Effects of Ce and Homogenizing on Microstructure and Mechanical Properties of ZM21 Magnesium Alloy

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Abstract. In this paper, ZM21 and ZM21+Ce magnesium alloy extrusion in different processes before homogenization treatment, the microstructure was observed extrusion products and test their mechanical properties, analysis of rare earth cerium and homogenizing influence of annealing process on magnesium alloy ZM21 and mechanism. The results showed little effect on the ZM21 homogenization magnesium alloy, and even degrade the performance of the alloy, magnesium alloy in ZM21 adding rare earth Ce, fine grain size of the alloy than ZM21 alloy, effectively improve the mechanical properties, and with uniform annealing temperature, the grain does not grow along.

1. Introduction

At present, the study of excluding rare earth magnesium alloy homogenization annealing, more research on homogenizing annealing containing rare earth magnesium alloys are mostly limited to the higher alloy content of magnesium alloys [1, 3, 4, 5, 6]. This test after homogenization of the ingot casting, further squeezing with squeezed state alloy plasticity index to judge the merits of the homogenization process, more can reflect the homogenization process on the influence of alloy and plastic processing capacity. Before the ZM21 and ZM21+ Ce magnesium alloy extrusion for different temperature homogenizing annealing, by analyzing the squeezed state alloy performance to determine the effects of homogenizing annealing, the analysis of rare earth cerium to ZM21 alloy homogenization annealing effect [2].

2. Experiments

Experiment was carried out on the two alloy ZM21 and ZM21 + Ce homogenizing annealing experiments, the chemical composition of the alloy are shown in table 1. Test preparation with the method of the semicontinuous casting into phi 92 mm ingot casting, after different homogenizing annealing, ingot stripping into phi 90 mm, followed by ingot casting under the 693 k will be squeezed into a bar phi is 16 mm. Extrusion state bars in accordance with GB/T 16865-1997 were processed into phi 8 mm diameter, the distance of 40 mm tensile specimen tensile test. In ingot homogenizing annealing resistance furnace, annealing temperature is 603 k, 633 k, 663 k, respectively, 693 k, the heat preservation 10 h, from air cooling. The microstructure of samples after the homogenizing annealing on being future-proof metall ographic microscope observation, metall ographic specimen with nitric acid of 4.0% alcohol solution corrosion. With XL30 - TMP sem observation of fracture morphology and the second phase in the alloy. Room temperature mechanical properties test in WE - 10 type universal material testing machine.

Table. 1 Chemical compositions of experimental alloys (mass fraction, %)

Alloy	Si	Fe	Zn	Mn	Ce	Mg
ZM21	0.0063	0.0046	1.98	0.95	0	Bal.
ZM21+Ce	0.0058	0.0016	2.06	0.92	0.39	Bal

3. Test results and analysis

ZM21 alloy as-cast organization bulky, dendritic segregation and there are a certain number of grain boundary was obviously granular Mg-Zn photograph. By the 603 k, 10 h after annealing, part of the solution to the alpha Mg alloy phase matrix. With the increase of annealing temperature, Mg-Zn phase quantity reduced, gradually reduce the dendritic segregation degree, grain boundary gradually become straight and clear; By the 633 k, 10 h after annealing, granular Mg-Zn phase all solid solution; By the 693 k, 10 h after annealing, grain to grow up. ZM21+Ce alloy as-cast and homogenizing annealing state grain size is smaller than ZM21 alloy obviously. In the as-cast ZM21+Ce alloy Ce_2Zn_{17} and Ce_5Mg_{41} net-like distribution, with the temperature increasing of homogenizing annealing, the alloy phase has gradually solid solution in the matrix. By 633 k, 10 h after annealing, dendritic solidification characteristics of the alloy has subsided, alloy phase is broken and grain boundary is flat; By the 693 k, 10 h after annealing, the basic solution to the matrix alloy phase, only a small amount of residual, grain growth is not obvious, in the flat state grain boundary.

