HEAT TREATMENT PROCESS OF ALUMINIUM ALLOY TO MINIMIZE THE PRECIPITATE FREE ZONES AND IT EFFECT TO WEAR RESISTANCE

SHAIRULAFIZAN BIN MUHAMMAD SHAMSUDDIN

KOLEJ UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA

HEAT TREATMENT PROCESS OF ALUMINIUM ALLOY TO MINIMIZE THE PRECIPITATE FREE ZONES AND IT EFFECT TO WEAR RESISTANCE

SHAIRULAFIZAN BIN MUHAMMAD SHAMSUDDIN

A thesis report is submitted to Faculty of Mechanical Engineering in partial to fulfillment the requirements for award of Bachelor's Degree of Mechanical Engineering (Structure & Material)

Faculty of Mechanical Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia

May 2006

DECLARATION

"I am authorized that this thesis report are my own work except the shortcut and article which each of that I am explained clearly the source of contents. I am also fully aware of the policy of the university relating to the retention of degree report project and not used any copying medium to copy the other people thesis report or article a to complete my final report "

Signature : ....

Name of Student : Shairulafizan B. Muhammad Shamsuddin

Date : 30 MEI 2006

DEDICATION

To my dearest parent,

Encik Muhammad Shamsuddin Bin Mat Salleh and Puan Wan Jah binti Wan Ibrahim

My Brothers and Sisters,

Fairuz Mazahiri

Nur Adilawati

Nur Elina

Mohd Baihaqi

Mohd Fikri

Nurul Azreen

Amirul Hakim

And for my grandmother, grandfather, cousin, uncle, aunty and my special girlfriend

ACKNOWLEDGEMENT

AssalamualaikumW.B.T

Alhamdulilah, a pray for Allah SWT because of His will have to completed this Projek Sarjana Muda report with title Heat Treatment Process of Aluminium alloy to minimize the precipitate free zones and effect to the wear resistance of aluminium alloy.

A special thank you and praise to Puan Anita Akmar Kamarolzaman, Puan Siti Hajar Sheikh Fadzulah and also Encik Wan Mohd Farid Wan Mohd beloved lecturer as a supervisor of this project for guidance and teach about topic for this project which is used to come out with this report. Thank you madam for your help and I appreciate it so that I can apply all about your explaination and information in the future to defined a good result in this research.

Also I would like to praise and say thank you a lot to Mr.Ruztamreen Jenal, Manager of laboratory and all technicians at KUTKM especially Mr.Mahathir and Mr Raduan for help and guidance during preparing the material and equipment that should be used in this project. I appreciate it and will used it as well as possible to make experiment of this project become successful.

Thank you to all of friends for help and cooperation given during preparing this final thesis and I hope friendship forever and nothing is more valuable rather than our friendship. I would like to express my gratitude to my family, especially father, mother and grandmother altough we have been apart for years, has alway provided me with undivided support, constant encouragement and love.

Also thank you to all personnel and other party who have helped either directly-or indirectly during preparing this final report for Projek Sarjana Muda (PSM). All of your guidance is so valuable to me and may Allah blessed all of you.

ABSTRACT

Heat treating processes for aluminum are precision processes. Based on the objectives of this research, Precipitate Free zones in the aluminum alloy 6061 actually give bad effect to the mechanical properties of that alloy. The mechanical properties of the aluminum alloy should be altering properly to improve their behavior using precipitation hardening which one of the heat treatment types. Precipitation hardening is the most suitable heat treatment that should use to minimize the precipitate free zones in the microstructure of the aluminum alloy 6061 series. In the precipitation hardening process, the thermal and temperature condition is under control with high precision to ensure the transformation of the aluminum alloy structure is in good condition and supervision limit. The samples of the material are placed in the furnace to make a heating process and then quench it in the water for quenching medium. The material testing that had been applied is based on hardness, impact and microstructure analysis. The purpose of the hardness testing are to find out the hardness reading for all samples that used to look the wear resistance effect that occur after make a heat treating process to the aluminum alloy 6061. From the impact test, the purposes are to know impact energy that absorbed to fracture the samples of the material and then make a comparison data between after and before heat treat treatment. Lastly, for microstructure analysis it is important to determine because to look the narrow evaluation of precipitate free zones in the microstructure of aluminum alloy after make a precipitation hardening process. From the data and result that already determined, it shown the positive result based on the objectives and scope of this project.

