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Influence of T5 Aging Heat Treatment on Microstructure and Mechanical Properties of as-extrued ZK80 Mg alloy

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Abstract: The micrstructure and mechanical properties of as-extruded ZK80 Mg alloy after artificial aging heat treatment was investigated. The results show that the hardness of the alloy first increases with the increase of time under different aging temperature, and then begins to decrease after reaching the peak value.Under the condition of the same aging temperature and different holding time, the hardness increases gradually with the increase of aging temperature, and then decreases with the increase of aging temperature. The best aging temperature of ZK80 Mg alloy is 180℃, the ultimate comprehensive mechanical properties of ZK80 alloy aging at 180℃ for 7h reaches the maximum, which σ_b, $\sigma_{0.2}$, δ, HBR, respectively is 326.7 MPa, 236.7 MPa, 10% and 77.8 HB, and the mechanical properties of untreated extruded state increased by 39.4%, 28.8% and 19%，respectively, The reason is that during the aging treatment, finely dispersed MgZn and $MgZn_2$ phases are precipitated in the alloy structure, so that the mechanical properties of the extruded ZK80 magnesium alloy are optimized.

1. Introduction

Magnesium alloys are widely used in the fields of automobile, aviation, aerospace and 3C products due to their advantages of low density, high specific strength and stiffness, good heat dissipation and shielding, good damping and shock absorption, etc. Because of its rich resources, no pollution and good recyclability become the materials of choice for energy saving and emission reduction and green sustainable development, is known as the green environmental engineering materials in the 21st century[1-4].

Compared with the cast Mg alloy, the deformed Mg alloy has higher strength, better ductility and more diverse mechanical properties, which can better meet the diversified needs of engineering structures[5]. Because of its advantages, it is very improtant to enhance the microstructure and mechanical properties of Mg alloy in some key components or key stress structure. The improvement of mechanical properties of deformed Mg alloys can be achieved by heat treatment to develop a reasonable heat treatment process can further excavate the mechanical properties of materials to exert its own advantages[6]. Therefore, ZK80 Mg alloy as the research object in the paper, through different conditions of heat treatment to explore and analyze the evolution of microstructure and mechnical properties of the alloy, and determine the best heat treatment process lead to play a certain theoretical guidance in production practice.

2. Experimental Materials and Methods

The semi-continuous casting method was used to prepare the experimental alloy, based on the ZK60 Mg alloy, magnesium ingot, Zn ingot and Mg-Zr master alloy were proportionally added according to

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the weight of the melt, refined with Ar gas, and then Φ112mm×125mm ingot , Alloy composition shown in Tab.1. ingot after 400℃×12h solid solution treatment in 800t extruder into a plate-shaped profile with a cross section as shown in Fig.1, the extrusion temperature was 420°C, and the extrusion ratio was 16:1. Tensile specimens were cut by line cutting. The gauge length was 25mm×6mm×3.5 mm.

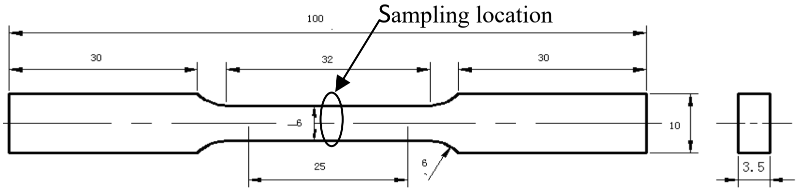

Fig.1 Tensile samples

Table 1 chemistry composition of alloy (mass fraction: %)

alloy	Chemistry composition							
	Zn	Mn	Fe	Si	Ni	Cu	Zr	Mg
ZK80	8.26	0.0158	0.008	0.0044	0.0008	0.0015	0.7057	Bal.

Metallographic specimens were taken from the middle of the gauge length of the tensile specimen. After grinding and polishing, the mixture solution was treated with picric acid 1.5 g, ethanol 25 ml, acetic acid 5 ml and distilled water 10 ml, and the etching time was 3-8s. to obersver the change of microstructure by metallographic microscope.

In order to explore the effect of aging treatment on the microstructure and mechanical properties of as-extruded ZK80 Mg alloy, the ZK80 Mg alloy was heated at different temperatures (150 ℃, 160 ℃, 170 ℃, 180 ℃, 200 ℃, 220 ℃) via the oil bath heating treatment method and and the rockwell hardness testing, each sample taken an average of 10 points; by universal tensile testing machine on the mechanical properties test, tensile speed of 1mm / min, take the average of the three samples of the results, as well as the best alloy under the condition of heat treatment on mechanical properties of the test and analysis.

