# EFFECTS OF HEAT TREATMENT ON NON-DENDRITIC GRAINS MICROSTRUCTURE AND MECHANICAL PROPERTIES OF A356 ALLOY

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**Faculty of Mechanical and Manufacturing Engineering Technology**

# Effects of heat treatment on non-dendritic grains microstructure and mechanical properties of A356 alloy

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**Bachelor of Manufacturing Engineering Technology with Honours**

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**A thesis submitted**
**in fulfillment of the requirements for the degree of**
**Bachelor Engineering Technology Manufacturing with Honours**

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**2023**

**DECLARATION**

I declare that this Choose an item. entitled " Effects of heat treatment on non-dendritic grains microstructure and mechanical properties of A356 alloy" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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**APPROVAL**

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (BMMW) with Honours.

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## DEDICATION

I dedicate my dissertation work to my family and my supervisors Ts. Dr. Hanizam Bin Hashim. A special feeling of gratitude to my loving parents W Ishak Bin W Musa and Che Rohani Binti Hussain whose words of encouragement and push for tenacity ring in my ears. My brothers and sisters have never left my side and are very special. I also dedicate this dissertation to my many friends and family who have supported me throughout the process. I will always appreciate all they have done. I dedicate this work and give special thanks to my supervisor Ts. Dr. Hanizam Bin Hashim for being there for me throughout the entire bachelor program.

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## ABSTRACT

A post-casting thermal treatment such as T6 temper is a normal process in the aluminium alloys foundry for car parts production industry. T6 has three step thermal treatments, solution treatment, quenching and artificial ageing. In addition, a semi-solid processing method will help to increase further the robustness of the alloys. In semi solid processing, the alloy must posseses a thixotropic behaviour of non-dendritic microstructures. Currently, the effects of both processes, T6 heat treatment and semi-solid, on A356 aluminum alloy reported were still lacking. Therefore, objectives of the study are to determine the macro hardness of non-denrtitic grains microstructure A356 alloy and its evolution at each stage of the T6. The non-dendritic microstructure of the A356 feedstock has been prepared via a spiral channel casting. The T6 thermal cycle includes solution treatment at 540℃ for 6 hours, water quenching, and artifical ageing for 6 hours at 180℃. Methods used to perform an inspection of grain microstructure by using microscope ZEISS AX10 and Mitutoyo Rockwell will be used for the hardness test. As results, the macro hardness increased by 42.67 %, from 7.25 RHB to 18.04 RHB and grain size mean areas increased by 5.3 %, that is from 9 µm to 1.4 µm. These values obtained by different tests are significant based on the P-values of T-Test. Furthermore, a direct comparison between the dendritic A356 using direct casting method was also reported. The improvement in strength of alloy after T6 heat treatment is due to elimination of microporosities and rearragement of the allo microstructure.

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# *ABSTRAK*

*Rawatan terma selepas tuangan seperti T6 temper adalah proses biasa dalam faundri aloi aluminium untuk industri pengeluaran alat ganti kereta. T6 mempunyai tiga langkah rawatan terma, rawatan penyelesaian, pelindapkejutan dan penuaan buatan. Di samping itu, kaedah pemprosesan separa pepejal akan membantu meningkatkan lagi keteguhan aloi. Dalam pemprosesan separa pepejal, aloi mesti mempunyai kelakuan thixotropic struktur mikro bukan dendritik. Pada masa ini, kesan kedua-dua proses, rawatan haba T6 dan separa pepejal, pada aloi aluminium A356 yang dilaporkan masih kurang. Oleh itu, objektif kajian adalah untuk menentukan kekerasan makro aloi A356 butir bukan dertitik dan evolusinya pada setiap peringkat T6. Struktur mikro bukan dendritik bahan suapan A356 telah disediakan melalui tuangan saluran lingkaran. Kitaran terma T6 termasuk rawatan penyelesaian pada 540 ℃ selama 6 jam, pelindapkejutan air, dan penuaan buatan selama 6 jam pada 180 ℃. Kaedah yang digunakan untuk melakukan pemeriksaan struktur mikro butiran dengan menggunakan mikroskop ZEISS AX10 dan Mitutoyo Rockwell akan digunakan untuk ujian kekerasan. Hasilnya, kekerasan makro meningkat sebanyak 42.67 %, daripada 7.25 RHB kepada 18.04 RHB dan saiz bijian min kawasan meningkat sebanyak 5.3 %, iaitu daripada 9 µm kepada 1.4 µm. Nilai-nilai yang diperolehi oleh ujian yang berbeza ini adalah signifikan berdasarkan nilai-P Ujian-T. Tambahan pula, perbandingan langsung antara dendritik A356 menggunakan kaedah pemutus langsung juga dilaporkan. Peningkatan kekuatan aloi selepas rawatan haba T6 adalah disebabkan oleh penghapusan mikroporositi dan penyusunan semula struktur mikro allo.*

