**Magnesium Technology 2011**
*Edited by: Wim H. Sillekens, Sean R. Agnew, Neale R. Neelameggham, and Suveen N. Mathaudhu*
***TMS (The Minerals, Metals & Materials Society), 2011***

# WIDE STRIP CASTING TECHNOLOGY OF MAGNESIUM ALLOYS

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Keywords: Strip casting, Twin roll casting, Magnesium sheet, Magnesium coil

## Abstract

Extensive investigations relating to the production of high performance and low cost magnesium sheet by strip casting have been performed for the application to automotive parts and electronic devices. Research on magnesium sheet production technology started in 2004 by *Research Institute of Industrial Science and Technology* (RIST) with support of *Pohang Iron and Steel Company* (POSCO). POSCO has completed the world's first plant to manufacture magnesium coil. Another big project in order to develop wide strip casting technology for the automotive applications of magnesium sheets was started in succession.

In this paper, the recent results for wide magnesium strip casting will be presented. Magnesium coils of ~16 tons with 2,000 mm width, 2,500 mm diameter and 4~8 mm thickness were successfully manufactured by the strip casting process. Surface defects like inverse segregations could be minimized by adequate process control. As-cast cross-sectional microstructures of magnesium strips consist of a surface chill zone, a dendritic columnar structure and a central region.

## Introduction

Magnesium alloys have high potentials as structural materials due to their excellent properties such as lightweight, high specific strength and excellent damping capacity. Recently, request for low cost magnesium sheet-typed materials has been drastically increased for applications to automotive and electronic industries. The research project in order to satisfy these demands has been begun from 2004 by RIST with support of POSCO. The purpose of that project was to confirm which high quality magnesium sheet coil was just able to be produced through twin roll casting technology. For that reason, the maximum width of the as-strip cast strips was limited to about 600 mm, which strip has been tried to be apply to the narrow parts such as electronic parts and kitchen goods. The new integrated process of strip casting and warm coil rolling have been established at the pilot plant scale, and the successful research results have led the construction of POSCO Magnesium coil plant, which has commenced magnesium coil production since summer 2007 in the world' first.

It is necessary to secure competitiveness against aluminum alloys for expanding the demand of magnesium sheets. This is able to be achieved by applying magnesium sheets into large scaled markets such as automotive industry. The process development to produce the wider sheets is requested thus, because the sheet of 600 mm in width was too narrow to be utilized for the main parts of vehicles. A big project relative to magnesium sheet production accordingly has been planned since the completion of POSCO plant in succession. This new one was focused on broadening the width of magnesium strip coil for entering into automotive markets. The project in order to comply with this purpose was finally launched from 2008. The core in the project is the establishment of strip casting technology to be able to produce highly graded magnesium sheet coils with 2,000 mm width for automotive parts.

In this paper, the current results for magnesium 'wide strip casting technology' – being able to produce the strip with much wider width than that in 2004 project – will be introduced. In addition, the as-cast microstructures of different magnesium alloys produced via this process are discussed.

## Wide Strip Casting

Strip casting is a well-known economical production technology to manufacture thin sheets of various metallic materials directly from its melt. Recently, a similar technology has been applied to magnesium thin strip production [1-9]. In strip casting, molten metal is fed into gap between a pair of water-cooled rolls, where it is solidified and rolled, then produced to sheet directly from melt.

There are mainly two types of defects: inverse segregation and inclusions. The inclusions, which are divided into metallic and non-metallic, can be controlled by prevention of magnesium oxidation and melt cleanliness. Evolution of inverse segregation, however, is closely correlated with solidification mechanism during strip casting process. The word of inverse segregation means the segregation formed in the opposite side of the position to have to be segregated metallurgically. In as-cast magnesium strip, the inverse segregation is just observed on both surfaces which the solidification begins, as follows; firstly, highly concentrated liquid phase is trapped into central region of strip (Figure 1a) and then the trapped liquid outflow from the center region to strip surface by pushing of a pair of casting rolls through weak inter-dendrite (Figure 1b).

