Reinforcing Mechanical Properties of AZ31 By in Situ Autogenous Mg_2Si

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Abstract: AZ31 commercial magnesium alloy is unable to meet the requirements of load-bearing structural components due to its limited strengthening effect as its strengthening phase is only Mg17Al12 phase. In this work, the mechanical properties of AZ31 alloys are improved by in situ autogenous Mg2Si phases. The results show that the Mg2Si phase transforms from a short rod-like to a Chinese structure-like to a coarse bulk-like as the Si content increases from 0 to 3%. After extrusion, the Chinese structure Mg2Si phase is refined, but the coarse massive Mg2Si phase is not refined. In addition, with the increase of Si content, the ultimate tensile strength and yield strength of AZ31 alloys increase and then decrease, and the elongation first decrease slowly and then sharply. The best overall performance of the alloy is obtained at 2% Si.

Keywords: AZ31, Mg_2Si, extrusion.

1 Introduction

AZ31 alloy is widely used in automotive components, engine housings and communication equipment due to its good mechanical properties and abundant commercial availability[1]. As aerospace has become more demanding in terms of lightweight and performance, AZ31 is not able to meet the performance requirements and is mainly used in non-structural applications. AZ31 consists mainly of an α-Mg matrix and the $Mg_{17}Al_{12}$ phase[2], which has a limited reinforcing effect. The Mg_2Si phase is used as a reinforcing phase due to its inherent advantages, such as low density, high hardness, and high modulus of elasticity. However, the Mg_2Si phase formed during the casting process has a coarse crystalline structure, and these large particles are highly brittle, leading to deterioration of the mechanical properties[3]. Recently, many researchers have modified Mg_2Si by adding alloying elements[4], but the effect is not obvious. In this study, we improved the mechanical properties of AZ31 alloy by in situ autogenous Mg_2Si phase in AZ31 alloy, followed by refinement of the Mg_2Si phase with Chinese character structure and homogeneous distribution of the Mg_2Si phase in the matrix by extrusion, which significantly improved the yield strengths (YS) and ultimate tensile strengths (UTS) of AZ31 alloy with virtually no reduction in the elongation (E) of AZ31.

Experimental procedure

The raw materials for the experiments are pure Mg, pure Al, pure Zn, pure Mn and pure Si. AZ31 is melted at 750°C using a box resistance furnace and Si powder is added at 580°C to obtain AZ31-xSi (x=0, 1, 2, 3) alloy ingots. The ingots are solution treated at 420°C for 12 hours and then hot extrude, holding for 1 hour before extrusion. The extrusion temperature is 240°C, the extrusion ratio is 25:1, the extrusion angle is 30°, and the extrusion speed is 0.4 mm/s.

2 Result and discussion

Microstructure of alloys

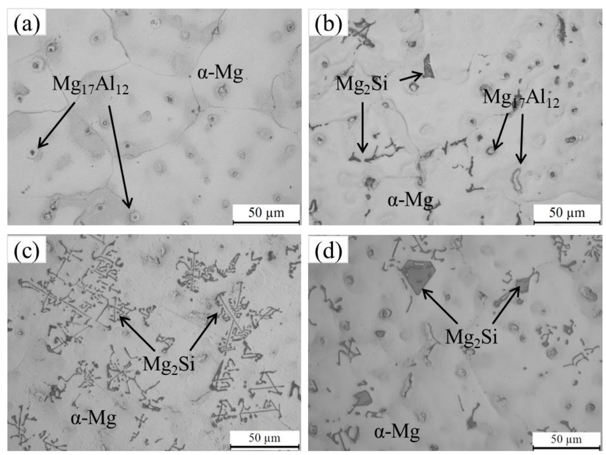

Fig. 1. Optical microstructure (OM) of as-cast AZ31-xSi: (a) AZ31, (b) AZ31-1Si, (c) AZ31-2Si, (d) AZ31-3Si.