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| Si | - | Silicon |
| Cu | - | Copper |
| Mg | - | Magnesium |
| Mn | - | Manganese |
| Zn | - | Zinc |
| Ni | - | Nickel |
| Fe | - | Ferroalloys |
| Pb | - | Plumbum |
| Ti | - | Titanium |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background Research

Aluminium-silicon casting alloys are widely used in the vehicle industry because of their outstanding formability, corrosion resistance, high tensile stiffness to weight ratio, and recycling capabilities at low energy costs. Furthermore, appropriate heat treatments may greatly enhance the mechanical characteristics of as-cast components. However, in industry, applying a post-casting thermal treatment to high-pressure die-cast (HPDC) components is still uncommon. Internal or sub-surface porosity, resulting from entrapped gases, may often develop in die castings because of the highly turbulent flow of molten metal during the filling of the die chamber. As a consequence, during routine thermal treatment at high temperatures (470-500°C), a gas expansion on the components may generate unwanted surface blisters.

Apart from employing vacuum-assisted HPDC to remove entrapped gas, semi-solid metal (SSM) technologies have been recognised as a feasible alternative for producing sound Al-Si-based light-weight parts with a satisfactory response to heat treatments, especially in the automotive sector. Example parts include fuel rails, engine brackets steering knuckles, control arms,  and even engine blocks. In contrast to the turbulent metal flow experienced during die cavity filling in traditional HPDC, both SSM casting approaches use a laminar flow of semi-solid metal with a higher viscosity than the liquid state. As a result, the risk of gas entrapment is greatly reduced, and blistering during subsequent heat treatments or welding operations are avoided.

T6 tempering is a popular thermal treatment for Al foundry alloy vehicle components, which often results in enhanced alloy strength. The T6 thermal cycle includes solution heat treatment, quenching, and age hardening (or precipitation hardening). Intermetallic phases dissolve and eutectic Si spheroid during the solution heat treatment, resulting in improved alloy ductility. The time it takes to treat a solution varies substantially depending on the microstructural scale, ranging from a few minutes to many hours.

## 1.2 Problem Statement

Aluminium alloy widely used in automotive and one of them is A356 alloy which commonly used for pump bodies. At the moment, all these parts are interacting for weighty alloy can be lightened. Therefore, one method for doing this is by using semi-solid procedures, which boost the material's strength. Because of increased strength, are able to remodel the pump bodies of the company's parts. In order for the material to exhibit semi-solid qualities, it must undergo a heat treatment to improve its hardness and mechanical properties.

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## 1.3 Research Objectives

The objective of this project is as below:

a) To compare A356 alloy grain microstructure of direct casting and spiral channel before and after T6 heat treatment.
b) To analyze microstructure evolution of A356 alloy after each T6 heat treatment stage.
c) To determine macrohardness of A356 alloy before and after heat treatment T6.

## 1.4 Scope of Research

This research is to examine the mechanical properties of aluminum alloy. The material use is A356 alloy. The experiment needs to use the Rockwell hardness tester machine, polisher and grinder machine and etc. The method experiment is an optical microscope to see the microstructure of A356 alloy before and after heat treatment.

