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

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| Signature: | : ........................................ |
| Name of supervisor | : Mr Wan Mohd Farid Bin Wan Mohamad |
| Date | : May 2006 |

# A STUDY ON THE ANNEALING PROCESS OF ALUMINUM BRONZE ALLOY BASED ON THEIR MICROSTRUCTURE GROWTH AND MECHANICAL PROPERTIES

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A thesis report submitted to faculty of mechanical engineering in partial fulfillment of the requirements for the award of Bachelor's degree of Mechanical Engineering (Structure and Material)

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"I hereby the author, declare this report entitled "A STUDY ON THE ANNEALING PROCESS OF ALUMINUM BRONZE ALLOY BASED ON THEIR MICROSTRUCTURE GROWTH AND MECHANICAL PROPERTIES"is my own except for quotations and summaries which have been duly acknowledged"

Signature : ....................................

Author : Azane Azran Bin Mohd Latif

Date : May 2006

## DEDICATION

*To my dearest parent*

Mr Mohd Latif bin Hasan and Mrs Ramlah binti Kalil

My brothers and sisters,

Azira Azreen

Azare Azan

Azrae Azzad

*A special dedication also goes to my beloved grandmother, cousin, uncle, aunty and my special girlfriend for their care and support.*

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Besides that, I would like to express my sincere thanks to all my family and friends because understand, patience and co-operation. May Allah bless all of them. Finally the author is expressing his sincere gratitude to Allah once again who made the study to complete.

# ABSTRACT

This project concerned with the investigation on the annealing process of aluminum bronze alloy based on their microstructure growth and mechanical properties. This is important in order to identify the effect of annealing process on the hardness, tensile strength and microstructure of the alloy. This research also wants to predict the relationship between mechanical properties and microstructure growth. Parameters that have been use is temperature and time range of temperature between 100°C until 700°C while for time parameter range around 30 minute until 120 minute. It begin with literature survey until laboratory work be conducted on the alloy with different annealing temperature with various of annealing period is to identify and establish the critical factor in annealing process. Finding of this research is, tensile strength and hardness value will be inversing with increasing of annealing period while percentage of ductility is proportional with increasing of annealing temperature. Finally microstructure observation and mechanical testing will be done to predict its relationship

# ABSTRAK

Projek ini adalah berkenaan kajian dan pemerhatian terhadap proses sepuh lindap terhadap bahan aloi 'aluminum bronze'. Kajian dibuat terhadap perkembangan saiz mikro struktur dan sifat-sifat mekanikal yang ada pada bahan tersebut. Kajian adalah penting kerana untuk mengenal pasti kesan kaedah sepuh lindap terhadap kekuatan kekerasan,daya regangan,dan mikro struktur aloi tersebut. penyelidikan ini juga untuk melihat dan meramal hubungan antara sifat mekanikal bahan serta perubahan struktur mikro bahan.Perubahan suhu dan masa adalah parameter yang akan digunakan dimana julat suhu ialah antara 100°C hingga 700°C manakala perubahan masa yang akan digunapakai adalah antara 30 minit sehingga 120 minit tempoh rawatan haba tersebut. Ianya bermula dengan pencarian maklumat terhadap kajian persuratan penyelidikan sehinggalah membuat kerja-kerja di makmal terhadap proses sepuh lindap ini. Kaedah sepuh lindap dilakukan dengan melihat pada perubahan suhu dan masa yang pelbagai untuk mencari dan memperkuatkan faktor kritikal yang terbentuk. Hasil kajian dapat dilihat setelah sampel sepuh lindap diuji dan dianalisis strukturnya sekali gus perkaitan antara struktur mikro dan sifat mekanikal dapat dilihat.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction to annealing process

Annealing is one of process for heat treatment where in annealing, it heating to and holding at a suitable temperature and then cooling at a suitable rate, for such purposes as reducing hardness, improving machine ability, facilitating cold working, producing a desired microstructure, or obtaining desired mechanical, physical or other properties. When applied to ferrous alloys, the term "annealing," without qualification, implies full annealing. When applied to nonferrous alloys, the term "annealing" implies a heat treatment designed to soften a cold worked structure by recrystallization or subsequent grain growth or to soften an age-hardened alloy by causing a nearly complete precipitation of the second phase in relatively coarse form.

