Changing the Shape of the Second Phase Distribution Improves the Mechanical Properties of Mg-6.7Y-2.5Zn Alloy by Adding Trace Ta

Limin Li[1], Pengya Lei[1], Zhuo Song[1,3], Huanqing Li[1], Liwen Chen[1], Hua Hou[1,3], Yuhong Zhao[1,2,4*]
1 School of Materials Science and Engineering, Collaborative Innovation Center of Ministry of Education and Shanxi Province for High-performance Al/Mg Alloy Materials, North University of China, Taiyuan, 030051, China
2 Beijing Advanced Innovation Center for Materials Genome Engineering, University of Science and Technology Beijing, Beijing, 100083, China
3 School of Materials Science and Engineering, Taiyuan University of Science and Technology, Taiyuan, 030024, China
4 Institute of Materials Intelligent Technology, Liaoning Academy of Materials, Shenyang, 110004, China
*Corresponding address: e-mail: zhaoyuhong@nuc.edu.cn

Abstract: The addition of tantalum (Ta) to magnesium alloys, as an alloying element, has not been widely studied. This research employed optical microscopy, scanning electron microscope, and compression tests to investigate the influence of Ta addition on the microstructural evolution and mechanical properties of Mg-6.7Y-2.5Zn alloy. The results indicated that the inclusion of Ta leads to an increase in texture strength and a reduction in the network-like morphology of the second phase. Multiple strengthening mechanisms synergistically contribute to the superior mechanical performance of the Mg-6.7Y-2.5Zn-0.1Ta alloy, with compressive strength and ultimate compressive strength values of 98.6 MPa and 253.4 MPa, respectively. The phase-field simulation unveiled the microscopic mechanisms involved in the sintering process. The synergy between experimentation and simulation enhances our comprehension of the intricate relationship between microstructure evolution and mechanical properties.

Keywords: Mg-6.7Y-2.5Zn-0.1Ta alloy, Phase-field, Second phase, Texture strength, Mechanical properties.

1 Introduction

The tensile yield strength of Mg-Y-Zn alloys produced by sand casting or permanent casting methods is significantly lower [1]. In order to enhance its strength, this study attempts to employ spark plasma sintering to fabricate the alloy. Furthermore, the exploration of the microstructural and macrostructural alloying elements has been undertaken to understand the evolution of the Mg-Y-Zn alloy. Recent research on Mg-Y-Zn alloys has primarily focused on their composition ratios, and the influence of adding Ta on their mechanical properties has not been extensively studied [2]. The impact of Ta addition on the mechanical behavior of Mg-Y-Zn alloys and how it affects the microstructure evolution remain less understood and explained. Therefore, this paper reports on the influence of Ta addition on the microstructural evolution and mechanical properties of Mg-6.7Y-2.5Zn alloy. By combining traditional compression tests with scanning electron microscopy techniques, a deeper understanding of the microstructural evolution of Mg-Y-Zn alloys after Ta addition can be achieved. Additionally, this study aims to explore how microstructural changes affect the mechanical properties of the alloy. In addition, not only did the phase-field simulation study the temporal evolution of porosity at different particle locations, but it also investigated the grain coarsening process through the phase-field simulation. The combination of experimentation and simulation facilitates a better understanding of the relationship between microstructure evolution and mechanical properties.

2 Experimental procedure

High-purity Mg powder (99.99wt.%), high-purity Zn powder (99.9999wt.%), high-purity Y powder (99.99wt.%), and high-purity Ta powder (99.99wt.%) with particle sizes ranging from 75 to 150 μm were ball-milled for half an hour to prepare the alloy powders. The microstructure of the powders is shown in Fig. 1. Using a Spark Plasma Sintering furnace (SPS-20T-10-III), cylindrical samples were prepared with a diameter of 30 mm. The heating rate was set at 20 °C/min, the temperature reached 360 °C, and the samples were held at this temperature for 5 minutes.