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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

An "alloy" is a mixture of several metallic components designed to improve the material's strength and endurance. Depending on the intended purpose, an aluminum alloy often has the latter as the principal metal in the mix, with additional components, such as silicon, tin, manganese, or even copper, tin, and magnesium. Apart from that, there's the matter of heat treatment. Heat treatment is a technique for improving a substance's physical properties. During a heat treatment method, a material is normally heated to the required temperature, at which time its physical properties are altered. After then, the temperature slowly decreased. That about the microstructure, the microstructure is the surface structure of things like thin foil that can be seen with a magnification of 25 or more. Lastly, the chapter will tell about hardness.

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## 2.2 Aluminum Alloy A356

A356 is a common aluminium alloy used in casting. 1xx.x, 2xx.x, 3xx.x, 4xx.x, 5xx.x, 6xx.x, 7xx.x, 8xx.x, and 9xx.x are the nine series of the cast aluminium alloy identification system. In the 3xx.x series, silicon is combined with copper and/or magnesium as the primary alloying component. The minimal proportion of aluminium is shown in the second and third values. If the alloy is cast, the decimal point after the decimal point shows this (Either 1 or 2). The letter A in front of an alloy name represents a purer form of the chemical composition. The Aluminum Association has designated this substance as A356.0 (AA). The UNS designation is A13560, whereas the SAE designation is 336. The aluminium die casting alloy A356 has exceptional casting and machining qualities, making it well suited for usage in impellers, aircraft, high-velocity blowers, pump housings, and other castings requiring high strength. A356 aluminum is often used in the manufacture of complex and sophisticated aluminum castings that can provide lightweight, pressure tightness, and outstanding mechanical properties. Copper, magnesium, manganese, silicon, zinc, and other alloying elements stand out. (Dwivedi et al., 2014). Table 2.1 show chemical composition A356 (Hanizam et al., 2022).

Table 2.1 Chemical Composition (A356) by wt.% (Hanizam et al., 2022)

**Table 1 – Chemical composition (A356) by wt.%.**

| Al | Si | Cu | Mg | Mn | Zn | Ni | Fe | Pb | Ti |
|---|---|---|---|---|---|---|---|---|---|
| Balanced % | 6.5 | 0.2 | 0.2 | 0.3 | 0.1 | 0.1 | 0.5 | 0.1 | 0.2 |

The characteristics of A356-based metal matrix composites are influenced by microstructure, volume, grain size, and the size of the second phase, among other things.Porosity and interdimeric shrinkage are other important factors in determining the lloy's mechanical characteristics. Temperature, strain rate, and other test circumstances have an impact on mechanical characteristics. Because of its superior corrosion and creep resistance, A356 alloys are often employed in aviation applications. For missiles and space applications, high specific strength and stiffness, as well as simplicity of manufacture, are critical. The automotive industry is the most recent benefactor of the A356 alloy, which is actively exploring its full potential. Aviation pump components, automobile gearbox cases, aircraft fittings and control parts, and water-cooled cylinder blocks are examples of typical applications. Other applications that need high-strength permanent mold or investment castings include Aeroplan structure and engine control, nuclear energy installations, and some other applications that require great castability and pressure tightness, weldability, and corrosion resistance (Dwivedi et al., 2014).

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### 2.2.1 Semi Solid of A356

Semi-solid metal (SSM) processing is a manufacturing method in which an alloy is injected into a die as a slurry of near-globular primary particles in a liquid matrix, enabling near-net-shape components to be produced. The fundamental benefit of this technique is connected to the flow characteristics of metal in the form of a slurry, which is non-Newtonian and shows shear thinning behavior in the semi-solid state. (Pola et al., 2018). The viscosity of the SSM slurry is higher than when fully liquid, reducing the risk of turbulent or spray flow, which is more typical of conventional pressure die-casting (Pola et al., 2018).The investigation of the hot ripping of steel during solidification led to the discovery of SSM in 1971 at the Massachusetts Institute of Technology (MIT). When it comes to the production of a wide range of metal components, one method that is recognized as being both cost-effective and highly productive is the use of semi-solid metal.