Bronze alloys consist of several families named for the principal solid-solution alloying element. These alloys provide an excellent combination of strength, formability, softening resistance, electrical conductivity, and corrosion resistance. Aluminum bronze alloys typically contain 9-12% aluminum and up to 6% iron and nickel. Alloys in these composition limits are hardened by a combination of solid solution strengthening, cold work, and precipitation of an iron rich phase. High aluminum alloys are quenched and tempered. Objective to study annealing for bronze alloy is to define the mechanical properties characteristics and to make observation for the grain grow size, microstructure view.

Mechanical properties are based on the hardness, ductility, and their tensile. Hardness defines as "Resistance of metal to plastic deformation, usually by indentation. However, the term may also refer to stiffness or temper or to resistance to scratching, abrasion, or cutting. It is the property of a metal, which gives it the ability to resist being permanently, deformed (bent, broken, or have its shape changed), when a load is applied. The greater the hardness of the metal, the greater resistance it has to deformation. In metallurgy hardness is defined as the ability of a material to resist plastic deformation. The dictionary of Metallurgy defines the indentation hardness as the resistance of a material to indentation. This is the usual type of hardness test, in which a pointed or rounded indenter is pressed into a surface under a substantially static load.

Materials which develop significant permanent deformation before they break are called *ductile.* Ductile materials permit manufacturing methods which involve bending them to the required shapes or using a press to squash the material into the required shape. Brittle materials cannot be formed to shape in this way.A measure of the ductility of a material is obtained by determining the length of a test piece of the material, then stretching it until it breaks and then, by putting the pieces together, measuring the final length of the test piece A brittle material will show little change in length from that of the original test piece, but a ductile material will indicate a significant increase in length. The *percentage elongation* of a test piece after breaking is thus used as a measure of ductility.

In order to compare the strengths of various materials it is necessary to carry out some standard form of test to establish their relative properties. One such test is the standard tensile test in which a circular bar of uniform cross-section is subjected to a gradually increasing tensile load until failure occurs. Measurements of the change in length of a selected *gauge length* of the bar are recorded through out the loading operation by means of extensometers and a graph of load against extension or stress against strain is produced.

Grain growth is the growth of a grain at the expense of surrounding recrystallized grains. There is usually no sharp distinction between the recrystallization and grain-growth stage of annealing, since grain growth may be going on in the part of the structure that recrystallized first while other regions are still recrytallizing. The driving force for grain growth is the surface energy of the grain boundaries of the recrystallized grains where the large the grain size, the smaller the amount of grain boundary in the material and the lower its energy. The major change observed during this stage is the growth of the grain boundaries and reaching the original grain size.

Microstructural analysis is used in research studies to determine the microstructural changes that occur as a result of varying parameters such as composition, heat treatment or processing steps. Typical research studies include microstructural analysis and materials property testing. Through these research programs the processing - structure - property relationships are developed. The microstructural features sometimes considered are grain size, amount of impurities, second phases, porosity, segregation or defects present. The amount or size of these features can be measured and quantified, and compared to the acceptance criterion. Various techniques for quantifying microstructural features, such as grain size, particle or pore size, volume fraction of a constituent, and inclusion rating, are available for comparative analysis.

## 1.2 Research Objective

This research objective is to identify the effect of annealing process on the hardness, tensile strength and microstructure of the alloy. Beside that it also wants to predict the relationship between mechanical properties and microstructure growth. Temperature and time is parameters have been used to define their effect in mechanical properties and microstructure growth.

