AENSI Journals
Australian Journal of Basic and Applied Sciences
ISSN:1991-8178
Journal home page: www.ajbasweb.com

Effect of Aluminium Content on the Tensile Properties of Mg-Al-Zn Alloys

[1,2]N. Abdul Latif, [1]Z. Sajuri, [1]J. Syarif

[1]*Universiti Kebangsaan Malaysia, Department of Mechanical and Materials Engineering, Faculty of Engineering and Built Environment, Malaysia*
[2]*Universiti Tun Hussein Onn Malaysia, Department of Mechanics, Faculty of Mechanical and Manufacturing Engineering, Johor*

ARTICLE INFO
Article history:
Received 15 April 2014
Received in revised form 22 May 2014
Accepted 25 October 2014
Available online 10 November 2014

Keywords:
Magnesium alloys; aluminium content; microstructure; tensile properties; work hardening.

ABSTRACT
Background: The aim of this study is to investigate the effect of aluminium content on microstructure, tensile properties and work hardenability of Mg-Al-Zn alloys. **Objective:** Two types of magnesium alloys were investigated i.e. AZ31 and AZ61, where the aluminium contents were 3 wt% and 6 wt%, respectively. **Results:** Microstructure observation revealed that higher aluminium content decreases the grain size and increases the volume of $Mg_{17}Al_{12}$ precipitations. From the tensile test, AZ61 demonstrated higher yield stress and tensile strength while maintaining the elongation as compared to AZ31. **Conclusion:** The work hardening rate for AZ61 was also greater compared to that of AZ31.

To Cite This Article: N.Abdul Latif, Z.Sajuri and J.Syarif., Effect Of Aluminium Content On The Tensile Properties Of Mg-Al-Zn Alloys. ***Aust. J. Basic & Appl. Sci.,*** *8(19): 276-279, 2014*

INTRODUCTION

In recent years, magnesium alloys are widely used as structural materials in automotive and aerospace industries due to their low density, high strength to the weight ratio, etc. Excellent mechanical properties of magnesium alloys have attracted engineers' attention to choose these alloys for engineering structures but so far the application in major load bearing components in which reliability, durability and safety are of major concern is still very limited (Noradila, A.L., 2013). One of the most popular magnesium alloys used in automotive and aerospace industries are the Mg-Al-Zn alloy series i.e. AZ31, AZ61, AZ90 and AZ80. These alloys are now becoming the premier choices for light weight application due to their improved mechanical properties with addition of certain percentage of aluminium and zinc.

Addition of aluminium as an alloying element in magnesium alloys is very important for high precipitation density of $Mg_{17}Al_{12}$ phase. This □ □$Mg_{17}Al_{12}$ will act as strengthening phases that increase the tensile strength of magnesium alloys. Beside aluminium, the addition of zinc will also affect the strengthening of magnesium alloy (Cheng, Y.L., 2009; Kainer, K.U., 2003; Marya, M., 2006). However, the different composition of aluminium and zinc elements in Mg-Al-Zn alloy series could results in different mechanical properties especially the work hardenability and the tensile properties. In present study, effect of aluminium content on microstructure, tensile properties and work hardenability of constant Zn content in Mg-Al-Zn alloys were investigated.

Experimental Procedure:

The materials used in this study were extruded AZ31 and AZ61 of the Mg-Al-Zn alloy series. The two letters followed by two numbers designate the name of the magnesium alloys. The two letters tell the main alloying elements (A is for aluminium and Z is for zinc). The numbers tell the nominal compositions of main alloying elements respectively. The aluminium contents of AZ31 and AZ61 are 3wt% and 6wt%, respectively. The zinc content for both alloys is maintained at 1wt%.

Both alloys were polished and etched to reveal their microstructure. It was then observed under the optical microscope. To obtain the mechanical properties of the magnesium alloys, tensile tests were performed on dumb-bell shaped specimens with a gage length and gage diameter of 10 mm and 3 mm, respectively. Tensile test was conducted using the Universal Testing Machine with a capacity of 100 kN at strain rate of $1 \times 10^{-3}\ s^{-1}$ in room temperature. Detail stress-strain responses were recorded using a data acquisition system. Further analyses of work hardening behavior for both alloys were performed and identified by using the following equations (1) to (3).

Corresponding Author: N. Abdul Latif, Universiti Kebangsaan Malaysia, Department of Mechanical and Materials Engineering, Faculty of Engineering and Built Environment, Malaysia , Universiti Tun Hussein Onn Malaysia, Department of Mechanics, Faculty of Mechanical and Manufacturing Engineering, Johor

Australian Journal of Basic and Applied Sciences, 8(19) Special 2014, Pages: 276-279

$$\sigma = \frac{F}{A_T} \qquad (1)$$

where, σ is the stress, F is the force and A_T the area of cross section and the strain ε is defined as

$$\varepsilon = \ln\left(1 + \frac{dL}{L_O}\right) \qquad (2)$$

where dL is the elongation and L_O the original gage length. The work hardening rate is given as

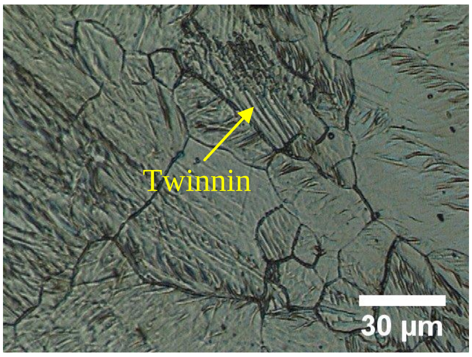
$$\frac{d\sigma}{d\varepsilon} = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \qquad (3)$$

where $d\sigma$ is the increment of true stress and $d\varepsilon$ the increment of true strain.

