Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Solidification Behavior of Mg-Al-Ca Alloys with Different Aluminum and Calcium Contents.

Hiroki Kako[1], Seiji Saikawa[2], Susumu Ikeno[3], Kazunori Shimizu[4] and Hiroaki Iwakawa[4]
[1] Graduate School of Science and Engineering for Education, University of Toyama, 3190Gohuku, Toyama, Toyama930-8555, Japan
[2] Science and Engineering for Research, University of Toyama, 3190Gohuku, Toyama, Toyama930-8555, Japan
[3] Hokuriku Polytechnic Corporation, 1289-1Kawaberi, Uozu, Toyama937-0856, Japan
[4] Sankyo Tateyama Inc., Sankyo Material-Company, 8-3Nagonoe, Imizu, Toyama934-8515, Japan

Magnesium alloys have the characteristic with high specific tensile strength and lightweight properties. Therefore, it is used for auto mobile industry, aircraft industry, and electronic equipment parts, and a future use expansion attracts attention. In this study, behavior of solidification structure in Mg-0~12mass%Al-0~10%Ca alloys cast into sand mold were investigated by XRD measurement and OM, SEM-EDS observation. In the as-cast state of all alloys, solidification structures mainly consist of the primary crystallized α-Mg and secondary crystallized eutectic, such as Mg_2Ca, $Mg_{17}Al_{12}$ and Al_2Ca phases. The shape of primary crystallized α-Mg phase changed from cellular to dendritic, when Al and Ca content increased. On the other hands, shape of secondary crystallized Al_2Ca and Mg_2Ca phases were lamellar, while $Mg_{17}Al_{12}$ phase was crystallized at grain boundary and cell gaps with blocky shaped. Temperature stagnation region due to the latent heat release by crystallization of primary crystal with the increase of Al concentration and the Ca concentration is reduced.

Keywords: *Mg-Al-Ca alloys, microstructures, sand-mold, cooling curves*

1. Introduction

In recent years, lightweight of the vehicle body has been required in the automobile industry. Magnesium alloys have characteristic of high specific strength and lightweight properties. Therefore, the application of magnesium alloys have been expanded in the auto parts.

The conventional alloys Mg-Al-Zn(AZ) and Mg-Al-Mn(AM) series, have good strength at room temperature and ductility with sufficient corrosion resistance. However, the application of these alloys is limited to components operating at high- temperature below 393K because of their rapid degradation of creep properties.

The development of a variety of heat-resistant magnesium alloy has been carried out. Recently, rare metal-free heat-resistant Mg alloy has been attracting attention. Among them, Mg-Al-Ca-based alloy has the characteristics of high heat resistance and low cost.

We have examined such as the castability of Mg-Al-Ca alloys. As a result, hot tearing generated in the solid-liquid coexistence region was reduced by the increasing Al and Ca contents.

In this study, we investigated the influence of Al and Ca content on the solidification behavior and structure of Mg-Al-Ca alloy cast by sand mold.

2. Experimental procedures

The target composition is Mg-0-12mass%Al-0-10mass%Ca alloys. The Samples were melted using pure Mg, pure Al, pure Ca, Mg-Mn and Al-Be master alloys. These alloys were melted in an electric furnace while blowing protective gas (CO_2 + SF_6 gas) to the melt surface. Mold was molding a sand mold with a cavity of cylindrical shape as shown in Fig.1. To average cooling rate of casting, it was placed a thermocouple in the center of the cavity.

The observation specimen cut from the castings, and it was polished by grind emery paper of #80-2000. Then diamond paste with the diameter of 1μm was used. Finally, polished surfaces were etched in 1% nitric acid ethanol. These microstructures were examined using an optical microscope(OM), field emission scanning electron microscope(FE-SEM) equipped with an energy dispersive X-ray system(EDS) and X-ray diffraction method(XRD).

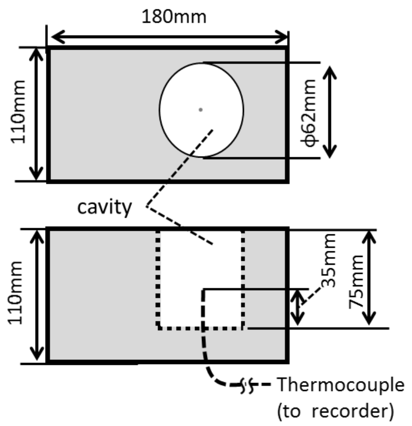

Fig.1 Schematic drawing of sand mold for measuring of cooling curves.