## 1.3 Research Scope

This research begins with literature survey and conduct laboratory work on the alloy with different annealing temperature and time. Finally, it to identify and establish the critical factor in annealing process also to predict relationship between microstructure analysis and mechanical testing.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Annealing

Annealing is heating to and holding at a temperature in which a material (marten site) is softened by high temperature for an appropriate time. There is a comparable heat treatment in which the hardness of mechanically deformed microstructures is reducing at high temperature. In order to appreciate the details of this micro structural development, need to explore 4 items where is cold work, recrystallization, grain growth, and their mechanical properties.

### 2.1.1 Cold Work

Is the phenomenon whereby a ductile becomes harder and stronger as it is plastically deformed. It is sometimes convenient to express the degree of plastic deformation as percent cold work rather than as strain. Percent cold work (%CW) is define as:

$$\%CW = \left( \frac{A_o - A_d}{A_o} \right) \times 100 \quad \text{..............(1)}$$

Where $A_o$ is the original area of the cross section that experiences deformation and $A_d$ is the area after deformation.

### 2.1.2 Recrystallization

The marked loss or strength that occurs on annealing cold-worked materials at temperature above a critical temperature is attributable to recrystallisation, with the formation completely new grains (primary recrystallisation). It start with the formation of crystal nuclei at those points of the crystal lattice that have been most deformed by cold work. The new grains then grow within the existing deformed crystal lattice until they impinge on other new grains that are undergoing the same nucleation and growth process. The amount of prior cold work, the annealing temperature and the annealing time determine the course of the recrystallisation process and the size of the recrystallised grains. Alloy composition and the size of existing precipitates can also play a decisive role under certain circumstances.

### 2.1.3 Grain growth

In this stage the tensile strength and hardness continue to decrease but at much less rate than the recrystallization stage. The major change observed during this stage is the growth of the grain boundaries and reaching the original grain size. During recrystalization, grains of undistorted material nucleate and grow into the surrounding deform material. The growth of a grain at the expense of surrounding recrystallized grains it called grain growth. There is usually no sharp distinction between the recrystallization and grain-growth stage of annealing, since grain growth may be going on in the part of the structure that recrystallized first while other regions are still recrytallizing. The driving force for grain growth is the surface energy of the grain boundaries of the recrystallized grains where the large the grain size, the smaller the amount of grain boundary in the material and the lower its energy. [T. S. SRIVATSAN, Relationship between annealing and recrystallization, Virginia 22044 USA]. All stage of grain growth shown in **Figure 2.1**.

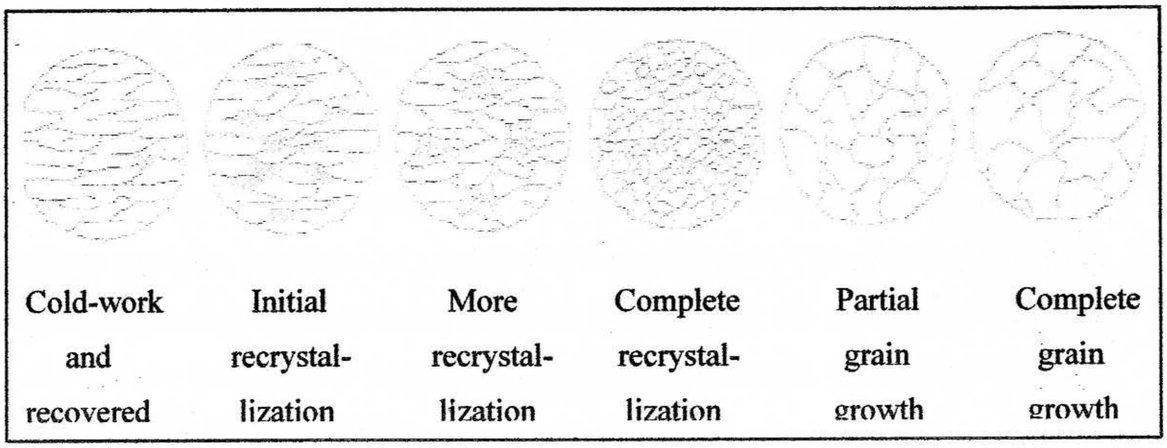


*Figure 2.1: Microstructure for annealing process* [Mike Meier, Recovery, recrytallization and grain growth, September 13, 2004].

