THE EFFECT OF HEAT TREATMENT ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF 6061 ALUMINUM ALLOY

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This report submitted in partial fulfillment of the requirements for the award of Bachelor of Mechanical Engineering (Structure & Materials)

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledgement."

Signature :……

Author :……

Date :……

DEDICATION

Special for

My beloved family

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Apart from the efforts of me, the success of any works depends largely on the encouragement and guidelines of many others. First and foremost, I would like to thank to my supervisor for final year project. Mr. Ridhwan Bin Jumaidin for the valuable advice and guidance. He inspired me greatly to work in this project. His willingness to motivate me contributed tremendously to my project.

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ABSTRACT

Aluminum has been used in wide range of applications. Al alloy 6061 most used in the automotive components and construction of aircraft structures. Heat treatment process helps in improve the mechanical properties and strength of aluminum. The objective of this research is to identify the effect of various heat treatment process on the microstructure and mechanical properties of 6061 aluminum alloy. The heat treatment process involve in this research are, annealing, quenching, normalizing or naturally aged, solution heat treated and precipitating hardening or artificial aging. Besides that, this research also analyzes the effect of cooling rate on aluminum alloy during heat treatment by using three different methods. The effect of aging time in the precipitation hardening process was also identified. This study shows that fast cooling rate from quenching sample produce finer grain size and higher mechanical properties while slow cooling rate from annealing sample produce coarser grain size and lower mechanical properties. Quenching sample shows the highest hardness value (68 HRB) while annealing sample shows lowest hardness value which is 13 HRB. In addition, this study shows that in precipitating hardening process higher temperature of aging produce peak aged at shorter time of aging. For precipitating hardening process, the highest hardness recorded is 97 HRB from sample aging at 100^0C for seven hours of aging time. In addition, the peak of aging in precipitating hardening at 200^0C sample is at 2 hours of aging time. As a conclusion, after the heat treatment process, the microstructure and mechanical properties of Al alloy were altered accordingly.

ABSTRAK

Aluminium banyak digunakan secara meluas di dalam pelbagai aplikasi. Aloi Al 6061 banyak digunakan di dalam komponen automotif dan didalam pembinaan struktur kapal terbang. Proses rawatan haba menolong dalam meningkatkan sifat-sifat mekanikal dan kekuatan aluminium. Objektif kajian ini adalah untuk mengenal pasti kesan pelbagai proses rawatan haba terhadap microstruktur dan sifat-sifat mekanikal aloi aluminium 6061. Proses rawatan haba yang terlibat dalam kajian ini, penyepuhlindapan, pelindapkejutan, menormalkan atau semulajadi berusia, penyelesaian haba dirawat dan pemendakan pengerasan atau penuaan tiruan. Selain itu, kajian ini juga menganalisis kesan kadar penyejukan pada aloi aluminium semasa rawatan haba dengan menggunakan tiga kaedah yang berbeza. Kajian ini menunjukkan bahawa penyejukan kadar cepat dari sampel pelindapkejutan menghasilkan saiz butiran yang lebih halus dan sifat-sifat mekanikal yang lebih tinggi manakala kadar penyejukan perlahan daripada sampel penyepuhlindapan menghasilkan saiz kasar bijirin dan sifat-sifat mekanikal yang lebih rendah. Sampel pelindapkejutan menunjukkan nilai kekerasan yang tertinggi (68 HRB) manakala sampel penyepuhlindapan menunjukkan nilai kekerasan yang paling rendah iaitu 13 HRB. Di samping itu, kajian ini menunjukkan bahawa dalam proses pemendakan pengerasan suhu penuaan yang lebih tinggi menghasilkan puncak berusia pada masa penuaan pendek. Untuk proses pemendakan pengerasan, kekerasan yang tertinggi dicatatkan adalah 97 HRB daripada sampel penuaan pada 100 ^{0} C selama tujuh jam masa penuaan. Di samping itu, puncak penuaan dalam pemendakan pengerasan pada sampel 200 ^{0} C adalah pada 2 jam masa penuaan. Kesimpulannya, selepas proses rawatan haba, mikrostruktur dan sifat-sifat mekanikal telah berubah sewajarnya.

