SEMISOLID PROCESSING OF ALUMINIUM LM6 ALLOY USING COOLING SLOPE CASTING

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process)(Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory is as follow:

………………………………

(Dr. Mohd Shukor bin Salleh)

ABSTRACT

This study is about the semi solid metal processing of aluminium LM6 alloy using cooling slope casting. In this study, the most influential parameters between the pouring temperature and the length of cooling slope that affect the globulization of LM6 alloy during cooling slope casting were studied. Besides, the hardness and tensile strength of cooling slope casting and conventional casting samples were investigated. All the experimental works were accomplished by using same LM6 alloy. The aluminium LM6 alloy feedstock billets were prepared through the cooling slope technique and conventional casting. Several of samples were then treated with a T6 heat treatment that is solution treatment 530°C for 8 hours, quenching in water, followed by aging at 155°C for 3 hours. All of the samples were then characterised by optical microscopy (OM), hardness tests as well as tensile tests. The results revealed that at pouring temperature of 735°C and 300 mm cooling slope length, the LM6 alloy exhibits the spherical microstructural feature due to all dendritic structures were altered into α-Al globule and rosette. The Vicker's hardness value indicated that cooling slope casting sample promoted the higher hardness than conventional casting. In addition, it was observed that for ultimate tensile strength, the sample poured at 715°C with cooling slope length of 300 mm which is 150.451 MPa has the higher value compared to other conditions and as-cast sample. In all investigations and mechanical testing, the cooling slope casting that underwent T6 heat treatment revealed the positive results which became the most dominant properties in microstructure distribution, hardness and tensile properties, in contrast with non heat treated sample.

ABSTRAK

Kajian ini adalah mengenai pemprosesan logam separa pepejal untuk aloi aluminium LM6 menggunakan kaedah tuangan cerun penyejukan. Dalam kajian ini, parameter-parameter yang paling berpengaruh di antara suhu tuangan dan panjang cerun penyejukan yang mempengaruhi globulisasi aloi LM6 semasa tuangan cerun penyejukan telah dikaji. Selain itu, kekerasan dan kekuatan tegangan tuangan cerun penyejukan dan tuangan konvensional juga telah dikaji. Semua ujikaji eksperimen telah dilakukan dengan menggunakan aloi aluminium LM6 yang sama. Bilet aloi aluminium LM6 telah disediakan melalui teknik cerun penyejukan dan tuangan konvensional. Beberapa sampel kemudian telah menjalani rawatan haba T6 dengan rawatan larutan pada suhu 530°C selama 8 jam, lindap kejutan di dalam air, diikuti oleh proses penuaan pada suhu 155°C selama 3 jam. Semua sampel telah dicirikan dengan menggunakan mikroskopi optik (OM), ujian kekerasan dan juga ujian tegangan. Keputusan ujikaji telah menunjukkan pada suhu 735°C dan panjang cerun penyejukan pada 300 mm , aloi LM6 menunjukkan mickrostruktur berbentuk sfera disebabkan semua struktur dendrit telah berubah kepada bentuk globul α-Al dan bentuk roset. Nilai kekerasan Vicker menunjukkan sampel melalui teknik cerun penyejukan lebih keras berbanding tuangan konvensional. Tahap kekuatan tegangan ke atas sampel yang dituang pada 715°C dan panjang cerun penyejukan pada 300 mm bernilai 150.451 MPa mempunyai nilai kekuatan yang tinggi berbanding sampel-sampel lain. Melalui semua jenis ujikaji yang dijalankan, sampel yang menjalani rawatan haba T6 menunjukkan ciri paling dominan dalam pembahagian mikrostruktur, ujian kekerasan dan ciri tegangan berbanding sampel yang tidak menjalani rawatan haba.

DEDICATION

I am dedicating this work to my beloved parents, Sarjuni bin Kubais and Nor Zalila bt. Amir, who always inspire and support me with their boundless love to endeavour in achieving a success in everything I do.

To my supervisor, Dr. Mohd Shukor bin Salleh, family and all my friends, without whom none of my success would be possible.

