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Effect of Cryogenic Treatment on Mechanical Properties of Mg-2Zn-0.7Ce Alloy

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Abstract. In this paper, The tensile tests of Mg-2Zn-0.7Ce (at. %) alloys before and after cryogenic show that the cryogenic treatment can significantly increase the plasticity of the alloy. The yield strength, tensile strength and elongation of the as-extruded alloy were 245 MPa, 197 MPa and 9.6%, respectively. After cryogenic treatment at -196°C for 24h, the elongation of the alloy increased to 17.5%, but the tensile strength did not change significantly, the hardness slightly increased, and the yield strength decreased slightly. The fracture mechanism of alloy after cryogenic treatment changes from brittle fracture to ductile fracture.

Keywords: Magnesium alloy; Cryogenic Treatment; Mechanical properties.

1. Introduction

Magnesium alloys are the lightest structural materials for the industry of aircraft, spacecraft and missiles. However, the applications of magnesium alloys are strongly limited by their low ductility, poor corrosion resistance and weak wear resistance. Thus, an efficient is urgently needed to overcome such shortcoming of magnesium alloy [1-4]. Cryogenic treatment means the treatment of material under cryogenic temperature (-230℃-190℃). CT is widely applied in the manufacture of steel since the hardness and wear resistance of steel are significantly improved after cryogenic treatment. The investigation of cryogenic treatment on magnesium alloy is very significant, while rare studies are reported. Therefore, the present work investigates the effect of cryogenic treatment on the microstructure and mechanical properties of Mg-2Zn-0.7Ce alloy. As a systematic study to the precipitating behavior, microstructure evolution and mechanical properties of Mg alloy under cryogenic treatment, this work has presents a new way for the research of Mg alloy. In addition, a new process has also been suggested for Mg alloy, which may be with great significance and application prospects [5-8].

2. Experiments

The raw materials are mainly commercial pure Mg and pure Zn, with a purity of 99.9%. Ce is added in the form of a Mg-25wt.% Ce intermediate alloy. The raw material is smelted in an electric resistance furnace at an atomic ratio of Mg-2Zn-0.7Ce (at. %) and then smelted in an electric resistance furnace at a temperature of 650°C. After the molten metal is cooled to 650°C, it is allowed to stand for 30 minutes and then poured into preheating. In the 200°C cylindrical metal mold, the cavity size is Φ50mm×200mm. It was then left to stand in the air and the ingot was allowed to cool to room temperature. Prior to hot extrusion, the Mg-2Zn-0.7Ce ingot was homogenized at 400° C for 12h, the extrusion temperature was 300°C, the extrusion ratio was 16:1, and the bar with a diameter of 25 mm was extruded. The speed is 1-1.2 mm/s. After extruding the molding material, the bar is air-cooled to room temperature. The hot extruded Mg-2Zn-0.7Ce alloy sample was directly immersed in a metal tank filled with liquid nitrogen for cryogenic treatment. The cryogenic temperature was -196°C and the holding time was 1 min, 10 min, 1 h, 2 h, and 24 h, respectively. After the insulation is completed, the specimen is quickly removed using a jig, and the surface of the specimen is washed with alcohol and allowed to stand in the air to return to room temperature. The microstructure of the alloy before and after cryogenic treatment was observed by metallographic microscope and scanning electron microscope. Tensile tests at room temperature were performed on a Tenman Capability Material Tester at a draw rate of 10-3s-1. Each set of tensile tests tested three specimens. The measured tensile strength, yield strength, and section elongation were the average of the three specimen test results. The tensile specimens are shown in Figure 1.