Figure 1 is ZM21 and ZM21+Ce alloy before and after the homogenizing annealing energy spectrum analysis, the first element of atomic scores listed in table 2. Alloy ZM21 homogenizing annealing, point A of Mg-Zn phase, combined with XRD can determine for Mg-Zn phase, no Mn element content on the high side of the second phase was observed. After annealing, alloy ZM21 dendritic segregation basically eliminated, there are only a few of the second phase distribution in the matrix, and combined with XRD analysis for point B for Mg-Zn phase, C point for Mn, Mg-Zn is not completely disappear from the alloy, is due to air cooling after 693k homogenization of as-cast organization a small amount of Mg-Zn. Because Mg-Zn phase is metastable phase, then became stable $MgZn_2$ phase, from granular shape into rectangular shape, alloy happened ageing, strengthening effect. We also found in the ZM21 alloy matrix is the presence of a small rectangular shape $MgZn_2$ phase, is due to the homogenizing annealing to dissolve a small amount of Zn in the matrix, and shows that due to the homogenization over aging temperature alloy.

ZM21+Ce alloy homogenization annealing before, E, F the EDS analysis results show that the alloy ZM21+Ce of the second phase of the Ce and enrichment of Zn, Ce and Mg has the potential to form ternary alloy phase, according to the Mg-Ce-Zn ternary phase diagram, possible ternary compound phase τ_1 ($CeMg_7Zn_{12}$), including τ_2 (Ce $(Mg_{0.5}Zn_{0.5})_{10.1}$) or τ_3 ($CeMg_3Zn_5$). According to the E and F Zn/Ce atomic ratio, a possible for tau ternary phase τ_2 (Ce $(Mg_{0.5}Zn_{0.5})_{10.1}$) or τ_3 ($CeMg_3Zn_5$. Combined with XRD analysis, inference as $Mg_{17}Ce_2$, $MgCe_{12}$, and Ce_5Mg_{41} phase. For solute segregation in the process of alloy solidification, the effect of Ce and zinc and Mn atoms are against to the forefront of solidification interface in the liquid phase and continuous enrichment, hinder the growth is the secondary dendrite arm, eventually form low melting eutectic with Mg and net-like distribution at the interfaces. After homogenizing annealing, dendrite gaps of Mn by oversaturated precipitation become elemental Mn, such as H point containing Mn elemental phase, according to the XRD analysis of H point also contains $Mg_{17}Ce_2$ phase, H point is definitely too high content of Zn, possibly Mg-Zn phase.

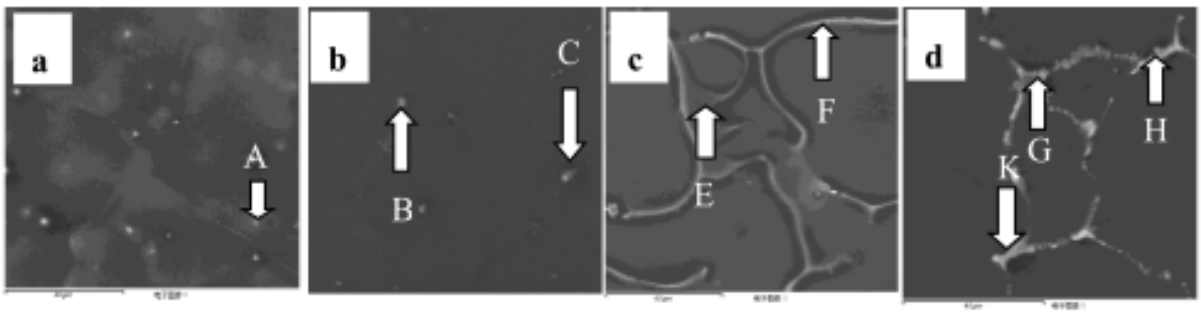

Fig.1 EDX results of ZM21 and ZM21+Ce Mg alloy before and after homogenization (a) ZM21, as-cast; (b) ZM21, 693K; (c)ZM21+Ce, as-cast; (d)ZM21+Ce, 693K.

Table. 2 EDX results of ZM21 and ZM21+Ce alloy before and after homogenization (at, %)

location	Mg	Mn	Zn	Ce
A	94.93		5.07	
B	98.86		1.14	
C	93.98	2.45	3.58	
E	93.98	0.37	4.81	0.84
F	91.97	0.37	6.46	1.20
G	78.3	1.06	15.16	5.02
H	80.43	4.46	14.14	0.97
K	83.43	0.81	11.68	4.08

