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EFFECT OF Mg CONTENTS ON FLUIDITY OF Al-xMg ALLOYS

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Abstract

This study is focused on a basic approach for the fluidity of the Al-Mg binary system. The objective of this study is to investigate the fluidity change of the Al-Mg alloys with increasing Mg content. As a result of fluidity test, pure Al showed the highest value in all the examined alloys. With 2.5%Mg addition, it decreased rapidly. On the other hand, the gain of the flow length was shown with increasing Mg content from 5%Mg addition. The change of the fluidity shown in this study is roughly similar to that reported previously. However, they also showed the difference in the Mg content which has the most viscous fluidity. It is considered that it is attributed to the different experimental conditions. In microstructures, with increasing the Mg content, the dendritic α-Al was developed and the existence of precipitation regarded as β-phase (Mg_5Al_8) is shown in the grain boundary. This tendency became conspicuous from the 5wt%Mg addition. And then, the grains were refined with the formation of the precipitation.

Introduction

Al-Mg based alloy has attracted considerable attention because of its superiority in mechanical properties, corrosion resistance, weldability, as well as low density. With this promising potential, the demand for Al-Mg based alloy in vehicle and aircraft industries has increased [1-3]. On the other hand, further improvement of strength is required for a practical performance on a par with steel. The reinforcement by Rib had been considered for additional strengthening of the alloy [4, 5]. The addition of Rib, however, leads to the complication of product shape, causing a defect in mold filling. Therefore, material design for good fluidity is an important task in Al alloy process.

Oxide layer and inclusion formed in melting process could be one of factors to reduce melt fluidity [6]. It is well-known that the Mg in Al-Mg system causes the formation of the oxide inclusion in melt due to its affinity to oxygen. The oxide clusters affect melt fluidity and mechanical properties of the final product [7, 8]. To avoid such a problem, the use of SO_2 gas and Be addition have been considered [9, 10]. Due to the limitation in utilizing SO_2 and toxicity of Be, the eco-friendly alternative measure is required [2, 11-13]. In an earlier study, it was reported that the oxidation resistance of the molten Al-Mg alloy was improved by the addition of Mg in the form of the master alloy including Al_2Ca [14].

The present study focuses on a basic approach for the fluidity of the Al-Mg system. The objective of this study is to investigate the fluidity change of the Al-Mg alloys with increasing Mg content.

Experimental procedure

Alloys were prepared by electric resistance furnace with 2.5 to 10wt%Mg addition. Pouring temperature of each alloy was determined with adding 40 ℃ to liquidus temperature obtained with JMatPro. This is to make the same condition in superheat, which is an factor to affect the fluidity [15]. Drawing and photograph of fluidity mold with spiral type are shown in Fig. 1. Fluidity test was carried out after the holding for 10 minutes. The determined pouring temperatures are summarized in Table 1. The mold temperature was held to 250 ℃ being controlled by the inserted heating bars. The flow lengths with the gain of the Mg content were measured with the samples obtained after the pouring into the mold. The microstructure observation by OM (optical microscopy) were carried out about the cross section at 1 cm distance from the fore end. The samples were grinded and polished, finally with 1 ㎛. And also, the samples were cleaned using pure alcohol and etched with keller's etchant.

