THE INFLUENCES OF HOLMIUM ON THE SOLIDIFICATION, MICROSTRUCTURE AND MECHANICAL PROPERTIES OF ELEKTRON 21 MAGNESIUM ALLOYS

NURUL RAIHAN BINTI SHAHIZAN

A thesis submitted in
fulfillment of the requirement for the award of the
Master's Degree of Mechanical Engineering

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

JULY 2018

DEDICATION

Teristimewa buat emak tersayang, Romlah Abu Bakar & baba, Shahizan Sudin..
Untuk adik-beradik tercinta..
Shah Hafeezul Wazir, Shahrul Izhar, Shahril Azwan, Nurul Sajida, Nurul Najihah & Shahril Akmar..
Terima kasih atas sokongan dari semua sudut..
Ini untuk kalian..

ACKNOWLEDGEMENT

I would like to thankful to Allah S.W.T for give me a good health in all the way through this thesis. Special thanks to my supervisor Assoc. Prof. Dr. Rosli bin Ahmad for the greatest encouragement, guidance, critics, advices, motivations as well as giving some brilliant ideas for me throughout this project going on and ultimately the opportunity to work towards my Master’s degree. Additionally, much of the experimental work and analysis couldn’t have been achieved without the help of Dr. Mohammed Bsher, Ashraf Elaswad and our team. Their expertise within the field, and their devotion to sharing her knowledge allowed me to get up to speed and become productive far quicker than I would have been able to do solo. Also, special thanks to my beloved *emak*, Romlah Abu Bakar and also to my brothers and sisters who are always give me motivations and moral support to finish this project.

Furthermore, not to forget the entire FKMP’s support technical especially to Mr. Anuar Ismail, Mr. Mohd Tarmizi, Tuan Haji Amin and Mr. Yusof that always give some support and guidance in order to finish this thesis project successfully. Honestly without their supports and helps, this thesis would not have been the same as presented here. I also would like to acknowledge the financial sponsorship provided by Malaysian Ministry of Higher Education (MOHE) under MyBrain15 scheme. Moreover, my fellow friends also should be recognized for their direct and indirect support, critics and assistances to me in order to get the project going on smoothly. I hope to one day be able to give back my time and effort to those in a similar position as myself, as you have done for me. Thank you.

ABSTRACT

The solidification parameter of Elektron 21 magnesium alloys with various Ho concentrations were investigated using computer-aided cooling curve thermal analysis system, and the solidification microstructure and phase constitution of the investigated alloys were characterized by SEM, EDX, and XRD. The mechanical properties were also investigated comparatively. The Ho was selected due to the ability to develop new intermetallic phases together with Mg and have a positive potential to reflect the properties of Mg alloys. As the outcome from this study, the cooling parameter of Elektron 21 with lower addition Ho content, the nucleation and growth temperature of α-Mg in Elektron 21 magnesium alloy decreased, where the Ho changed the solution degree of Zn, which resulted in refinement of microstructure. The results of solidification parameters showed the addition of 0.083 and 0.16 wt. % Ho cause a decrease of the solidification temperature alloys, which lead to the grain size about 64.0 %, which being a most effective addition. The microstructure of the result indicated that the intermetallic phases in the Elektron 21 cast alloy consisted mainly of α-Mg matrix, $Mg_{12}Nd$, $Mg_{41}Nd_5$, Mg_3Gd and Mg_3Nd phase. The lower addition of Ho consists of Mg-Zn-Ho phase appears in the cast alloys. However, after adding 0.5 to 3.0 wt. % Ho, the Mg-Zn-Ho phase was suppressed and the phase has earlier been mixed Mg_2Ho and Mg_3Ho phase. Moreover, the addition of 0.083 wt. % of Ho exhibited an excellent improvement of ultimate tensile strength, yield strength and hardness of 139.7 MPa, 105.62 MPa and 103.52 Hv, respectively. The solidification, microstructure and mechanical properties of Elektron 21 magnesium alloys influenced by the Ho concentration in the magnesium alloys; Elektron 21 with 0.083 wt.% Ho exhibited the refinement of microstructure and displayed the best properties compared to other alloys.

ABSTRAK

Parameter pemejalan aloi magnesium Elektron 21 dengan pelbagai kepekatan Ho telah disiasat dengan menggunakan sistem analisis haba lengkung penyejukan bantuan komputer, dan penyusunan mikrostruktur dan fasa perlembagaan aloi yang disiasat telah dicirikan oleh SEM, EDX, dan XRD. Sifat-sifat mekanik juga disiasat secara relatif. Ho dipilih disebabkan oleh keupayaannya untuk membentuk fasa baru bersama Mg dan mempunyai potensi yang positif terhadap sifat aloi Mg. Berdasarkan hasil dari kajian ini, ia didapati dari parameter penyejukan Elektron 21 dengan 0.083, 0.16 dan 0.32, nukleasi dan suhu pertumbuhan α-Mg dalam aloi Magnesium Elektron 21 menurun dengan penambahan yang lebih rendah, di mana Ho telah mengubah tahap pelarutan Zn dan mikrostruktur tuangan aloi adalah sangat ditapis dengan penambahan Ho yang lebih rendah. Hasil parameter menunjukkan penambahan 0.083 dan 0.16 % Ho menyebabkan penurunan aloi suhu pepejal, yang membawa kepada saiz bijian kira-kira 64.0 %, yang merupakan penambahan yang paling berkesan. Struktur mikro hasil menunjukkan bahawa antarafasa dalam Elektron 21 terdiri terutamanya daripada matriks α-Mg, $Mg_{12}Nd$, $Mg_{41}Nd_5$, Mg_3Gd dan Mg_3Nd. Penambahan yang lebih rendah Ho terdiri daripada fasa Mg-Zn-Ho yang muncul dalam aloi tuangan. Walau bagaimanapun, selepas menambah 0.5 hingga 3.0 % berat Ho, fasa Mg-Zn-Ho ditindas dan fasa sebelum ini telah bercampur fasa Mg_2Ho dan Mg_3Ho. Selain itu, penambahan 0.083 % Ho mempamerkan peningkatan tegasan mutakhir, pemanjangan dan kekerasan 139.7 MPa, 105.62 MPa dan 103.52 Hv. Pemisahan, mikrostruktur dan sifat-sifat mekanik elektron 21 aloi magnesium dipengaruhi oleh kepekatan Ho dalam aloi magnesium; Elektron 21 dengan 0.083 % Ho mempamerkan penghalusan mikrostruktur dan mempamerkan sifat terbaik berbanding dengan aloi lain

