EFFECT OF EQUAL CHANNEL ANGULAR PRESSING ON MICROSTRUCTURE AND MECHANICAL PROPERTIES ON NON DENDRITIC LM25 ALUMINIUM ALLOY

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

by

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Date :22 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka 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)

ABSTRAK

Kajian ini adalah mengenai pemprosesan logam separa pepejal aloi aluminium LM25 menggunakan penyejukan pemutus cerun diikuti oleh saluran sama sudut menekan. Dalam kajian eksperimen ini, parameter yang paling berpengaruh di antara suhu tuangan dan panjang penyejukan cerun yang memberi kesan globalisasi aloi LM25 semasa penyejukan pemutus cerun telah dikaji. Selain itu, kekerasan, kekuatan tegangan dan tingkah laku patah penyejukan pemutus cerun dan sampel pemutus konvensional telah disiasat. Semua kerja-kerja eksperimen telah dilakukan dengan menggunakan sama aloi aluminium LM25. Aluminium LM25 bilet aloi bahan mentah telah disediakan melalui teknik cerun penyejukan dan pemutus konvensional yang telah dibuang terus ke dalam acuan. Beberapa sampel kemudiannya dirawat dengan rawatan haba T6 iaitu rawatan penyelesaian 520 ° C selama 8 jam, penyejukan dalam air, diikuti oleh penuaan pada 154 ° C selama 4 jam. Semua sampel kemudiannya diperhatikan dengan menggunakan mikroskop optik (OM), Mikroskop Imbasan Elektron (SEM), kekerasan dan ujian tegangan serta sifat-sifat patah. Keputusan mendedahkan bahawa pada mencurah suhu 650 ° C dan 400 mm penyejukan panjang cerun, aloi LM25 yang mempamerkan ciri mikrostruktur sfera kerana semua struktur dendrit telah diubah ke dalam α-Al globul dan roset. nilai kekerasan Vicker yang digambarkan bahawa sampel ECAP diproses dipertingkatkan kekerasan tertinggi daripada pemutus konvensional dan penyejukan pemutus cerun. Di samping itu, ia telah diperhatikan bahawa untuk kekuatan tegangan muktamad, sampel ECAP dengan satu laluan sahaja yang 188,98 MPa mempunyai nilai tertinggi berbanding syarat lain dan sampel as-tuang. Dalam semua penyiasatan dan ujian mekanikal, pemutus cerun penyejukan yang menjalani T6 rawatan haba mendedahkan hasil yang jelas yang menjadi sifat-sifat yang paling dominan dalam pengagihan mikrostruktur, kekerasan dan tegangan hartanah, berbeza dengansampelbukanhabadirawat

ABSTRACT

This study is about the semisolid metal processing of aluminium LM25 alloy using cooling slope casting followed by equal channel angular pressing. In this experimental study, the most influential parameters between the pouring temperature and the length of cooling slope that affect the globalization of LM25 alloy during cooling slope casting were studied. Besides, the hardness, tensile strength and fracture behavior of cooling slope casting and conventional casting samples were investigated. All the experimental works were accomplished by using same LM25 aluminium alloy. The aluminium LM25 alloy feedstock billets were prepared through the cooling slope technique and conventional casting that were cast directly into mould. Several of samples were then treated with a T6 heat treatment that is solution treatment 520°C for 8 hours, quenching in water, followed by aging at 154°C for 4 hours. All of the samples were then observed by using optical microscopy (OM), Scanning Electron Microscope (SEM), hardness and tensile tests as well as fracture properties. The results revealed that at pouring temperature of 650°C and 400 mm cooling slope length, the LM25 alloy exhibits the spherical microstructural feature due to all dendritic structures were altered into α-Al globule and rosette. The Vicker's hardness value depicted that ECAP processed sample enhanced the highest hardness than conventional casting and cooling slope casting. In addition, it was observed that for ultimate tensile strength, the sample of ECAP with one pass only which is 188.98 MPa has the highest 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 obvious results which became the most dominant properties in microstructure distribution, hardness and tensile properties, in contrast with non-heat treated sample.