The annealing temperature and the squeezed state mechanics performance of the test alloy are shown in table 3. You can see from table 3, ZM21 alloy ingot casting direct extrusion, extrusion state of elongation is 14.5%, the different temperature of homogenization annealing after extrusion, extrusion state between elongation is 14.4%~14.4%, slightly lower than the former one, this is mainly because with the increase of annealing temperature, the grain grew up with. ZM21+Ce alloy ingot casting direct extrusion, extrusion state of elongation is 16.9%, the homogenizing annealing after extrusion, extrusion elongation is 20.2%~20.8%, about 20% higher than that of ingot casting direct extrusion, and the difference between different annealing temperature. Thus, Ce for homogenizing annealing improve the strength of the squeezed state alloy and plastic. ZM21+Ce alloy grain size is smaller than the ZM21 alloy, fine grain to activate the basal slip system advantage, is the main cause of plastic to improve. ZM21 alloy ingot casting direct extrusion, extrusion state of tensile strength of 248 MPa, different homogenizing annealing after extrusion, extrusion state alloy strength is slightly lower, reduce the range of 2~20 MPa. Alloy solid solution to reduce strengthening phase and matrix phase with the annealing temperature, grain growth, the lower the strength of alloy. ZM21+Ce alloy ingot casting direct extrusion, extrusion state of tensile strength of 256 Mpa. After homogenizing annealing extrusion, the strength of the squeezed state of 285~290 MPa, squeezed state alloy strength has improved significantly. Thus, adding Ce as-cast direct extrusion and squeeze the squeezed state alloy strength after homogenization has obviously improved, which improve the alloy ZM21 homogenizing annealing make alloy extrusion state strength is reduced.

Table.3 Relationship between different temperature and mechanical properties of as-extruded ZM21 and ZM21+Ce

location	Mg	Mn	Zn	Ce
A	94.93		5.07	
B	98.86		1.14	
C	93.98	2.45	3.58	
E	93.98	0.37	4.81	0.84
F	91.97	0.37	6.46	1.20
G	78.3	1.06	15.16	5.02
H	80.43	4.46	14.14	0.97
K	83.43	0.81	11.68	4.08

4. Conclusions

ZM21 magnesium alloy after homogenization heat treatment, the alloy as-cast organization gradually grew up, dendritic segregation and there are a certain number of grain boundary was obviously granulated Mg-Zn phase, and with the increase of annealing temperature, Mg-Zn quantity reduced, gradually reduce the dendritic segregation degree, grain boundary gradually become straight and clear. ZM21+Ce alloy as-cast and homogenizing annealing state grain size is smaller than ZM21

alloy, alloy net-like Ce_2Zn_{17} and Ce_5Mg_{41} phase in the distribution, and rare earth Ce played the obstacles in the process of alloy homogenization annealing grain growth and slow the effect of alloying elements diffusion velocity, therefore, with the temperature increasing of homogenizing annealing, grain don't grow up.

ZM21 magnesium alloy after homogenizing annealing dendritic segregation basically eliminated, only a few of the second phase distribution in the matrix, the existence of a small rectangular shape $MgZn_2$ phase in the matrix. ZM21+Ce alloy after homogenizing annealing, dendrite gaps of Mn by oversaturated precipitation become elemental Mn, add Ce alloy, in addition to Mg and Mn and high temperature stable phase $Mg_{17}Ce_2$ and $CeMg_1$ phase.

ZM21 magnesium alloy after different process of homogenizing annealing, alloy plasticity and mechanical properties are dropped. ZM21+Ce alloy after different process of homogenizing annealing, elongation increased from 16.9% to 20%, the tensile strength from 256 MPa to 290 MPa, and the difference between different annealing temperatures.

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References

[1] Bussiba A, Ben Artzy A, Shtechman a et al, 2001. Grain refinement of AZ31 and ZK60 Mg alloys-towards super plasticity studies [J]. Materials Science and Engineering, A302:56}62.

[2] Dale Latwell, Matthew R Barnett, 2007. Extrusion limits of magnesium alloys [J]. Metallurgical and Materials Transactions A, 38(12): 3032-3041.

[3] Li Wenxian, 2005. Magnesium and magnesium alloys [M]. Changsha: Central South University Press 6.

[4] Pan Fusheng, Han Enhou, 2007. High-Performance Wrought Magnesium Alloy and Their Processing Techniques [M]. Beijing: Science Press.18.

[5] Swiostek J, Letzing D, Kainer K U, 2006. Hydrostatic extrusion at 100℃ and its effect on the grain size and mechanical properties of magnesium alloys [J]. Metal Science and Heat Treatment, 48 (11-12): 499-503.

[6] Yu Kun, Li Wenxian, Zhang Shijun, 2005. Mechanism of Grain Refining by Adding Cerium in Mg and Mg Alloys [J]. Rare Metal Materials and Engineering, Vol. 34 (7): p. 1013-1016.