Investigation of the Ageing Behaviour of As-cast A356 Aluminium Alloy with Strontium-addition

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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

The effect of T6 heat treatment on hardening respond of A356 aluminium alloy is investigated using Vickers micro hardness test machine and microscope. Three experimental conditions are being found. First, investigate the characterization of hardness and microstructure variation in response to solid solution treatment. Second, investigate the aging behaviour for different time duration at 3 different aging temperatures. Third, investigate the behaviour of 2-step aging at 140°C followed by 200°C, with variation in staging interval between two aging steps. Based on the results, artificial aging in higher temperature expedites the attainment of peak hardness with comparatively lower hardness recorded. As for the 2-step aging, hardness is increasing overall even through there are some fluctuation during the process.

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DEDICATION

This thesis is dedicated to my beloved parents
who educated me and making this possible.
This thesis also dedicated to every gentle and
attentive reader.

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PSB	Persistent slip bands
LCH	Low cycle fatigue
HCF	High cycle fatigue
SEM	Scanning electron microscopy
EDS	Energy dispersive spectrometer
TEM	Transmission electron microscope
ASTM	American Society for Testing and Materials

CHAPTER 1

INTRODUCTION

1.1. Background

The Al–Si casting alloys being broadly used in automobile, aerospace and engineering industries due to its strength-weight ratio. In these casting alloys, Mg is added into Al–Si alloys as a key alloying element in order to induce aging hardening behaviour through Mg–Si precipitates. Nowadays, hypoeutectic cast A356 alloys (Al–7%Si–0.3%Mg) were used as common industry products (Zhu et al., 2012). However, the as-cast A356 alloys are made up of coarse primary α-Aluminium dendrites and acicular-shaped eutectic silicon, which lowers the mechanical properties and limits its industry application. According to previous studies, the mechanical properties of A356 alloys are strongly dependent the heat treatment given. Besides, it has been found that the addition of certain elements or modifiers to the Al–Si alloys greatly affects the heat treatment process and mechanical properties. Closset and Gruzleski, (1982) found that the eutectic structure can be well modified by introducing small amount of Sr and rare earth element. Modification treatment results in a finely dispersed Si phase across the aluminium matrix eventually increase the strength and ductility in alloy (Samuel et al., 2014).

1.2. Problem Statement

AAI is looking for a way to improve the consistency of their product specification, for example, hardness. The hardness and elongation are sometimes does not fulfill the requirement costing wastage. After heat treatment and ageing, alloy wheel are subsequently go through finishing process. Finishing and rework at elevated temperature might alter the mechanical properties.

1.3. Objectives of the Research

Study the ageing behaviour and find out the relationship between hardness and T6 heat treatment process. The overall objectives of the research are pointed out as follows:

- To investigate the characterization of hardness and microstructure variation in response to solid solution treatment,
- To investigate the aging behaviour for different time duration at 3 different aging temperatures,
- To investigate the behaviour of 2-step aging at 140°C followed by 200°C, with variation in staging interval between two aging steps.

1.4. Scope of the Research

Manipulate the ageing parameter and find out the effect of each parameter used in order to establish hardness against ageing time curve.

1.5. Report Organization

Chapter 1 is introduction that giving the idea to reader on the topic and content of this paper. Information like type of research of this paper and what to expect at the end of this paper.

Chapter 2 is literature review that summarise ideas, theories, and results from papers or journals published by other researcher. Related information are extracted and blended in this chapter.

Methodology in Chapter 3 recorded the approaching and the experiment details. Method of approach and experiment plans is attached. Equipments used and procedures are listed in detail.

Chapter 4 tabulated all the results obtained from the experiment. Furthermore, trend of gathered data and reasons are discussed.

Chapter 5 concluded key finding and recommended research path to enrich the contents.

CHAPTER 2

LITERATURE REVIEW

Spheroidization of eutectic silicon particles in the microstructure and formation of huge amount of fine precipitates that strengthen the aluminium matrix and improve the ductility and fracture toughness are the main purpose of heat treatment. (Zhang et al., 2002).

T6 heat treatment of aluminium alloy involved 3 processes which are solution heat treat, followed by quenching and finish by aging the aluminium to desire mechanical properties. Commercial T6 heat treatment is first solution-treated at 540C±10C for 6 hours, and subsequently quenched by warm water at 50°C. It was then aged at 160C±10°C for 2.5h.