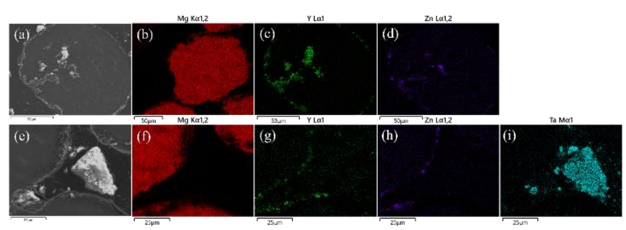

Fig. 1. SEM images of alloys powder particles: (a-d) Mg-6.7Y-2.5Zn, (e-i) Mg-6.7Y-2.5Zn-0.1Ta.

Prior to hardness measurement, the sintered alloy was ground to 1500 grit SiC. Vickers hardness tests were performed on the sintered samples using a TMHVS-1000 microhardness tester under a load of 0.5 kgf. Hardness values for each sample were obtained from 20 indents made along the diameter. In the compression tests, the compressive mechanical properties of the sintered samples were measured using a universal testing machine (AG-X plus). The average mechanical properties were determined from three measurements.

3 Result and discussion

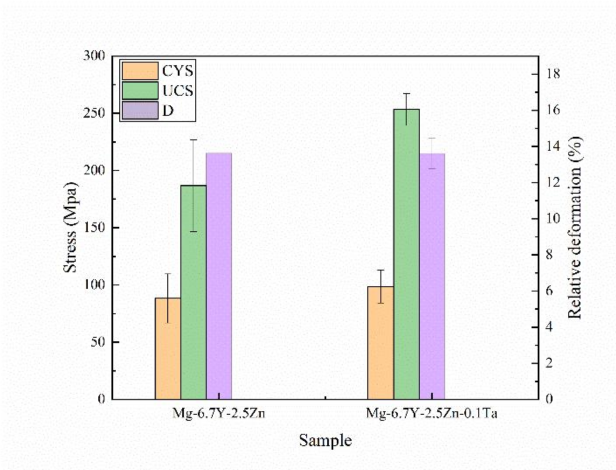

Fig. 2. Compressive properties of sintered alloy.

A comparison of the typical mechanical properties of the two sintered alloys is shown in Fig. 2. The yield compressive strength of Mg-6.7Y-2.5Zn-0.1Ta alloy is 98.6±14.3 MPa, which is approximately 1.1 times higher compared to Mg-6.7Y-2.5Zn alloy. The ultimate compressive strength of Mg-6.7Y-2.5Zn-0.1Ta alloy is 253.4 MPa, approximately 1.4 times higher than that of Mg-6.7Y-2.5Zn alloy. However, relative strain slightly decreased with increasing CYS and UCS. The addition of Ta enhanced both the UCS and CYS of Mg-6.7Y-2.5Zn alloy.The increase in strength in Mg-6.7Y-2.5Zn-0.1Ta alloy can be attributed to multiple strengthening mechanisms working in tandem [3]. The main strengthening mechanisms in different alloys include dislocation strengthening, texture strengthening, solid-solution strengthening, and precipitation strengthening. In summary, the enhanced strength of the Mg-6.7Y-2.5Zn-0.1Ta alloy results from the synergistic effects of these strengthening mechanisms working together. Dislocation strengthening restricts dislocation motion, texture strengthening increases the energy required for deformation, solid-solution strengthening involves lattice distortions, and precipitation strengthening occurs due to interactions with precipitate particles. Additionally, the unique coarse-grained and twin-containing microstructure of the Mg-6.7Y-2.5Zn-0.1Ta alloy may also contribute to its strength. The alloy's elongation did not significantly decrease after the addition of Ta, likely because twin boundaries and dislocation accumulation in grain-dense regions effectively inhibit crack initiation and propagation, ensuring consistent ductility between the two alloys.

4 Conclusion

(1)The addition of Ta enhances the mechanical properties of Mg-6.7Y-2.5Zn alloy, resulting in higher strength in the Ta-containing magnesium alloy.

(2)The increase in compressive strength in Mg-6.7Y-2.5Zn-0.1Ta alloy is complex and may be attributed to the combined action of multiple strengthening mechanisms.

(3)imulation of the phase-field method provides a better understanding of the relationship between microstructure evolution and mechanical properties.

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