Effects of Nd and Homogenizing on Cast Microstructure and Mechanical Properties of ZM21 Alloy

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Abstract. In this paper, by adding different amounts of magnesium in ZM21 alloy we look into the influence that Trace Nd has on the microstructure and mechanical properties of magnesium alloy cast ZM21 and how homogenizing effects the mechanism of its organization and performance. The results showed that the addition of rare earth Nd doesn’t make the refined grains smaller but make them larger. The hot compressive deformation resistance of ZM21 as-cast alloy increases significantly with the increase of Nd content.

1. Introduction

In the research of magnesium alloy, Nd is mainly added as the primary element to improve the mechanical properties of alloy at room and high temperature [1-2] by generating Mg-Nd dual strengthening phase. There are also some research to add Nd as micro alloy elements to magnesium alloy. For example, we add Nd to Mg-Zn alloy, which mainly generates the Mg-Zn-Nd ternary alloy phase, to strengthen the effect to the alloy. However, there are just a few research about the effect on the plasticity of magnesium alloy. It is necessary to do more research on it so as to extend the application of Nd in the magnesium alloy and provide basic research for developing high plastic deformation of magnesium alloys on the basis [3-5]. In this paper, by adding different amounts of magnesium in ZM21 alloy we look into the influence that Trace Nd has on the microstructure and mechanical properties of magnesium alloy cast ZM21 and how homogenizing effects the mechanism of its organization and performance.

2. Experiments

Raw materials used in the experiment of alloy for pure Mg (mass fraction 99.98%), Zn (mass fraction 99.7%), Mg-34%Mn and Mg-20%Nd alloy, with low carbon steel crucible in 60 kw resistance furnace refining, 5 flux as refining agent and coating agent, by water-cooled semi continuous casting system of Φ92 mm ingot casting, melting and pouring process with CO₂ and SF₆ gas mixture for their own protection. By adding ZM21 magnesium alloy to the successive Nd intermediate alloy, we get Mg-20%Nd for ZM21 magnesium alloy as substrate. The alloy has different contents of Nd, whose components through laser spectrometer detecting are as shown in table 1.
Give the sample 420°C x 10 h homogenization annealing treatment in 12 kw wind circulation box and put it in the corrosion of picric acid. Then observe it with the OPTEC MDS organization metallographic microscope. Conduct the deformation resistance test on Gleeble1500D,

| Table 1. Chemical component of the alloy (wt. %) |
|---------------------------------------------|
| Alloy Number | Zn | Mn | Nd | Mg |
| 1#           | 1.93 | 0.86 | — | other |
| 2#           | 1.97 | 0.88 | 0.07 | other |
| 3#           | 1.97 | 0.87 | 0.22 | other |
| 4#           | 1.99 | 0.87 | 0.35 | other |
| 5#           | 1.94 | 0.88 | 0.47 | other |

hot compress temperature is 400°C, the heating rate 3°C/s, insulation 5 min, the compression rate is 0.5s^{-1}. Give the tensile test at room temperature on the new CMT- 5105 electronic universal material testing machine, the tensile rate of 4 mm/min.

3. Test results and analysis

As the pictures shown in figure1, figure 1(a) ~ (e) are the alloy as-cast dendritic structure, which shows that 1#~5# alloy has compounds in the inter dendritic segregation. 1# alloy has less compounds, most of which are granular and there is a small amount of short strip. After adding trace rare earth Nd, the compounds in 2# alloy increase and become bigger, and has intermittent strip. With the increase of Nd content, strip compounds increase gradually and become gradually continuous. 3#~4# alloy formed more fine mesh compounds in a row. We also found that the spacing between secondary dendrite in 1#~3# alloy is similar, but the secondary dendrite spacing of 4# alloy is obviously thinner than that in 1#~3# alloy. So when Nd content reached 0.5%, it is conducive to refine the secondary dendrite spacing in as-cast alloy.