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List of Abbreviations, Symbols and Nomenclatures

CS	-	Cooling Slope
ANOVA	-	Analysis of Variance
UTM	-	Universal Testing Machine
SEM	-	Scanning Electron Microscope
CNC	-	Computer Numerical Control
EDM	-	Electrical Discharged Machining
DoE	-	Design of Experiment
SSM	-	Semisolid Metal
OM	-	Optical Microscopy
FKP	-	Fakulti Kejuruteraan Pembuatan
FTK	-	Fakulti Teknologi Kejuruteraan

CHAPTER 1

INTRODUCTION

This chapter discuss the background of the study. In addition, this chapter also presents the problem statement, research objective, scope of study and the chapter overview.

1.1 Background of study

Semisolid processing of metallic alloys and composites has been acknowledged as an innovative manufacturing methods based on its thixotropic properties. The terms thixotrophy can be defined as reversible behaviour of certain gels that will turns dilute when they are shaken, stirred, or otherwise disturbed and reset after being allowed to stand. High mechanical properties can be accomplished due to fascinating microstructure and flow behaviour. The history of semisolid metal forming has been developed from a scientific approach at the MIT back to the early 1970s, when Flemings and colleagues investigated the flow trend of metals in a semisolid state. The outstanding semisolid forming processes can be achieved by precise tolerances in all process procedures, including feedstock formulation, reheating and the forming process. Throughout the years, the early work of semisolid forming has been emerged widely via the process routes and process preference. Reviews and papers regarding these technologies and their application in industry have been published by researcher and academician.

The Cooling Slope (CS) casting process is the advanced semisolid process which engages with simple equipment and employs low operating cost. Cooling slope method is made by the simple process of pouring the lightly superheated melt down a cooling slope and consequent solidification in a mould. According to Legoretta et al. (2008), there are several parameters have been highlighted in the cooling slope casting process such as mould material, mould temperature, length of cooling slope, angle of cooling slope, superheat and temperature of pouring molten metal which directly contribute to the final microstructure of the solidified slurry. Granular crystals nucleate and grow on the slope wall and are removed from the wall by fluid motion. In addition, the melt which consists numerous amount of these nuclei crystals, solidifies in the mould or die ensuing to a fine globular microstructure. The size of ingot then is determined by the weight of molten metal and the diameter of the mould. Eventually, the ingots can be utilized directly for rheo- or thixoprocessing after desirable reheating.

Therefore, this study is focusing on the semisolid processing of aluminium alloy type of metal by applying the cooling slope casting process. The microstructural behaviour and the mechanical properties of aluminium alloy are to be examined after the cooling slope process is conducted on this material. The primary crystal of the ingot cast by semisolid casting using the cooling slope becomes globular when the ingot is remelted. Thus, this present study is also to determine the most influential factor that affects the globulization of the primary crystal in this process.

1.2 Problem Statement

In the previous study by Toshio Haga et al.(2001), the effects of melt temperature, contact length between the melt temperature and the cooling slope, and the material used to construct the mould (cooling rate) on the morphology of the primary crystal were investigated. It was observed that cooling slope casting produced more homogenous microstructure than conventionally casting. It was found that the information regarding the parameters which influenced the globulization of α-Al during slope casting is still in shortage. The primary crystal of the ingot used to boost the cold deformation becomes globular after heating in the semisolid state. Furthermore, the knowledge about the mechanical properties of LM6 alloy in cooling slope casting is still inadequate and not to be emphasized in previous study. Due to the shortcoming of conventional casting, this present study is conducted to examine the microstructural behaviour and mechanical properties of aluminium LM6 alloy using cooling slope casting. In addition, the primary crystal of the aluminium specimen that was cast by the process examined in the present study was compared to the conventional casting.

1.3 Research Objectives

To solve the above mentioned problems, this study is conducted to achieve the following objectives:

1. To study the most influential parameter that affects the globulization of the primary crystal in LM6 alloy.
2. To identify the tensile strength and hardness of the specimen after cooling slope casting process.