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LIST OF SYMBOLS

Al	=	Aluminum
Mg	=	Magnesium
Si	=	Silicone
Cu	=	Copper
Cr	=	Chromium
Fe	=	Ferum
Mn	=	Manganese
Ti	=	Titanium
Zn	=	Zinc
$°C$	=	Degree Celsius (Temperature)
mm	=	Millimeter (Size)
MPa	=	Mega Pascal (Strength)
HV	=	Hardness Vickel
ARB	=	Accumulative Roll Bonding
SEM	=	Scanning Electron Microscope
EDX	=	Energy Dispersive X-Ray Analysis
UTS	=	Ultimate tensile Strength

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Aluminum is one of the major elements on earth. It is an important material in our modern world after steel. Aluminum makes it possible for structures that would be too heavy to be use if made from other material like steel. The example of structures that made up from aluminum is aircraft, ferries, missiles, satellites, automobile component, architectural components that do not rust and many more. Aluminum is lighter than other common structural material, have better corrosion resistance, and a good conductor of heat and electricity. In this research, Al Alloy 6061 is chosen to undergo various heat treatment processes in order to improve its properties. 6061 aluminum alloy was chosen because of its wide range of applications and well known properties. Aluminum alloy is a precipitation hardening alloy. The major alloying elements are magnesium and silicon which has good mechanical properties and exhibits good weldability. Aluminum alloys is one of the most common for general purpose application.

Heat treatment is the combination of operations involving the heating and cooling alloys in the solid state. The aim of heat treatment is to alter the mechanical properties of the alloy, besides to soften the alloy and form more strength material. The required results achieved by the heat treatment process by either permanent or temporary modification of the alloy grain structure.

1.2 BACKGROUND

In recent years, aluminum is one of the materials that always become a choice for researcher, engineers and designer for their usage. Aluminum which is widely used throughout the world for a wide range of products is an abundant metallic chemical element. Many consumers interact with some form of it on a daily basis, especially if they are active in the kitchen. The element is identified with the symbol Al on the periodic table of elements and has an atomic number of 13. It is classified in the poor metals, sharing the property of extreme malleability with metals like tin and lead (Wisegeek, 2012).

Aluminum have used since ancient times for dyeing, tanning and to stop bleeding. Alum is potassium aluminum sulfate. In the 1750s German chemist Andreas Marggraf found that to precipitate a new substance from aluminum he could use an alkaline solution. The substance of aluminum that was obtained by Marggraf was named alumina by French chemist Louis de Morveau in 1760. In 1807 or 1808, to obtain a metal, English chemist Humphry Davy decomposed alumina in an electric arc. The metal was not pure aluminum, but an alloy of aluminum and iron. Davy called the new metal alumium, then renamed it aluminum. Aluminum was first isolated in 1825 by Hans Christian Ørsted (Oersted) in Copenhagen, Denmark who reported, "a lump of metal which in color and luster somewhat resembles tin." Ørsted produced aluminum using a potassium-mercury amalgam by reducing aluminum chloride (Ian McNeil, 1996). For almost three decades, until in 1854 Henri Saint-Claire Deville in Paris, France found a way of replacing potassium with much cheaper sodium in the reaction to isolate aluminum, it remained a novelty, expensive to produce and more valuable than gold. Aluminum then became more popular but, because it was still quite expensive, it was used in ornamental rather than practical situations (Dr. Doug Stewart, 2012).

In the Earth's crust, aluminum is the third most common element, and the most common metallic element on Earth. Pure aluminum is silvery white and extremely lightweight but very strong alloys, and it conducts both heat and electricity very well. In addition, it can be a highly useful property in some applications due to its non-magnetic material. The usage of the metal and its compounds including the

automotive parts, construction, paints, packaging, cooking utensils, antacids, antiperspirants, and astringents.