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREAVIATIONS

ΔT_S	-	Solidification temperature range
Δt_S	-	Solidification time range
Ar	-	Argon
ASTM	-	American Society Testing Method
EDS	-	Electron diffraction spectroscopy
FKMP	-	Fakulti Kejuruteraan Mekanikal dan Pembuatan
Gd	-	Gadolinium
Ho	-	Holmium
HRE	-	Heavy rare earth
Hv	-	Hardness value
IQ	-	Icosahedral
Mg	-	Magnesium
Nd	-	Neodymium
RE	-	Rare earth
SAED	-	Selected area electron diffraction
SF6	-	Sulfur hexafluoride
TEM	-	Transmission electron microscopy
T_N	-	Nucleation temperature
t_N	-	Nucleation time
T_S	-	Solidification temperature
t_S	-	Solidification time
Zn	-	Zinc
Zr	-	Zirconium
α	-	alpha
β	-	beta
UTHM	-	Universiti Tun Hussien Onn Malaysia

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background of study

Magnesium is the lightest structural metal, with a density 1.74 g/cm^3, which found successfully use in a variety of applications (Brown, 2006; Luo, 2013a). In 1808, Sir Humphrey Davy discovered the magnesium oxide of a newly recognized metal (Neelameggham, 2013). The primary production of magnesium has greatly increased in the past decade, as shown schematically in Figure 1.1 (Wulandari *et al.*, 2010). In late 90's, China leads and being the main producer of primary magnesium production compared to other country (Wulandari *et al.*, 2010). It is used as an alloy material, where it can be formed by any of the bulk working process including castings, forgings, extruding, rolled sheet and plate (Brown, 2006).

As reported by United State Geological Survey, the leading use, which is 35 percentages for primary metal was aluminium-base alloys that used in packaging, transportation and other applications. Primary metal consumption accounted for 15 percentages of structural uses of magnesium (castings and wrought products). Consumption of primary metal on desulfurization of iron, steel and other uses sharing the same percentage which is 10 % (Bray, 2015).

Figure 1.2 shows the magnesium consumption in the last ten years and its forecast until 2015 (Luo, 2013a). The third most-commonly used structural metal is magnesium and followed by steel and aluminum (Luo, 2013b). As the lightest metallic materials, with its density about one-fourth of steel and two-thirds of aluminium, magnesium are considered to be promising candidate which offer significant oppurtunities for lightweight application in automotive, aerospace, power tools, and 3C (computer, communication and consumer products) industries (Luo, 2013b; Wang *et al.*, 2016).

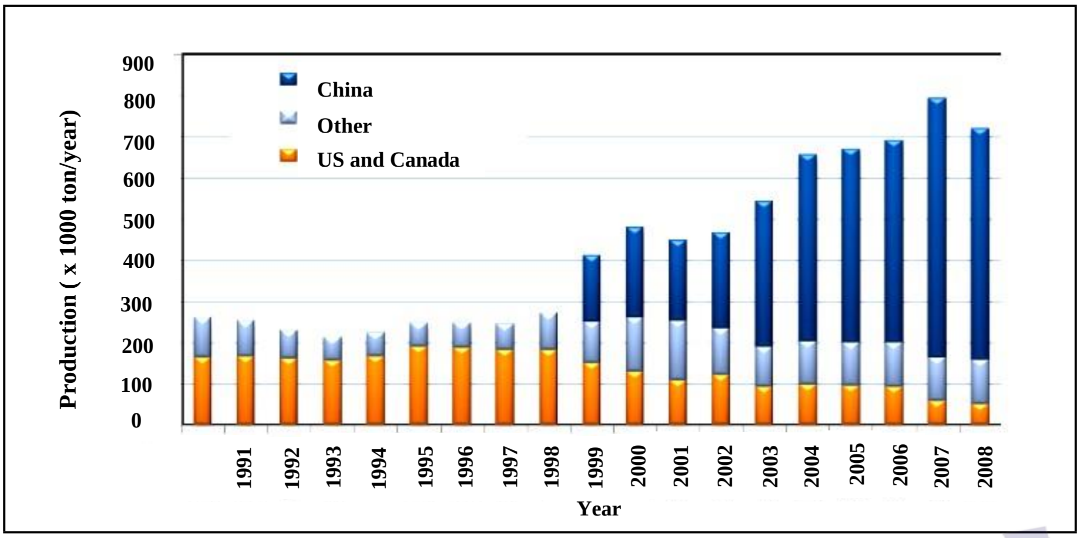

Figure 1.1: Primary magnesium production from International Magnesium Association (2010) (Wulandari *et al.*, 2010).

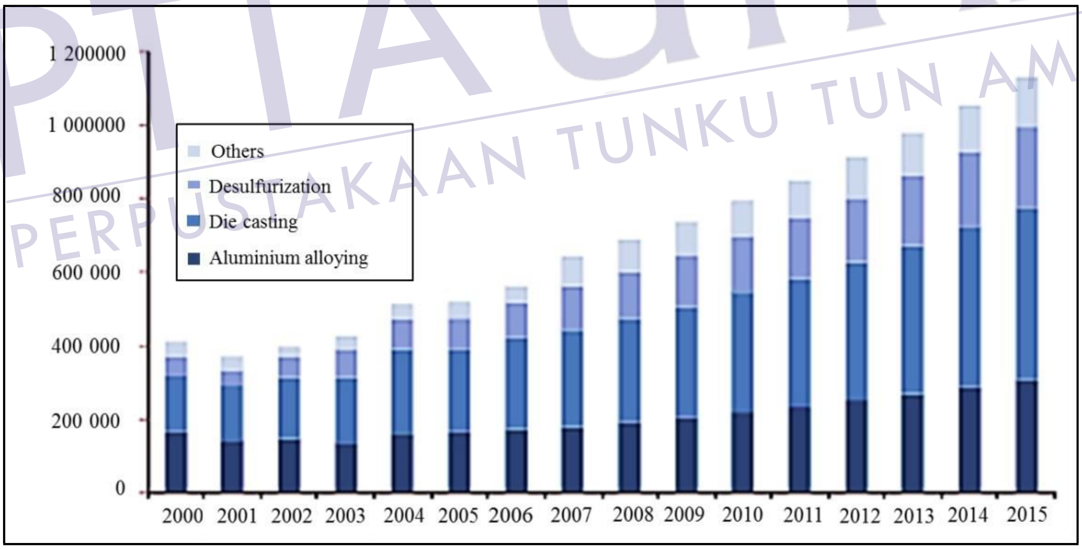

Figure 1.2: Magnesium consumption by end uses in 2000–2015 (Luo, 2013a)

Magnesium alloys are divided into two groups which is cast magnesium alloys and wrought magnesium alloys. More than 90% of structural components of magnesium alloys are produced by casting. Currently, casting is still the main industry forming method for magnesium alloys (Li *et al.*, 2011b; Sahoo & Thomas, 2011). Cast aluminium alloys have been extensively studied and served as structural components in automobiles, aircraft, and computers due to their high specific strength and good castability (Zhang & Zhao, 2012).