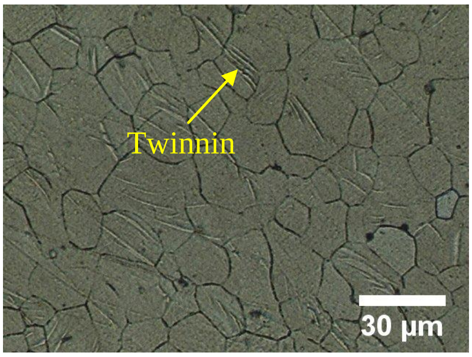
RESULT AND DISCUSSION

Microstructure:

Figure 1 shows the microstructures of AZ31 and AZ61 observed under the optical microscope. From the figure, it shows that both alloys have an equiaxed grain structure. The average grain size for AZ31 and AZ61 were 24 µm and 15 µm, respectively.



(a)



(b)

Fig. 1: Microstructure of (a) AZ31 (b) AZ61.

From Figure 1, it is clearly seen that the AZ31 has a larger grain size compared to that of the AZ61. Microstructure of AZ31 as shown in Figure 1(a) indicated more twinning (see arrow) which probably due to the extrusion process while, less twinning for AZ61 as shown in Figure 1(b). Higher density of twinning was observed in AZ31 which had a larger grain size compared to that of the AZ61. Twinning might also resulted from the polishing and/or extrusion manufacturing process (Marya, M., 2006). For AZ61 as in Figure 1(b), it is assumed that more precipitates in the alloy pinned the twinning formation so that less twinning was observed compared to that in AZ31. The smaller grain size and higher density of $Mg_{17}Al_{12}$ precipitation in AZ61 are believed to be caused by higher aluminium content that formed the solid solution in the alloy (Kainer, K.U., 2007). On the other hand, the existence of twinning in a material would also contribute to higher strength and more work hardening to the alloys. However, in most Mg-Al-Zn alloy series, finer grain size and $Mg_{17}Al_{12}$ precipitation have more influenced to improve the strength, work hardening and ductility despite of the smaller grain size would be suppression the twinning.

Tensile test and work hardening:

Figure 2 shows nominal stress-strain curves of AZ31 and AZ61 magnesium alloys. The result shows that AZ61 exhibited higher tensile strength and more work hardening compared to that of the AZ31. The result was also indicated that the smaller grain size and higher density of $Mg_{17}Al_{12}$ precipitation in AZ61 would resulted in high tensile strength and more work hardening (Khan, S.A., 2006; Ryu, H.J., 2000). The tensile properties of AZ31 and AZ61 were summarized in Table 1. Yield stress and ultimate tensile strength of AZ61 were higher than that of AZ31 with 14.7% and 36.3%, respectively. More work hardening of AZ61 could be recognised by the large increment of differences between yield stress and ultimate tensile strength in nominal stress-strain curve. On the contrary, AZ31 clearly possessed less work hardening compare to AZ61. However, the elongation for both AZ31 and AZ61 were found identical.

Work hardening rate for AZ31 and AZ61 were clearly shows in Figure 3. It is noted that the work hardening rate for AZ61 was greater compared to that of AZ31 due to the existence of precipitation and finer grain size of alloy. These factors have influenced to the dislocation piles up against the microstructure for delayed fracture. Work hardening rate for AZ61 was considered after yielding up to the ultimate tensile strength,

Australian Journal of Basic and Applied Sciences, 8(19) Special 2014, Pages: 276-279

while the hardening process for AZ31 was diminished after yielding. The difficulty of deformation would be induced by the presence of dislocation density to allow more hardening of the alloy.

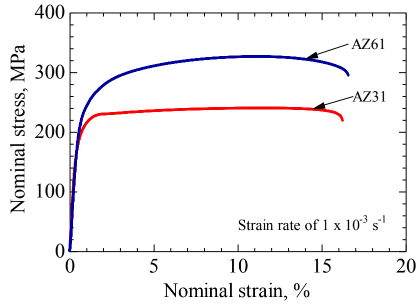


Fig. 2: Nominal stress-strain curves of AZ31 and AZ61.

Table 1: Tensile properties of AZ31 and AZ61.