1.3 PROBLEM STATEMENT

Pure aluminum is too soft for most mechanical applications and some of industrial applications need the aluminum that has more strength and better properties. Thus, by alloying, aluminum can have better properties and strength. In addition, heat treatment is needed in order to further improve the properties of aluminum alloy so the range of application can be broadening to heavier task.

1.4 OBJECTIVE

The main objectives of this research are:

1) To investigate the effect of various heat treatment processes on the microstructure of 6061 aluminum alloy.
2) To identify the effect of various heat treatment processes on the mechanical properties of 6061 aluminum alloy.

1.5 SCOPE OF STUDY

The scopes of this study are:

1) To conduct heat treatment processes on the 6061 aluminum alloy.
2) To conduct tensile test on 6061 aluminum alloy before and after heat treatment.
3) Metallurgical investigation and material characterization of aluminum before and after heat treatment.

1.6 SUMMARY

This report has been sorted into five chapters. The introduction of this research is on chapter 1, while the literature review for this research is shown in chapter 2. For the research methodology it clearly shown in chapter 3 while the result and discussion of this research is shown in chapter 4. Lastly, the conclusion and recommendation is on chapter 5. In the process of doing this research work, several journal papers from previous study are being used to compare the result from this research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A literature review is a body of text that determines the aims to review the critical points of current knowledge including substantive findings as well as theoretical and methodological contributions to a particular topic. In this chapter, the information and details about previous finding is being discussed and summarized in order to develop a relevant research methodology for this study as well as supporting the findings from it.

2.2 ALUMINUM ALLOY

An alloy is a material that made up from two or more metals. Alloys have certain specific, desirable characteristics, including strength, formability, and corrosion resistance. Some of the common alloying elements with aluminum include copper, manganese, silicon, magnesium, and zinc. Aluminum alloy is the most wanted material as promising structural materials for automotive industry, aerospace applications and many other applications. Aluminum alloys are alloy that contain aluminum as predominant metal. In addition, due to the light weight, better corrosion resistance, good conductor of heat and material do not rust, aluminum alloy is always became the preference compared to other material. There are two principal

classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminum is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminum alloys yield cost effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminum alloy system is Al-Si, where the high levels of silicon (4.0% to 13%) contribute to give good casting characteristics. Aluminum alloys are widely used in engineering structures and components where light weight or corrosion resistance is required (Budinski, 2002).

Table 2.1: Wrought Aluminum major alloying elements code

TYPE	SERIES
Aluminum (99% minimum purity)	1xxx
Aluminum - Copper alloys	2xxx
Aluminum - Manganese alloys	3xxx
Aluminum - Silicon alloys	4xxx
Aluminum - Magnesium alloys	5xxx
Aluminum - Magnesium and Silicon alloys	6xxx
Aluminum - Zinc alloys	7xxx
Aluminum – Other aluminum alloys	8xxx
Aluminum - Unused	9xxx

(Source: Markusfarkus, 2008)

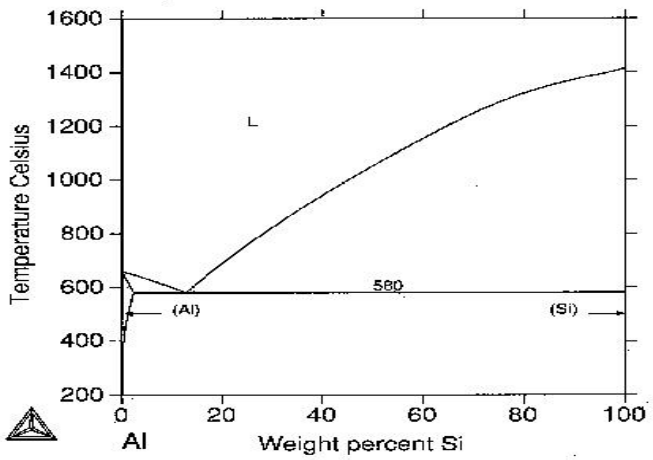

Figure 2.1: Phase diagram of aluminum alloy

(Source: Chen, 2004)