DEDICATION

I am dedicating this work to my beloved parents, Mokhtar bin Malid and Sopiah bt Md. Isa, who always support and inspire me with their boundless love in achieving a success in everything I do.

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

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LIST OF ABBREVIATIONS

CNC	-	Computer Numerical Method
CS	-	Computer Slope
ECAP	-	Equal Channel Angular Pressing
EDM	-	Electrical Discharge Machine
FKP	-	Fakulti Kejuruteraan Pembuatan
FTK	-	Fakulti Teknologi Kejuruteraan
OM	-	Optical Microscopy
SEM	-	Scanning Electrone Microscope
SSM	-	Semisolid Metal

LIST OF SYMBOLS

°C	-	Degree Celcius
μm	-	Micrometer
MPa	-	Mega Pascal
%	-	Percentage

CHAPTER 1

INTRODUCTION

In introduction of Chapter 1, it will discuss and explain briefly about the background of conducted study. From this chapter 1, the problem statement of study, research objective, scope of study and chapter overview will be discussed.

1.1 Background of study

Equal channel angular pressing (ECAP) is a metal forming process that is well-known used to improve the microstructure as well as the mechanical properties. This process is one of an interesting technique because of its simple procedure. It also gives the metals that ultrafine grained microstructure which can lead in increasing the mechanical properties. The materials used for equal channel angular pressing is ranging from hardened alloys, pure metals to precipitation, intermetallic and also metal matrix composites. Back to the early age of 1980s, the equal channel angular pressing techniques was introduced by Segal. From the method, the materials produced will be high-strength and also gives a very high strains into bulk using of pure iron and pure copper. The effect of using ECAP method on the mechanical behaviour has proven increase in the strength and hardness of the material. One of the success way to increase the strength of metals is using severe plastic deformation (SPD) technique by accumulating very large plastic strain without changing the area of cross section in workpiece. During the equal channel angular pressing based severe plastic deformation process, the cross section of workpiece retain same thus it can be process repeatedly until achieved the required level of deformation. When the simple shear taking place in a thin layer equal channels crossing plane, the deformation of billet will occur. Thus, with the high strain and more fine grains of materials the behaviour of physical along with mechanical will be improved.

In general principle of ECAP, basically the square or round cross section of billet is crossed through is pressed through a rigid die. Then, the flow is forced to go through an angled channel. The factor for a successive ECAP technique is that using the same outer dimensions of billet in order to press for several times so that a high cumulative strains can be achieved. Recently, this method is widely used and is well established. ECAP method is utilized to enhance the characterization of metallic materials. The ultra-fine grained structure of ECAP process have make them the most applied technique to obtain the high performances level of some materials. In this regard, aluminium and its alloy are commonly used in various application in industry such as in automotive and aircraft. Besides that, aluminium alloy is also a light weight material. Over the last two decades Abd El Aal & Sadawy (2015), materials with nanostructured and sub-microstructure have shown that an improvement in their mechanical properties affected by ECAP method.

In order to produce products that having similarly or near net-shaped products, specifically in automotive applications, semisolid metal (SSM) processing is the most effective method for that reason. Semisolid metal process is chosen because of its advantages over the conventional casting. Back to the few years before, the development of new alloys and modified commercial alloys have turn to broad enthusiastically. Nowadays, this method is used widely in manufacturing technology as an important role for producing engineering stuffs. Semisolid processing is said to be capable in long-life die due to the reduced thermal shock as well as reduce the macrosegregation.

Among all of the methods to produce semi-solid slurries including mechanical vibration, mechanical stirring, new rheocasting process (NRP), twin screw reo-molding process, narrow melt stream (NMS) and strain induced melt activation (SIMA), cooling slope casting is the most preferable method. Cooling slope casting is one of the technique that is simple and yet cost effective manner. In addition, a non-dendritic and globular microstructure can be obtained through this cooling slope technique when it is heated at the range of semi-solid.