3. Experimental results and analysis

3.1 microstructure of ZK80 magnesium alloy

Fig. 2 shows the microstructure morphology of the as-cast and as-extruded ZK80 Mg alloy. As can be seen in Fig.2(a), the as-cast microstructure consists of coarse α-Mg matrix with obvious dendritic segregation, black dot phase dispersed in the matrix and network eutectic structure distributed continuously or discontinuouly, including grain boundary in the triangle to intracrystalline grain boundary, Fig. 3 shows that the black dot-like phase or continuous or discontinuous reticular structure as MgZn phase or $MgZn_2$, the matrix is relatively clean, the grain size of about 70μm, indicating that the thermoplastic and work performance is poor; Fig.2(b) is microstructure of as-extruded of ZK80 alloy, alloy after hot extrusion froming, the grain size is not uniform, the obvious strip-like structure, along the extrusion direction of the grain was obviously elongated, and close to the edge of a large number of needle shape twin group, and there are a small amount of secondary twins, part of the twin torsion happens, coarse grains, the grain size of about 23μm; deformation is under at higher temperatures, due to the low magnesium fault energy, sensitive to deformation temperature, in center of the extruded sections presents obvious dynamic recrystallization microstructure, part of the dynamic recrystallization grain inclusions between serious defromation of grain, and the grain size is about 5.3 μm. To illustrate that the grain size of the alloy in the extrusion deformation process to make discontinuous distribution of dendritic by three-dimensional stress lead to the formation of grain refinement, strengthening and toughening, the tensile strength and yield strength of the alloy because hot extrusion deformation can produce high density dislocations.

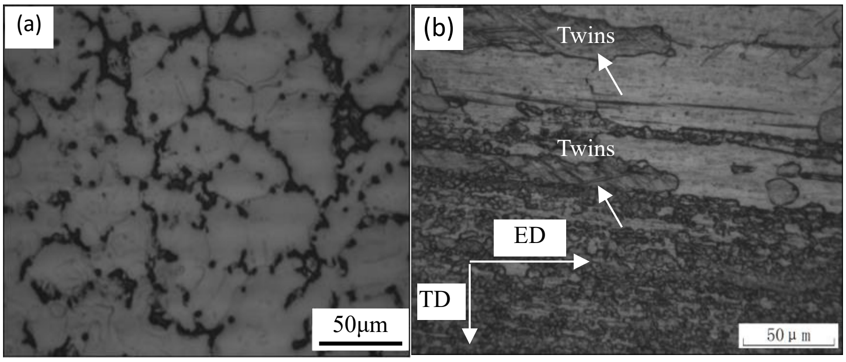

Fig.2 Microstructure of ZK80 Mg alloy
as-cast; (b) as-extruded

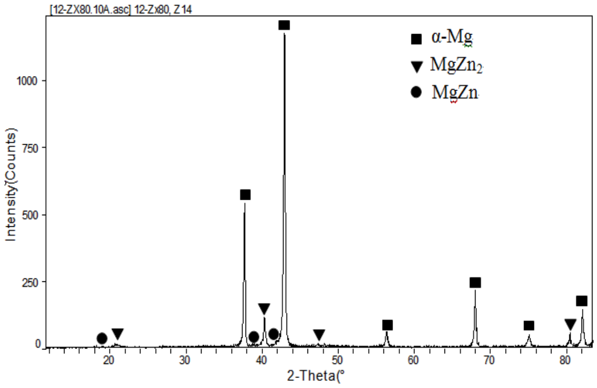

Fig.3 XRD of ZK80 Mg alloy

3.2 Influence of aging heat treatment on the mechanical properties of ZK80 Mg alloy

As shown in Fig.4 that the tensile strength, yield strength and elongation of ZK80 magnesium alloy increased by 32.3%, 17.5% and 89.3% respectively from as-cast to extruded. Mainly due to extrusion deformation makes the second phase of as-cast state in the process of three-dimensional compressive stress occurred significantly refined, there has been a marked improvement of the second phase in the as-cast structure, respectively, and as a result of the action of dynamic recrystallization, make the mechanical properties of alloy improve obviously. The general trend of the overall performance of the alloy was first increased and then decreased.