Figure 1 shows the microstructure of as-cast AZ31 with different Si contents. The as-cast AZ31 mainly consists of α-Mg matrix and uniformly distributed dotted $Mg_{17}Al_{12}$ phases. As shown in Fig. 1(b), when 1% Si is added, some short rod-like Mg_2Si phases appear. With further addition of Si up to 2%, a large number of Mg_2Si phases with Chinese character structure are clearly observed (Fig. 1(c)). Interestingly, when the Si content is increased to 3%, the Mg_2Si phases with Chinese character disappear and is replaced by a massive Mg_2Si phase. When the Si content is low, the Mg_2Si phase exists mainly in eutectic form, and when the Si content is high, the Mg_2Si phase exists mainly in primary massive form. Figure 2 shows the microstructure of as-extruded AZ31 with different Si contents. From Fig. 2, it can be clearly observed that the microstructure of the as-extruded alloys undergoes significant changes, in addition to the significant grain refinement, the Mg_2Si phase shows a band-like distribution along the extrusion direction. It is noteworthy that the Mg_2Si phase with Chinese character is crushed into small particles during the extrusion process, while the bulk Mg_2Si phase did not undergo any significant change in morphology during the extrusion process.

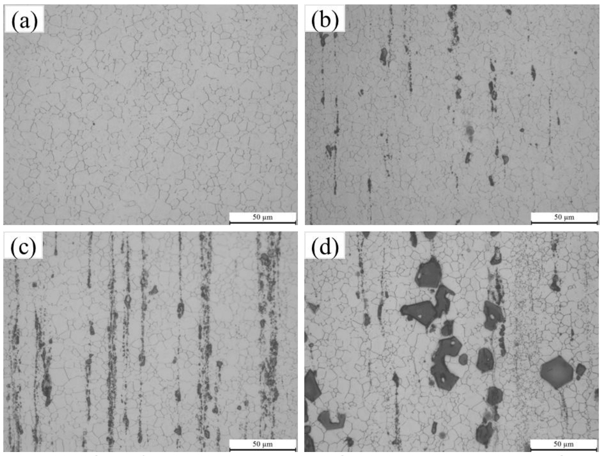

Fig. 2. The OM of as-extruded AZ31-xSi: (a) AZ31, (b) AZ31-1Si, (c) AZ31-2Si, (d) AZ31-3Si.

Mechanical properties of alloys

Table 1. Mechanical properties of as-extruded AZ31 with different Si content

Alloy	UTS	YS	E
0Si	218.6	110.1	28.0
1Si	231.5	128.6	27.2
2Si	289.8	167.8	26.0
3Si	279.1	172.5	19.3

Table 1 summarizes the mechanical properties of as-extruded AZ31 with different Si contents. As the Si content increases from 0 to 2%, the UTS and YS of as-extruded AZ31 alloys increase significantly, while E decreases slightly, especially 2% Si. This indicates that the Mg_2Si phase with Chinese character improves the mechanical properties of AZ31 by extrusion refinement. The refined Mg_2Si phase acts as a reinforcing phase to increase the UTS and YS of the alloys by hindering the movement of dislocations. However, when the Si content is 3%, the E of alloy decreases drastically, and there is a slight decrease in UTS. This result is closely related to the massive Mg_2Si phase, and the coarse massive Mg_2Si tends to lead to early crack initiation, which significantly reduces the E and also has a detrimental effect on the UTS. In conclusion, the Mg_2Si with Chinese character can significantly improve the mechanical properties of AZ31 alloy after extrusion refinement, and the coarse massive Mg_2Si phase is not favorable to the mechanical properties of AZ31 alloy.

3 Conclusion

The Mg_2Si phase with Chinese character is significantly refined after extrusion and deformation, which significantly improves the UTS and YS of the AZ31 alloy with a slight decrease in E. The mechanical properties of the AZ31 alloy are deteriorated due to the fact that the massive Mg_2Si phase is not refined during the extrusion process. The best overall alloy properties are obtained when the Si content is 2%.

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