Effect of Aging Treatment on Mg-Zn-Y alloy

Diqing Wan*, Houbin Wang, Yinglin Hu, Shuting Ye
School of Materials Science and Engineering, East China Jiaotong University, Nanchang 330013, China

*Corresponding author e-mail: divadwan@tom.com

Abstract. As cast magnesium alloys have poor comprehensive properties, such as ductility, hardness, damping properties, etc., which greatly limit the wide application in the industry. In this study, we performed aging treatment on Mg97Zn1Y2 to study the performance changes of the alloy and found that: the particles in the microstructure became finer, and with the aging time increases, the volume fraction of the precipitated phase increases. The mechanical properties of alloys increased significantly. The hardness under aging is 20% higher than that in as-cast, reaching 85.3. The tensile strength increase obviously, reaching 145MPa. The damping property after aging treatment decreases.

1. Introduction
Magnesium alloy is the lightest metal structural material in industrial applications, which has low density, high specific strength and high specific stiffness, it is praised as "the most developed and applied in the 21st century potential engineering materials", and has been widely used in aerospace, shipbuilding and electronics[1]. However, the poor mechanical properties limit the wider application and development of magnesium alloys [2-4]. In order to improve the performance of alloys, scientists have made many works. Liao [5] improved the morphology of Mg2Si phase by adding Sb. According to the results, it can be seen that the addition of Sb can indeed improve the morphology of Mg2Si phase and refine it, and the refined Mg2Si phase can promote the mechanical properties of the alloy and its damping performance. L. B. Ren et al. [6] performed solution treatment of Mg-Y alloys with different Y contents in as-cast and exhibited good damping performance. After Mg-1 wt. %Y alloy was treated with T4 Damping performance has been improved. Zhang [7] et al. performed solid solution and aging treatment on the AZ91D alloy, the conclusion are as follows: When the material is solution-treated, the second phase began to dissolve into the matrix, and the matrix became supersaturated. In the solid solution, the pinning point that acts as a pinning point for the dislocation has been completely dissolved into the matrix, so the solution-treated material has a higher damping value. Ma et al [8] added Zn and Y elements with a mass ratio of 5 to the Mg-0.6% Zr alloy to obtain a quasi-crystalline phase for strengthening. The increase of Zn and Y content improved the mechanical properties of the alloy. The tensile strength reaches 170 MPa, but the addition of quasi-crystals has an bad effect on the damping properties. This shows that the surface treatment of magnesium alloys, alloy composition design, heat treatment, etc., is a good way to improve the performance of magnesium alloys. In this article, the effects of aging treatment on the microstructure and mechanical properties of magnesium alloys are discussed in detail and provide basis for further embodying the effects of aging treatments.
2. Experimental

Pure magnesium (purity greater than 99.95wt%), pure zinc (purity greater than 99.95wt%), and Mg-Y (the mass fraction of Y is 25wt%) master alloy were selected to prepare the designed alloy. The conventional casting method is used to manufacture magnesium alloys, and a 40 mm×120 mm sample is obtained by casting with an iron mold. Then the sample was linear cutting and cleaned the surface. Polishing on sandpaper until metallic luster is exposed. Then the SEM analysis, XRD detection and mechanical test were used to study magnesium alloys, and the effect of aging treatment on the performance of magnesium alloys were studied systematically.

3. Results and Discussion

3.1. Microstructure

The microstructures of the as-cast Mg97Zn1Y2 alloy after solid solution at 520°C for 12 hours are shown in figure 1 at 250°C for different time. Compared with the alloy structure after T4-12h, when the T6 treatment time is relatively short it can be seen that there are more fine particles in the grain interior, and there are also fine long stripes at the grain boundary. As the aging time increases, the volume fraction of the precipitated phase increases gradually, and the fine long stripe precipitates begin to grow and grow into the grain interior. When the aging time reaches 15 hours, the volume fraction of the precipitated phase reaches the peak, and the morphology of the precipitates is usually long and massive. According to the results of EDS analysis, such stripes (as shown in figure 2(b) "002") and block (as shown in figure 2(b) "003") are long-period phases and particles (as shown in figure 2 (a) "001") are Mg, Zn and Y compounds.

Figure 1. The microstructures of as cast Mg97Zn1Y2 alloys heated by T6 at different time (a) 6h; (b) 9h; (c) 12h; (d) 15h
Table 1 Energy Spectrum Analysis of As-cast Mg97Zn1Y2 after T6-12h Treatment

| spot | Mg (At %) | Zn (At %) | Y (At %) |
|------|-----------|-----------|----------|
| 001  | 23.69     | 1.38      | 74.93    |
| 002  | 93.06     | 3.88      | 3.07     |
| 003  | 90.12     | 5.33      | 4.55     |

Fig. 2. SEM images of as-cast Mg97Zn1Y2 alloys treated by T6-12h

Fig. 3 shows the XRD diagram of the as-cast Mg97Zn1Y2 alloy after different aging treatments. The results of XRD analysis show that the microstructure after aging treatment is still composed of LPSO phase and $\alpha$-Mg. With the increase of aging time, the LPSO phase gradually precipitated from the matrix, and the volume fraction of the precipitated phase reached its peak at the age of 15 hours. Therefore, the diffraction peak strength of LPSO phase increases slightly with the increase of aging time.

