EFFECTS OF STIRRING PARAMETERS ON THE RHEOCAST MICROSTRUCTURE AND MECHANICAL PROPERTIES OF MAGNESIUM ALLOY

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This report is submitted in accordance with the University Teknikal Malaysia Melaka (UTeM) requirement for a bachelor's degree of Manufacturing Engineering (Hons.)

by

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I hereby, declared this report entitled "Effects of stirring parameters on the rheocast microstructure and mechanical properties of magnesium alloy" is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Pemprosesan keadaan separa pepejal menukar struktur mikro dendritik as-cast kepada mikrostruktur bukan dendritik globular dengan ciri mekanikal yang dipertingkatkan. Faedah proses penuangan, yang melibatkan logam yang dikisar secara mekanikal dalam keadaan separa pepejal, dikaitkan dengan parameter pemprosesan. Aloi magnesium AM50 dicairkan dan disejukkan kepada suhu pemprosesan separa pepejal (610°C) untuk mengkaji kesan masa kacau dan kelajuan kacau. Selain itu, kacau selama 1, 2, 4, dan 8 minit dengan kelajuan kacau 200, 300, 400, dan 600 rpm akan dilakukan. Untuk menyiasat pengaruh kacau, sampel silinder dengan diameter berbeza akan dikumpul dalam setiap eksperimen. Struktur mikro aloi magnesium AM50 telah dianalisis melalui OM, SEM, dan XRD. Ujian mekanikal juga dijalankan untuk menilai sifat bahan. Masa kacau selama 8 minit dengan kelajuan kacau 600 rpm adalah optimum semasa penuangan untuk mengubah aloi dendritik menjadi zarah pepejal primer yang lebih halus. Kelajuan kacau yang lebih tinggi dan masa kacau yang lebih lama mempunyai taburan saiz seragam zarah primer disebabkan oleh pembentukan gugusan yang lebih besar. Sebatian antara logam ($Mg_{17}Al_{12}$, Al_8Mn_5) telah dikesan dalam struktur mikro, diperhatikan oleh SEM, dan dikenal pasti melalui XRD. Sebatian antara logam terlarut ke dalam α-Mg semasa kelajuan kacau tinggi. Kekerasan aloi telah meningkat dengan ketara sebanyak 66.67%, dengan nilai 100.70 HV. Kekuatan hasil aloi meningkat daripada 124 MPa kepada 131.05 MPa, manakala kekuatan tegangan muktamad menunjukkan peningkatan sebanyak 9.1%, peningkatan sebanyak 251 MPa, dan pemanjangan untuk pecah mempunyai pertumbuhan yang besar daripada 15% kepada 20%.

ABSTRACT

Semisolid state processing converts as-cast dendritic microstructure into globular non-dendritic microstructure with improved mechanical characteristics. The benefits of the rheocasting process, which involves mechanically churning metals in a semisolid state, are linked to processing parameters. Magnesium alloy AM50 is melted and cooled to semisolid processing temperature (610°C) to examine the effects of stirring time and stirring speed. In addition, stirring for 1, 2, 4, and 8 minutes with stirring speeds of 200, 300, 400, and 600 rpm will be performed. To investigate the influence of stirring, cylindrical samples with different diameters will be collected in each experiment. The microstructure of magnesium alloy AM50 was analyzed through OM, SEM, and XRD. Mechanical testing is also conducted to evaluate the properties of the material. A stirring time of 8 minutes with a stirring speed of 600 rpm is optimal during casting to transform the dendritic alloy into a more refined primary solid particle. Higher stirring speed and longer stirring time have uniform size distribution of the primary particles due to little formation of a larger cluster. The intermetallic compounds ($Mg_{17}Al_{12}$, Al_8Mn_5) were detected in the microstructure, observed by SEM, and identified via XRD. The intermetallic compounds dissolved into α-Mg during high stirring speed. The hardness of the alloy was significantly improved by 66.67%, with a value of 100.70 HV. The yield strength of the alloy increased from 124 MPa to 131.05 MPa, while the ultimate tensile strength exhibited an improvement of 9.1%, an increase of 251 MPa, and the elongation to break had substantial growth from 15% to 20%.