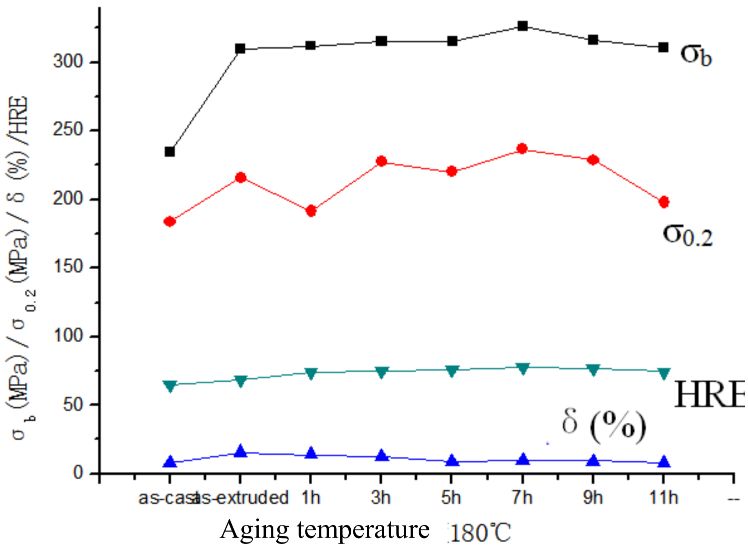

Fig.4 mechanical properities of ZK80 Mgalloy at different state

Fig.5 is artificial aging curve of ZK80 Mg alloy at different temperatures. It can be seen from the figure that the hardness of the alloy with the aiging time is basicalloy the trend of increaseing shock. The reason may be due to aging in the beginning of the second phase precipitated MgZn phase or MgZn2 softer, Screw rolling impact on the grain boundary is poorer, cause at the start of the alloy in aging hardness is low, the extension of this phenomenon with the aging time become increasingly obvious, and the extension of time under different temperature, the hardness of the material reaches a peak, and then started to shake down hardness value. At lower temperature (150°C ~ 170°C) during aging treatment, the hardness increased gradually with the aging time, and gradually decreased after reaching the peak value. After the peak at 150°C, 160°C and 170°C aging temperature, a peak time is 27h, 24h, 22h, respectively, and the peak shows a gradual increase trend. It can be seen from Fig. 5 that the time for the increase of oscillation appears earlier; Aging at the higher temperature (180 °C, 200 °C, 220 °C), the hardness reaches the peak time of 7h, 4h, 1h, respectively, the hardness increase gradually with the increase of time before reaching the peak, but did not appear oscillation phenomenon, began to appear after the peak shocks to reduce the trend, at the same time the peak with increase of tamperature. Experiments also showed that the highest peak value of 77.8HB reached at 180℃×7h. It shows that the effect of pinning at the grain boundaries of the second relative alloy precipitated during aging deteriorates with the increase of temperature. When the hardness reaches a certain extreme value, it begins to decline, that is to enter the over-aging stage.

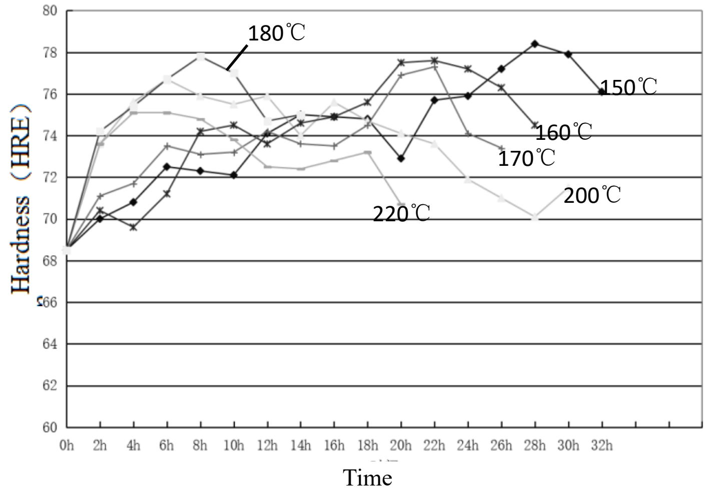

Fig.5 Artificial aging curves of ZK80 Mg alloy

3.3 microstructure of aging heat treatment

Fig.6 shows the microstructure of ZK80 magnesium alloy during artificial aging at 180℃. As can be seen from the figure, it is found in the aging process that after deformation treatment at 180℃×1h, significant deformations remain in the alloy and a large amount of twin crystal grains are retained in addition to the dynamic recrystallization grains. But, the grain size compared with extrusion state change is not obvious, mekes the mechanical properties of the alloy changes little; With the increase of the aging time, the twins in the alloy gradually disappeared, When aging treatment conditions were 180℃×5h, new crystals appeared on the grain boundaries, the grain also left some twins at the same time. When the aging conditions were 180℃×7h, the twins in the grains disappeared, but a large number of new fine grains appeared and fine second phase precipitated ($MgZn_2$ or MgZn), These small precipitation relative alloy strength and ductility improvement are beneficial, but with the T5 time continues to increase, the growth of the alloy in the trend, when the aging time reaches 11 hours, the grain grew significantly, the hardness was significantly Decline, indicating the emergence of over-aging phenomenon. According to the above analysis, the σ_b, $\sigma_{0.2}$, δ are 326.7MPa, 236.7MPa and 10% respectively when the aging treatment is 180℃×7h, and the mechanical properties of the extruded state are increased by 39.4% 28.8%, 19%, the best aging process is 180℃×7h.