Therefore, this present study is to analyse the microstructure on non-dendritic LM25 aluminium alloy by doing experimental test using cooling slope process and equal channel angular pressing respectively. Thus, this study will be followed up by examined the effect of ECAP on microstructure and mechanical behaviour of the alloy.

1.2 Problem Statement

According to the past study by Abd El Aal & Sadawy (2015) to produce the ultra-fine grained (UFG) bulk pure aluminium it has be in increasing the number of passes by equal channel angular pressing (ECAP) method. Based on his study, the sample are said to have high misorientation angle, high mechanical properties and resistance to corrosion. While, in the previous study Darban et al. (2016), the effect of equal channel angular pressing of Al-7075 alloy on the fracture toughness is experimentally investigated by processing the ECAP technique up to four passes but with the different routes used. Furthermore, the yield strength, ultimate strength and microhardness depicted an improvement after four passes of ECAP. Besides, the average grain size shown in transmission electron microscope (TEM) is obviously refined from 40µm to less than about 500nm. There is less research that has been carried out using this technique thus lack of information regarding the parameters that affect the morphology of the sample and also the mechanical properties. This approach may give a refine microstructure compared to other routes due to the high plastic strain rate undergone by the specimen. It is important to know the effect of the process on the morphology and mechanical properties. Regarding to this shortage, this project is conducted to visualize both of microstructure and mechanical characteristics after the ECAP process. In addition, the LM25 aluminium alloy was cast earlier by cooling slope method to produce a non-dendritic microstructural specimen.

1.3 Research Objectives

Based on the stated problem above, this present study is conducted to achieve the following objectives:

1. To produce the feedstock or billet by using cooling slope technique.
2. To investigate the microstructure behaviour of aluminium alloy after cooling slope combined with equal channel angular pressing (ECAP).
3. To investigate the mechanical properties of LM25 aluminium alloy after ECAP method.

1.4 Scope

This study is practically conducted to investigate on the microstructural properties and also the mechanical behaviour of the ECAPed specimen. The ECAPed specimen is then examined using Vickers hardness tester. In this work, the aluminium LM25 alloy is chosen as the workpiece. Subsequently, the reason that affects the microstructural properties on non-dendritic LM25 aluminium alloy will be identified.

1.5 Chapter Overview

For the overview in chapter one, it contains the background of study and also the problem statement of project. Apart from that, the research objectives, the study scope and chapter overview are also included. The important objectives of this study is being highlighted earlier as to produce the feedstock or billet by using cooling slope method in order to get the globular or non-dendritic microstructure properties. The mechanical properties is also have to be investigated just after the equal channel angular pressing method in order to know the improvement on the specimen properties. Next, during this study there are only two main priotities that have being construct on the test specimen which is the microstructure and mechanical properties by using equal channel angular pressing machine. In chapter two, it explain about the literature review of project. The purpose of the review is to assist the discussion and also the methodology of study. Lots of journals and other legal resources is searched and being studied in detail so that the information and knowledge about the project is accurate. The apparatus and method used within this study is consist in chapter three. While in chapter four, the result and data obtained throughout the project has been discussed and applied. Lastly, the overall of the study has been conclude in chapter five along with the recommendations for the future improvement.

CHAPTER 2

LITERATURE REVIEW

The chapter of this literature review on effect of equal channel angular pressing on microstructure and mechanical properties on non-dendritic LM25 aluminium alloy that is widely used in industry of manufacturing to produce smaller grain size of material. Furthermore, this chapter will begin on the semisolid metal processing review of aluminium alloy. Apart from that, the LM25 aluminium alloy that is preferred to use in this study is also assisted in this chapter.

2.1 Alloy (Aluminium)

2.1.1 LM25 Aluminium Alloy

Aluminium-Magnesium-Silicon alloy or LM25 aluminium alloy is one of the aluminium material that is widely used by industry especially automotive industry. Nowadays, automotive industry has dominated the aluminium casting with two thirds of all aluminium castings. Aluminium casting is said to grow continually at the expense of iron castings because the uses of aluminium has become important in some industry. Despite of its cost that is obviously expensive than ferrous castings, the requirement of its characteristics as