1.4 Scope

This present study is focusing only on two main priorities including microstructural behaviour and mechanical properties on cast specimen. The paths of mechanical properties are narrowed to the tensile strength and the hardness of specimen. In this study, the aluminium LM6 alloy is chosen as samples. Thus, the result from microstructural behaviour is applied to examine the factor that affects the globulization of the primary crystal of LM6 alloy.

1.5 Chapter overview

In chapter one, it provides background of the study, the problem statements of the study, research objectives, scope of the study and also the chapter overview. The main objectives of this study are to identify the mechanical properties which focusing on tensile strength and hardness of the specimen after the process has been conducted and to study the most influential factor that that affects the globulization of the primary crystal of aluminium alloy specimen in this process. The scope and limitations of the project is focusing only on two main priorities including microstructural behaviour and mechanical properties on cast specimen by using cooling slope casting. In chapter two, the literature review is provided in order to support the discussion and the methodology of study. The literature review was performed by online search by journals and other reliable resources. Chapter three discusses the method applied to conduct this study. Chapter four presents the data and results obtained through the experiment conducted. Last but not least, chapter five concludes the findings of study and it provides recommendations for future improvement.

CHAPTER 2

LITERATURE REVIEW

This chapter provides the literature review on semisolid processing of aluminium alloy specifically and cooling slope casting that had been conducted in manufacturing industry. Additionally, reviews on cooling slope casting process on other aluminium alloys are presented. Generally, this chapter begins with review on semisolid metal processing of aluminium alloy. Besides, the preference of the aluminium LM6 as a primary material used in this study also supported in this chapter.

2.1 Semisolid metal processing (SSM)

2.1.1 Semisolid casting of aluminium alloy

Semisolid metal processing (SSM) that has been conducted in industry contributes into some benefits in the field of processing. The global comprehensive attempts in manufacturing field to establish semisolid metal processing are inspired by the compelling technological and scientific capabilities in which these factors can afford to certain advantages in properties. According to Gerhard Hirt et al. (2009), semisolid metal produces high viscosity which let obvious turbulence during die filling to be prevented and consequently diminishes the parts failure that could be due to the air porosity compared to the traditional casting. Furthermore, semisolid metal forming is capable to lower the volume lost during thorough solidification because of high solid portion which make up to 40% during die filling. This condition contributes to the reduced shrinkage porosity which eventually permits greater cross sectional adjustment that probably occurred in conventional casting. In addition, semisolid processing will produce low gas composition that leads to suitable microstructure for heat treatment and welding especially in very lattice parts which is important in current thixocasting manufacturing of aluminium alloy in automotive industry.

2.1.2 Microstructure of semisolid casting particles

Semisolid processing provides different benefits over other near net shape in manufacturing industry. In previous study by Salleh et al. (2013) have stated that this process depend on the thixotropic nature of alloys which become globular rather than a dendritic microstructure in the semisolid condition as shown in Figure 2.1.