Numerous studies on different addition into magnesium cast alloys have been discovered. A lot of researches have been developed for the approach to improving the strength of magnesium alloys by alloying elements. The addition of rare earth (RE) element into magnesium alloys were known for the excellent performance at both the elevated temperature and the room temperature *(Sun et al.*, 2015*;* Zhang *et al.*, 2012; Zhang *et al.*, 2015). Recently, by optimizing the thermo-mechanical process and the addition of trace amounts of rare earth elements are believed to improve the quality of properties, especially strength and ductility by microstructure optimization and various strengthening mechanisms, including grain refinement and grain boundary optimization (Tekumalla *et al.*, 2014). However, to our knowledge, the effect of holmium addition on the solidification, microstructure and mechanical properties of magnesium alloy has not been investigated. Therefore, expending holmium for future application is another reason for this study. Previous researcher had found (by reducing the amount of Holmium will optimize the microstructure due to well combination between Ho and the other element) the lower addition of Holmium will optimize the microstructure where Ho combined well with the other element where presence Ho-containing intermetallic phase and thus improved the corrosion resistance of Mg-9Al alloys (Zhou *et al.*, 2006). A moderate addition of holmium also significantly enhanced the strength and ductility as the microstructure refined and the fracture modes changed from partial brittle to ductile fracture (Charles *et al.*, 2016). It is known that the size of a grain of the alloy without RE is larger compare to the alloy with RE addition; therefore affect the mechanical properties of the alloys (Liu *et al.*, 2010; Meng *et al.*, 2015). Also, according to the existing literature, highlights that the precipitation of dense and fine rare earth containing dispersed phases within the matrix grains, and along the grain boundaries of these alloys generally strengthen the base material (Bettles *et al.*, 2009; Zhu *et al.*, 2010).

Recently, new alloys known as Elektron 21 alloys (contains of 2.5 weight percent neodymium, 1.5 weight percent gadolinium, 0.5 weight percent zinc, 0.5 weight percent zirconium and magnesium as remainder) seeking an attention among the researchers to introduce the new design of magnesium alloy. However, the work studies by Kielbus (2010), found the further aging treatment decreased the hardness value due to the formation of $Mg_{41}Nd_5$ phase on the grain α-Mg grain boundaries. The majority work done with Mg-2.8Nd-1.5Gd-0.5Zn-0.5Zr or known as Elektron 21 magnesium alloys is focusing on the improvement of corrosion resistance and creep (Pikos *et al.,* 2014), constituent phase (Kielbus *et al.,* 2010) and corrosion (Kiełbus, 2007)(Kannan *et al.,* 2008). However, there are no findings on the effect of rare earth metal addition on the Elektron 21 magnesium alloys. Therefore, this study is focusing on the benefits obtained by monitoring the solidification parameters of metallurgical phase transformation together with the microstructural behaviour and mechanical properties with different addition of Ho.

1.2 Problem statement

Magnesium alloys have received the broad attentions in the industry due to their competitive strength to density ratio, but poor ductility and strength has limit wide range of its applications as engineering materials. Magnesium alloys containing rare earth elements (RE) have great application potentials in the fields of automobiles and aerospace due to their high specific strength and better heat-resistant property compared with those without RE addition. Holmium (Ho) is known as one of promising element in the heavy rare earth group and used as an alloying element especially magnesium. It has a high solid solubility in the magnesium and there is a potential of Ho to form a larger solution which contribute to the enhancement of the properties of alloys. Recently, a lot of studies focusing on the processing and improvement of the properties on magnesium alloys, however, only fewer investigations concerned on the effects of the RE on the solidification parameters together with the corresponding microstructure and properties had been conducted. As a result, the application of magnesium cast alloys containing rare earth element is still hindered by lack of knowledge about their solidification characteristic together with the corresponding microstructure and properties.

1.3 Objectives

The objectives of this research are:

i. To study the effect of Ho on solidification parameters of metallurgical phases.

ii. To investigate the role of Ho on microstructure and formation of intermetallic phases.

iii. To collerate the effect on mechanical properties and behaviour with the finding on microstructure and thermal analysis.

1.4 Scopes of the study

In order to realize the above objectives the following scopes was formulated.

a) Mg-Nd-Gd-Zn-Zr (Elektron 21) magnesium alloy was used in this present investigation as a base alloy was provided from the Magnesium Elekron (MEL).

b) The composition of Nd (2.6-3.1 wt. %), Gd (1.0-1.7 wt. %), Zn (0.2-0.5 wt. %), Zr (saturated) and Mg as the remainder were used in this study as base alloy.

c) The addition of Holmium in the Elektron 21 magnesium alloys is 0, 0.083, 0.16, 0.32, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 wt. %.

d) The casting experimental was conducted in the Foundry Lab UTHM.

e) The solidification of the sample was obtained based on recording analysis of the temperature versus time data using Computer-aided cooling curve analysis (CA-CCA).

f) Microstructural and phase analysis studies of magnesium alloy using optical microscopy, scanning electron microscope and X-ray diffraction.

i) Optical microscope (OM) to determine the quantitative information from the grain size and volume fraction of the sample

ii) Scanning Electron Microscope (SEM) with Energy Dispersive Spectrometer (EDS) is a qualitative and quantitative analytical technique to determine chemical composition.

iii) Energy Dispersive X-Ray Spectroscopy (EDS or EDX) is a chemical microanalysis technique used in conjunction with scanning electron microscopy (SEM). X-ray diffraction is used to identify and characterize the compounds based on the diffraction pattern.

g) Vicker's Hardness Test and Ultimate Tensile Strength Test (UTS) are used to obtain the mechanical properties of the samples and provide the quantitative measurement.

1.5 Significant of study

Generally, a study on the magnesium casting process is relatively new and through this study, it will give us the opportunity to improve the knowledge of the mechanism of the casting process. The higher demands of magnesium alloys allow us to improve the way of casting method to produce the alloys with an excellent property. A quality of casting was identified in this study by monitoring the solidification, together with the corresponding microstructure and mechanical properties of the alloys. Therefore through this study, it is beneficial approach especially for foundry engineers, once the solidification, microstructure and mechanical properties is understood, it is capable to improve the existing alloys and also it may applied in the field of various applications for real.