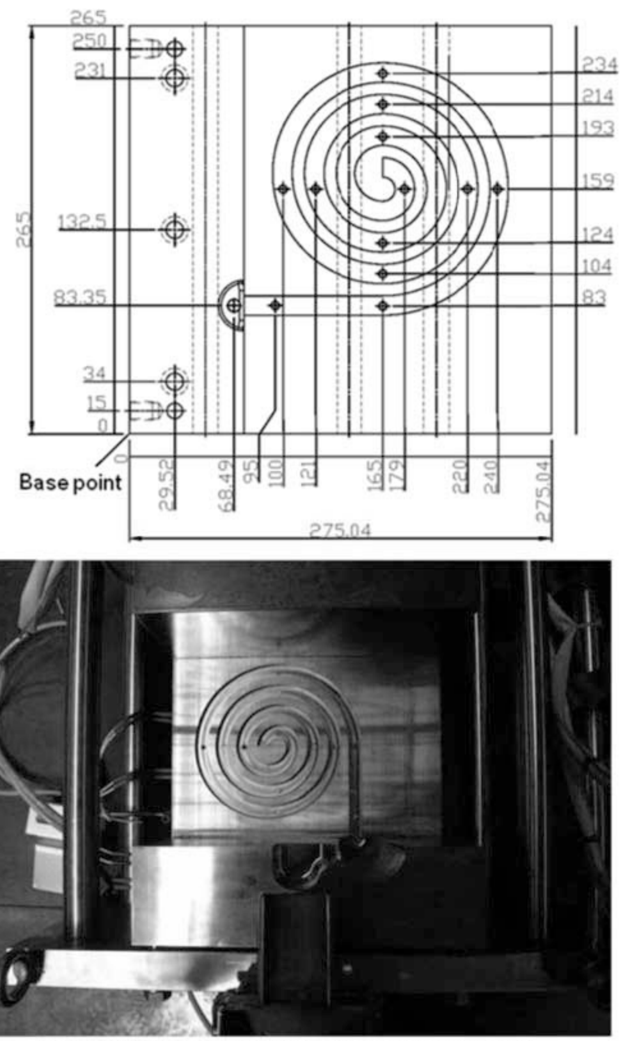

Figure 1. Drawing and photograph of fluidity mold.

Table I. Liquidus and solidus temperatures with Mg contents

Mg contents (%)	**Liquidus (℃)**	**Solidus (℃)**	**ΔT (℃)**	**Pouring temperature (liquidus + 40, ℃)**
0	660.4	660.4	0	700.0
2.5	648.1	623.3	24.8	690.0
5.0	635.7	583.9	51.8	675.0
10.0	609.9	512.2	97.7	650.0

Results and Discussion

Figure 2 and Table I show liquidus and solidus temperatures calculated from JMatPro. Pure Al showed 660.4 ℃, close to the melting temperature of Al reported generally. With increasing Mg content, the liquidus temperature decreased to 609.9 ℃, about 50 ℃ lower than that of pure Al. As shown in Figure 2, the liquidus temperature linearly decreased with increasing the Mg content.

The results of fluidity test are shown in Table II and Figure 3. The results of each alloy have low standard deviation. Pure Al showed the flow length of 44.8 mm, the highest value in the examined alloys. This arises from the different solidification mode with that of alloy [15]. Pure metal solidifies with planar front, while alloy does with mushy front [15]. With 2.5%Mg addition, it decreased rapidly, to 40.4mm. And then, the gain of the flow length was shown with increasing Mg content. From the ΔT values in Table I, it was confirmed that the mushy zone was extended with increasing the Mg content. Therefore, it was considered that the extension of the mushy zone led to the fluidity improvement.

According to the previous report [15], fluidity decreased significantly in the solid solution portion of the system up to 4.9%Mg and increased as the fraction of eutectic formed. And then, the fluidity increase was reached to its peak in the hypereutectic region.

The change of the fluidity shown in this study is roughly similar to that explained above [15]. It is considered that the difference in the Mg content with the most viscous fluidity is attributed to the different experimental conditions.

Figure 4 shows the microstructures of the fluidity tested samples. In the case of pure Al, it is thought that the existence of grains was not clear. With increasing the Mg content, the dendritic α-Al solid solution was developed and the existence of precipitation regarded as β-phase (Mg_5Al_8) was shown in the grain boundary. This tendency became conspicuous from the 5wt%Mg addition. And then, the grains were refined with the formation of the precipitation.

Based on the Al-Mg phase diagram [16], from the 2.5wt%Mg, the solid solution would be supersaturated with Mg solute atoms, because the Mg content is higher than 1.9wt%Mg, which is the solubility of Mg in Al at room temperature [17]. As the solidification proceeded, the precipitation, an equilibrium β-phase (Mg_5Al_8) would be formed as along the grain boundaries. And then, the grain refinement would be occur by the pinning effect.

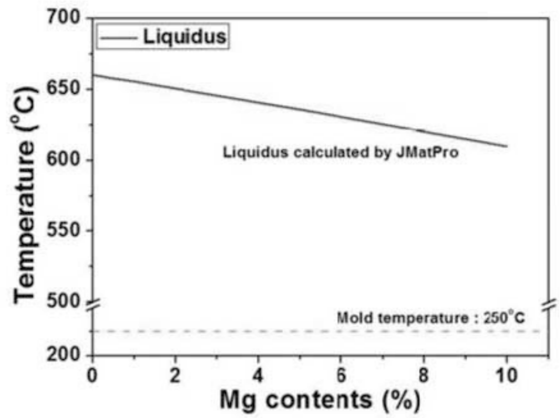

Figure 2. Liquidus and solidus temperatures with Mg contents.

