APPROVAL

INVESTIGATION OF THE AGEING BEHAVIOR OF AS-CAST A356 ALUMINIUM ALLOY

by

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DECLARATION

I, the undersigned, hereby declare that this report is my own independent work except as specified in the references and acknowledgements. I have not committed plagiarism in the accomplishment of this work, nor have I falsified and/or invented the data in my work. I am aware of the University regulations on Plagiarism. I accept the academic penalties that may be imposed for any violation.

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ABSTRACT

Pure aluminum has mechanical properties that are not suitable when it comes to strength factor for commercial uses. Aluminum alloy has been proven to be highly valuable in the car wheels manufacturing industries as well as other industries which manufacture aluminum alloy based products which commonly is A356 Al alloy. Currently T6 heat treatment is used for A356 aluminum alloy to increase the hardness. The T6 heat treatment process uses artificial ageing which consists of further heating the material at relatively low temperatures (120-210°C) and it is during this stage that the precipitation of dissolved elements occurs. These precipitates are responsible for the strengthening of the material. It is theorized that the ageing temperature and the ageing time interval plays a big factor in the formation of precipitate that determines the peak hardness that can be achieved within acceptable industrial manufacturing time. The T6 heat treatment is highly efficient process and beneficial to the manufacturing industry, but the additional cost and the time taken to produce the alloy are some of the setbacks that need to be overcome. This report aims to find the suitable peak hardness along with a fitting ageing process temperature and time that can reduce time and cost as well as increase production. The sample aluminium alloy was received in as-cast condition from AAI (Aluminium Alloy Industries (M) Sdn. Bhd.). The sample consists of four main parts of rim which is the outer & inner flange, spoke and profile. The sample was then cut into smaller pieces, heat treated, grinded and polished before performing hardness test and observing the precipitate distribution in A356 microstructure. The objective of the present work is to establish the hardness vs ageing time curve, microstructure examination for different heat treatment conditions was observed and optimization of the heat treatment was done with a more detailed understanding of the precipitation process. The present experimentation involved cases with different temperatures and the amount of time taken for artificial ageing. The results show that it is possible to reach a high level of hardness within a short period of time as compared as-cast condition. The 2-step ageing process is also analyzed to compare the peak age period and hardness level of the material. 2-step results are then compared with the three different ageing temperatures to conclude which has the most suitable peak hardness for commercial use.

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DEDICATION

This thesis is dedicated to my beloved parents, faithful friends and committed lectures.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAI	Aluminium Alloy Industries (M) Sdn. Bhd.
DAS	Dendrite Arm Spacing
Al	Aluminium
Si	Silicon
Fe	Iron
Cu	Copper
Ti	Titanium
Mn	Manganese
Zn	Zink
Mg	Magnesium
HV	Vickers Pyramid Number

NOMENCLATURE

Symbol	*Definition*
^{0}C	Degree Celcius
d_1	Measurement of impression
d_2	Measurement of impression

CHAPTER 1

INTRODUCTION

1.1. Background

The advancement of manufacturing industries thrives on the evolution of material technology. Regarding that, aluminium alloy is the one of the most prominent metal that used to manufacture parts or components. Aluminium alloy is an alloy with predominantly consists of aluminium element. The major elements that used together with aluminium to create alloy are copper, manganese, tin, magnesium, zinc and silicon. There are two important types of aluminium alloy. This includes casting alloys and wrought alloys. The two types of aluminium can be split into another two parts which is non-heat treatable and heat treatable. A wrought alloy generally consists of 85% of aluminium products like foils and rolled plates. Meanwhile, cast aluminium alloys are highly used in metal industries due to cost effective factor. This is due to the fact that aluminium alloys generally has low melting point. However, this also leads to the cast aluminium to have lower tensile strength or properties. The most significant and widely used aluminium alloy combination is the Al–Si combination. This aluminium alloy has high levels of silicon which is between 4.0-13%. This percentage of silicon in the aluminium alloy gives the aluminium good casting properties.

Due to its mechanical properties of this alloy which is having a high strength, the Al-7%Si-0.3%Mg alloy is commonly and extensively used in fields like automotive and aerospace as well as other heavy industries. This is due to the fact that Al-Si has a very good cast ability, pressure tightness, corrosion and strength. Al-Si aluminium alloy retains the previous mentioned properties in the cast molds such as permanent mold and sand casting (Francisco & Paz 2003).