ABSTRAK

Proses rawatan haba adalah proses yang memerlukan ketelitian dan kawalan yang meyeluruh. Berdasarkan kepada objektif kajian ini pemendakan kawasan bebas dalam aloi aluminium siri 6061 sebenarnya mendatangkan kesan buruk kepada sifat-sifat mekanikal aloi tersebut. Bagi meningkatkan keupayaan sifat-sifat mekanikal aloi tersebut seperti kekerasan dan kemuluran rawatan haba perlu dilakukan dengan menggunakan kaedah pemendakan pengerasan dimana ia adalah jenis rawatan haba yang sesuai diaplikasi bagi mengurangkan luas pemendakan kawasan bebas. Dalam teknik pemendakan pengerasan, haba dan suhu ditetap dan diselaraskan mengikut piawaian aloi aluminium yang digunakan serta pengawasan yang teliti. Sampel aloi yang digunakan akan dibakar didalam ketuhar pembakaran pada suhu tinggi bagi mengubah struktur aloi aluminium tersebut daripada keadaan asal. Kemudian sampel tersebut akan melalui proses penyejukan dengan menggunakan air sebagai medium penyejukan bagi kajian ini. Terdapat tiga keadaan yang diaplikasikan iaitu pemeraman penyejukan sampel, pemeraman semulajadi sampel dan pemeraman pemanasan sampel dimana perbandingan keputusan diantara ketiga-tiga keadaan tersebut. Ujian bahan yang digunakan dalam kajian ini ialah ujian kekerasan, ujian pelanggaran dan analisis terhadap mikrostruktur sampel tersebut. Bagi ujian kekerasan ia penting bagi melihat perubahan sifat kehausan bahan tersebut selepas menjalani proses rawatan haba dan ujian keliatan pula adalah untuk melihat tahap keliatan sampel aloi selepas proses rawatan haba berdasarkan jumlah tenaga pelanggaran yang diserap bagi mematahkan sampel aloi aluminium siri 6061 dan membuat perbandingan data sebelum melakukan rawatan haba. Selain itu, analisis terhadap mikrostruktur aloi dilakukan adalah untuk melihat perubahan kawasan pemendakan bebas samada ia semakin sempit atau tidak serta membuat perbandingan di antara tiga keadaan iaitu pemeraman penyejukan sampel, pemeraman semulajadi sampel dan pemeraman pemanasan sampel.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL

SYMBOL	DEFINITION
A	Area
H	Height
C	Concentration Point
ID	Identity
F	Fabricate
H	Strain Hardened
L	Length
O	Annealed
W	Width
W	Solution Heat treated
J	Joule
T	Temper Codes
T	Thermal Condition

GREEK SYMBOl	DEFINITION
°	Degree of Angle
°C	Degree Celcius
Ω	Resistance
V	Voltan
Θ	Angle
α	Angle of fall
β	Lifting angle
ε	Poison Ratio
δ	Elongation

SUBSCRIPT	**DEFINITION**
Max	Maximum
Min	Minimum
Dia	Diameter
Temp	Temperature
temp	Temper Designation
PFZ	Precipitate Free Zones
GP	Grain Precipitate zones
Al	Aluminium
Cu	Cuprum
Mg	Magnesium
HRB	Hardness Rockwell B

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Introduction

Aluminum is for structural application, therefore it is usually alloyed with several elements to improve its corrosion resistance, inhibit grain growth and to increase its strength. Aluminum naturally generates a protective oxide coating and is highly corrosion resistant. Different type of surface treatment such as anodizing, painting or lacquering can further improve this property. It is particularly useful for applications where protection and conservation are required. The optimum strengthening of aluminum is achieved by alloying and heat treatments. There are many type of aluminums alloy series in it alloy systems which the each series has their own mechanical and physical properties depends on the composition in that alloys (P.J. Gregson and S.J. Harris, 2002).

The main components of the 6000 series alloys are magnesium and silicon to form $\mathbf{Mg_2Si}$. There is often an iron corrector such as manganese or chromium; occasionally small amounts of copper or zinc to improve the strength without substantial loss of corrosion resistance; boron in conductors to remove titanium and vanadium; zirconium or titanium to control the grain size. Lead and bismuth are sometimes added to improve machinability, but they are less effective than in magnesium-free alloys.

That promotes the formation of small, hard precipitates, which interfere with the motion of dislocations. The strengthening properties of aluminum are achieved by making an alloying process with other material with a good combination of composition in the aluminum alloy. The strength of aluminum also can be defined with heat treatment process which that promote the formation of small, hard precipitates which interfere with the motion of dislocations. Aluminum alloys that can be heat treated to form these precipitates are considered heat treatable alloys. Pure aluminum is not heat treatable because no such particles can form while many heat treatable aluminum alloys are not weldable because welding would destroy the microstructure produced by careful heat treatment.

Normally, heat treatment aluminum alloy would be strengthened with precipitation hardening process of that alloy. Precipitation hardening (otherwise known as age hardening) is a process whereby a fine precipitate structure is formed in the alloy matrix following a heat treatment process. Precipitation hardening is involves raising the temperature of the alloy into single phase region so that all of the precipitates dissolve. These alloys actually are quenched to form the supersaturated solid solution in the phase diagram of this alloy. It is can also excess the vacancy and dislocation loop, which can be act as nucleation for precipitation hardening.