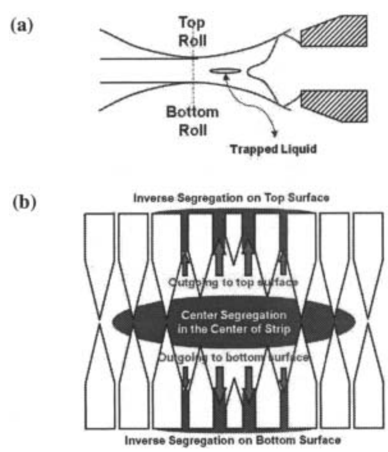


Figure 1. Schematic diagrams for the formation of inverse segregations; (a) trapping of liquid phase into central region, and (b) outgoing of the trapped liquid phase from center to each surface of strip.

Following aspects in this process are important control parameters for decreasing the defect like inverse segregation; casting speed, melt temperature, roll separation force, roll gap and setback distance, etc. In addition, the following factors are especially important to control the quality of final products for magnesium alloys; prevention of magnesium oxidation and melt cleanness.

Width of as-cast strip is able to be extended by broadening the exit slit of nozzle tip that feed melt into roll gap in horizontal strip casting. The extension of nozzle tip makes the optimization of melt flow difficult in general. The broadness of the strip width therefore results in irregular state during strip casting and the decrease of strip quality. High graded wide strip is able to be manufactured by tight control for the above process parameters and a great improvement of nozzle tip design as well.

As shown in Figure 2, wide magnesium coil of about 16 tons with 2,000 mm width, 2,500 mm diameter and 4~8 mm thickness were successfully manufactured during more than 10hrs by the accurate combination of the above-mentioned key parameters in the strip casting process. Magnesium coil in Figure 2 was side-trimmed directly during producing in wide strip caster of our laboratory.

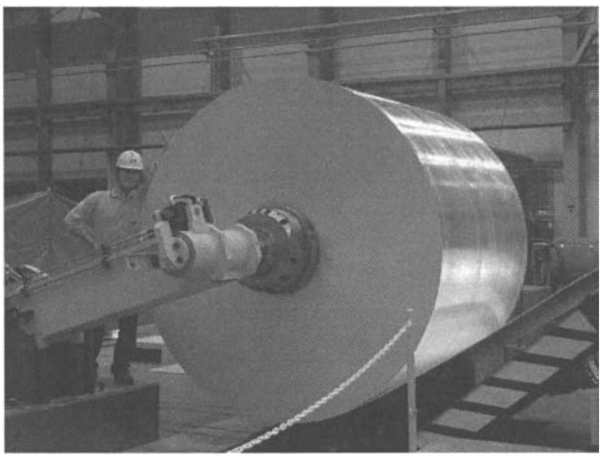

Figure 2. As-cast strip AZ31 alloy coil of about 16 tons with 2,000 mm width, 2,500 mm diameter and 4~8 mm thickness.

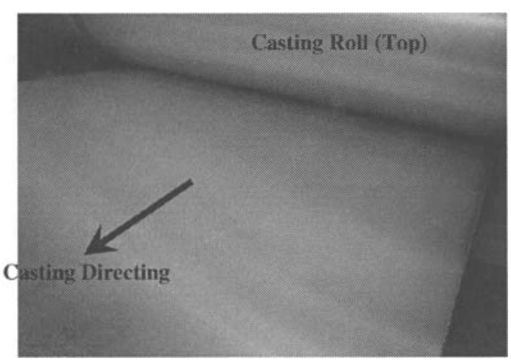


Figure 3. Strip casting process that magnesium strip is produced through the gap of a pair of casting rolls.

Figure 3 shows twin roll casting process that magnesium wide strip was produced through the gap of a pair of casting rolls. As-cast strip had clean surface with silver color and smooth edge shape without the deviation of the width. There were no defects such as inverse segregations and oxide inclusions on the surface of as-cast strip.

### Strip Cast Microstructure

Figure 4 shows a typical microstructure of as-cast strip AZ31 alloy produced by wide twin roll casting system with 2,000 mm width named as Supercaster Plus® of Fata Hunter. This microstructure consists of surface chill zone near top and bottom surfaces, central equi-axed zone in the center of strip thickness, and dendritic columnar zone between surface chill zone and central equi-axed zone. The dendritic columnar zone is especially inclined against casting direction as shown in Figure 4. The microstructure was naturally similar to the one of strip cast AZ31 sheet with 600 mm width [6].