3. Results and discussion

The cooling curves of Mg-6%Al-0-10%Ca alloys cast by sand mold is shown in Fig.2. Fig.2 (a) occurs the crystallization of the primary crystallized α-Mg phase at about 893K.Then temperature stagnation by latent heat release has been confirmed to about 714K. In Fig.2 (b)-(d), crystallization temperature of the primary crystallized α-Mg phase with an increase in the Ca addition amount was confirmed that the decrease. In addition, the temperature stagnant due to the latent heat release was observed at about 789K to 807K by addition of Ca.

Fig.3 shows microstructure of Mg-6%Al-0-10%Ca alloys sand mold castings. Fig.3 (a) was observed matrix of α-Mg phase and non-equilibrium crystallized β-$Mg_{17}Al_{12}$ phase. Fig.3 (b)-(d) were observed in the grain boundaries and cell gap as fine or relatively coarse lamellar crystallized phase.

Fig.4 shows SEM-EDS analysis results of crystallized phase in the Mg-6%Al-6%Ca alloys cast by sand mold. These images show α-Mg phase with an interdendritic eutectic structure containing intermetallic phases that are identified as the Al_2Ca phase(1) and the Mg_2Ca phase(2).

4. Conclusions

Temperature stagnation region due to the latent heat release by crystallization of primary crystallized α-Mg phase with the increase of Al concentration and the Ca concentration is reduced.

References

[1] S.Saikawa. Japan Institute of Light Metals. 60(11)(2010)571-577.

[2] A.Suzuki, N.D. Saddock, J.W. Jones, T.M.Pollock. Acta Materialia. 53(2005)2823-2834.

[3] S.W.Xu, K. Oh-ishi, S.Kamado, H.Takahashi, T. Honma. Matrials Science and Engineering. A542(2012)71-78.

[4] H.Niwa et al., The Japan Light Metals Society 124, Spring meeting, (2013), 101-102

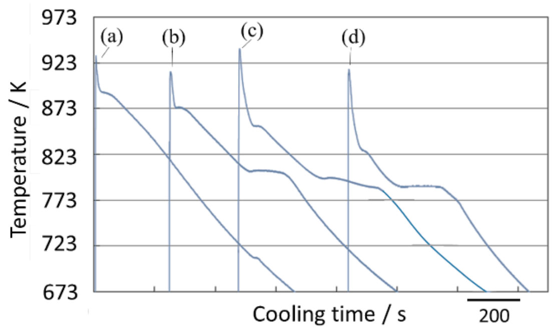

Fig.2 Cooling curves of Mg-6%Al-0-10%Ca alloys cast by sand mold: (a)6%Al-0%Ca, (b)6%Al-3%Ca, (c)6%Al-6%Ca, (d)6%Al-10%Ca.

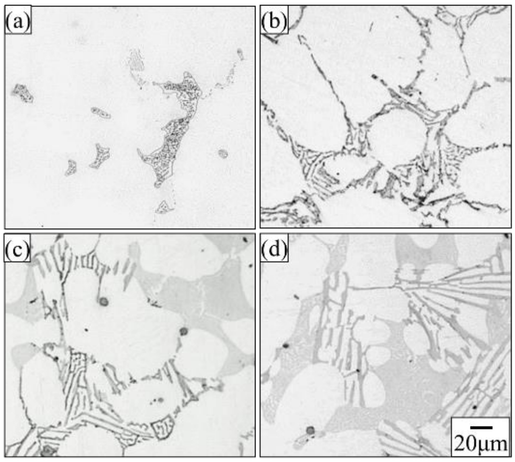

Fig.3 Optical micrographs of Mg-6%Al-0-10%Ca alloys sand mold castings: (a)6%Al-0%Ca, (b)6%Al-3%Ca, (c)6%Al-6%Ca, (d)6%Al-10%Ca.

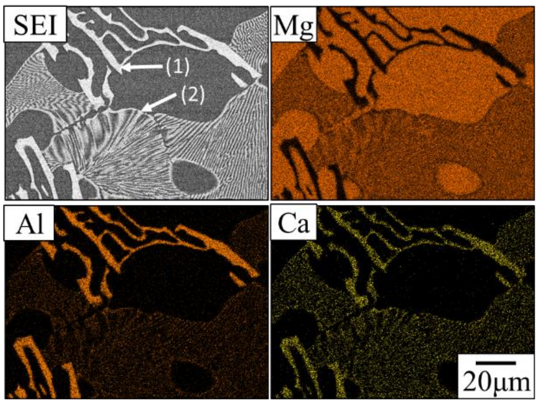

Fig.4 SEM-EDS analysis results of Mg-6%Al-6%Ca system alloys cast by sand mold.