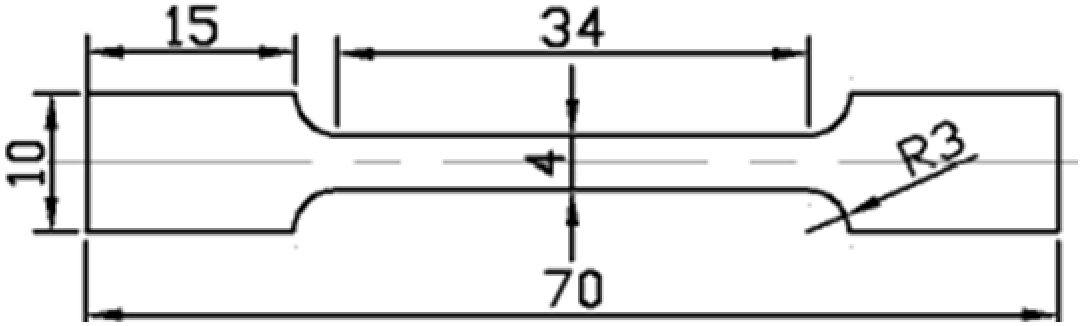

Fig. 1. The dimension and appearance of tensile specimen

3. Test results and analysis

Figure 2 shows room temperature tensile properties of Mg-2Zn-0.7Ce alloy after cryogenic treatment at different times. The tensile strength (UTS), yield strength (YS) and elongation (Elongation) of the as-extruded alloy are: 245 MPa, 195 MPa and 9.6%, respectively. After 1min of cryogenic treatment, the tensile strength and elongation did not change significantly. When the cryogenic time was extended to 10 minutes, its elongation rate increased to 17.5%, an increase of 80%. At this time, the tensile strength was 208 MPa, and there was no significant change. As the cryogenic time continues to increase to 24 h, the elongation rate is always maintained at about 18%. This shows that the cryogenic treatment can significantly increase the elongation of the extruded Mg-2Zn-0.7Ce alloy without significant changes in tensile strength. In addition, it is worth mentioning that as the cryogenic treatment time increases, the yield strength of the material decreases first and then recovers. After cryogenic 1 h, it decreased to a minimum of 167 MPa, which was mainly due to the decrease of solid solution strengthening effect due to the precipitation of solid solution elements during the cryogenic treatment. It returned to 186 MPa after being cryogenic for 24 hours. This may be due to the fact that there has been sufficient precipitation of W phase to play a role in dispersion strengthening.

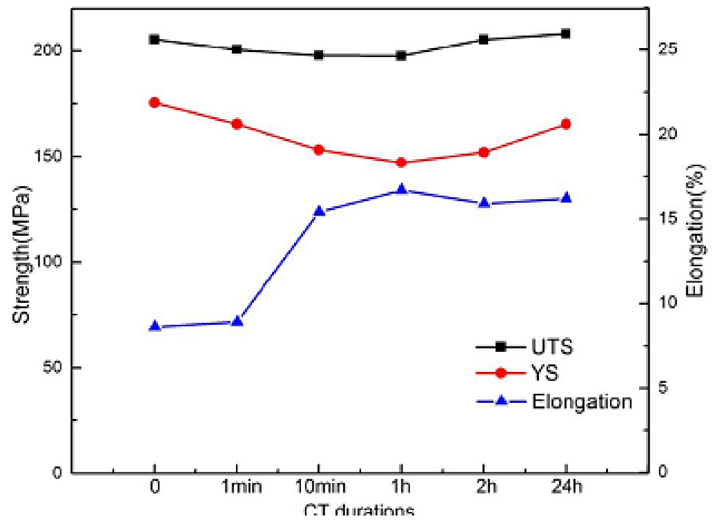

Fig.2. The tensile properties of Mg-2Zn-0.7Ce alloy after different CT durations.

Figure 3 shows the microhardness of the Mg-2Zn-0.7Ce alloy after cryogenic treatment at different times. The hardness of the as-extruded alloy is 52 Hv. After a certain period of cryogenic treatment, its hardness slightly increases. When the cryogenic treatment time is 24 hours, the hardness increases to 60 Hv. But overall, the increase in hardness is not significant.

Figure 4 is an SEM photograph of the fracture of the alloy before and after cryogenic treatment. As shown in Fig. 4(a), the fractures of the as-extruded alloy mainly consisted of cleavage planes and tear zones, and cracks along the grain boundaries could be observed, which is a typical brittle fracture structure. After cryogenic treatment for 24 hours, as shown in Fig. 4(b), developed river patterns and more dimples can be found on fractures, and granular protrusions can be found on the quasi-cleaved surface. This is a kind of Brittle-toughness composite fracture mechanism. According to fracture analysis, after the cryogenic treatment, the fracture mechanism of the material changes from brittle fracture to ductile fracture, so the plasticity of the Mg-2Zn-0.7Ce alloy is improved.