DEDICATION

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LIST OF ABBREVIATIONS

OM	-	Optical Microscopy
SEM	-	Scanning Electron Microscopy
XRD	-	X-ray Diffraction
DoE	-	Design of Experiment
Y	-	Yttrium
Ce	-	Cerium

LIST OF SYMBOLS

g/cm^3	-	Gram Per Cubic Centimetre
MPa	-	Mega Pascal
wt. %	-	Weight Percentage
℃	-	Degree Celsius
Hv	-	Vickers Hardness
Mm	-	Millimetre
G	-	Gram
µm	-	Micrometre

CHAPTER 1

INTRODUCTION

1.1 Background

It is notable for magnesium alloy being the lightest structural material (T.T.T. Trang, 2018). It is made of magnesium, the most lightweight primary metal, blended in with other metal elements to work on the actual properties. These components incorporate manganese, aluminium, zinc, silicon, copper, zirconium, and uncommon earth metals. (National Research Council, 1975)

Magnesium alloys are materials of interest for the most part because of their high-solidarity to-weight proportions, outstanding machinability, and minimal expense. It has low explicit gravity of 1.74 g/cm^3 and a generally low Young's modulus (42 GPa) contrasted with other standard compounds, for example, aluminium or steel amalgams (Mallick, 2010). However, Magnesium alloys suffer from poor formability and brittleness at room temperature (Mallick, 2010). Their formability increments with expanding temperature; however, that requires high energy. Besides, studies have shown that formability can be improved to the detriment of solidarity by debilitating the basal texture of the Mg compounds (T.T.T. Trang, 2018). Magnesium alloys are expanding their uses in different fields, from auto to aviation and biomedical designing, due to their fantastic ductility, high stiffness, and solidarity to-weight proportions. (Sergiu-Valentin Galatanu, 2020). Magnesium alloys can be grouped into two groups which are wrought alloys and cast alloys. To reach the desired shape, wrought alloys are subjected to mechanical working, such as forging, extrusion, and rolling operations.

Be that as it may, the mechanical properties of wrought Mg alloys are still highly unsatisfactory. In any case, the industry's light-weighting benefits and assimilation of wrought Mg alloys has been drowsy so far. (B.L. Mordike, 2001). While cast magnesium combinations have overwhelmed the market for quite a long time, a new advancement in handling innovations has invigorated a quickly developing revenue to improvement also, usage of created Mg alloys. (Schumann, 2005)

Cast alloy is produced by pouring the molten liquid metal into a mould, within inside which it hardens into the necessary shape. cast magnesium alloys were conceived in the early 1900s as described by (A. LUO, 1994) as structural materials, and nearly 30 variations of cast alloys currently exist (Housh S, 1990). AM50 is quite possibly the most utilized in useful application among commercial Magnesium-Aluminium cast alloy. (Sergiu-Valentin Galatanu, 2020). Various tests and numerical studies have been created somewhat recently on AM50 Magnesium alloys to research dissipative properties (Kaczyński, 2019), fatigue behaviour (Marsavina et al., 2019), the material microstructure, (Kiełbus, 2006), tensile ductility (Lee S. G., 2005), corrosion peculiarities (Liang, 2009) just as mechanical conduct (Şerban, 2019). Exploratory tests to research the fatigue crack micro growth mechanisms in high-pressure diecast on cast AM50 alloy were likewise done by (El Kadiri, 2006).

1.2 Problem Statement

Semi-solid metal handling has been utilized for around 40 years in the metal projecting industry to deliver more excellent parts than traditional dust projecting with lower costs than manufacturing processes (R. CANYOOK, 2010). Two semi-solid metal handling courses are utilized economically: thixocasting and rheocasting. Thixocasting can yield excellent parts with high mechanical properties. Nonetheless, the overheads of the forming machines, aluminium feedstock billets, and reheating systems are very high. In any case, the new pattern in semi-strong metal handling is centred around applying the rheocasting route due to rheocasting can offer expense benefits over thixocasting. In this solid-state metal course, liquid alloy is handled into semi-strong metal at the creation site, and salvaged materials can be reused in-house (Jorstad, 2004)

The semi-strong shaping strategy introduced during the 1970s found by (Spencer, 1972) is another assembling innovation and has been generally applied in the auto and correspondence industry detailed (Phillion, 2008). Moreover, a third modern insurgency design: "Green assembling" with less energy utilization, is coming, (Nafisi, 2006) suggested that semi-strong handling might be marked as a critical stage, as it devours less energy than its regular partners. (Flemings, 1991) argued that an essential part of the semi-strong framing process is the sphericity and consistency of microstructure, which decides the rheological conduct of slurry. (Czerwinski, 2016) found that the nature of the slurry microstructure additionally affects the last exhibition of parts. (Nafisi, 2006) acquired the outcome that the better conveyance of virtual particles, better and rounder α-Al in the billets can keep away from fluid isolation during the filling system to ensure superior grade of items. New strategies and more compounds (high-temperature amalgams, created composites with limited cementing range, etc.) for semi-solid slurry are improved for this new gathering development.

