"Saya akui bahawa saya telah membaca karya ini dan pada pandangan saya karya ini adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal (Struktur & Bahan)"

Tandatangan : ....

Nama Penyelia : **Lee Yuk Choi**

Tarikh : **Mei 2006**

A STUDY ON PRECIPITATION HARDENING OF 6061-T6 ALUMINIUM ALLOY

AW CHENG HWAI

Laporan ini diserahkan kepada Fakulti Kejuruteraan Mekanikal sebagai memenuhi sebahagian daripada syarat penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal (Struktur & Bahan))

Fakulti Kejuruteraan Mekanikal
Kolej Universiti Teknikal Kebangsaan Mekanikal

Mei 2006

"Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya jelaskan sumbernya"

Tandatangan : ....

Nama Penulis : Aw Cheng Hwai

Tarikh : Mei 2006

ABSTRACT

This project presents an experimental study on precipitation hardening of 6061-T6 aluminum alloy to determine the effects of artificial ageing on the effect of strength. The precipitation hardening usually undergoes a thermal treatment, which consists of a solution heat treatment (550°C for 1 hour), quenching (water, at room temperature) and artificial ageing. This study was mainly focus on artificial ageing upon which the temperature is varying between 175°C to 420°C at different period of time. The Vickers hardness test was then be carried out to evaluate the hardness before and after ageing. The microstructure variation was analyzed using scanning electron microscope (SEM) and also optical microscope to observe the important features such as precipitate before and after being placed into the heat treatment solution. Tensile tests were therefore conducted after ageing to establish the relationship between hardness and tensile strength. The optimum ageing time and temperature were also determined at the end of this experiment to obtain reductions in energy and total cost. This study leads to the conclusion that the optimum / peak aged can be achieve within 175°C to 195°C with 2 to 6 hours of ageing time. The contribution of short time ageing is comparable to that of longer ageing time from previous researcher.

ABSTRAK

Kajian ini merupakan experimen pemendakan kekerasan dengan menggunakan aluminium aloi 6061-T6 dimana kesan tindakbalas penuaan tak semulajadi terhadap tegasan akan dikaji. Pemendakan kekerasan akan melalui proses pepejal larut dalam air (550°C selama 1 jam), proses lindap kejut (medium: air, dalam suhu bilik), dan penuaan tak semulajadi. Kajian ini mengutamakan penuaan tak semulajadi dari 175°C hingga 420°C pada masa yang berbeza. Ujian kekerasan 'Vickers' akan dijalankan untuk mengkaji kekerasan sebelum dan selepas penuaan tak semulajadi. Selain daripada itu, penggunaan 'Scanning Electron Microscope' (SEM) dan mikroskop optik akan digunakan untuk memerhatikan tanda-tanda pemendakan kekerasan sebelum dan juga selepas 'ageing' tak semulajadi. Akhir sekali, ujian tegasan-terikan dijalankan untuk mendapatkan hubungan di antara kekerasan dengan tegasan. Masa dan suhu penuaan yang optimum akan dikaji bagi mengurangkan perbelanjaan kos pengeluaran dan meningkatkan mutu aluminium aloi 6061-T6 ini. Kajian ini dapat disimpulkan bahawa 'aged' yang optima dapat dihasilkan dalam masa 2 hingga 6 jam dari suhu 175°C hingga 195°C. Keputusan penuaan jangka pendek dalam kajian ini dapat dibandingkan dengan penuaan jangka panjang oleh kajian lepas.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

CHAPTER I

INTRODUCTION

1.1 Overview

For over fifty years, aluminium ranks only second to iron and steel in the metal market. Its growth rapidly because it is attributed to a unique combination of properties which makes it one of the most versatile of engineering and construction materials. Aluminium is light in weight, the specific gravity of aluminium is 2.7; thus it is only 30% as heavy as copper and one-third as heavy as iron. Except for magnesium, it is the lightest of all common metals. Some of its alloy even has greater strengths than structure steel. Besides that, it has good electrical and thermal conductivities and high reflectivity to both heat and light. It is highly corrosion-resistant under a great many service conditions and is nontoxic. Aluminium can be given a wide variety of surface finishes and it can be cast and work into almost any form. It is not surprising that aluminium have come to be of prime importance as engineering materials with all these outstanding properties.

Strength is further improved by cold working, by refining the grain size, by precipitation hardening and dispersion hardening process. In this study, the strength of aluminium alloy 6061-T6 was conducted by using precipitation hardening. Precipitation hardening is a process that enhanced the strength and hardness of some metal alloys by the formation of extremely small uniformly dispersed particle of a second phase within the original phase matrix. In the other way, the general requirement for precipitation strengthening of supersaturated solid solution involves the formation of finely dispersed (ASM Handbook, Volume 4, 1991).