Figures 1(f) ~ (j) are for the alloy microstructure of color. It can be seen from the diagram that the grain size of alloy as-cast is very uneven. After adding trace rare earth Nd, refine as-cast alloy grain doesn’t become smaller but has a tendency to coarsen with the increase of Nd. The average grain size of the alloy microstructure of is as shown in figure 2, from which we found that after adding trace rare earth Nd the average size increases obviously, from 323μm to 507μm microns. With Nd content increasing, the average size gradually increases to 795μm microns. From the error bars in the graph (statistical standard deviation of the grain size and uniformity of statistical data size) you can see that the smaller and closer the standard deviation of the alloy 1# and 2# alloys, the more even the grain sizes are. Moreover, after adding 0.2%~0.5% Nd, 3#~5# alloy standard deviation is bigger, which shows that the alloy grain size uniformity is poor, which is the same as the result observed in figure 1 (f) ~ (j).

Figures 1 (k) ~ (o) are for alloy homogenization organization shape. We can see from the graph that after 420°C x 10 h homogenizing annealing, the dendrites’ segregation of as-cast alloy eliminate to some extent. The alloy 1# and 2# alloy dendrites’ segregation basically eliminated, and the grain boundary is clearly visible. However, with the increase of the content of Nd, the elimination in 3#~4# alloy is obviously reduced and the inter dendritic that is not completely dissolved gradually increases, the grain boundary is increasingly unclear.

1#~5# alloy at 400°C of hot compression true stress-strain curve are shown in figure 3. As can be seen from the figure, when the deformation in the 1#~5# alloy is small, all the work hardening, as with the increase of the strain on the curve, alloy flow stress increases and when it increases to the maximum, with the increase with strain, flow stress of alloy is reduced, the dynamic recrystallization softening occurred. But different alloys has different work hardening rate, the largest flow stress and strain of different dynamic
Fig1 microstructure of as cast and homogenized alloy

Fig.2 Average grain sizes of different as-cast alloys

(a) microstructure of as-cast 1# alloy; (b) microstructure of as-cast 2# alloy; (c) microstructure of as-cast 3# alloy; (d) microstructure of as-cast 4# alloy; (e) microstructure of as-cast 5# alloy; (f) color metallography of as-cast 1# alloy; (g) color metallography of as-cast 2# alloy; (h) color metallography of as-cast 3# alloy; (i) color metallography of as-cast 4# alloy; (j) color metallography of as-cast 5# alloy; (k) 420°C × 10h 1# alloy; (l) 420°C × 10h 2# alloy; (m) 420°C × 10h 3# alloy; (n) 420°C × 10h 4# alloy; (o) 420°C × 10h 5# alloy;
Recrystallization. With Nd content increasing, the work hardening rate of alloy also increases and the curve shows the stage of strain hardening curve slope. The peak stress of the alloy increases significantly with the increase of the content of Nd, from 51 Mpa to 93 Mpa, which is mainly due to the hard Mg-Zn-Nd ternary phase formed after adding the trace rare earth Nd under high temperature, so the deformation resistance of the alloy increased. After adding 0.1% Nd to the alloys in the dynamic recrystallization, the strain decreased from 0.41 to 0.23. Then with the increase of Nd, it gradually increases to 0.36, which is still less than 1# alloy strain. This shows that with the increase of the content of Nd, hot compressive deformation resistance of as-cast alloy is remarkably improved and alloy stress-strain curve peak appears significantly ahead of time, and with the increase of Nd content, it continues to advance gradually. Because of the added Nd, Mg-Zn-Nd ternary phase forms, which helps the grain nucleation of the dynamic recrystallization.

![Fig3 True stress-strain curves of as-cast alloys](image)

### 4. Conclusions

After adding different content of Nd in ZM21 alloy, with the increase of the content of Nd, the average size of the grains becomes obviously bigger, gradually increasing from 323μm to 795μm but the as-cast alloy grain size uniformity declines with the increase of Nd content.

The hot compressive deformation resistance of ZM21 as-cast alloy increases significantly with the increase of Nd content, from 51 Mpa to 92 Mpa, alloy rheological stress-strain curve peak appears obviously earlier after adding 0.1% Nd and gradually advances as the Nd content increases to 0.7%.

### References

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