O-86

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Grain Refinement of Cast Magnesium Alloy Containing Aluminum

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Experiments were conducted to examine the grain refinement ability of AMC master alloy for Al containing Mg alloys. The addition of AMC master alloy shows excellent grain refinement ability in the AZ91 alloy and the Al-Mn morphology change to polygonal type cause by duplex nucleation hypothesis. Refining efficiency was not disappeared after re-melting of refined AZ91 alloy and its refining ability was maintained for 4 hours holding time in melt condition. Therefore, the AMC master alloy can be confidently contributed to make grain refined Mg-Al base alloys with commercialized casting processes.

Keywords: *Magnesium alloy, grain refinement, AZ91 alloy.*

1. Introduction

Grain refinement is an important technique to improve the mechanical properties of magnesium alloys. In general, refined microstructure in as-cast components leads to more uniform microstructure, secondary phases and microporosity on a fine scale. And also it can provide superior extrudability, rollability and forgeability, excellent resistance to hot tearing, good surface finish and so on, leading to considerable cost reduction for production of wrought magnesium alloys [1-3].

Currently, Al-free magnesium alloys can be grain refined simply by zirconium addition, but for Mg-Al based alloys which comprise the main of the magnesium industry, there are no commercialized grain refiners and refining process despite numerical researches of grain refinement such as carbon inoculation, Elfinal process, superheating, and so on [4, 5]. Although, carbon inoculation using C_2Cl_6 is a very effective way for grain refinement of Mg-Al based alloys, the emission of toxic gases causes environment problems and workplace, resulting in the restriction of its use [6-9]. Therefore, alternative grain refiners and refining technology, i.e. effective, reliable and easy to apply for industry, should be developed. Recently, KIMS obtained excellent refining efficiency by developing a new refiner, AMC master alloy composed of Al and Mn as main components and it improved refining ability by inoculation carbon through various ways. The purpose of this study was to evaluate microstructure change after re-melting and fading time in order to apply AMC master alloy to mass production process.

2. Experiments

AMC master alloy was added so that the final composition is the same as commercial AZ91D alloy. In order to measure fading time of AMC master alloy, the alloy melt including Mg, Al, Zn and AMC hold at 710^{o}C for a period of time from master alloy addition using steel crucible and was poured in cylindrical mold that was 80mm in diameter preheated at 200^{o}C. Cast billets were cut 20mm high from the bottom and mechanically polished and etched for microstructure analysis. To confirm the duration of refining efficiency of AMC master alloy after re-melting, grain refined AZ91 alloy by AMC master alloy was melted again at 710^{o}C, and hold for 30 minutes, and then manually stirred for five minutes. It was then casted in the same methods before and microstructure was observed. The grain size was measured by linear intercept method.

3. Results and Discussion

Figure 1 shows the microstructures of commercial AZ91 alloy and grain refined AZ91 alloy by using AMC master alloy. The average grain size of not refined and refined alloy was measured at 400 ± 50 μm and 80 ± 5 μm, respectively.

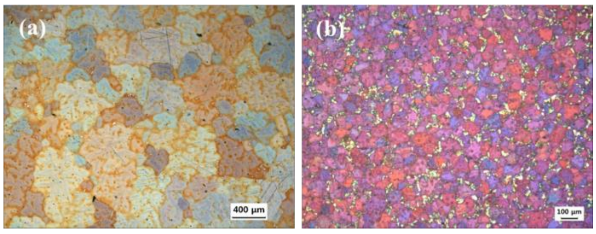

Fig. 1 Microstructures of the cast AZ91 alloy; (a) commercial and (b) grain refined by AMC master alloy.

Figure 2 show the SEM micrographs of commercial and grain refined AZ91 alloy which conducted heat treatment at 400 °C for 10h. Remined particles showing bright after heat treatment is confirmed Al-Mn phase. Two samples show a distinct difference in morphology of Al-Mn phase. The irregular needle shape existed in boundary is shown in case of commercial AZ91 alloy, while the refined AZ91 alloy is showing polygonal shape with the size of 5μm and exist inside the grains . This is because grain refinement using AMC master alloy accompanied with morphology change of Al-Mn phase due to the duplex nucleation mechanism reported by Kim and Wang [10-12].

In the case of AMC master alloy, it cannot be used in commercial AZ91 alloy directly due to the additional Al content in master alloy. So AMC master alloy should be added when AZ91 alloy making. In this case, grain refined AZ91 alloy should re-melt to make products in final manufacturing process. After re-melting, grain refinement efficiency can reduce or disappear during final manufacturing process due to fading phenomenon. Figure 3 shows change of refining efficiency of refined AZ91 alloy after re-melting and during holding in melt state. As shown in figure, the average grain size is 80 μm even after re-melting, and then grain size increased after about 4 hours. Although casting time in industrial fields may differ greatly based on the processes, 4 hours fading time is thought tobe sufficient time to produce grain refined product for use in low pressure die casting, sand casting, or direct chill casting process.

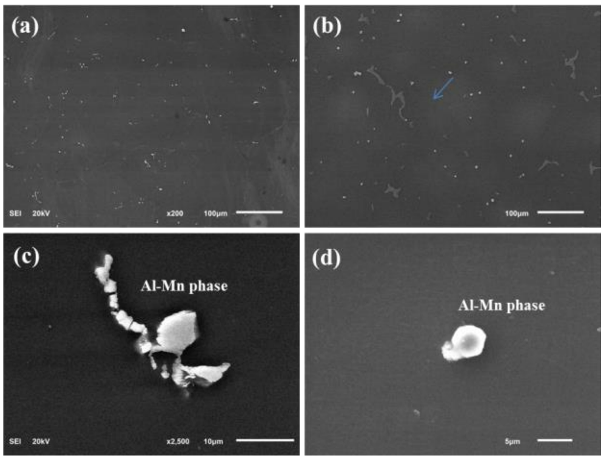

Fig. 2 Scanning electron micrographs of AZ91 alloy heat treated at 400 °C for 10h; (a), (c) commercial AZ91 alloy and (b), (d) grain refined AZ91 alloy by addition of AMC master alloy.

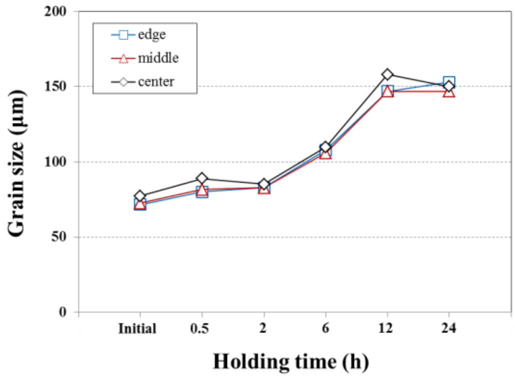

Fig 3. Grain size changes after re-melting and the holding time of refined AZ91 alloy.

4. Conclusion

AMC master alloy that was developed for grain refinement of Al containing Mg alloys is added during AZ91 alloy making process. It was proved that the AMC master alloy addition leads to considerable grain refinement and refining efficiency maintains even after re-melting and 4 hours holding time.

Acknowledgements

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