### 2.1.4 Mechanical properties

The mechanical properties are about the behavior of materials when subject to forces. When a material is subject to external forces, the internal forces are set up in the materials which oppose the external forces. The material can be considered to be rather like a spring. Spring, when stretched by external forces, sets up internal opposite forces which are readily apparent when the spring is released and the force it to contract. A material subjected to external forces which stretch said to be in *tension force.* A material subject to forces which squeeze it is said to be in *compression.* If a material subject to forces which cause it to twist or one face slide relative to a opposite face then it is said to be in *shear.* An object, in some situations, can be subject to both tension and compression, example beam which is being bent, the bending causing the upper surface to contract and so be in compression and the lower surface to extend and be in tension. These are the properties displayed when a force is applied to a material and include strength, stiffness, hardness, toughness, and ductility.

**(a) Tensile**

In order to compare the strengths of various materials it is necessary to carry out some standard form of test to establish their relative properties. One such test is the standard tensile test in which a circular bar of uniform cross-section is subjected to a gradually increasing tensile load until failure occurs. Measurements of the change in length of a selected *gauge length* of the bar are recorded through out the loading operation by means of extensometers and a graph of load against extension or stress against strain is produced as shown in **Figure 2.2** this shows a typical result for a test on a mild (low carbon) steel bar; other materials will exhibit different graphs but of a similar general.

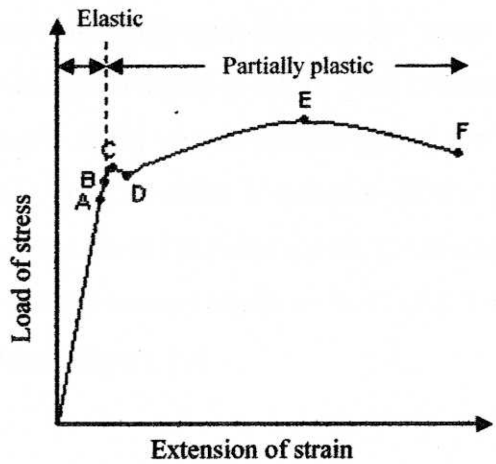


*Figure 2.2: typical tensile test curve for mild steel bar [E.J.HEARN, Butterworth Heinemann, 1997]*

For the first part of the test it will be observed that Hooke's law is obeyed, i.e. the material behaves elastically and stress is proportional to strain, giving the straight-line graph indicated. Some point *A* is eventually reached, however, when the linear nature of the graph ceases and this point is termed the *limit of proportionality.* For a short period beyond this point the material may still be elastic in the sense that deformations are completely recovered when load is removed (i.e. strain returns to zero) but Hooke's law does not apply. The limiting point *B* for this condition is termed the *elastic limit*. For most practical purposes it can often be assumed that points *A* and *B* are coincident.

Beyond the elastic limit *plastic deformation* occurs and strains are not totally recoverable. There will thus be some permanent deformation or *permanent set* when load is removed. After the points C, termed the *upper yield point,* and *D,* the *lower yield point,* relatively rapid increases in strain occur without correspondingly high increases in load or stress. The graph thus becomes much more shallow and covers a much greater portion of the strain axis than does the elastic range of the material. The capacity of a material to allow these large plastic deformations is a measure of the so-called *ductility* of the material.

