimen’s surface also influenced the value of endurance limit or fatigue limit. From the experiments that the surface specimens were being change and all materials shows that if the lower cutting speed acted on the specimens , they were easily fracture compared to the highest spindle speed because the rougher the surface the easiest materials to fracture.

As a conclusion, a material must be selected properly before making a decision to uses it to manufacture a product. The higher the endurance limits the higher fatigue strength of a material. The higher fatigue strength value of a material, the better its endurance under loading. Moreover, it may lead to a long life of the products.

5.2 RECOMMENDATION

Studies of Endurance limit or fatigue strength can still be expanded and widened due to the other properties that can be tested such as curvature radii and elongation of the materials due to a break point.

Following factors and process can reduce fatigue strength or endurance limit:

a) Decarburization
b) Surface pits (due to corrosion) that act as stress raisers.
c) Hydrogen embrittlement
d) Galvanizing

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

a) Inducing compressive residual stresses on surface for example, by shot penning or by roller burnishing.
b) Surface (case) hardening by various means.
c) Producing a fine surface finish and thereby reducing the effects on notches and other surface imperfections.
d) Selecting appropriate materials and ensuring that they are free from significant amounts of inclusions voids and impurities.
e) Eliminate or reduce stress raisers by streamlining the part
f) Avoid sharp surface tears resulting from punching, stamping, shearing, or other processes.
g) Prevent the development of surface discontinuities during processing.

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