Zeng et al. (2014) studied the effects of the eutectic silicon particles on its fatigue strength characteristics and the initiation and propagation of fatigue cracks in cast aluminium alloy A356. Wide range of fatigue cycle was used as manipulated variable in the experiment to study the behaviour of aluminium and the effect of Si particle in the alloy by varying the load. The cycle fatigue will infinitely increase if the load is significantly low and no crack initiation will happen. If any crack initiated, it will often be found very close to the eutectic Si particle. The crack will indicate the location of high local stress concentration. Eutectic Si particle acts as a barrier against fracture in the alloy and thus it will effectively influence the toughness of the alloy.

2.1. Solid solution/ solution treatment

Sjölander and Seifeddine, (2010) has made a summary on what does solution heat treatment do and how it alters the hardness of A356:

1. Dissolve Cu and Mg clusters formed during solidification after casting;
2. Homogenize the alloying elements;
3. Spheroidizes the eutectic Al-Si particles.

Solution treatment temperature directly varies the rate of change of the microstructure. The higher the temperature, the faster the process can be finish without exceeding too much from eutectic point that is at 550°C. The highest solubility of solute, which is available in the matrix will increase and improve the strength of the alloy after aging. Shivkumar et al., (1990) suggested that as-cast Al-Si-Mg alloys can be solution treated at 540–550°C. Solution heat-treating at relatively high temperature is required to activate diffusion mechanisms, first, to dissolve Mg-rich phases formed during solidification. Other than solid solution treatment temperature, concentration of alloying elements, size and distribution of the phases present after solidification also deciding the time needed to spheroidize and homogenise.

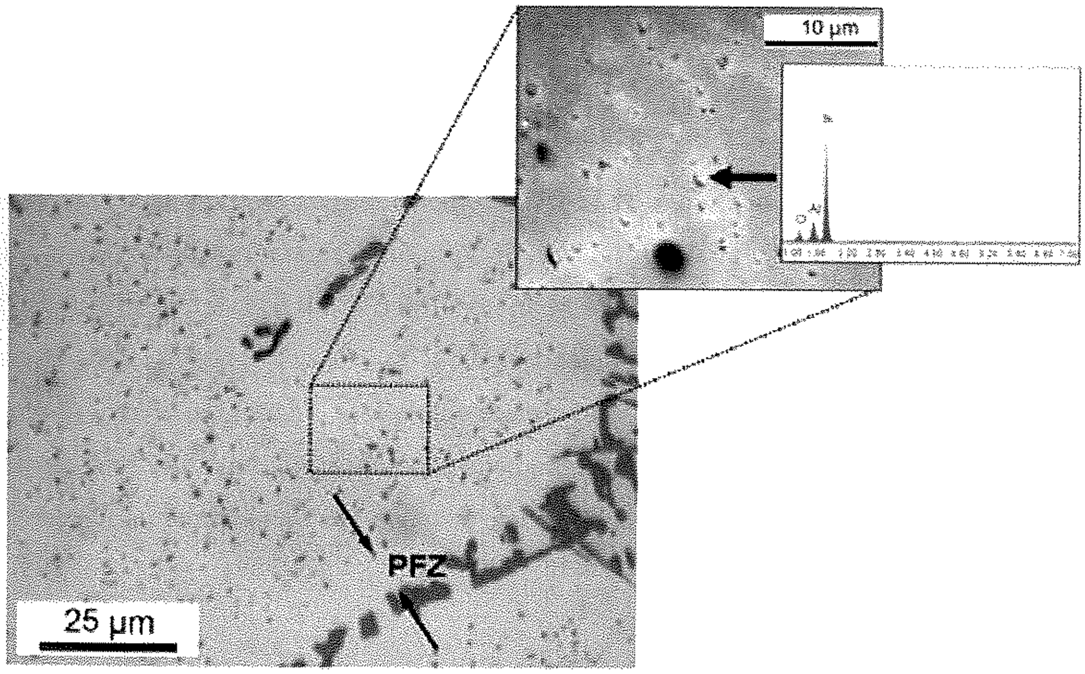

Figure 2-1 Silicon precipitates within dendrites in A356-T6 wheels. Precipitate-free zone (PFZ) is indicated near the eutectic regions

(Source: Optimizing the Heat Treatment Process of Cast Aluminium Alloys 2011)

Experiment by Zhang & Zheng, (1996) shows that α-Aluminum matrix contained a large number of areas with coarse rods β'-Mg_2Si grouped parallel to each other. During the solid solution heat treatment, these precipitates and large portion of Si clusters (as seen in Fig 2-1) in aluminium dendrites will dissolve into the matrix to form homogenized solid solution.