



In this work, the segregation of solute elements in magnesium alloys AZ91D and AM60B in a crucible during hot-chamber die casting process has been investigated. The sampling of molten metal for chemical composition analysis was carried out at three positions within a crucible of 600 mm in depth. The picked molten metal was poured into a steel mold to cast into a rod 40mm diameter and 120mm length.

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SEGREGATION OF SOLUTE ELEMENTS IN CRUCIBLE DURING DIE CASTING

Introduction

The uses of magnesium alloys to structural components of automobiles, aircraft, electronics, and computers have been increased and are expected to further grow during next decades because they offer good castability and high specific strengths [1, 2]. Currently, most of the magnesium-alloy components are produced by die-casting process, during which, in many cases, molten metals are maintained in the crucible for up to several hours before subsequent charging. Commercial magnesium alloys contain aluminum, zinc, or manganese as major alloying elements, while they limit the presence of copper, nickel, and iron because of their harmful effect on corrosion resistance [3]. The segregation of the alloying or impurity elements in the crucible may result in severe variations in mechanical properties or corrosion resistance of the magnesium products. Thus, it is important to maintain the compositional consistency of molten metals in the crucible during the casting process.

The objective of this study is to investigate the variations in chemical compositions of magnesium alloys AZ91D and AM60B within a melting crucible during hot chamber die-casting process. The variations on the position from the bottom of crucible and on the holding times have been investigated.

Experimental Procedure

The sampling of molten metal for chemical composition analysis was carried out at three positions (A; bottom, B and C; 100 and 300 mm upside from the bottom, respectively) within a crucible of 600 mm deep (Fig. 1, a) after stirring, using a tool shown in Fig. 1, b. The entrance of gooseneck was located at 300 mm upside (position C) from the bottom of crucible. The samplings were carried out three times at each condition. The picked molten metal was poured into a steel mold to cast into a rod 40mm dia. and 120mm long. The specimen for

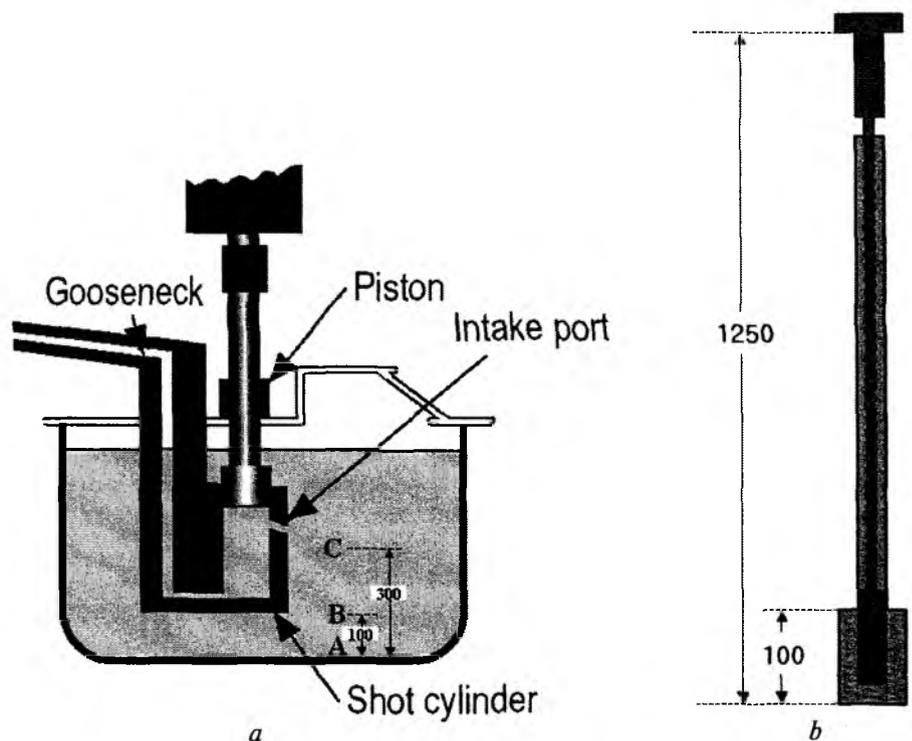


Fig. 1. Schematic diagram showing (a) sampling position in crucible and (b) sampling tool for chemical composition analysis

chemical composition analysis was cut from the casting into a disc 40mm dia. and 20 nun long, which was polished using a #800 emery paper prior to the analysis.