	σ_y (MPa)	σ_{UTS} (MPa)	ε (%)
AZ31	191	240	16.2
AZ61	219	327	16.6

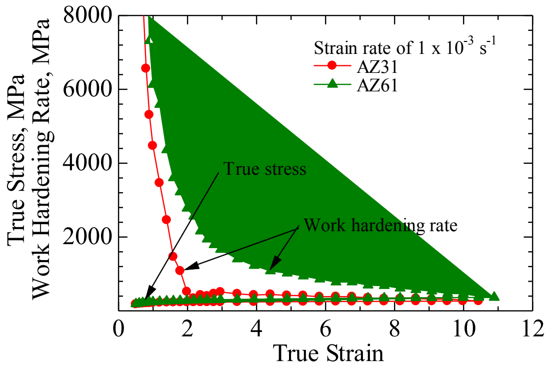
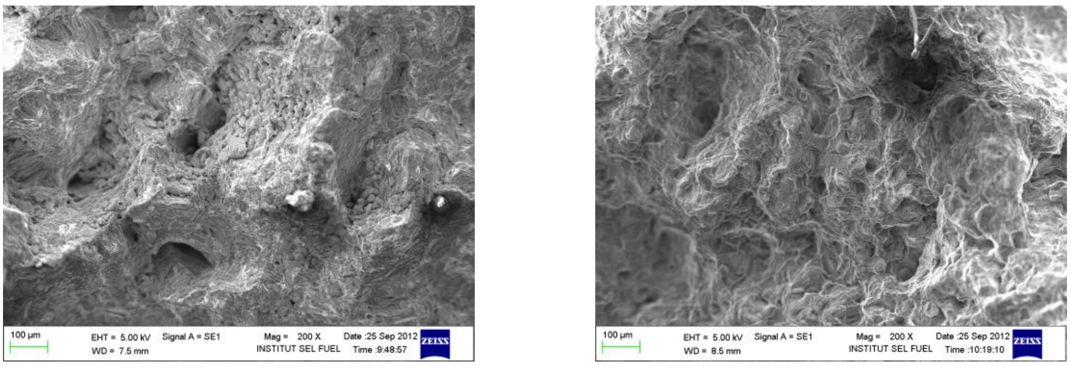


Fig. 3: Work hardening rate of AZ31 and AZ61.

Fracture surface:

In Figure 4 shows the fracture surface of AZ31 and AZ61. Both alloys clearly show ductile fracture behaviour where many dimples observed on the fracture surface. Similar observation was reported by Marya *et al*. (2006). However, fracture surface of AZ61 as shows in Figure 4(b) indicated more ductile fracture behaviour where more dimples and micro voids present in the fracture surface than that of AZ31 at Figure 4(a).



(a) (b)

Fig. 4: Fracture surface of (a) AZ31 (b) AZ61.

Conclusion:

Aluminium content in Mg-Al-Zn alloy series influenced the microstructure, grain size and precipitation of $Mg_{17}Al_{12}$ phase. The grain size refinement and precipitation increases tensile strength and allow for more work hardening of the alloy due to more dislocation piles up and blocked at the grain boundaries before further deformation of the material. AZ61 exhibited better tensile properties than that of AZ31 with the yield stress and ultimate tensile strength of 14.7% and 36.3%, respectively. However, both AZ31 and AZ61 fractured in ductile manner with more dimples and microvoids in fracture surfaces.

ACKNOWLEDGEMENT

The authors acknowledge the supports from the Universiti Kebangsaan Malaysia, Ministry of Higher Education Malaysia (ERGS/1/2011/TK/UKM/02/9), Nagaoka University of Technology and Universiti Tun Hussein Onn Malaysia.

REFERENCES

Cheng, Y.L., T.W. Qin, H.M. Wang and Z. Zhang, 2009. Comparison of corrosion behaviors of AZ31, AZ91, AM60 and ZK60 magnesium alloys. Transactions of Nonferrous Metals Society of China, 19: 517-524.

Kainer, K.U., 2003. Magnesium-alloys and technologies, Wiley-vch, Germany.

Kainer, K.U., 2007. Magnesium : Proceedings of the 7th international conference on magnesium alloys and thier applications, Wiley-vch, Germany.

Khan, S.A., Y. Miyashita, Y. Mutoh and Z.B. Sajuri, 2006. Influence of Mn content on mechanical properties and fatigue behavior of extruded Mg alloys. Materials Science and Engineering, A420: 315-321.

Marya, M., L.G. Hector, R. Verma and W. Tong, 2006. Microstructural effects of AZ31 magnesium alloy on its tensile deformation and failure behaviors. Materials Science and Engineering, A 418: 341-356.

Noradila, A.L., Z. Sajuri, J. Syarif, Y. Miyashita and Y. Mutoh, 2013. Effect of strain rates on tensile and work hardening properties for Al-Zn magnesium alloys. International Conference on Manufacturing, Optimization, Industrial and Material Engineering 46.

Ryu, H.J., H.K. Baik and S.H. Hong, 2000. Effect of thermomechanical treatments on microstructure and properties of Cu-base leadframe alloy. Journal of Materials Science, 35: 3641-3646.