For certain materials, for example, high carbon steels and non-ferrous metals, it is not possible to detect any difference between the upper and lower yield points and in some cases no yield point exists at all. In such cases a *proof stress* is used to indicate the onset of plastic strain or as a comparison of the relative properties with another similar material. This involves a measure of the permanent deformation produced by a loading cycle; the 0.1% proof stress, for example, is that stress which, when removed, produces a permanent strain or "set" of 0.1 % of the original gauge length, refer **Figure 2.3** and **Figure 2.4**.

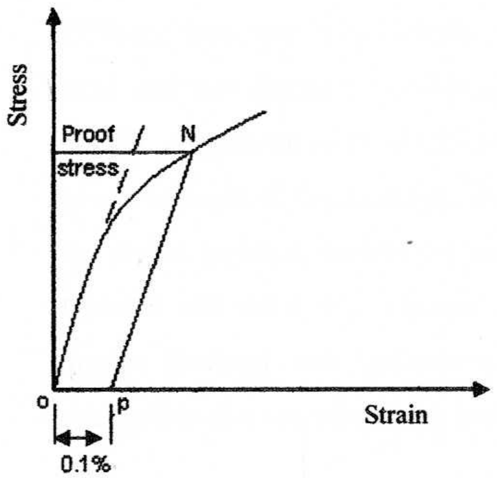


*Figure 2.3:*

*Determination of 0.1% proof stress*

*[E.J.HEARN. Butterworth Heinemann, 1997]*

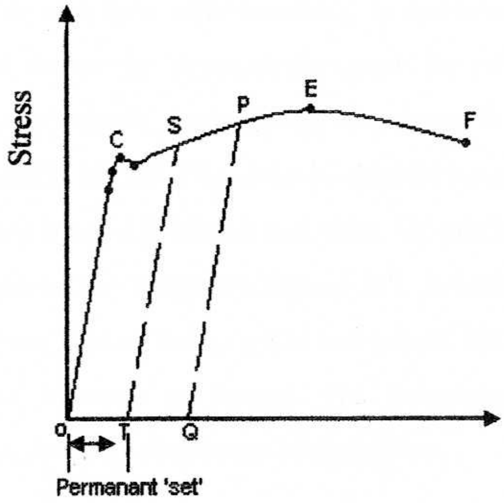


*Figure 2.4:*

*Permanent deformation or "set"*

*[E.J.HEARN. Butterworth Heinemann, 1997]*

In fact, careful observation shows that the materials will no longer exhibit true elasticity since the unloading and reloading lines will form a small *hysteresis loop,* neither being precisely linear. Repeated loading and unloading will produce a yield point approaching the ultimate stress value but the elongation or strain to failure will be much reduced.

**(b) Ductility**

Glass is a *brittle material* and if you drop a glass it breaks; however it is possible to stick all the pieces together again and restore the glass to its original shape. If a car is involved in a collision, the bodywork of mild steel is less likely to shatter like the glass but more likely to dent and show permanent deformation (the term *permanent deformation* is used for changes in dimensions which are not removed when the forces applied to the material are taken away). Materials which develop significant permanent deformation before they break are called *ductile.* Ductile materials permit manufacturing methods which involve bending them to the required shapes or using a press to squash the material into the required shape. Brittle materials cannot be formed to shape in this way.

The stress-strain graph for cast iron in **Figure 2.5** shows that very little plastic deformation occurs, no sooner has the stress raised to the yield point then failure occurs. Thus the length of a piece of cast iron after breaking is not much different from the initial length. **Figure 2.6** shows the stress-strain graph for mild steel and this shows a considerable amount of plastic strain before breaking; it is ductile. A measure of the ductility of a material is obtained by determining the length of a test piece of the material, then stretching it until it breaks and then, by putting the pieces together, measuring the final length of the test piece **Figure 2.7**. A brittle material will show little change in length from that of the original test piece, but a ductile material will indicate a significant increase in length. The *percentage elongation* of a test piece after breaking is thus used as a measure of ductility: