“I admit to have read this report and it has followed the scope and quality in Partial Fullfillment of Requirement for the Degree of Bachelor of Mechanical Engineering (Structure and Material)

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Date: JUNE 2012

EFFECT OF HEAT TREATMENT ON IMPACT STRENGTH OF ALUMINIUM ALLOY

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ADMISSION

I admit that this report is the result of my own work except for the summary and each passages which I have mentioned the source.

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ABSTRAK

Kajian ini akan dijalankan untuk menyiasat kesan yang akan berlaku kepada kekuatan impak, kekerasan dan pencirian mikrostruktur terhadap aloi aluminium yang dirawat menggunakan rawatan haba. Aloi aluminium akan diletakkan dalam proses rawatan haba dan akan disejukkan secara mengejut dengan menggunakan media yang berbeza. Aloi aluminium tersebut akan dirawat di pada suhu 529 darjah celcius untuk satu masa tertentu yang telah ditetapkan. Ia juga akan disejukkan secara mengejut dengan menggunakan media yang berbeza iaitu air dan minyak. Rawatan penuaan akan dijalankan pada suhu 160 darjah celcius dimana suhu ini dikatakan terbaik untuk menjalankan proses ini. Pengukuran kekerasan akan dijalankan menggunakan Penguji Kekerasan Brinell. Akhir sekali, mikrostruktur aluminium tersebut akan dilihat di bawah SEM (Scanning Electron Microscope) untuk menentukan sifatnya sebelum dan selepas rawatan haba dijalankan ke atasnya.

ABSTRACT

This study was undertaken to investigate the effect impact strength, hardness and microstructure characterization of heat treated aluminium alloy. The aluminium alloy will be examined in the heat treated conditions, using different quenching media. The alloy will be solution treated at temperature of 529ºC for certain time that have been set. It also will be quenching using different media which is water and oil. Aging treatment will be carried out at temperature of 160ºC which is believed to be the best temperature for ageing process. Hardness measurement will be carried out using a Brinell Hardness Tester. Lastly, microstructure of the material will be seen under SEM (Scanning Electron Microscope) to determine its behavior.

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CHAPTER 1

INTRODUCTION

This chapter will simply discuss about an introduction to this research. Topics that will be included are research background, research objectives, research questions, importance of research, problem statement, scope and expected results.

1.1 RESEARCH BACKGROUND

Aluminium alloy is a material that always being used in industry. It is because the advantages that it has such as low price, easy to fabricate and high resistance to corrosion. But, aluminium alloy also has some disadvantages. As an example it has low strength compare with other material such steel or titanium which can lead to fracture easily. Because of that, this research will concentrate to review the strength (especially impact strength) either it can be improve or not after heat treatment process. In this introduction section, research objective, problem statement, scope, importance of research, research questions and expected result will be discuss.

1.2 OBJECTIVES OF RESEARCH

1. To determine impact limit for alloys after solution, quenching, and ageing heat treatment.
2. To investigate the relationship between solution heat treatment time and impact strength of the aluminium alloy.
3. To investigate the relationship between the type of quench medium and impact strength of the aluminium alloy.
4. To investigate the relationship between the ageing time and impact strength of the aluminium alloy.
5. To observe the microstructure of aluminium alloy after the impact test.

1.3 RESEARCH QUESTIONS

1. What are effects that will happen to aluminium alloy on impact strength while / after the heat treatment processes?
2. How the heat treatment processes change the material properties of the aluminium alloy?
3. How the heat treatment processes change the microstructure of the aluminium alloy?
4. Between all the processes in the heat treatment (solution heat treatment, quenching and aging), at which stage the aluminium alloy has the strongest impact strength?
5. In the quenching process, what medium that will provide the strongest impact strength to the aluminium alloy.

1.4 IMPORTANCE OF RESEARCH

Heat treatment is well known appreciated in relation to steel / alloys. The magnificent advantage of the vast range of aluminium alloy as engineering materials is their adaptability. By using heat treatment process, one or other of given aluminium alloy characteristics can be improve; indeed, much of the versatility of aluminium alloy actually based on the fact that its substance can be adjusted and change by heat treatment. Even though the chemical composition of aluminium alloy is clearly important, through controlling the nature, distribution and quantities of its constituent's aluminium alloy of a given composition can be modified. The science of heat treatment deals with the agent and mechanisms incorporate in this control of substances and properties; heat treatment processes in the industrial technology faces with 'getting it right' in processing, environmentally, and economically. If this research can be done and been prove that heat treatment can make impact strength of aluminium alloy stronger, there is no doubt that it can gives good side effect to industries and people. Such as in industry, they can avoid to use more money to use other materials which have higher price than aluminium alloy. As for people, actually we are surrounded with a lot of aluminium alloy in our daily life. One of the examples is car that we used (many of the car frame made of aluminium alloy). When accident happen which involving impact, we can rely with the aluminium alloy (which have been heat treated and proven to have higher impact limit) to save more passenger lives and reduce damage cost that been caused by the accident.

1.5 PROBLEM STATEMENTS

Aluminium has a low impact strength compare to other material such as steel, titanium and carbon fiber. But compare with that material, aluminium alloy is the cheapest and being used a lot in industry. Such as in automotive industry, this material being used as a car's frame. Nowadays there are many accidents happen and impact strength is applied to the material. So, it is very important to find a way to increase its impact strength. Heat treatment process is believed to be one of the ways to increase it

1.6 SCOPE OF RESEARCH

The scope of this research covers solution heat treating, quenching and aging of the aluminium alloy. Factors affecting the effectiveness of the solution heat treatment (time), quenching (medium) and aging (time) will be the parameters in this research. While / after the heat treatment processes being held, the impact strength of the aluminium alloy will be test on the impact test machine. From the test, we can determine at what stage / parameters of the heat treatment processes will give the strongest impact strength of aluminium alloy. Lastly, the microstructure observation using optical microscope and SEM will be use to determine the failure surface.

1.7 EXPECTED RESULTS

Results that I been expected after this research is done are:

1. Specimens that have been through all the process (until ageing) will have the strongest impact strength compare to all other specimen.
2. The specimens that have longest duration in solution heat treatment and ageing also will have greater strength compare to those which have shorter duration.
3. Water is a better quenching medium compare to cold water (provide greater impact strength).
4. Artificial ageing provide better impact strength to the specimens compare to natural ageing.
5. I will gain many different shapes of aluminium alloy microstructure because of all the parameters that I have been use in this research.

CHAPTER 2

LITERATURE REVIEW

In this section, I have done some of my literature review based from the project's title which is effect of heat treatment on impact strength of aluminium alloy. It is to make sure that there are clear tie between my research topic and others who have done it before me.

2.1 STRENGTH OF MATERIALS

In study of material science, the strength of a material is a capability to withstand an applied stress or without failure. Tensile stress, compressive stress and tensile stress are examples of applied stress that can be experienced by materials. Material's strength always have to deal with masses and load which serve on a material A load applied to a mechanical member will induce internal forces within the member called stresses. Mechanical member which have applied load will stimulate internal force called stress. Later on, the stresses that act will cause the deformation on the material. The deformation that happens to the material will called as strain, while internal forces concentration is called stress. There are three different types of analytical method which the strength of a material depends on and they are strength, stiffness, stability. Strength is refers to the load carrying power, stiffness refers to the deformation, and lastly stability refers as the ability to keep its original configuration. In engineering, material yield strength refers to the curve of stress-strain which the deformation that happens to the material will not be completely reversed when the load being removed. Meanwhile, ultimate strength is refers as stress-strain curve which is related to the stress that creates fracture.

A material's strength is reliable on its microstructure. This microstructure can be improved by some engineering process to which the material is focused. There are many types of strengthening mechanism which can change the strength of a material such as work hardening, solid solution strengthening, precipitation hardening and grain boundary strengthening. All of the mechanism can be clarified quantitative and qualitatively. In order to make the material stronger, some of its mechanical properties may degenerate by strengthening mechanisms which come with caveat. Basically, the yield strength of a material is a sufficient sign of its mechanical strength. Compressive strength, tensile strength, and shear strength are the terms which stated strength. They are namely the limit states of stress, tensile and shear stress, respectively. Loading which repeated always has a high tendency to initiates brittle cracks, which later on the crack will grow until failure occurs. The cracks always start at stress concentrations, especially changes in cross-section of the product, near holes and corners.

Various methods of calculating stresses in structural members, such as beams, columns and shafts are the subjects that always been referred in the study of strength of materials. These methods are being used to predict the response of a structure under loading and its weakness to a variety of failure modes. Various properties other than material (yield or ultimate) must been taken into account too. Buckling failure which is dependent on material stiffness (Modulus Young) is one of the examples.

2.1.1 Impact strength

The definition of impact strength is the ability of the material to endure a suddenly applied load and is articulated in terms of energy. Izod or Charpy impact test, is the test that both been done to measured impact strength. Both of the tests measure the impact energy that will be required to break a sample. Volume, modulus of elasticity, and yield strength are examples of factors that can affect the material's impact strength To make sure the material have higher impact strength, the stresses must be spread equally throughout the object. Besides that, higher volume with a low modulus of elasticity and high material yield strength also can contribute to make the impact strength higher (Beer and Johnston, 2006).

2.2 INTRODUCTION OF HEAT TREATMENT

Heat Treatment is a method that controlled heating and cooling of metals to modify their physical and mechanical properties (Callister, 2007) without changing the product shape. Heat treatment is sometimes done accidentally because of manufacturing processes that either heat or cool the metal such as welding or forming.

Heat Treatment is always related with increasing the strength of material. But it can also be used to change some manufacturability objectives such as improve machining, improve formability, restore ductility after a cold working operation. Because of that, it is considered as a very enabling manufacturing process which can not only assist other manufacturing process, but it also can improve product performance by increasing strength or other wanted characteristics.

Heat treatment techniques including case hardening, annealing, precipitation strengthening, quenching and tempering (note that in this research, only solution heat treatment, quenching and precipitation strengthening are the technique that will be done).

2.2.1 Solution heat treatment

This be related to the heat treatable alloys and implicate a heat treatment process which the alloying constituents are taken into solution and retained by rapid quenching. Subsequent heat treatment at peak temperatures i.e. ageing or natural ageing at room temperature allows for a controlled precipitation of the constituents thereby greater hardness and strength can be achieved.

For solution treatment, time at temperature depends on the furnace load and the type of alloy. If maximum properties are to be obtained, sufficient time must be accepted to take the alloys into solution.

Temperature is critical to the success of the procedure in solution heat treatment. In order to get maximum solution of the constituents, it is preferable that the solution heat treatment is carried out as near as possible to the liquids temperature. Accurate furnace temperature and special temperature variation must be controlled to within a range of ±5°C for most alloys [Bodycote Heat Treatment, 2004).

Overheating is the important thing that must be avoided i.e. exceeding initial eutectic melting temperatures. The early stages of overheating always not clear, but it can result in a deterioration of mechanical properties.

Proper solution heat treatment of the aluminium alloys requires an expert knowledge of the alloy being treated plus the correct heat treatment plant.

2.2.2 Quenching

If optimum results want to be obtained, so this will be a critical operation and must be done to precise limits. The cooling rate must be fast enough to prevent solid-state diffusion and precipitation of the second phase (Callister, 1997). The objective of this process is to make sure that the dissolved constituents remain in solution down to room temperature.

Quenching speed is very important because the result can be affected by excessive delay in transferring the work/specimen to the quench. The latitude for the delay is dependent on section and varies from 5 to 15 seconds for items of thickness varying from 0.4mm to 12.7mm. Basically, around 450°C rapid precipitation of constituents commences for most alloys and the work must not be allowed to get below this temperature before quenching.

The work load and the ability of the quench ant is another factor to be counted in quenching in order to extract the heat at sufficient rate to achieve the results that we want.

The common quenching medium is water at room temperature. In some cases slow quenching is needed as this can improves the resistance to stress corrosion cracking of certain copper-free Al-Zn-Mg alloys.