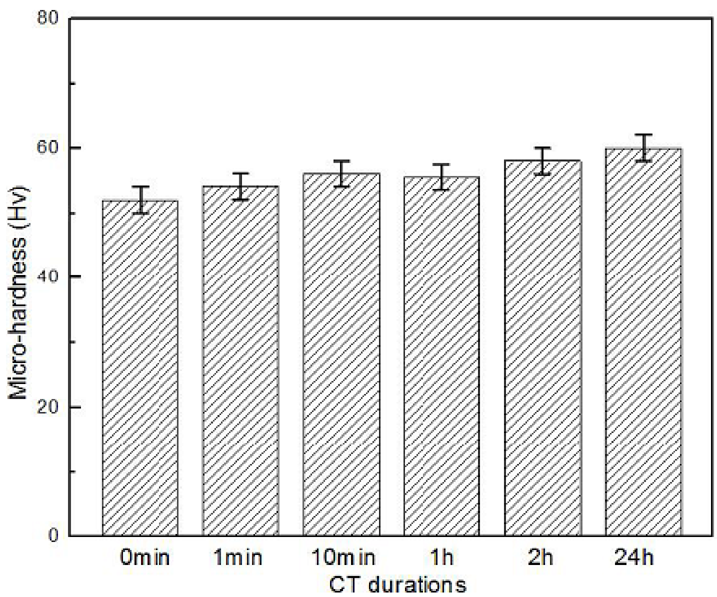

Fig. 3. The micro-hardness of Mg-2Zn-0.7Ce alloy after different CT durations

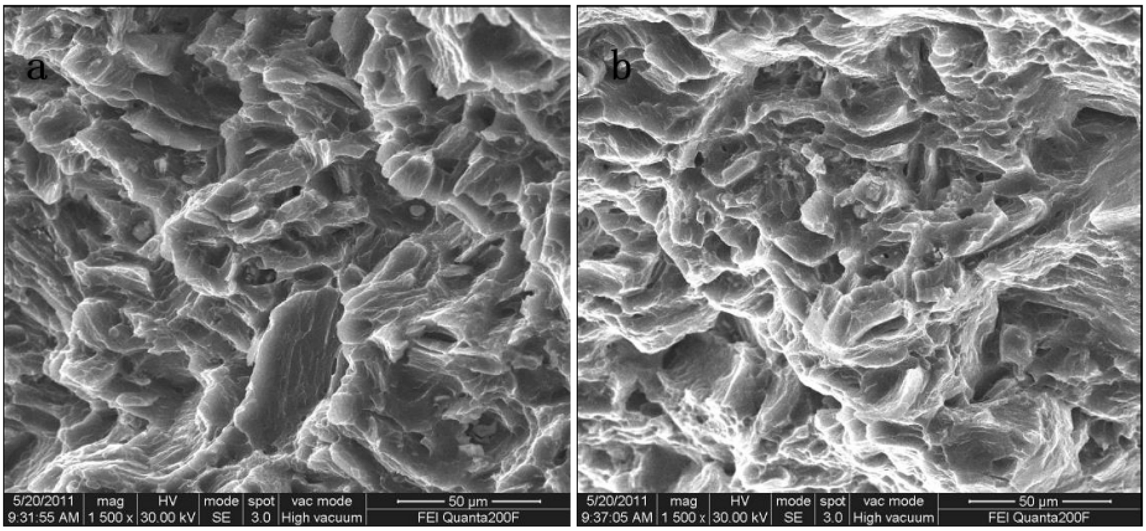

Fig. 4. The tensile fractures of Mg-2Zn-0.7Ce alloy before (a) and after CT24 (b)

4. Conclusion

Cryogenic treatment can significantly improve the plasticity of the as-extruded Mg-2Zn-0.7Ce alloy. After cryogenic treatment at -196°C for 24h, the elongation of the alloy increases by 80%, while the tensile strength does not change significantly. Ascension increases the yield strength slightly. The fracture mechanism of the alloy after cryogenic treatment changes from brittle fracture to ductile fracture.

Acknowledgements

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