Semisolid metal processing techniques may be classified into two groups based on the condition of the starting material: liquid routes and solid routes. In recent years, a wide range of new methods has been developed for the production of fine globular microstructures that may be used as feedstock. Significant efforts have been made in the investigation of feedstock production over the years, and the purpose of this work is to evaluate the different procedures, emphasise any variations, and present a revision of putative mechanisms leading to microstructural modifications during SSM slurry preparation.

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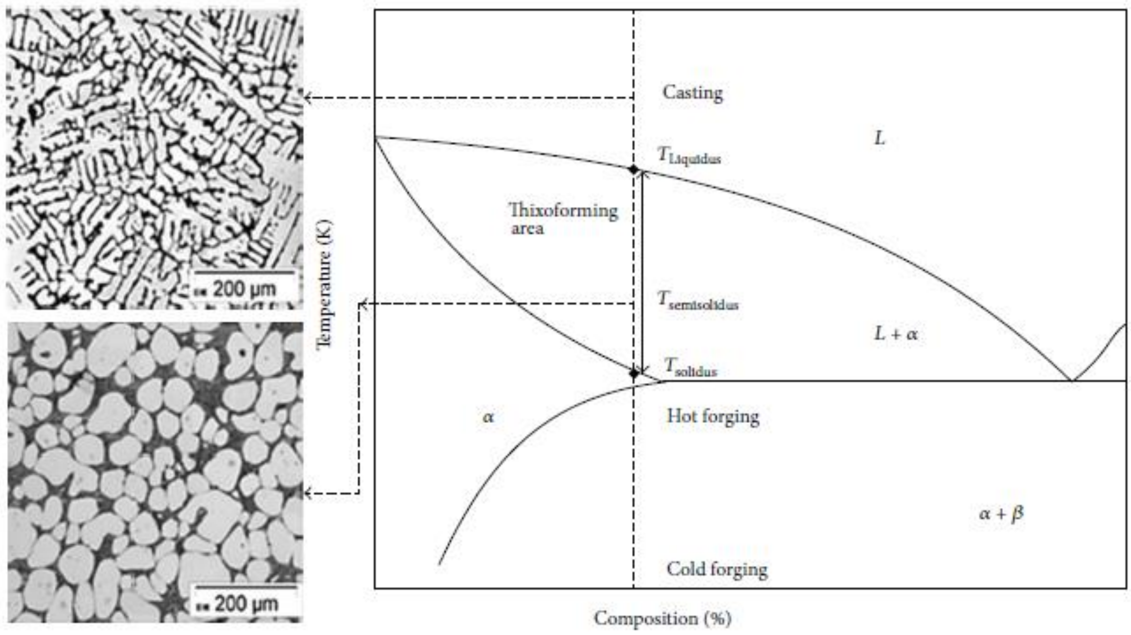


Figure 2.1 Micrograph of Dendritic and Globular Structures in a Semisolid Alloy; Simple Eutectic Phase Diagram for Alloy Grade X210CrW12 (Mohammed et al., 2013)

In the early experiments that were carried out by Spencer and colleagues on an Sn–Pb15 alloy (Pola et al., 2018), it was discovered that its microstructure of material was profoundly influenced by constant shearing of an alloy and it was in a semi-solid state. This was the case when the experiments were carried out on the alloy. In particular, that was shown that shearing effect results in the creation of a non-dendritic grain structure, and is the defining quality of semi-solid alloys. This is the case because shearing action is a shear deformation process. Additionally, it is possible to create spheroidal particles by performing additional shearing during the cooling process. These particles often include some entrapped liquid. According to the authors' other findings, the development of spherical particles, as opposed to rosette-like ones, may be encouraged by high shear rates in conjunction with slow cooling rates (Pola et al., 2018). It has been proposed by Vogel et al. that dendrite arms possess plasticity, which makes it possible for them to bend when subjected to shearing forces. This results in the formation of large misorientations within the dendrite arms, which

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