Parts of complicated shapes such as forgings, castings, impact extrusions and components produced from sheet metal may be quenched at slower quenching rates to upgrade distortion characteristics.

Thus to get a balance of properties in some instances, a compromise must be considered. Quench ants used in slower quenching applications include water heated to 65-80°C, boiling water, aqueous solutions or forced air blast.

2.2.3 Age Hardening

After solution treatment and quenching, hardening is achieved either at room temperature (natural ageing) or with a precipitation heat treatment (artificial ageing). Sufficient precipitation occurs in a few days at room temperature for some alloys. It is to produce stable products with properties that are adequate for many functions. In order to provide increased strength and hardness in wrought and cast alloys, sometime these alloys are precipitation heat treated (Key to Metals AG, 1997-2010). Alloys with slow precipitation reactions at room temperature are always precipitation heat treated before being used.

In some alloys, especially those of the 2xxx series, cold working of freshly quenched materials greatly increases its response to later precipitation treatment. By applying a controlled amount of rolling (sheet and plate) or stretching (extrusion, bar and plate), mills take opportunity of this phenomenon to produce higher mechanical properties. But, reheat treatment must be avoided if the higher properties are used in design.

Natural ageing is carried out the time may differently from around 5 days for the 2xxx series alloys to around 30 days for other alloys (Bodycote Heat Treatment,2004). 6xxx and 7xxx series alloys are considerably less stable at room temperature and continue to show changes in mechanical properties for many years. Natural ageing may be annihilate or delayed for several days by refrigeration at -18°C or lower for some alloys. Completing forming, straightening and coining are common practices before ageing changes material properties appreciably. For refrigeration of alloys 2014 - T4 rivets, conventional practice allowed in order to maintain good driving characteristics.

The artificial ageing or precipitation heat treatments are low temperature long time processes with temperatures range from 100-200°C (Howard, 2007) and times from 5-48 hours. Accurate temperature control and spatial variation temperatures are critical to the process which is same with solution treatment. Its temperatures generally should be held to a range of ±7°C.

The change of time-temperature parameters for precipitation treatment should receive careful consideration. Longer times and higher temperatures will be resulting larger particles or precipitates. Selecting the cycle that produces the optimum precipitate size and distribution pattern is the objective that we want to obtain. Unfortunately, the cycle required to maximise one property, such as tensile strength, is usually different from that required to maximise others such as yield strength and corrosion resistance. Consequently, the cycles used act as compromises that give the best combination of properties.

2.3 INTRODUCTION OF ALUMINIUM ALLOY

Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. Copper, magnesium, manganese, silicon and zinc are the typical alloying elements. There are two principal classifications for this material, namely casting alloys and wrought alloys. Both of which are further subdivided into two more categories which are heat-treatable and non-heat-treatable. Aluminium is used about 85% for wrought products, for example rolled plate, foils and extrusions. Cast aluminium alloys produce cost effective products because of the low melting point, even though they generally have lower tensile strengths than wrought alloys. The most important cast aluminium alloy system is Al-Si. It is where high levels of silicon about 4.0% to 13% help to give good casting characteristics. Aluminium alloys are largely used in engineering structures and components where light weight or corrosion resistance is needed (Polmear, 1995).

In aerospace manufacturing alloys comprised mostly of the two lightweight metals aluminium and magnesium has been really important since around before 1940. Aluminium-magnesium alloys are both lighter than other aluminium alloys and much less flammable than alloys that contain a very high percentage of magnesium.

Surfaces of aluminium alloy will hold their apparent shine in a dry environment due to the formation of a clear and protective layer of aluminium oxide. Galvanic corrosion can occur in a wet environment when an aluminium alloy is placed in electrical contact with other metals with more negative corrosion potentials than aluminium.

The Aluminum Association registered aluminium alloy compositions. There are lot of organizations brings forth more specific standards for the manufacture of aluminium alloy, including the Society of Automotive Engineers standards organization (SAE Aluminium Specification List and Aerospace Council, 2006) and ASTM International (ASTM 23-07a).