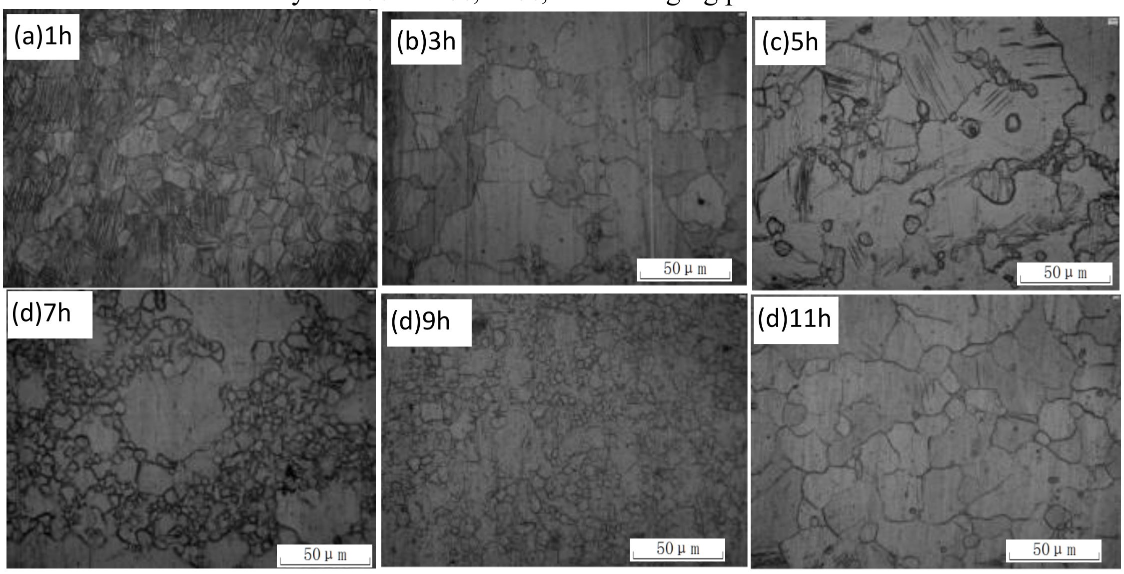

Fig.6 Microstructure of as-extruded ZK80 Mg alloy after T5 treatment

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4. Conclusion

(1) Under the same aging temperature, the tensile strength and hardness of the as-extruded ZK80 magnesium alloy were increased to the peak value after the increase of the aging time, and then oscillation decreased and the elongation improvement was not obvious.

(2) During the aging treatment at lower temperature (150℃~ 170℃), the trend of oscillation increased, and the oscillation trend decreased after reaching the peak value. During the aging treatment at higher temperature (180℃~220℃) peak time was significantly reduced, and did not appear softening phenomenon, and reached a peak gradually decreased after the shock. The heat treatment of ZK80 magnesium alloy is mainly caused by the precipitation of Mg-Zn. The optimum aging treatment process of the alloy is 180℃×7h, and its hardness reaches 77.8HB. The mechanical properties σ_b, $\sigma_{0.2}$, δ are respectively increased 39.4%, 28.8%, 19%.

Reference

[1] We stengen H K. Magnesium die casting: from ingots to automative parts[J]. Light Metal. Age., 2000,58(3-4)：44-52.

[2] Dwain M, Magers A. Global review of magnesium parts in automobile[J]. Light Metal. Age. , 1996,54(9-10): 60-63.

[3] Smola B, Stulíková I, von Buch F, et al. Structural aspects of high performance Mg alloys design [J]. Materials Science and Engineering A, 2002, 324(1- 2): 113- 117.

[4] Avedesian M M, Baker H. ASM Specialty Handbook-magnesium and magnesium Alloys [M]. USA: ASM international, 1999.1-30.

[5] Light metal materials processing manual compilation group Light metal materials processing manual (second) [M] Beijing: Metallurgical Industry Press 1988.