The chemical analysis was carried out using Hilger Poyvac E2000 emission mass spectrometer. The data are the average of five time measurements. In order to investigate the effect of holding time, the

specimens were sampled from the position 'C' at variable holding times ranging from 0 (right after stirring) to 120 minutes. The stirring was carried out manually for 10 minutes using a mechanical stirrer. Magnesium alloys used in this study were AZ91D and AM60B. The ASTM standard chemical compositions of the alloys were shown in Table 1.

Table 1. ASTM standard chemical compositions of AZ91D and AM60B

Alloys/ Density	Al	Zn	Mn	Cu	Si	Fe	Ni	Other	Mg
AZ91D	8.3-9.7	0.35-1.0	0.15-0.5	<0.03	<0.1	<0.005	<0.002	<0.3	bal.
AM60B	5.5-6.5	< 0.22	0.25-0.6	<0.01	<0.1	<0.005	<0.002	<0.3	bal.
Density (g/cm ³)	2.70	7.14	7.43	8.96	2.33	7.86	8.90	-	1.74

Results and Discussion

1. Effect of position in crucible

Fig. 2 shows the variation in the concentration of alloying elements and impurity in magnesium-alloy melts on the distance from the bottom of crucible.

The concentration of Al, Zn, and Mn was lower at the top of molten metals. Similar trend was also observed for impurity element Fe, as shown in Fig. 2(d). The concentration of the alloying elements increased as the sampling position approaches to the bottom of the crucible. At the bottom of the crucible, Al, Fe, Mn showed higher concentrations than the maximum limits of each alloy.

The macro-segregation of alloying elements and impurities within the crucible is related to the relative density and reactivity between the elements. In this study, the sampling was carried out immediately after mechanical stirring. However, the bottom of crucible did not completely mixed with the top or middle regions of the melt because of increased viscosity at the bottom. Although the viscosity of molten metal was not measured, it was found qualitatively that the resistance of stirrer was some-

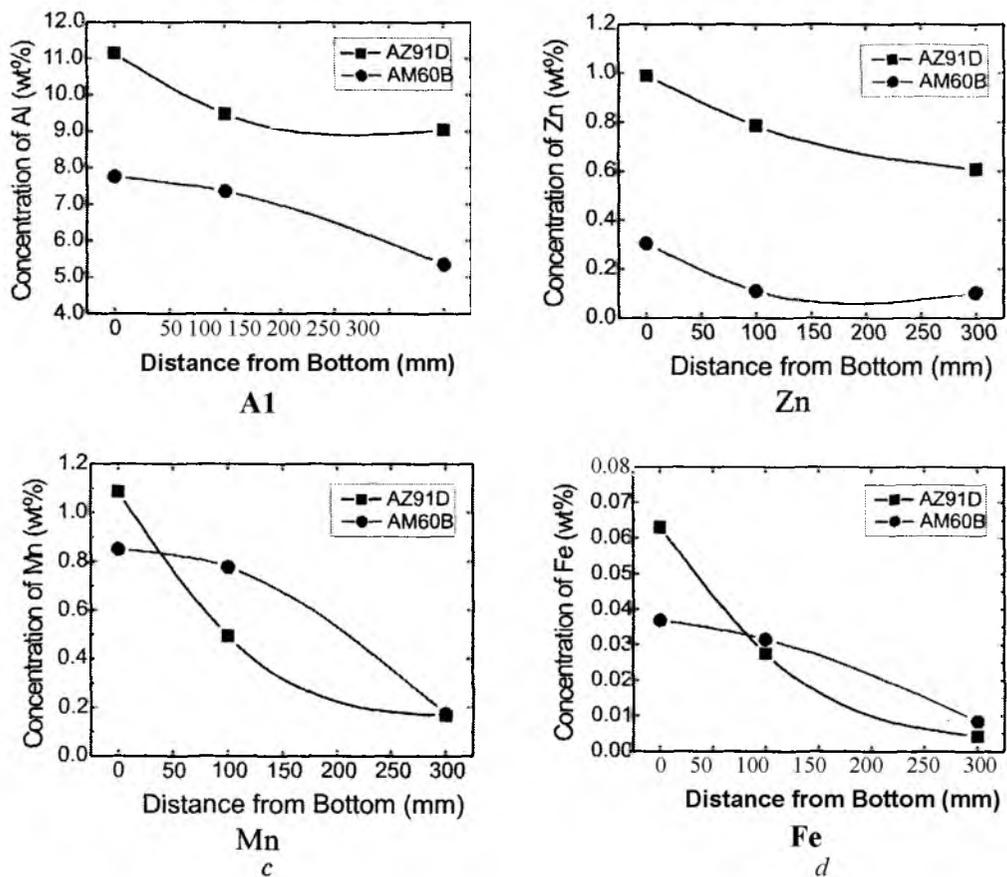
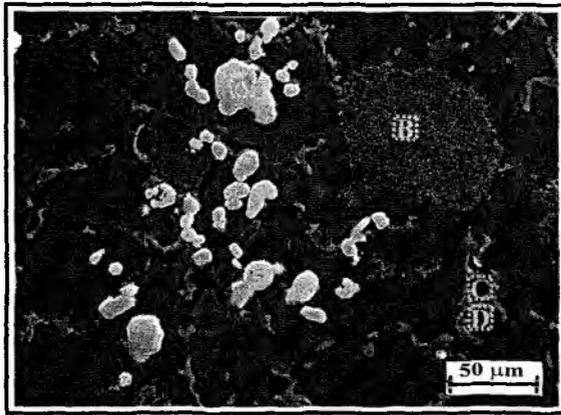


