Enhanced Mechanical and Damping Properties of Mg-8Zn-1.5Al-0.5Y Alloys By Rheo-Squeeze Casting

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Abstract: Due to their low density, high specific strength, and stiffness, Mg alloys have significant potential for applications in the automobile, aerospace, and other industries. However, the balance between mechanical properties and damping of Mg alloys has always been a challenge for its applications. The effects of ultrasonic and rheo-squeeze casting on the microstructure and mechanical properties of Mg-8Zn-1.5Al-0.5Y (ZAY8150) alloy were investigated. The results show that the alloy mainly consists of α-Mg, $Mg_{32}(Al, Zn)_{49}$ phase, and rich Y phase. Compared with conventional casting, ultrasonic and rheo-squeeze casting promote the formation and refinement of second phase. Notably, when both ultrasonic treatment and rheo-squeeze casting were applied simultaneously to the alloy, the volume fraction of second phase reaches 10.4%, with axial length decreasing to 2.1 μm and width decreasing to 1.3 μm respectively. At room temperature, the alloys subjected to ultrasound-assisted rheo-squeeze casting retained high damping properties (tanδ is found to be 0.04, and E" is measured as 1100MPa) at high mechanical properties. Tensile property is 260.4 MPa with an elongation of 20.2%.

Keywords: Ultrasonic, Rheo-squeeze casting casting, Quasicrystal, Mechanical, Damping

1 Introduction

Mg alloys exhibit significant potential for application in the aerospace, automotive, and 3C electronics industries due to their advantages of low density, high specific strength and excellent electromagnetic shielding. Meanwhile, Mg alloys are high damping material (tanδ>0.01) because of its good shock absorption and noise reduction properties, making it a candidate material for structural material. However, the balance between mechanical and damping properties of Mg alloys is also a bottleneck restricting its practical application. Therefore, improving the mechanical and damping properties of Mg alloys is the key to further improve the application field of Mg alloys.In this study, the four different treatments (semi-solid casting, ultrasonic vibration (USV), rheo-squeeze casting (SSE), and ultrasonic assisted rheo-squeeze casting casting(USV-SSE)) and conventional casting for Mg-8Zn-1.5Al-0.5Y (ZAY8150) were investigated. And the effect of solidification structure and mechanical properties of alloys under different conditions were compared.

2 Experimental procedure

Pure Mg, pure Zn, pure Al, and Mg-30Y (wt.%) were used to prepare ZAY8150 alloys. The metal ingot were placed in a stainless steel crucible according to its chemical composition and then heated in a resistance furnace. To prevent oxidation a gas mixture of $1\%SF_6+99\%N_2$ was continuously injected into the crucible during melting. Different parameters were employed to the melt.The microstructures of the alloys were analyzed using an X-ray diffractometer, and a scanning electron microscope. Room temperature tensile/compression tests were performed using a high-temperature electronic universal materials testing machine. Damping tests were performed using a dynamic thermo-mechanical analyzer. The frequency scan is a segmented scan: 0.1-5-100 Hz.

3 Result and discussion

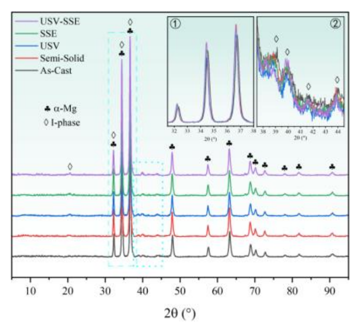

Fig. 1. XRD patterns of alloys under different processes

The XRD patterns in Fig. 1 reveal that the second phase of the alloy primarily consists of α-Mg, $Mg_{32}(Al, Zn)_{49}$, and rich Y phase. Compared to conventionally cast alloys, other alloys exhibit a leftward shift at 32, 34, and 36° (area ①), which can be attributed to the solid dissolution of elements with larger atomic radius into the matrix, resulting in an increase in lattice constant. Notably, quasicrystals show similarity in peak positions; however, their peak intensity slightly surpasses that of other alloys after ultrasonic-assisted rheo-squeeze casting (area ②). Due to the low Y content in the alloys, no Y-rich phase was detected via XRD.