1.6 Outline of thesis

This thesis was divided into five chapters. Chapter 1 will cover background of the study in this research. It will brief the introduction of magnesium and the effect of rare earth in this solidification method corresponding to the microstructure and mechanical properties. This chapter also includes problem statement and related to the objectives of the research. There are some limitations when running this experimental which were further explained in the scope of study. The important and purpose of the study were briefly explained in significant of the research. After an introduction of the research background the previous literatures were reviewed in Chapter 1, Chapter 2 begins with a concise introduction which supported by detail overview of previous theoretical studies in effects of rare earth elements on the solidification, microstructure and mechanical properties of magnesium alloys. Studies include the magnesium alloys theories, the effect of rare earth on microstructure and mechanical properties of magnesium alloys. The solidification behavior in magnesium alloys is also summarized as well in Chapter 2 from previous studies. Chapter 3 reported the experimental procedures and technologies in details. In Chapter 4, the results of experimental are presented, including the solidification parameters of Holmium as an addition of Mg-2.8Nd-1.5Gd-0.5Zn-0.5Zr (Elektron 21) magnesium alloys, the X-ray diffraction analysis of alloys as confirmation of the phase occurred, scanning electron microscope to analyzed the chemical composition of cast alloys, optical microscope to measure the grain size and volume fraction of cast alloy. Also, Chapter 4 were covered the tensile test and hardness test results from the experiment. In Chapter 5, the conclusion and recommendation were made based on the presented result from the previous chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Recently, magnesium (Mg) has become a focus and succeed in attracting the automotive industry which contribute to fuel efficiency and environmental conservation and also for aircraft construction (Meng *et al.,* 2015). The manufacturer is always looking forward with the improvement on magnesium itself, especially in saving the weight without losing the material properties (Hao *et al.* 2012). Compared to the other structural metal, magnesium has the lowest densities density (1.8 g/cm^3) which is over four times lighter than steel (7.85 g/cm^3) and 35 percent lighter than aluminium (2.7 g/cm^3) (Hamdy *et al.,* 2012). Magnesium offers an excellent casting ability, high specific strength and stiffness, good machining ability, good weldability and also having integrated recycling possible, compared to aluminum and steel (Davis, 1997; Fergus *et al.*, 2015).

Magnesium is an alkaline earth metal and it is the 8th most abundant element which constituting 2% of the total mass of the earth's crust and dissolved in seawater (Kainer, 2006; Luo, 2013a). In the 19th century, the first metal was produced using an electrolysis of a mixture of magnesia and mercury oxide (Luo, 2013a). Nowadays, the study of magnesium has been developed and broadly used in the engineering application, especially in an automotive and aerospace. However, magnesium rarely used in a pure form itself in the engineering application without being alloyed with other metals. Recently, the addition of rare earth element is widely used to obtain the strong and lightweight where are needed for structural uses (Avedesian & Baker, 1999). The introduction of rare earth addition into the magnesium alloys displayed an

excellent result which led to the grain refinement and also the mechanical properties (Zhu *et al.*, 2013).

2.2 Alloys designation

Magnesium alloys usually referred to their American Society for Testing and Materials (ASTM) designations which, together with their temper designations, are given in a four-part code (Koshal, 2014). Determination of the International Code for magnesium alloys is still not established. The methods used by ASTM B275 (standard practice for collection of certain non-ferrous metals and alloys, cast and wrought) have a tendency to prevail. In this system, the main alloying element refers to both first letter (refer to Table 2.1). In the nominal weight percent composition of a number of these elements will be rounded to the nearest whole number. Generally it refers to increasing the quality and suffix letters A, B, C are given chronologically. In this study, EV31A or known also as Elektron 21 is an alloy containing approximately 3 percent rare earth and 1 percent gadolinium

Table 2.1: ASTM codes for magnesium's alloying elements (Avedesian & Baker, 1999; Koshal, 2014; Mathaudhu *et al.*, 2016)

Letter alloying element	Alloying element	Letter alloying element	Alloying element
A	Aluminium	N	Nickel
B	Bismuth	P	Lead
C	Copper	Q	Silver
D	Cadmium	R	Chromium
E	Rare Earth	S	Silicon
F	Iron	T	Tin
H	Thorium	V	Gadolinium
J	Strontium	W	Yttrium
K	Zirconium	X	Any other
L	Lithium	Y	Antimony
M	Manganese	Z	Zinc

REFERENCES

Ahmad, R., Sheggaf, Z. M., Asmael, M. B. A., & Hamzah, M. Z. (2016a). Effect of Praseodymium addition on microstructure and hardness of cast ZRE1 magnesium alloy. *ARPN Journal of Engineering and Applied Sciences*, *11*(10), 6485-6489.

Ahmad, R., Sheggaf, Z. M., Asmael, M. B. A., & Hamzah, M. Z. (2016b). Effect of Yttrium addition on microstructure and hardness of cast ZRE1 magnesium alloy. *ARPN Journal of Engineering and Applied Sciences*, *11*(12), 6485-6489.

Ahmad, R., Hamzah, M. Z., Asmael, M. B. A., & Sheggaf, Z. M. (2016c). Effects of Gadolinium on microstructure and hardness of Mg-Zn-Ce-Zr cast alloy. *ARPN Journal of Engineering and Applied Sciences*, *11*(14), 8592-8597.

Angelini, V., Boromei, I., Ceschini, L., & Morri, A. (2015). Microstructure and mechanical properties of a rare earth rich magnesium casting alloy. *Metallurgia Italiana*, (9), 31-36.

Ann, R. Bob, A., Pete, V., Mary Ann, E., Frautschy, H.G & Ron, S. (2008). *Aviation Maintainance Technician Handbook General-Aircraft Materials, Processes and Hardware*. United State of America: Faderal Aviation Administration.

Avedesian, M. M., & Baker, H. (Eds.) (1999). *ASM Specialty Handbook: Magnesium and Magnesium Alloys*. United States of America: ASM International.

Bettles, C. J., Gibson, M. A., & Zhu, S. M. (2009). Microstructure and mechanical behaviour of an elevated temperature Mg-rare earth based alloy. *Materials Science and Engineering: A*, *505*(1), 6-12.

Bi, G., Li, Y., Zang, S., Zhang, J., Ma, Y., & Hao, Y. (2014). Microstructure, mechanical and corrosion properties of Mg–2Dy–xZn (x= 0, 0.1, 0.5 and 1 at.%) alloys. *Journal of Magnesium and Alloys*, *2*(1), 64-71.

Bohlen, J., Yi, S., Letzig, D., & Kainer, K. U. (2010). Effect of rare earth elements on the microstructure and texture development in Magnesium–Manganese alloys during extrusion. *Materials Science and Engineering: A*, *527*(26), 7092-7098.

Bray, E. L., (2015). *Magnesium Metal*. U.S. Geological Survey, Mineral Commodity Summaries, *1*(703), 98-99.

Brown, M. E. (2001). *Introduction to Thermal Analysis: Techniques and Application*. Netherlands: Kluwer Academic Publishers.

Brown, R. E. (2006). *Magnesium and Its Alloys, in Mechanical Engineer Handbook : Materials and Mechanical Design*, 1, 278-286.

Brya, K., Dutkiewicz, J., Faryna, M., Dobatkina, T. V., & Rokhlin, L. L. (2008). The Influence of Nd and Ho addition on the microstructure of Mg-7Al alloy. *Archives of Materials Science and Engineering*, *29*(1), 40-44.

Campbell Jr, F. C. (2011). *Manufacturing for Aerospace Structural Materials*. Amsterdam: Elsevier.