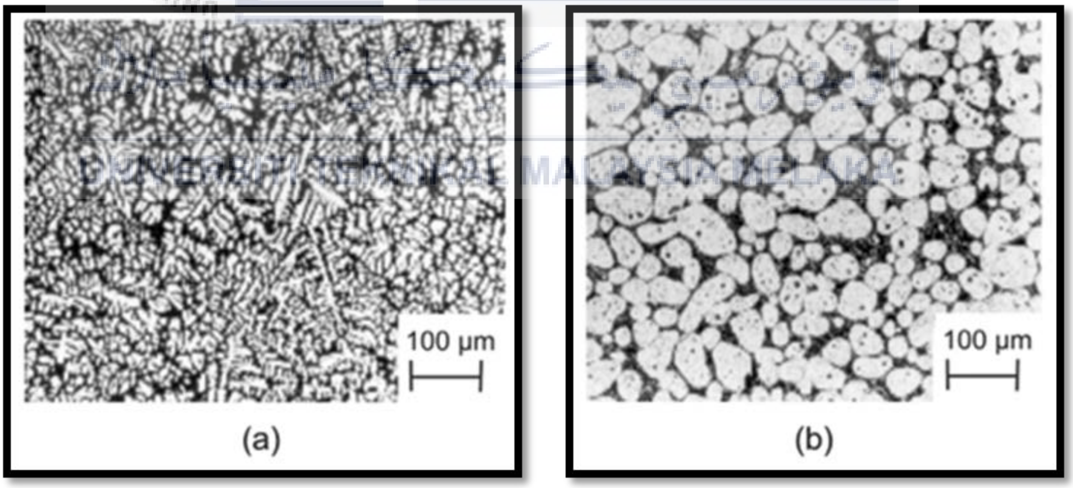

Figure 2.1: (a) Dendritic microstructure by liquid casting and (b) globular microstructure by common semisolid metal casting (Salleh et al., 2013).

The establishment of semisolid processing begins from the early work of Flemings in the 1970s, Gerhard Hirt et al. (2009) when he and his colleague analyzed the performance of solidifying metallic melts under condition in which the suspension of globular primary solid microstructure in a liquid metallic melt. The early observation exposed that the viscosity of semisolid state metal is influenced by the rate of shear, solid fraction and time as shown in Figure 2.2 under such circumstances.

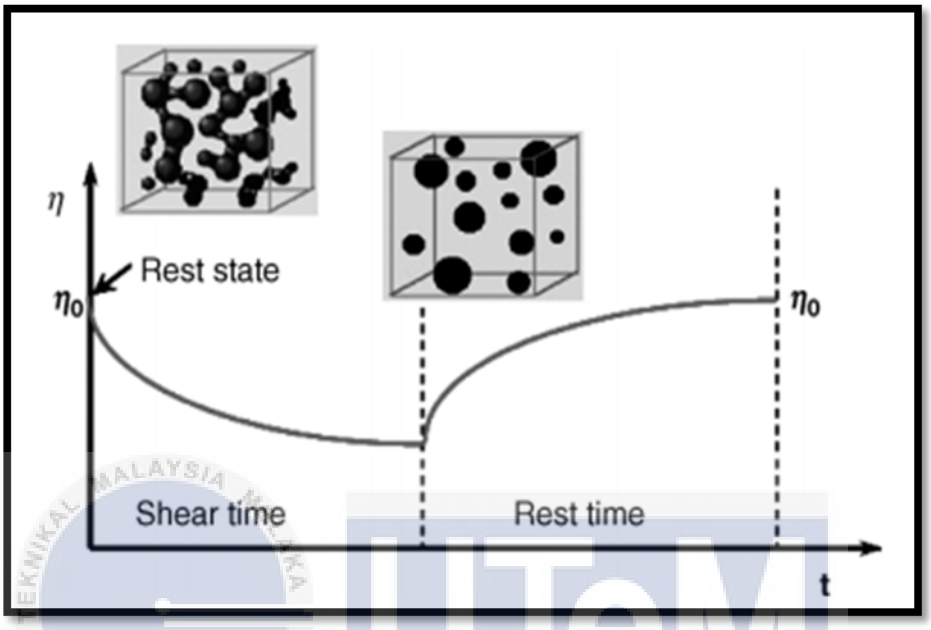

Figure 2.2: Time-dependent thixotropic behaviour (Gerard Hirt and Reiner Kopp, 2010)

In addition, Behnam Amin-Ahmadi and Hossein Aashuri (2010) highlighted that dendritic arrangement has turned into a rosette structure by ripening and coalescence mechanisms when the solidified dendrites from conventional casting are conducted at the semisolid condition. Besides, it can be observed that most of the dendrites are melted again inferred from the dispersion of hot molten metal into the inter-dendritic area or reverse action takes place. Briefly explained, affected dendrites diffused into high temperature molten metal the region. In the previous study by Tzimas and Zavaliangos (2000) have justified that some disintegrated dendrites are not melted and they develop into a globular shape as being implemented in semisolid state. From the result analysis, it can be certified that the non-dendrite structure comprising fine globular particles with homogenous distribution can be obtained on a ceramic cooling slope if an appropriate temperature of molten metal is applied.