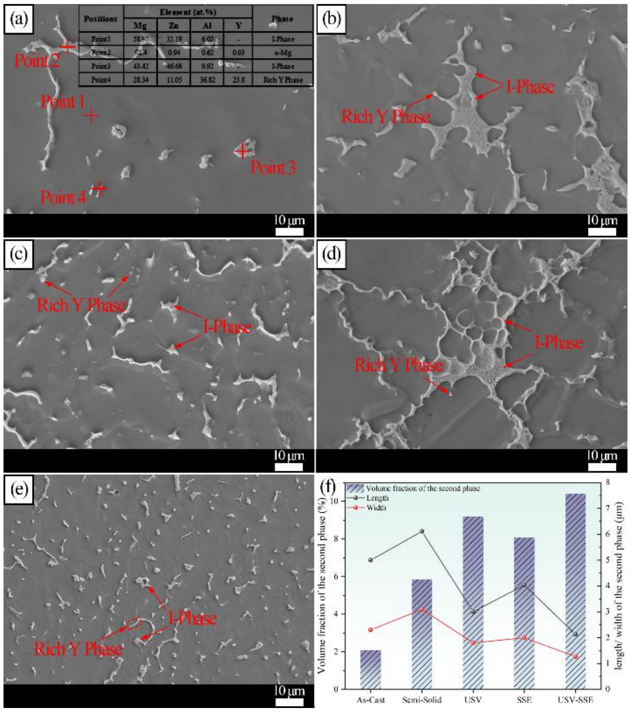

Fig. 2(a-e). SEM of alloys under different treatment processes. (a) As-cast, (b) Semi-Solid, (c) USV, (d) SSE, (e) USV-SSE, Fig. 2(f). Volume fraction and size of second phase

The SEM images of ZAY8150 alloysundergoing different treatment processeswere shown in Fig. 2(a-e). The morphology of the second phase of alloys mainly characterized as blocky, continuous, or granular structures. EDS indicates that the continuous and massive structures are $Mg_{32}(Al,Zn)_{49}$phase (I-Phase), while the granular structures are Y-rich. Both ultrasonic and rheo-squeeze casting promoted the formation and refinement of the second phase. From the Fig. 2(f), it is evident that in conventional casting, the volume fraction of the second phase is small and its size is large When both ultrasonic and rheo-squeeze casting were applied to the alloy, it resulted in the largest volume fraction of the second phase at approximately 10.4%. The average axial length and width of this second phase were reduced to 2.1 and 1.3 μm, respectively.

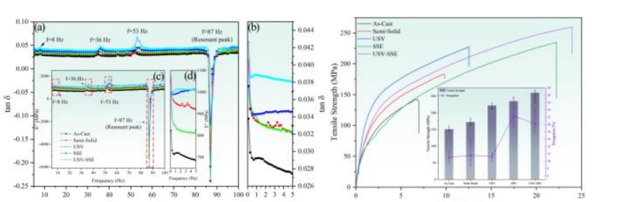

Fig. 3(a-d). tanδ and E" of alloys in frequency scanning mode; (a) tanδ of alloy at scanning frequency of 5-100 Hz, (b) tanδ of alloy at scanning frequency of 0.1-5 Hz, (c) E" of alloy at scanning frequency of 5-100 Hz, (d) E" of alloy at scanning frequency of 0.1-5 Hz, Fig. 3(e). Tensile properties of the alloys

The damping properties of ZAY8150 alloy at different frequencies are shown in Fig. 3(a-d). At low applied vibration frequencies (0.1-5 Hz), the tanδ and E"(Loss Modulus) of the alloys show a sharp decrease pattern as the frequency increases. Compared to the other alloys, alloys with ultrasound-assisted rheo-squeeze casting demonstrate higher damping properties. The tanδ and E" values for this alloy are 0.042 and 1070 MPa, respectively (At an applied vibration frequency of 0.1 Hz,); when the frequency is increased to 5 Hz, these values decrease to 0.038 and 1050 MPa, which are significantly larger than those of conventionally cast alloys (tanδ=0.0275, E"=680 MPa). As the vibration frequency increases further, peaks appear at 8, 36, 53, and 87 Hz. Notably, ultrasonic-assisted rheo-squeeze casting alloys exhibit higher tanδ and E" compared to the other alloys indicating superior damping properties (tanδ is found to be 0.04, and E" is measured as 1100MPa).

From Fig. 3(e), when ultrasound-assisted rheo-squeeze casting was applied to the alloys, their tensile properties increased to 260.4 MPa with an elongation of 20.2%. This represents a significant improvement of 72.7% in tensile strength and 82.0% in elongation compared to conventional casting.

4 Conclusion

In this study, the effects of ultrasonic and rheo-squeeze casting on the microstructure and mechanical properties of the ZAY8150 alloy were systematically investigated. Ultrasonic-assisted rheo-squeeze casting promoted the formation and refinement of the second phase of the alloy, compared with the conventionally cast alloy, the volume fraction of the second phase of alloy (USV-SSE) was 10.4%, and the average length and width were 2.1 and 1.3 μm, respectively. At room temperature, the alloys subjected to ultrasound-assisted rheo-squeeze casting retained high damping properties at high mechanical properties (Tensile strength of 260.4 MPa with elongation of 20.2%).

Acknowledgments

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