Cao, L. J., Wu, Y. J., Peng, L. M., Wang, Q. D., & Ding, W. J. (2014). Microstructure and tribological behavior of Mg–Gd–Zn–Zr alloy with LPSO structure. *Transactions of Nonferrous Metals Society of China*, *24*(12), 3785-3791.

Chandler, H. (Ed.). (1998). *Metallurgy for the Non-metallurgist*. ASM International.

Charles, M. Hao, G., Yun, Z., Songsong X., & Z. Zhang, (2016). Effects of Holmium and hot-rolling on microstructure and mechanical properties of Mg-Li based alloys. *Journal of Rare Earths*, *34*(12), 1269-1276.

Chen, T. J., Zhang, D. H., Wang, W., Ma, Y., & Hao, Y. (2014). Effects of Zn content on microstructures and mechanical properties of Mg–Zn–RE–Sn–Zr–Ca alloys. *Materials Science and Engineering: A*, 607, 17-27.

Chen, T. J., Zhang, D. H., Wang, W., Ma, Y., & Hao, Y. (2015). Effects of Y content on microstructures and mechanical properties of as-cast Mg-Zn-Nd alloys. *China Foundry*, *12*(5), 339-348.

Chia, T. L., Easton, M. A., Zhu, S. M., Gibson, M. A., Birbilis, N., & Nie, J. F. (2009). The effect of alloy composition on the microstructure and tensile properties of binary Mg-rare earth alloys. *Intermetallics*, *17*(7), 481-490.

Choi, H. Y., & Kim, W. J. (2015). Effect of thermal treatment on the bio-corrosion and mechanical properties of ultrafine-grained ZK60 magnesium alloy. *Journal of the Mechanical Behavior of Biomedical Materials*, 51, 291-301.

Chu, P. W., & Marquis, E. A. (2015). Linking the microstructure of a heat-treated

WE43 Mg alloy with its corrosion behavior. *Corrosion Science*, *101*, 94-104.

Czerwinski, F. (Ed.) (2008). *Magnesium Injection Molding*. New York.: Springer.

Davis, J. R. (Ed.) (1992). *ASM Materials Engineering Dictionary*. United State of America: ASM International.

Davis, J. R. (Ed.) (1997). *ASM Specialty Handbook: Heat-Resistant Materials*. United State of America: ASM International.

Ding, Y., Lin, J., Wen, C., Zhang, D., & Li, Y. (2016). Mechanical properties, in vitro corrosion and biocompatibility of newly developed biodegradable Mg-Zr-Sr-Ho alloys for biomedical applications. *Scientific Reports, 6*, 1-10.

Dobrzański, L. A., Krol, Tanski, M., & Maniara, R. (2009). Effect of cooling rate on the solidification behavior of magnesium alloy. *Journal of Materials Processing Technology*, *37*(1), 21-24.

Dybowski, B., Kiełbus, A., & Jarosz, R. (2013). Mould components impact on structure and quality of Elektron 21 alloy. *Archives of Foundry Engineering*, *13*(2), 17-23.

Emadi, D., Whiting, L. V., Nafisi, S., & Ghomashchi, R. (2005). Applications of thermal analysis in quality control of solidification processes. *Journal of Thermal Analysis and Calorimetry*, *81*(1), 235-242.

Engler, O., & Randle, V. (2009). *Introduction to Texture Analysis: Macrotexture, Microtexture, and Orientation Mapping*. United State of America: CRC Press.

Fergus, J. W., Mishra, B., Anderson, D., Sarver, E. A., & Neelameggham, N. R. (Eds). (2015). *Engineering Solutions for Sustainability: Materials and Resources II,* United State of America: John Wiley.

Ghali, E. (2010). *Corrosion Resistance of Aluminium and Magnesium Alloys: Understanding, Performance, and Testing,* Canada: Wiley.

Goldstein, J. I., Newbury, D. E., Michael, J. R., Ritchie, N. W., Scott, J. H. J., & Joy, D. C. (2017). *Scanning Electron Microscopy and X-Ray Microanalysis*. United State of America: Springer.

Guo, J. T., Sheng, L. Y., Tian, Y. X., Zhou, L. Z., & Ye, H. Q. (2008). Effect of Ho on the microstructure and compressive properties of NiAl-based eutectic alloy. *Materials Letters*, *62*(23), 3910-3912.

Hamdy, A. S., Doench, I., & Möhwald, H. (2012). The effect of vanadia surface treatment on the corrosion inhibition characteristics of an advanced magnesium Elektron 21 alloy in chloride media. *International Journal of Electrochemical*

Science, *7*(9), 7751-7761.

Hao, Z., Wang, Q. D., Jie, C. H. E. N., Bing, Y. E., & Wei, G. (2012). Microstructure and mechanical properties of extruded Mg–8.5Gd–2.3Y–1.8Ag–0.4Zr alloy. *Transactions of Nonferrous Metals Society of China*, *22*(8), 1891-1895.

He, S. M., Zeng, X. Q., Peng, L. M., Gao, X. Q., Nie, J. F., & Ding, W. J. (2006). Precipitation in a Mg–10Gd–3Y–0.4 Zr (wt.%) alloy during isothermal ageing at 250 C. *Journal of Alloys and Compounds*, *421*(1), 309-313.

Huang, Z. H., Liang, S. M., Chen, R. S., & Han, E. H. (2009). Solidification pathways and constituent phases of Mg–Zn–Y–Zr alloys. *Journal of Alloys and Compounds*, *468*(1), 170-178.

Huang, Z. H., Qi, W. J., & Xu, J. (2013). Microstructures and mechanical properties of ZK60-xHo wrought magnesium alloys. *Materials Science Forum*, 747, 359-368.

Jafari, H., Rahimi, F., & Sheikhsofla, Z. (2016). In vitro corrosion behavior of Mg-5Zn alloy containing low Y contents. *Materials and Corrosion*, *67*(4), 396-405.

Kainer, K. U. (Ed.) (2003). *Magnesium Alloys and Technology*. John Wiley & Sons.

Kainer, K. U. (Ed.) (2006). *Metal Matrix Composites: Custom-Made Materials for Automotive and Aerospace Engineering*. Germany: John Wiley & Sons.

Kannan, M. B., Dietzel, W., Blawert, C., Atrens, A., & Lyon, P. (2008). Stress corrosion cracking of rare-earth containing magnesium alloys ZE41, QE22 and Elektron 21 (EV31A) compared with AZ80. *Materials Science and Engineering: A*, *480*(1), 529-539.

Kashimoto, S., Nakano, H., Arichika, Y., Ishimasa, T., & Matsuo, S. (2000). Dependence of electrical resistivity and magnetoresistance on long-range (F-type) ordering in Zn–Mg–Ho icosahedral quasicrystals. *Materials Science and Engineering: A*, 294, 588-591.