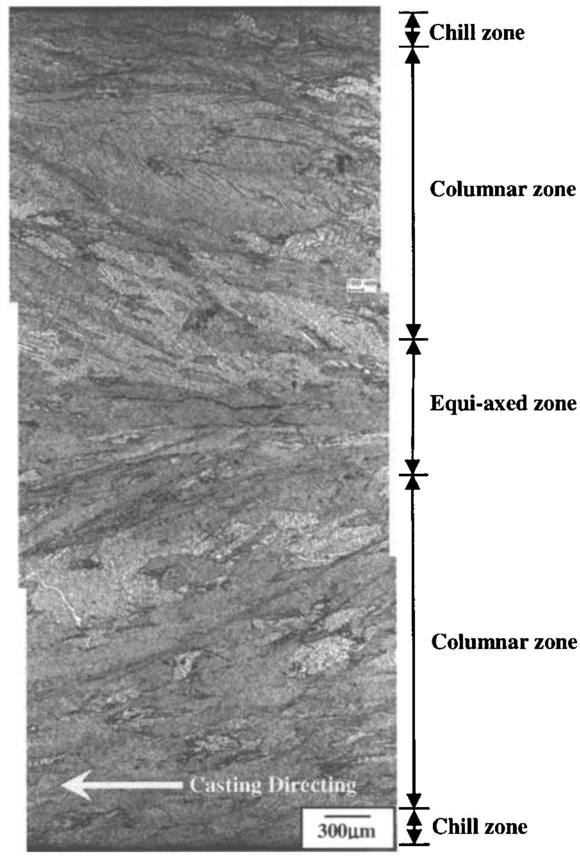


Figure 4. Cross-sectional microstructure of as-cast strip AZ31 alloy of 5.9 mm thickness.

Comparing wide strip cast microstructure of Figure 4 with that of 600 mm width [6], the most important difference in view of as-cast microstructure is the decrease in volume of center segregation in central equi-axed zone. As shown in Figure 1, the trapped liquid phase which induces the center segregation is the source of the principal surface defect of as-cast strip like inverse segregation. High quality of the wide strip overviewed in this paper consequently is due to the reduction in quantity of center segregation.

AZ61 alloy sheet coils were also produced using the same strip caster on the basis of the process condition that was able to manufacture AZ31 strip like Figure 4. As shown in Figure 5, segregation in AZ series alloys was the mixture of β-$Mg_{17}Al_{12}$ phase and α-Mg phase with a small amount of Al-Mn intermetallics and $Mg_2Si$ phase. The $Mg_2Si$ phase was especially supposed to be formed from impurity Si in the magnesium matrix. As the total quantity of alloy element increase, the volume of the segregation increase in AZ series alloys. It is more difficult to make high quality sheet with AZ61 alloy than AZ31 alloy.

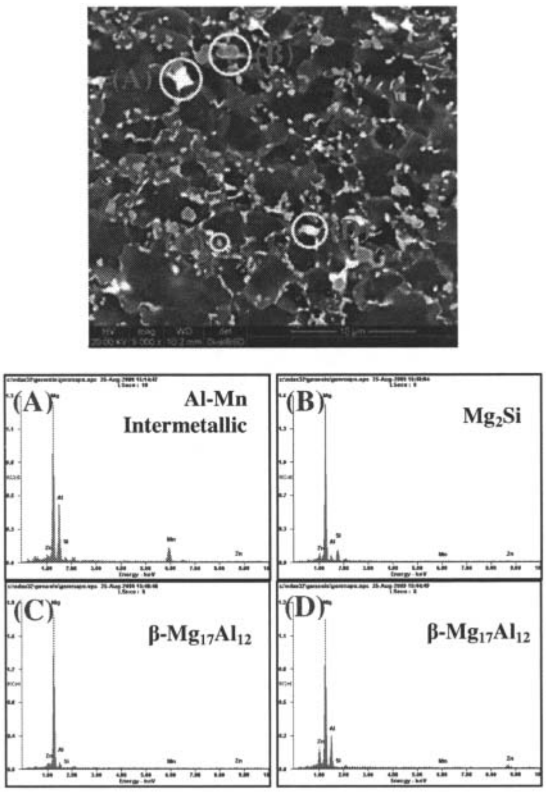


Figure 5. SEM/EDS results for the phases in segregation in as-cast strip AZ31 alloy.