This process can come slowly at the room temperature and quickly move at evaluated temperature typically 100°C to 200°C (artificial aging). The degree of precipitation hardening are obtained depends on the size, number and relative strength of the precipitates. These factors are determined by the composition of the alloy and by the tempering temperature and tempering time. The distribution of precipitates affects the hardness and yield strength. The hardness and yield strength are greater when the precipitates are small and finely dispersed in the kappa matrix than when the precipitates are large and not finely scattered.

1.2 Project Background

The types of 6XXX alloy are among those, which have responded positively to modify ageing procedure involving, interrupted ageing. These alloy widely used of medium strength with major application as extrusion product and automotive body sheet. These alloys undergo a complex decomposition during ageing and despite their commercial importance, the understanding of the precipitation process in these alloys still incomplete. Mechanical properties of the commercial alloys depend on content of **Mg**, **Si**, **Cu** and other alloying elements, treatment conditions (cold or hot treatment) and heat treatment. Commercial alloys, especially if they contain manganese or chromium, may show strengths some 10% higher. High strain rates lead to somewhat better properties. Fully hardened alloys show some tendency to intergranular fractures in tension testing, but manganese additions reduce this tendency. Silicon precipitates, as platelets, may be responsible for this brittleness.

Compressive strength is practically the same as tensile even at elevated temperatures. Shear strength is of the order of 70% of the tensile and is not substantially affected by subzero temperatures or nuclear radiation. The modulus of elasticity is of the order of 65 GPa. Heat treatment of the alloys is not too critical; in many alloys the temperature at which all the soluble constituents are dissolved is well below that of the beginning of melting. Heat treatment temperatures range from 720 to 850K. Solution treatment of wrought products requires very short times, reportedly of the order of seconds. High-temperature deterioration may result in dimensional growth.

1.3 Objective

For this project of research about heat treatment processes of aluminum alloy to minimize the precipitate free zones and it effect to the wear resistance of material, the main aim of the present work were to identify or determine the most suitable heat treatment process for aluminum alloys composition to eliminate and reduce the precipitate free zones and to look and study about wear resistance for aluminum alloy series and with heat treatment process.

1.4 Scope

The scopes of this research are based on the precipitation hardening processes of aluminium alloy 6061 series and also to look the effecting of heating process to the mechanical properties especially wear resistance of the material.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is intended to provide a lot of information about extensive background of heat treatment process with detail explanations as a reference for this research. The chapter begins with general overview of type of heat treatment process and also the mechanism of the precipitation hardening process.

2.2 Heat Treatment Process

The term "heat treating" for aluminum alloys is frequently restricted to the specific operations employed to increase strength and hardness of the precipitation-hardenable wrought and cast alloys. These usually are referred to as the "heat-treatable" alloys to distinguish them from those alloys in which no significant strengthening can be achieved by heating and cooling (Article www.key-to-metal.com). Heat treating in its broadest sense, refers to any of the heating and cooling operations are performed for the purpose of changing the mechanical properties, the metallurgical structure, or the residual stress state of a metal product (M Kellent, 2003).

2.3 Types of Heat Treatment

Heat treatments applied to aluminum and its alloys are **Preheating** or homogenizing to reduce chemical segregation of cast structures and to improve material workability. **Annealing** to soften strain-hardened (work-hardened) and heat-treated alloy components, to relieve stresses and to stabilize properties and dimensions. **Precipitation (age-hardening)** heat treatment to provide hardening by precipitation of constituents from solid solution. **Solution heat treatment** to improve mechanical properties by putting alloying elements into solution.

2.4 Heat Treatable Aluminum Alloys

The precipitation hardening process follows three main steps. **Solution treatment**, which the alloy is heated above the solvus temperature to dissolve any precipitates and ensure the alloying elements, is in solid solution. Besides that, **quench** which the alloy is quenched. The alloying elements in solution do not have time to diffuse and form precipitates. Thus, the alloying elements remain in solution forming what is known as a supersaturated solid solution. **Aging** which that alloys is heated to an intermediate temperature below the solvus temperature. The alloying elements are able to diffuse to form coherent precipitate clusters (known as GP zones).

The coherent precipitates increase the strength of the alloy by distorting the crystal lattice and creating resistance to dislocation motion. The number of precipitates increases with increasing time thus increasing the strength of the alloy. However, with excessive time the precipitates become large and incoherent and their strengthening effect decreases (R.G O'Donell, 2004). Thus, during precipitation hardening there are four main stages which solid solution strengthening in the supersaturated solid solution, coherency stress hardening from the coherent precipitates, precipitation hardening by resistance to dislocation cutting, hardening through resistance to dislocation between precipitates.