Kaveh, M., A. (Ed.) (2011). *Improving the Properties of Magnesium Alloys for High Temperature Applications, Magnesium Alloys - Design, Processing and Properties, Magnesium Alloys - Design, Processing and Properties*, InTech, Retrieved from: http://www.intechopen.com/books/magnesium-alloys-designprocessing-and-properties

Ke, L., Wang, Q. F., Du, W. B., Li, S. B., & Wang, Z. H. (2013). Failure mechanism of as-cast Mg-6Zn-2Er alloy during tensile test at room temperature

Transactions of Nonferrous Metals Society of China, *23*(11), 3193-3199.

Khan, M. I., Mostafa, A. O., Aljarrah, M., Essadiqi, E., & Medraj, M. (2014). Influence of cooling rate on microsegregation behavior of magnesium alloys. *Journal of Materials, 2014*, 1-8.

Kiełbus, A. (2007a). Corrosion resistance of Elektron 21 magnesium alloy. *Journal of Achievements in Materials and Manufacturing Engineering*, *22*(1), 29-32.

Kiełbus, A. (2007b). Microstructure and mechanical properties of Elektron 21 alloy after heat treatment. *Journal of Achievements in Materials and Manufacturing Engineering, 20*(92007), 127-130.

Kielbus, A. (2011). Microstructure and properties of Elektron 21 magnesium alloy. *Magnesium Alloys-Design, Processing and Properties*. Retrieved from: http://www.intechopen.com

Kiełbus, A., Rzychoń, T., & Przeliorz, R. (2010). DSC and microstructural investigations of the Elektron 21 magnesium alloy. *Materials Science Forum*, 638, 1447-1452.

Kiełbus, A., Stopyra, M., & Jarosz, R. (2013). Influence of sand-casting parameters on microstructure and properties of magnesium alloys. *Archives of Metallurgy and Materials*, *58*(2), 635-640.

Kim, Y. K., Kim, W. T., & Kim, D. H. (2014). Quasicrystal-reinforced Mg alloys. *Science and Technology of Advanced Materials*, 15(2), 024801.

Koshal, D. (2014). *Manufacturing Engineer's Reference Book*. Great Britain: Butterworth-Heinemann.

Kumar, K. A., Viswanath, A., Pillai, U. T. S., Pai, B. C., & Chakraborty, M. (2013). Influence of Neodymium addition on the microstructure, mechanical and thermal properties of Mg-Si Alloys. *Procedia Engineering*, 55, 103-108.

Lee, J. Y., Kim, D. H., Lim, H. K., & Kim, D. H. (2005). Effects of Zn/Y ratio on microstructure and mechanical properties of Mg-Zn-Y alloys. *Materials Letters*, 59(29-30), 3801-3805.

Li, D., Wang, Q., & Ding, W. (2011a). Effects of Ho on the microstructure and mechanical properties of Mg-Zn-Ho-Zr magnesium alloys. *Rare Metals*, 30(2), 131-136.

Li, H., Du, W., Li, S., & Wang, Z. (2012). Effect of Zn/Er weight ratio on phase formation and mechanical properties of as-cast Mg–Zn–Er alloys. *Materials & Design*, 35, 259-265.

Li, J. L., Chen, R. S., & Wei, K. (2011b). Microstructure and mechanical properties of Mg-Gd-Y-Zr alloy cast by metal mould and lost foam casting. *Transactions of Nonferrous Metals Society of China*, *21*(4), 761-766.

Li, J., Chen, R., Ma, Y., & Ke, W. (2013). Effect of Zr modification on solidification behavior and mechanical properties of Mg–Y–RE (WE54) alloy. *Journal of Magnesium and Alloys*, *1*(4), 346-351.

Li, J., Chen, R., Ma, Y., & Ke, W. (2014). Computer-aided cooling curve thermal analysis and microstructural characterization of Mg–Gd–Y–Zr system alloys. *Thermochimica Acta*, 590, 232-241.

Li, J., Du, W., Li, S., & Wang, Z. (2009). Icosahedral quasicrystalline phase in an as-cast Mg-Zn-Er alloy. *Rare Metals*, *28*(3), 297-301.

Li, Q., Wang, Q., Wang, Y., Zeng, X., & Ding, W. (2007). Effect of Nd and Y addition on microstructure and mechanical properties of as-cast Mg–Zn–Zr alloy. *Journal of Alloys and Compounds*, *427*(1), 115-123.

Li, Q., Wang, Q., Zhou, H., Zeng, X., Zhang, Y., & Ding, W. (2005). High strength extruded Mg–5Zn–2Nd–1.5 Y–0.6 Zr–0.4 Ca alloy produced by electromagnetic casting. *Materials Letters*, *59*(19), 2549-2554.

Liu, B. Z., Liu, J. J., Hou, X. L., Zhang, Z., Lei, L. I., & Wang, L. M. (2010). Microstructures and mechanical properties of Mg-10Ho-0.6Zr-xNd alloys. *Transactions of Nonferrous Metals Society of China*, *20*, 346-351.

Liu, H., Xue, F., Bai, J., Zhou, J., & Sun, Y. (2014). Microstructures and mechanical properties of Mg-2Y-xZn (x= 1, 2, 3 at%) Alloys. *Rare Metal Materials and Engineering*, 43(3), 570-574.

Liu, L., Chen, X., Pan, F., Wang, Z., Liu, W., Cao, P., & Xu, X. (2015). Effect of Y and Ce additions on microstructure and mechanical properties of Mg–Zn–Zr alloys. *Materials Science and Engineering: A*, *644*, 247-253.

Luo, A. A. (2013a). Applications: aerospace, automotive and other structural applications of magnesium. *Fundamentals of Magnesium Alloy Metallurgy*, 266-316.

Luo, A. A. (2013b). Magnesium casting technology for structural applications. *Journal of Magnesium and Alloys*, *1*(1), 2-22.

Lyon, P., Syed, I., & Heaney, S. (2007). Elektron 21–an aerospace magnesium alloy for sand cast and investment cast applications. *Advanced Engineering Materials*, 9(9), 793-798.

Magnesium Elektron, Elektron®21, Datasheet 455, 0-2, Retrieved from: http://www.magnesium-elektron.com

Mathaudhu, S. N., Luo, A. A., Neelameggham, N. R., Nyberg, E. A., & Sillekens, W. H. (Eds.) (2016). *Essential Readings in Magnesium Technology*. Switzerland: Springer.

Meng, L., Xinggang, L., Zhang, K., Yongjun, L. I., Minglong, M. A., Guoliang, & Jingbao, L. (2015). Effects of isothermal homogenization on microstructure evolution of Mg-7Gd-5Y-1MM-0.5 Zr alloy. *Journal of Rare Earths*, *33*(4), 439 - 444.

Mert, F., Blawert, C., Kainer, K. U., & Hort, N. (2012). Influence of Cerium additions on the corrosion behaviour of high pressure die cast AM50 alloy. *Corrosion Science*, 65, 145-151.