Fig. 2. Variations of the concentration of alloying elements and impurity on the position of crucible during hot-chamber die casting process

what greater at the bottom compared to the other regions. The higher viscosity of the melts indicates that the heavier elements than magnesium such as Al, Zn, Mn, and Fe were concentrated at the bottom, where they form complex intermetallic phases as shown in Fig. 3 by reacting one another during long term-exposure of hot chamber die-casting process.

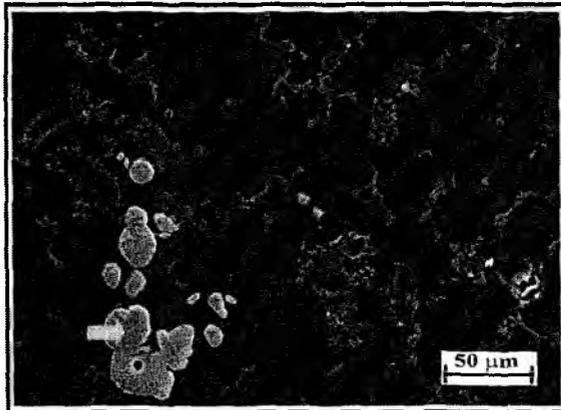
Fig. 3 shows the SEM microstructures of AZ91D obtained from the bottom, 10 and 30 cm higher region of crucible. The microstructure of AZ91D obtained from the bottom of crucible (Fig. 3, a) showed considerable volume of second phases including complex Al-Fe-Mn



Element	A	B	C	D
C	9.25	13.95	22.55	33.69
O		18.79	3.35	6.35
Mg	0.76	57.95	52.06	53.91
Al	35.51	7.80	18.20	5.31
Mn	49.12			
Fe	5.10			
Zn		1.51	3.84	0.74
Total	100.00	100.00	100.00	100.00

Al-Fe-Mn compound
 Oxide
 Inclusion or oxide

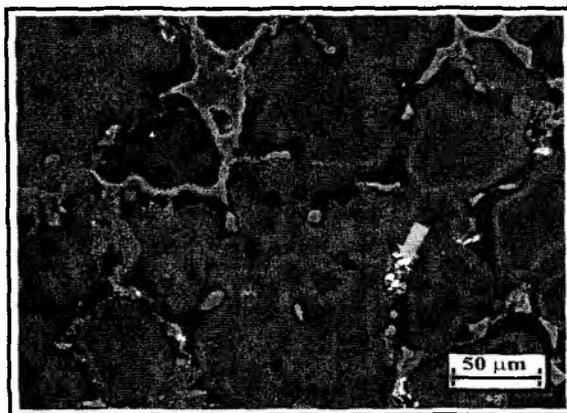
a bottom



Element	wt(%)	atomic(%)
C	8.53	23.33
Mg	0.77	1.05
Al	34.66	42.18
Mn	50.01	29.89
Fe	5.62	3.30
Total	100.00	100.00

Predicted Al-Fe-Mn compound

b 10cm high from the bottom



Element	wt(%)	atomic(%)
C	12.18	26.98
O	2.10	3.50
Mg	18.80	20.57
Al	32.96	32.50
Mn	33.96	16.45
Total	100.00	100.00

Predicted Al-Mn compound

c 30cm high from the bottom

Fig. 3. SEM microstructures of AZ91D samples obtained from different positions of crucibles

compound (A), oxides (B), and inclusions (C). However, the microstructure of AZ91D sample obtained at around gooseneck (Fig. 3, *b*) showed only trivial amount of Al-Fe-Mn phase. Thus, the increased viscosity at the bottom of crucible is mainly due to Al-Fe-Mn intermetallic phase, which caused macrosegregation during long-time operations.