Fig. 3. XRD analysis of as-cast Mg97Zn1Y2 alloy during aging treatment

3.2. Hardness Analysis
The micro hardness of the alloy after aging treatment is shown in figure 4. It can be seen from the diagram that the hardness of the alloy after aging treatment has increased to a peak value of T6-12 h and increased by nearly 20% compared with the as-cast alloy. Combined with the microstructure analysis, it is inferred that the second equivalent substance in the alloy is dissolved into the matrix by solid solution treatment, which provides the condition for precipitation of the aging treatment phase. The grain boundary and grain interior begin to precipitate strip and block material, and the strength of the alloy increases as a result. After aging treatment, the grain size and the second phase size of the second phase re-precipitated become fine and uniform, and the second phase separated from the
matrix and distributed in the matrix and the LPSO phase precipitated in the grain interior. The dispersion distribution of the precipitates after aging has the effect of hardening, thus enhancing the micro hardness of the alloy.

![Figure 4](image-url)  
**Figure 4.** The hardness of as cast Mg97Zn1Y2 alloys at different aging time

### 3.3. Tensile Strength and Elongation

Figure 5 shows the stress-strain curve of the alloy after T6 treatment of different time. It can be seen from the diagram that the tensile strength of the alloy increases with the increase of T6 time. After a long time of T6 heat treatment, more and more precipitated phases at grain boundaries are distributed in fine lamellar or stripe shape, which hinders the slip of dislocation. At the same time, the dispersion distribution of precipitates after aging treatment had the effect of dispersion hardening, and further improved the strength of the alloy.

![Figure 5](image-url)  
**Figure 5.** The stress-strain curve of as cast Mg97Zn1Y2 alloys at different aging time

### 3.4. Damping Properties

Fig. 6 shows the damping-strain amplitude curve of the alloy after aging treatment at different time. It can be found that the damping property of the alloy after aging treatment decreases and the damping value decreases with the increase of aging time. The critical strain amplitude is higher than that of the as-cast Mg97Zn1Y2 alloy.
Figure 6. Strain amplitude dependent damping of the Mg97Zn1Y2 alloy at different aging time

This may be because of the solute atoms which were dissolved into the matrix gradually precipitate after aging treatment and distribute in grain boundaries and grains, which hinder the movement of dislocation. Therefore, the dislocation line needs more external force to get rid of the binding of these pinning points. Macroscopically, the critical strain amplitude increases. In addition, with the increase of aging time, the second phase in strip and block gradually precipitated, which resulted in a strong pinning effect on the dislocation line, which resulted in the decrease of the damping property of the alloy, and the more precipitated phases became with the longer the aging time, the longer the aging time was, the more the second phase was precipitated. The stronger the pinning effect is, the lower the damping value is.

4. Conclusion
(1) After T6 treatment, more tiny LPSO particles began to precipitate in the microstructure of the alloy. With the increase of aging time, the morphology of the precipitates began to change into strips and polygons, which distributed in the matrix.

(2) After T6 treatment, the mechanical properties of the alloy increased to a certain extent compared with the as cast state, and increased with the increase of aging time. The hardness and tensile strength of T6-15h alloy were 85.3HV and 145MPa, respectively.

Acknowledgments
This work was financially supported by the National Natural Science Foundation of China (51665012, 51361010), Natural Science Foundation of Jiangxi province (No.196 20114BAB216015), Jiangxi province Science Foundation for Outstanding Scholarship(20171BCB23061), the Foundation of Jiangxi Educational Committee (No. GJJ12320) and the State Key Laboratory of Solidification Processing in NWPU (No. SKLSP201321).

References
[1] Wu Ruizhi, Zhang Jinghuai, Yin Dongsong. Advanced magnesium alloy preparation and processing technology [M]. Beijing: Science Press, 2012, 98-100.
[2] Zeng Rongchang, Kewei, Xu Yongbo, et al, The Latest Development and Application Prospect of Mg Alloys [J]. Chinese Journal of Metals, 2001, 37 (7): 674-685.
[3] Ding Wenjiang, Wu Yujuan, Peng Liming, et al, New Progress in Research and Application of High Performance Magnesium Alloys [J]. China Material Progress, 2010, 29 (8): 38-46.
[4] Kawamura Y, Hayashi K, Inoue A, et al. Rapidly solidified powder metallurgy Mg97Zn1Y2 alloys with excellent tensile yield strength above 600 Mpa [J]. Material Transaction, 2001 (42): 1171-1174.
[5] Liao Lihua, Zhang Xiuling. Influence of Sb on damping capacity and mechanical properties of Mg2Si/Mg-9Al composite materials [J]. Journal of Alloys and Compounds, 2007, 430: 292-
[6] L. B. Ren, G. F. Quan, Y. G. Xu. Effect of heat treatment and pre-deformation on damping capacity of cast Mg-Y binary alloys [J]. Journal of Alloys and Compounds, 2017, 699: 976.

[7] Zhang Zhenyan, Zeng Xiaojin. The influence of heat treatment on damping response of AZ91D Magnesium alloy [J]. Materials Science and Engineering: A. 2005, 392: 150-155.

[8] Marong, Dong Xuanpu. Quasicrystal-enhanced Mg-0.6%Zr alloy mechanical properties and damping properties [J]. China Nonferrous Metals Report, 2012, 10 (22): 2705-2710.