The precipitate particle nucleates and grows; by the diffusion of solute atoms into it from the matrix phase. It's called precipitation because the small particles of the new phase are termed "precipitates" (Zbigniew D.Jastrzebski, 1959). Artificial ageing will be accomplished not only below the equilibrium solvus temperature, but below a metastable miscibility gap called the Guinier-Preston (GP) zone solvus line.

Tensile testing will be conduct after the artificial ageing to investigate the ultimate strength of the specimen. Hardness test will also proceed to investigate the effect of variation in precipitation by artificial ageing. The highest and lowest hardness specimens were carry out to observe and examine the microstructure and the fracture surface by using microscope optic and scanning electron microscope (SEM).

1.2 Objectives of the Project

The project is concerned with a case study of 6061-T6 aluminium alloy by preceding an experiment. The objectives are as follows:

1. To determine the effects of artificial ageing on the effect of strength.
2. To determine the hardness before and after ageing, and obtain its microstructure.
3. To establish the relationship between hardness and tensile strength.

1.3 Scopes of the Project

The scopes of project are as follows:

1. Literature survey.
2. Conduct the experiment on 6061-T6 aluminum alloy with ageing temperature within 175°C to 420°C from ½ an hour to 10 hours.
3. Investigate the difference in mechanical properties and microstructure of 6061-T6 aluminium alloy for different ageing time and temperature by tensile test, hardness test and metallographic analysis.

1.4 Literature Review

The basic requirement of a precipitation hardening alloy system is that the solid solubility limit should decreases with decreasing the temperature. During the precipitation hardening heat treatment produce the alloy is first solution heat treated at the high temperature and then rapidly cooled by quenching into water or some other cooling medium. The rapid cooling suppresses the separation of the θ-phase so that the alloy exists at the low temperature in an unstable supersaturated state. If, however, after quenching, the alloy is allowed to 'age' for a sufficient of time, the second phase precipitates out (R.E.Smallman and R.J.Bishop, 1995).

A literature review on precipitation hardening will be presented. This literature review shows the investigation of the difference in mechanical properties and microstructure of different series of aluminium alloy for different ageing time and temperature by tensile test, hardness test and metallographic analysis.

Zhao, Y.H., Liao, X.Z., and Zhu, Y.T. (2004) performed the enhanced mechanical properties in ultrafine grained 7075 Al alloy. The highest strength for 7075 Al alloy was obtained by combining the equal-channel-angular pressing (ECAP) and natural ageing processes. The tensile yield strength and ultimate strength of the ECAP processed and naturally aged sample were 103% and 35% higher, respectively, than those of the coarse-grained 7075 Al alloy counterpart. The enhanced strength resulted from high densities of Guinier-Preston (G-P) zones and dislocations. This study shows that severe plastic deformation has the potential to significantly enhance the mechanical properties of precipitate hardening 7000 series Al alloys.

Kulkarni, A.J. and Krishnamurthy, K. (2004) were presented the effect of particle size distribution on strength of precipitation-hardened alloys. Ageing of precipitation hardened alloys results in particle coarsening, which in turn affects the strength. In this study, the effect of particle size distribution on the strength of precipitation-hardened alloys was considered, to better represent real alloys, the particle radii were distributed using the Wangner and Lifshitz and Slyozov (WLS) particle size distribution theory. The dislocation motion was simulated for a range of mean radii and the critical resolved shear stress (CRSS) was calculated in each case. Results were also obtained by simulating the dislocation motion through the same system but with the glide plane populated by equal strength particles, which represent mean radii for each of the ageing times. The CRSS value with the WLS particle distribution tends to decrease for lower radii than does for the mean radius approach. The general trend of the simulation results compares well with the analytical values obtained using the equation for particle shearing and Orowan equation. In this study, the effect of particle size distribution of the strength of ageing alloys was considered. Results obtained show the strength decreasing with the distribution in effect.

Dirras, G.F., Donnadieu, P., and Douin, J., (1991) analyzed the dislocation / precipitate mechanisms in 6xxx aluminum alloys. Transmission electron microscopy (TEM) investigation has been carried out to characterize the dislocation precipitate interaction mechanism of a compression-tested 6061-T6 aluminum alloy. The study was complemented by an approach combining image analysis by high resolution TEM which gives a direct measurement of the strain field around precipitates. Deformation mechanisms in heat treatable 6xxx aluminum alloys are particularly difficult to study because of the density, scale and complex morphology of the precipitates which in addition consist of metastable undefined phases. Therefore direct observations are necessary for the understanding of dislocation/precipitate