Another area where aluminium is extensively used is car rims. However, this alloy is mostly not used in the as-cast mold because it has mechanical properties which are not conducive for practical usage due to the presence of eutectic silicon in the form of coarse acicular plates which functions as internal stress inducer under an applied force. The properties of this alloy can be improved by chemical and heat treatment. The A356 alloy has been subjected to heat treatment effect for studies on its behavior in this report. Heat treatment is used in the aluminium alloy industry to increase certain properties that are advantageous to manufactured products like strength and ductility. There are many types of heat treatment types which is designated with 'T' prefix which includes T4, T5, T6 and others. In this report, the heat treatment used is the T6 heat treatment. T6 heat treatment is divided into three stages which is solution heat treatment, water quenching and artificial ageing. The solution heat treatment is done on the aluminium alloy at a temperature which almost reaches the temperature which is called eutectic temperature. This temperature is about 540°C for 4 to 8 hours. The hardening element in the A356 alloy is Al, Mg and Si. The heat treatment dissolves hardening elements into the aluminium structure matrix, homogenizes the casting and spheroidizes the eutectic silicon. After the solution treatment, castings must be quenched from this high temperature in order to avoid the precipitation of dissolved elements and to create a supersaturated solid solution at room temperature, an essential condition for further ageing. Artificial ageing is the step where the hardening elements are precipitated into the aluminium alloy to increase the strength of the aluminium matrix. The process is carried out at relatively low temperatures of 155°C to 200°C (Francisco & Paz 2003). This process hardens the aluminium alloy as its mechanical properties have changed from the previously lower tensile strength to a more durable and strong alloy due to the T6 heat treatment.

For this report, material was obtained from a local car rim manufacturing company known as Aluminium Alloy Industries (AAI). The aim is to observe the effects of heat treating temperature and time intervals to the strength and hardening of the aluminium alloy A356 through artificial ageing. Another aim of this report is to improve the time required for the manufacturing process of the rims by shortening the time required for the heat treatment and increasing the efficiency of the process but at the same giving a much higher strength and hardness to the aluminium alloy.

1.2. Problem Statement

Aluminium Alloy that is used the car rim manufacturing industry and in Aluminium Alloy Industry (AAI) goes through a rigorous process of heat treatment to strengthen the quality of the material as well as decreasing the overall manufacturing as typically for A356 aluminium alloy, it takes 10 hours for the process of ageing. The T6 heat treatment is highly efficient process and beneficial to the manufacturing industry, but the additional cost and the time taken to produce the alloy are some of the setbacks that needs to be overcome. The standard car aluminium alloy rims are made with the low pressure die-casting process. The low pressure die casting process usually takes no more than six minutes. In contrast to that, the common T6 heat treatment cycle takes more than 10 hours. Therefore, time reduction factor and the heat treatment cycle factor significantly affects the manufacturing and production cost involved (Manente & Timelli 2011). Although the aluminium alloy (A356) is relatively strong, malleable metal with good casting characteristics, it is still not strong enough when compared to other metals and alloys. In present technological era with more regulations imposed and safety requirement needed, it is crucial that the current material used for car manufacturing have to be updated to meet the current demands for a stronger, durable and light car rim material for commercial usage as well as off road, luxury and sports. It is also possible to increase the hardness of the alloy through T6 heat treatment that produces high quality rims for the current market demands. Some T6 heat treatment process stages have been investigated for the car rims manufacturing. In order to develop and optimize the manufacturing of the A356-T6, a new method was proposed. This new method proposes that the heat treatment interval time and heat treatment temperature can be varied and changed to get a much higher quality and stronger alumium alloy (Manente & Timelli 2011). This study focuses on examining both the result of heat treatment temperature and time intervals influence on the distortion of the precipitate hardening and dendrites formation in the solution treatment stage. The study also includes the hardness that can achieved after the casting process and quenching steps. In addition to that, the effect of temperature and time on artificial ageing was also studied. It is also important to observe the mechanical properties of the A356 at different ageing step than compared to normal ageing to identify the problems and step to improve it.

1.3. Objectives of the Research

The objective for this final year project (FYP) refers to the study, observation, or experimentation of the topic that needs to be completed within the given time period and dateline. Objectives are the general outline of the aim and the goal. The objective