2. Effect of post-stirring holding time

Post-stirring holding up to 250 minutes did not significantly change the composition of the molten

metals. Fig. 4 shows the variations in the concentration of aluminum and zinc in AZ91D and AM60B on holding time. In both cases, no remarkable variations in the concentration of alloying elements were observed although the concentration of Al in AZ91D slightly decreased after 240 minutes. In contrast, the concentration of Fe in AZ91D was relatively high (~0.007% in AZ91D) immediately after stirring, which was reduced under 0.005%, maximum limit in AZ91D, after 80 minutes holding. The initial high Fe content is considered as the result of flotation

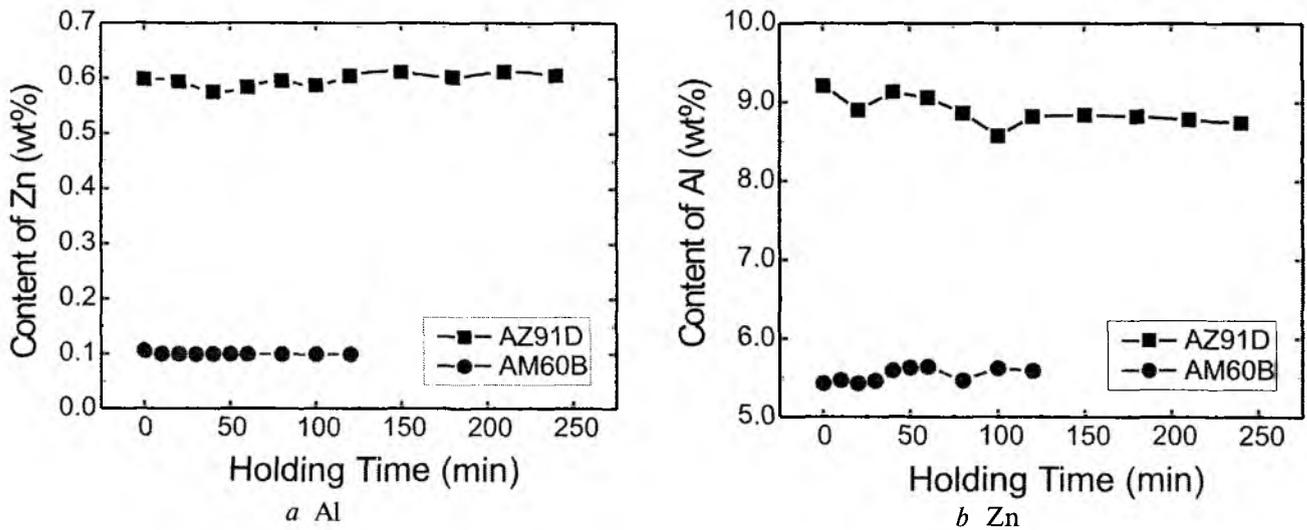


Fig. 4. Variations of the concentration of (a) Al and (b) Zn on holding time

of Fe-rich melts at the bottom of the crucible due to the stirring.

The above results indicate that the concentration of alloying elements such as Al and Zn does not significantly vary during short-periods of holding time at around the entrance of gooseneck in hot-chamber die casting system. However, repeated casting operation without bailing out may induce macro segregation in heavier elements such as Al, Zn, Mn, and Fe, etc. The increased Fe-concentration at the bottom of crucible may cause higher corrosion rate of die cast products, which need to be completely cleaned up periodically.

Conclusions

During a hot-chamber die casting process, the content of alloying elements and impurities varied with the position of crucible. Heavier elements such

as Al, Zn, Mn, Fe, etc. were concentrated at the bottom of crucible, which is resulted from long-time, repeated casting operations without bailing out. The macro-segregation of alloying elements and impurities within the crucible is related to the relative density and reactivity between the elements, by which considerable volumes of Al-Fe-Mn phase were formed at the bottom of crucible. Short-periods of holding time, however, did not significantly vary the concentration of Al and Zn at around the entrance of gooseneck.

References

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