Figure 6 shows as-cast strip microstructure of AZ61 alloy with more quantity of aluminum. Cross-sectional microstructure of as-cast AZ61 alloy consists of surface chill zone, central equi-axed zone and dendritic columnar zone too. In comparison of the cross sectional microstructure of AZ31 strip, the proportion of columnar zone in AZ61 microstructure was reduced and the ratio of surface chill zone and central equi-axed zone is increased. As mentioned above, inverse segregation of each surface originates from trapped liquid in central region. As the fraction of columnar structure decrease and the proportion of equi-axed structure increase, the inter-dendrite route from center to surface is wavier and longer. AZ61 sheet coil without surface defect in Figure 6 was due to the extension of the area with equi-axed dendrites and the decrease of columnar structure, even though the AZ61 alloy is containing more aluminum than the AZ31 alloy.

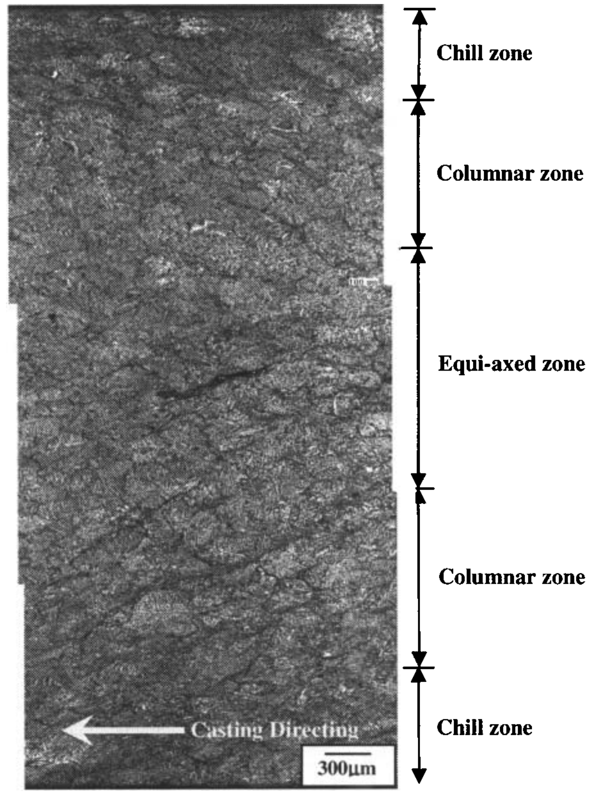


Figure 6. Cross-sectional microstructure of as-cast strip AZ61 alloy of 5.4 mm thickness.

## Conclusion

POSCO has started the world's first magnesium coil production since summer 2007 based on the successful results of the projects performed by our institute from 2004. A successive big project for developing wide strip casting technology has commenced in 2008.

Wide magnesium coil of about 16 tons with 2,000 mm width, 2,500 mm diameter and 4~8 mm thickness were successfully manufactured during more than 10 hrs through the accurate combination of key parameters in strip casting process.

As-cast strips show defect-free surface with silver color and smooth edge shape without the deviation of the width. As-cast strip microstructures of AZ31 and AZ61 alloy consists of surface chill zone, central equi-axed zone and dendritic columnar zone. Segregation-free surface of AZ31 strip was estimated to be due to the reduction of central segregation. Improvement of surface quality in AZ61 strip is deduced to be caused by extensive increase of the area with equi-axed dendrites.

Coil rolling test for the as-cast strip coils is going to be performed through the company with magnesium coil roller in future. The mechanical properties for the as-cast and rolled sheets will be evaluated in succession. And then more extensive researches for automotive applications of wide magnesium strip, such as forming, surface treatment, welding, are planning to be executed.

**Acknowledgements**

Financial support from POSCO is gratefully acknowledged. The authors also thank to Prof. N.J. Kim (POSTECH), Prof. S. Ahn (POSTECH), and Prof. K.S. Shin (Seoul National University) for their helpful advice and encouragement.

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