Miao, Y., Yaohui, L., Jiaan, L., & Yulai, S. (2014). Corrosion and mechanical properties of AM50 magnesium alloy after being modified by 1 wt. % rare earth element Gadolinium. *Journal of Rare Earths*, *32*(6), 558-563.

Mingbo, Y., Caiyuan, Q., Fusheng, P., & Tao, Z. (2011). Comparison of effects of Cerium, Yttrium and Gadolinium additions on as-cast microstructure and mechanical properties of Mg-3Sn-1Mn magnesium alloy. *Journal of Rare Earths*, *29*(6), 550-557.

Mingbo, Y., Tingzhang, G., Caiyuan, Q., & Fusheng, P. (2012). Microstructure, tensile and creep properties of as-cast Mg-3.8 Zn-2.2 Ca-xCe (x= 0, 0.5, 1 and 2 wt.%) magnesium alloys. *Journal of Rare Earths*, *30*(2), 181-188.

Mukhopadhyay, N. K., Belger, A., Paufler, P., Uhrig, E., Brühne, S., & Assmus, W. (2008). Nanoindentation studies on single crystals of Zn–Mg–Er and Zn–Mg–Ho icosahedral phases. *Journal of Alloys and Compounds*, *466*(2), 160-164.

Neelameggham, R. (2013). *Primary Production of Magnesium: Fundamentals of Magnesium alloy metallurgy,* Cambridge (United Kingdom), :Woodhead Publishing.

Pang, S., Wu, G., Liu, W., Sun, M., Zhang, Y., Liu, Z., & Ding, W. (2013). Effect of cooling rate on the microstructure and mechanical properties of sand-casting Mg–10Gd–3Y–0.5Zr magnesium alloy. *Materials Science and Engineering: A*, 562, 152-160.

Pekguleryuz, M. (2013a). Alloying behavior of magnesium and alloy design. *Fundamentals of Magnesium Alloy Metallurgy*, 152-196.

Pekguleryuz, M. O., Kainer, K., & Kaya, A. A. (Eds.) (2013b). *Fundamentals of Magnesium Alloy Metallurgy*. United State of America: Elsevier.

Peng, Q., Dong, H., Tian, Y., & Zhang, H. (2012). Effect of backward extrusion on microstructure and mechanical properties of Mg–Gd based alloy. *Materials Science and Engineering: A*, *532*, 443-448.

Peng, Q., Dong, H., Wang, L., Wu, Y., & Wang, L. (2007). Aging behavior and mechanical properties of Mg–Gd–Ho alloys. *Materials Characterization*, *59*(8), 983-986.

Penghuai, F., Liming, P., Haiyan, J., Jianwei, C., & Chunquan, Z. (2008a). Effects of heat treatments on the microstructures and mechanical properties of Mg–3Nd–0.2 Zn–0.4 Zr (wt.%) alloy. *Materials Science and Engineering: A*, *486*(2), 183-192.

Penghuai, F., Liming, P., Haiyan, J., Lan, M., & Chunquan, Z. (2008b). Chemical composition optimization of gravity cast Mg–yNd–xZn–Zr alloy. *Materials Science and Engineering: A*, *496*(2), 177-188.

Pikos, I., Rzychoń, T., & Kiełbus, A. (2014). Microstructural phenomenon occurring in Elektron 21 magnesium alloy during creep. *Materials Science Forum*, 782, 339-343.

Polmear, I. (2005). *Light Alloys: From Traditional Alloys to Nanocrystals*. United Kingdom: Butterworth-Heinemann.

Rokhlin, L. L. (2003). *Magnesium Alloys Containing Rare Earth Metals: Structure and Properties*. New York: CRC Press.

Rokhlin, L. L. (2007a). The regularities in the Mg-rich parts of the phase diagrams, phase transformations and mechanical properties of magnesium alloys with individual rare earth metals. *Archives of Metallurgy and Materials*, *52*(1), 5-11.

Roskosz, S., Dybowski, B., & Cwajna, J. (2012). Fractography and structural analysis of WE43 and Elektron 21 magnesium alloys with unmodified and modified grain size. In *Solid State Phenomena*, 91, 123-130.

Saccone, A., Delfino, S., Macciò, D., & Ferro, R. (1993). Magnesium-rare earth phase diagrams: Experimental investigation of the Ho-Mg system. *Journal of Phase Equilibria*, *14*(3), 280-287.

Sahoo, M., & Thomas, S. P. (2011). *Technology for Magnesium Castings: Design, Products & Applications*. United State of America: American Foundry Society.

Seetharaman, S., Blawert, C., Ng, B. M., Wong, W. L. E., Goh, C. S., Hort, N., &

Gupta, M. (2015). Effect of Erbium modification on the microstructure, mechanical and corrosion characteristics of binary Mg–Al alloys. *Journal of Alloys and Compounds*, 648, 759-770.

Smola, B., Stulıková, I., Von Buch, F., & Mordike, B. L. (2002). Structural aspects of high performance Mg alloys design. *Materials Science and Engineering: A*, *324*(1), 113-117.

Song, P., Wu, G. H., Liu, W. C., Zhang, L., Zhang, Y., Conrad, H., & Ding, W. J. (2014). Influence of cooling rate on solidification behavior of sand-cast Mg–10Gd–3Y–0.4 Zr alloy. *Transactions of Nonferrous Metals Society of China*, *24*(11), 3413-3420.

Song, P., Wu, G. H., Liu, W. C., Zhang, L., Zhang, Y., Conrad, H., & Ding, W. J. (2015). Influence of pouring temperature on solidification behavior, microstructure and mechanical properties of sand-cast Mg-10Gd-3Y-0.4 Zr alloy. *Transactions of Nonferrous Metals Society of China*, *25*(2), 363-374.

StJohn, D. H., Dahle, A. K., Abbott, T., Nave, M. D., & Qian, M. (2003). *Solidification of Cast Magnesium Alloys.* California, USA: In Magnesium Technology.

Sun, M., Hu, X., Peng, L., Fu, P., & Peng, Y. (2015). Effects of Sm on the grain refinement, microstructures and mechanical properties of AZ31 magnesium alloy. *Materials Science and Engineering: A*, 620, 89-96.

Tekumalla, S., Seetharaman, S., Almajid, A., & Gupta, M. (2014). Mechanical properties of magnesium-rare earth alloy systems: A review. *Metals*, *5*(1), 1-39.

Tong, G. D., Liu, H. F., & Liu, Y. H. (2010). Effect of Rare Earth Additions on Microstructure and Mechanical Properties of AZ91 magnesium alloys. *Transactions of Nonferrous Metals Society of China*, 20, 336-340.

Wang, J. F., Song, P. F., Pan, F. S., & Zhou, X. E. (2013). Microstructure and phase composition of as-cast Mg–9Er–6Y–xZn–0.6 Zr alloys. *Transactions of Nonferrous Metals Society of China*, *23*(4), 889-895.