Table II. Results of fluidity test and standard deviation

Alloys	Fluidity (cm)	Standard deviation
1. Pure Al	44.8	1.7
2. Al-2.5Mg	40.4	0.8
3. Al-5.0Mg	41.8	0.6
4. Al-10.0Mg	43.0	1.8

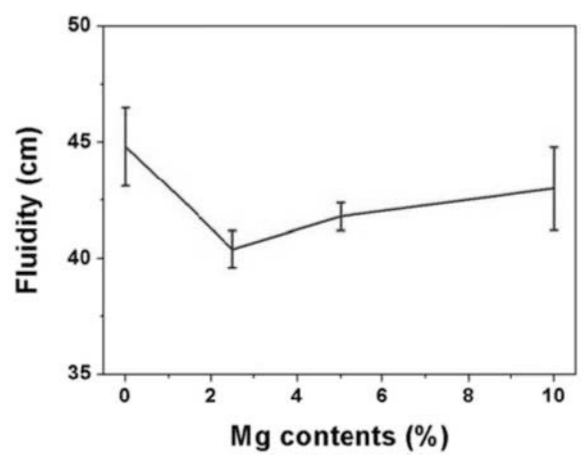

Figure 3. Result of fluidity test for Al-Mg alloys.

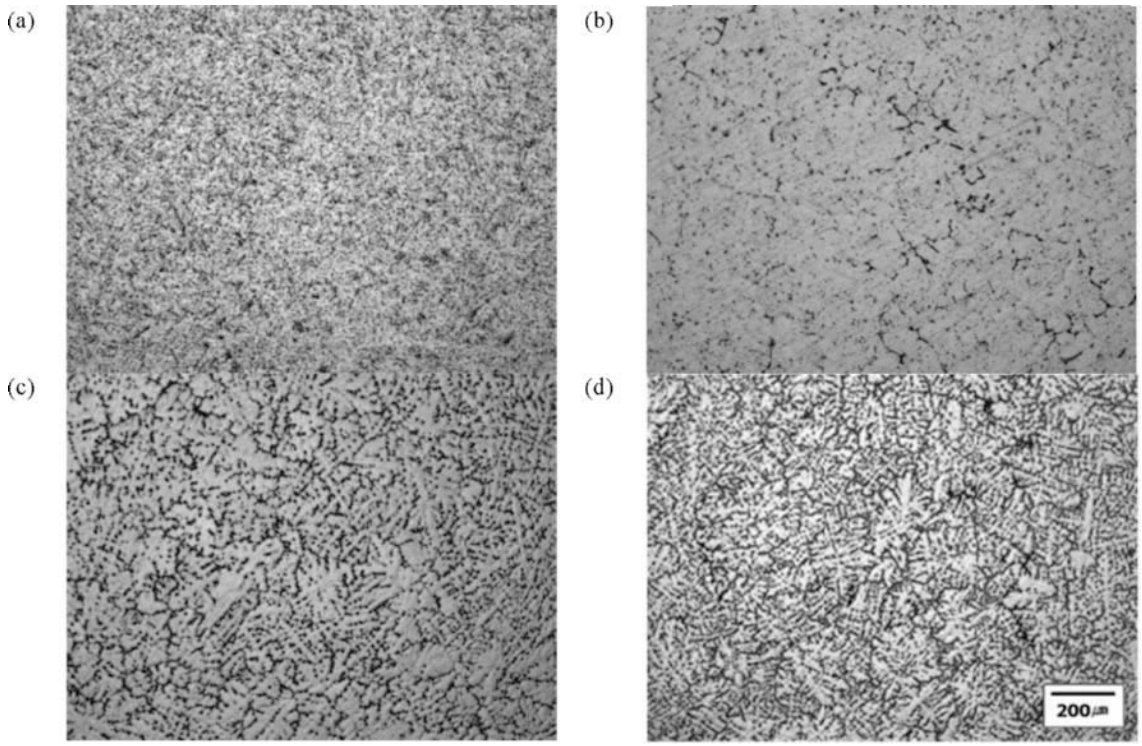

Figure 4. Microstructures of (a) pure Al, (b) Al-2.5Mg, (c) Al-5Mg and (d) Al-10Mg after fluidity test.

According to the previous report [15], the grain refinement can also have a positive effect on fluidity. Therefore, it was thought that the grain refinement also contributed to the increase of the fluidity.

Conclusions

As a result of fluidity test, pure Al showed the highest value in all the examined alloys. With 2.5%Mg addition, it decreased rapidly. On the other hand, the gain of the flow length was shown with increasing Mg content from 5%Mg addition. The change of the fluidity shown in this study is roughly similar to that reported previously [15]. However, they also showed the difference in the Mg content which has the most viscous fluidity. It is considered that it is attributed to the different experimental conditions. In microstructures, with increasing the Mg content, the dendritic α-Al was developed and the existence of precipitation regarded as β-phase (Mg_5Al_8) is shown in the grain boundary. This tendency became conspicuous from the 5wt%Mg addition. And then, the grains were refined with the formation of the precipitation.

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