The preparation of a new Mg-X-Si alloy

Abstract

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Mg_2Si is a common reinforcement in Mg/Al alloys because Mg_2Si can significantly improve the mechanical properties of the alloys. However, the coarse and brittle Mg_2Si phase shape and the weak bonds between Mg_2Si and the alloy's matrix greatly deteriorate the mechanical properties of these alloys. Therefore, how to refine the coarse Mg_2Si phase and to modify the weak bonds are the keys to obtain excellent mechanical properties. In this study, rapid solidification (RS), element modification (EM) and reciprocating extrusion process (REP) were used to prepare Mg alloys which containing Si element. The effects of RS, EM and REP on the microstructure evolution of the alloys were investigated. The following results were obtained:

The phase constituents of the as-cast and the REPed Mg-5Sn-1Si-0.8Y alloys consisted of α-Mg, Mg_2Si, Mg_2Sn and Mg(Si)Y compound. Due to the deformation strain's difference, the microstructure observed from edge to center on the cross section of the specimen was different. Increased extrusion temperature from 340 to 400 °C, the grain size increased, the broken Mg_2Si phase concentrated at grain boundaries and the amount of precipitated Mg_2Sn reduced. After REPed 4 - pass, the average grain size in the edge area at 340°C was 9.03 μm, at 360°C was 9.86 μm, at 380°C was 13.26 μm, and at 400°C was 15.53μm. The average grain size in the central area at 340°C was 13.7μm, at 360°C and 380°C were not uniform, and at 400°C was 21μm. After REPed 4 passes at 400°C, the distribution of Mg_2Si became uniform. Increased extrusion passes, however, the microstructure of the alloy was effectively refined, the distributions of the grain size and second phases became more uniform. After REPed 8 - pass at 340°C, the microstructure of the alloy was the finest and most homogeneous. The average grain size was 9 μm on the whole cross section. In comparing with temperature changing, to increase the REP passes was more effective to improve the homogeneity of the alloy.

The Mg-Sn-Si alloys modified with Y had primary MgSiY - (I, II, III) compounds with melting points being higher than that of the eutectic mixture of the alloy. The MgSiY compounds were in the coarse branch or column form consisting of many incompact short chain-like rods in

the as-cast alloys. The structural stabilities of MgSiY - (I, II, III) compounds were analyzed by using the first principles calculation. The calculated results indicated that the MgSiY - (I, II, III) compounds in compared with Mg_2Si had stronger alloying formation ability and more stable owing to its Si-Y Covalence bonds. The ideal crystal morphology of MgSiY was calculated by using BFDH (Bravais-Friedel Donnay-Halker) rules and the results gave that {111} planes of crystal MgSiY-I had the greatest Morphological Importance (MI) values, the ideal crystal morphology of MgSiY-I was octahedron or tetrakaidecahedron. For MgSiY-II, its {001} had the greatest MI values. The ideal final shape of crystal MgSiY-II was in a flat or tetragonal drum shape. For crystal MgSiY-III, the ideal morphology was in rod-shaped just as observed in this study.

Mg_2Si with point defects resulted from RS were calculated by using the first-principles method and the BFDH rules. The experimental results revealed that the microstructure of the Mg-4Zn-6Si-1Y alloy was significantly refined during RS and the growth morphology of Mg_2Si was effectively modified by RS. The growing mode of Mg_2Si transformed from discontinuous faceted growth in conventional solidification to continuous nonfaceted growth in RS. This crystal growth transformation made the reinforcement Mg_2Si crystallizing into spherical particles. The calculated results also revealed Mg_2Si tended to form Si anti-site, Mg and Si vacancies and Mg vacancy defects in RS. The point defects weakened the MI of the Mg_2Si {111} planes and increased that of the Mg_2Si {100} planes, and even made the {100} planes became important planes to determine the final growth morphology. Therefore, the point defects were considered to be one of the important reasons which changed the growth morphology of crystal Mg_2Si. So, the morphology of the primary Mg_2Si tended to be in the polyhedral and spherical particles after rapid solidification.

Key words: Mg-Sn-Si alloys, Reciprocating extrusion process, Rapid solidification, Element modification, Mg_2Si