Wang, L., Mostaed, E., Cao, X., Huang, G., Fabrizi, A., Bonollo, F. Alberto, C. Chengzhong, Wang, Lifei, & Vedani, M. (2016). Effects of texture and grain size on mechanical properties of AZ80 magnesium alloys at lower temperatures. *Materials & Design*, 89, 1-8.

Wang, Y., Wu, G., Liu, W., Pang, S., Zhang, Y., & Ding, W. (2014). Effects of chemical composition on the microstructure and mechanical properties of gravity cast Mg–xZn–yRE–Zr alloy. *Materials Science and Engineering: A*, 594, 52-61.

Wei, L. Y., Dunlop, G. L., & Westengen, H. (1995). The intergranular microstructure of cast Mg-Zn and Mg-Zn-rare earth alloys. *Metallurgical and Materials Transactions A*, *26*(8), 1947-1955.

Wulandari, W., Brooks, G. A., Rhamdhani, M. A., & Monaghan, B. J. (2010). Magnesium: current and alternative production routes. *Chemeca 2010: Engineering at the Edge*, 347.

Xiao, W., Jia, S., Wang, J., Wu, Y., & Wang, L. (2008). Effects of Cerium on the microstructure and mechanical properties of Mg–20Zn–8Al alloy. *Materials Science and Engineering: A*, *474*(1), 317-322.

Xiaohui, L. (2013). *Enhanced Ductility of Mg Alloys Containing Rare Earth Elements*. RWTH Aachen University: Thesis Ph.D.

Xu, C., Wang, X., Zhang, J., & Zhang, Z. (2014). Effect of Nd and Yb on the microstructure and mechanical properties of Mg-Zn-Zr alloy. *Rare Metal Materials and Engineering*, *43*(8), 1809-1814.

Xu, D. K., Liu, L., Xu, Y. B., & Han, E. H. (2006). The effect of precipitates on the mechanical properties of ZK60-Y alloy. *Materials Science and Engineering: A*, *420*(1), 322-332.

Xu, Y. D., Hu, S. S., Nie, J. J., Wang, J., Wang, R., & Zhu, X. R. (2012). The Microstructure and Properties of Extruded Mg-Nd-Gd-Zn-Zr Alloy. In *Advanced Materials Research*, 554, 465-471.

Xudong, W. A. N. G., Wenbo, D. U., Zhaohui, W. A. N. G., Ke, L. I. U., & Shubo, L. I. (2012). Stable icosahedral phase in Mg44Zn44Gd12 alloy. *Journal of Rare Earths*, *30*(5), 503-506.

Yamagata, H., Kasprzak, W., Aniolek, M., Kurita, H., & Sokolowski, J. H. (2008). The effect of average cooling rates on the microstructure of the Al–20% Si high pressure die casting alloy used for monolithic cylinder blocks. *Journal of materials processing technology*, *203*(1), 333-341.

Yin, D. D., Wang, Q. D., Gao, Y., Chen, C. J., & Zheng, J. (2011). Effects of heat treatments on microstructure and mechanical properties of Mg–11Y–5Gd–2Zn–0.5 Zr (wt.%) alloy. *Journal of Alloys and Compounds*, *509*(5), 1696-1704. Yoshida, T., Itoh, K., Tamura, R., & Takeuchi, S. (2000). Plastic deformation and hardness in Mg–Zn–(Y, Ho) icosahedral quasicrystals. *Materials Science and*

Engineering: A, 294, 786-789.

Yu, H., Hongge, Y., Jihua, C., Bin, S., Yi, Z., Yanjin, S., & Zhaojie, M. (2014). Effects of minor Gd addition on microstructures and mechanical properties of the high strain-rate rolled Mg–Zn–Zr alloys. *Journal of Alloys and Compounds*, 586, 757-765.

Zhang, A., Hai, H., Xiaoteng, L., & Zhang, X. (2014a). Effects of precipitates on grain size and mechanical properties of AZ31-x% Nd magnesium alloy. *Journal of Rare Earths*, *32*(5), 451-457.

Zhang, H., & Senkara, J. (2011). *Resistance Welding: Fundamentals and Applications*. *Second Edition*. United State of America: Taylor & Francis.

Zhang, J., He, Q. B., Pan, F. S., Zhang, X. F., & Liu, C. P. (2008). Effects of Erbium on microstructure and mechanical properties of as-cast Mg-7Zn-3Al alloy. *Transactions of Nonferrous Metals Society of China*, 18, 22-26.

Zhang, J., Zhang, M., Meng, J., Wu, R., & Tang, D. (2010). Microstructures and mechanical properties of heat-resistant high-pressure die-cast Mg–4Al–xLa–0.3 Mn (x= 1, 2, 4, 6) alloys. *Materials Science and Engineering: A*, *527*(10), 2527-2537.

Zhang, J., Zhang, W., Bian, L., Cheng, W., Niu, X., Xu, C., & Wu, S. (2013). Study of Mg–Gd–Zn–Zr alloys with long period stacking ordered structures. *Materials Science and Engineering: A*, 585, 268-276.

Zhang, S., & Zhao, D. (Eds.) (2012). *Aerospace materials handbook*. United State of America: Taylor & Francis.

Zhang, X. B., He, X. C., Xue, Y. J., Wang, Z. Z., & Wang, Q. (2014b). Microstructure and corrosion resistance of as cast Mg–Nd–Gd–Sr–Zn–Zr alloys for biomedical applications. *Materials Technology*, *29*(3), 179-187.

Zhang, X., Yuan, G., Mao, L., Niu, J., & Ding, W. (2012). Biocorrosion properties of as-extruded Mg–Nd–Zn–Zr alloy compared with commercial AZ31 and WE43 alloys. *Materials Letters*, *66*(1), 209-211.

Zhang, Z., Liu, X., Wang, Z., Le, Q., Hu, W., Bao, L., & Cui, J. (2015). Effects of phase composition and content on the microstructures and mechanical properties of high strength Mg–Y–Zn–Zr alloys. *Materials & Design*, 88, 915-923.

Zhou, X., Huang, Y., Wei, Z., Chen, Q., & Gan, F. (2006). Improvement of corrosion resistance of AZ91D magnesium alloy by Holmium addition. *Corrosion*

Science, *48*(12), 4223-4233.

Zhu, S. M., Gibson, M. A., Easton, M. A., & Nie, J. F. (2010). The relationship between microstructure and creep resistance in die-cast magnesium–rare earth alloys. *Scripta Materialia*, *63*(7), 698-703.

Zhu, S., Liu, Z., Qu, R., Wang, L., Li, Q., & Guan, S. (2013). Effect of rare earth and Mn elements on the corrosion behavior of extruded AZ61 system in 3.5 wt% NaCl solution and salt spray test. *Journal of Magnesium and Alloys*, *1*(3), 249-255.