Alloys composed mostly of aluminum and magnesium has been very important in aerospace manufacturing since the introduction of metal skinned aircraft. Aluminum-magnesium alloys are both lighter than other aluminum alloys and much less flammable than alloys that contain a very high percentage of magnesium. Aluminum alloy surfaces will keep their apparent shine in a dry environment due to the formation of a clear, protective layer of aluminum oxide. In a wet environment, galvanic corrosion can occur when an aluminum alloy is placed in electrical contact with other metals with more negative corrosion potentials than aluminum (International, 2012).

2.3 6061 ALUMINUM ALLOY

6061 aluminum alloy is a precipitation hardening aluminum alloy, containing magnesium and silicon as its major alloying elements. It has good mechanical properties and exhibits good weld ability. It is one of the most common alloys of aluminum for general purpose use. The defining composition of the 6xxx series is the addition of Magnesium and Silicon to create Mg_2Si. Aluminum 6061 also contains many other materials to give it some of its defining features. The addition of copper and zinc aids in the strength of the aluminum without significantly reducing its corrosion resistance. Titanium can be added to aid in controlling grain size. Sometimes, the series can have some excess of Magnesium or Silicon. Having an excess of magnesium can lead to better corrosion resistance; however, it can also reduce its strength and formability. Alternatively, having an excess of silicon can increase the strength without hurting the formability or weldability but can lead to the aluminum being more susceptible to corrosion. Al 6061 combines these alloying properties to achieve a good balance of corrosion resistance, strength, machinability and price (Michael et. al, 2010). It is commonly available in pre-tempered grades such as 6061-0 (annealed), 6061-T4 (solution heat treated, quenched and naturally aged) and 6061-T6 (solution heat treated, quenched and artificial aged).

The applications of aluminum alloy are:

- Aircraft and aerospace components
- Automotive parts
- Marine fittings
- Transport
- Bicycle frames
- Camera lenses
- Driveshafts
- Scuba tanks
- Electrical fittings and connectors
- Brake components
- Valves
- Couplings

Table 2.2: Composition in 6061 aluminum

Element	% Composition (by weight)
Al	95.8 -98.6 %
Mg	0.80 -1.20 %
Si	0.40 – 0.80 %
Cu	0.15 – 0.40 %
Cr	0.040 -0.35 %
Fe,Mn,Ti,Zn,Others	0.00 – 1.45 %

(Source: Michael et.al, 2010)

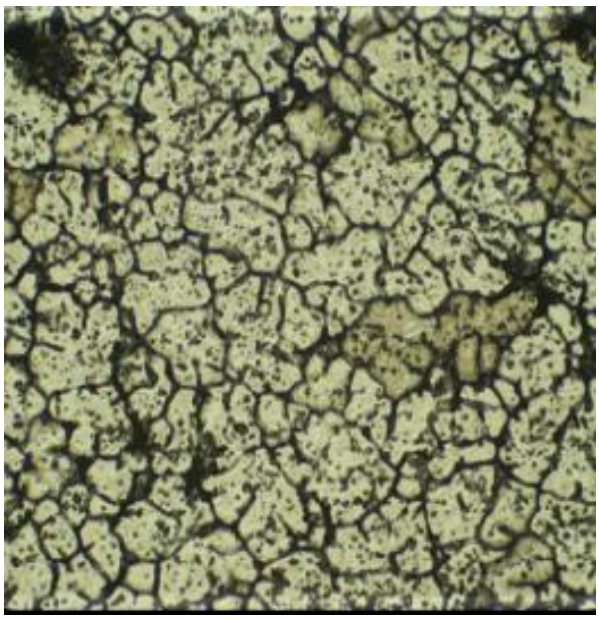

Figure 2.2: Microstructure of aluminum alloy

(Source: Michael et. al, 2010)