To effectively apply the rheocasting system, it is significant that the nature of the slurry is painstakingly controlled during the creation. Also, it is beneficial that the cycle effectively creates semi-solid metal in a brief time frame with homogeneous and globular microstructure (KIRKWOOD D H, 2009). Semi-solid metal handling is being created in die projecting applications to give a few money-saving advantages. To effectively apply this arising innovation, comprehend the development of microstructure in semi-solid slurries to control the rheological conduct in a semi-solid state (R. CANYOOK, 2010). The microstructure of rheocast magnesium amalgams is like microstructure of converse alloy materials comprising delicate essential particles appropriated in a rigid lattice. The size and state of the virtual particles are impacted by handling factors like mixing temperature, blending rate, and mixing time (Shin, 2005).

Virtual particles cemented initially might develop dendritically during the primary stage, although the compound is blended. The dendrite arms might be divided into fine particles because of plastic bowing and melting once again with keeping mixing (R.D. Doherty, 1984). The separated grains may grow dendritically immediately; in any case, the morphology of the virtual particles is changed from dendritic shape to rosette or round shape considering the accident and scratched spot between the virtual particles as the blending has continued. The impacts of the handling factors like the blending rate, cooling rate, mixing temperature, and mixing time on the microstructures of the rheocast have been read perseveringly two compounds (J.M.M. Molennar, 1987) and super combinations (J.-J.A. Cheng, 1986)since the underlying disclosure of the semi-strong handling. As a rule, it has been observed that the actual molecule size is refined, and uniform size dissemination is obtained by expanding the cooling rate, blending rate, and mixing temperature. Notwithstanding, test results unexpectedly have additionally been accounted for (G. Wan, 1990). These perceptions recommend that the connection between the handling factors and microstructures is not settled. Another study by (Shin, 2005) concerning the effects of dealing with factors like the blending temperature, mixing rate, and blending time on the microstructure and hardness of the rheocast AZ91HP magnesium mix were assessed. The experimental results show that the rheocast ingots were made with different taking care of conditions. The size and sphericity of the elementary particles were changed with the taking care of needs. Magnesium alloys possess a poor formability especially at room temperature according to (T.T.T. Trang, 2018). the poor formability of it makes hard it to be applied in various application and could not meet the standard (Aitao Tang, 2008). Hence, this study focuses on the effect of the stirring time for the semisolid state processing for magnesium alloy AM50. The microstructural for the sample will be analysed and undergoing mechanical testing. This study then forth will give new insight to Magnesium alloy in semi solid state processing.

1.3 Objectives

The objectives are as follow:

1. To study the microstructures of magnesium alloy feedstock.
2. To investigate the mechanical properties of magnesium alloy feedstock.
3. To study the optimal parameter of stirring time and speed of magnesium alloy feedstock.

1.4 Scopes

This study focuses on stirring time and speed effects on magnesium alloy's rheocast microstructure and mechanical properties. This experiment will be using magnesium alloy AM50 as a sample to evaluate the stirring time and speed effects. The experiment will be conducting cylindrical samples with two different diameters of 6mm and 12mm to analyse the stirring time effect, and the stirring time will be executed in four separate units. The microstructure analysis using optical microscope (OM), scanning electron microscopy (SEM) and X-ray diffraction (XRD) will be done to study the impact of the stirring time and speed. Two types of mechanical testing will be conducted, such as hardness test and tensile test, to determine the material's properties. Using this strategy, the researcher will know the influence of stirring time based on the microstructure and the mechanical testing results.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This part predominantly depicts the hypothesis and research characterized and done by different research years prior. Related data of past investigations is removed as references and conversations dependent on their research. In these sections, research or data on Magnesium allot AM50, mechanical properties, the technique of rheocasting, the effect of stirring, and the microstructure of the composite will be covered.

2.2 Magnesium Alloy

(Agnew, 2012) describe that maybe no subject of Mg metallurgy has been more effectively contemplated than deformity instruments liable for the complex mechanical practices displayed by Mg and its amalgams. Single gem studies give a more significant part of data regarding the matter. As of late, the utilization of latest exploratory and computational methodologies has brought significant, new comprehension of polycrystal distortion, which is of the best importance to designing applications (Raynor GV, 1959). Qualifications between the earlier single-gem-based understanding and the new polycrystal-based agreement were not set in stone to emerge because of the joined impacts of alloying and microstructure impacts that were unrealistic to test utilizing single-precious stone techniques (Agnew, 2012). This new arrangement assists in giving direction to current composite and microstructure plan systems to further develop strength, flexibility, and sturdiness. There are