UDK 669.721.5:669.892:620.17
Original scientific article/Izvirni znanstveni članek

ISSN 1580-2949
MTAEC9, 47(3)299(2013)

ADDITION OF STRONTIUM TO AN Mg-3Sn ALLOY AND AN INVESTIGATION OF ITS PROPERTIES

DODATEK STRONCIJA ZLITINI Mg-3Sn IN PREISKAVA NJENIH LASTNOSTI

Mediha Öbekcan[1], Aysun Ayday[1], Hüseyin Şevık[2], Süleyman Can Kurnaz[1]

[1]Sakarya University, Engineering Faculty, Department of Metallurgical and Materials Engineering, Sakarya, Turkey
[2]Mersin University, Engineering Faculty, Department of Metallurgical and Materials Engineering, Mersin, Turkey
ckurnaz@sakarya.edu.tr

Prejem rokopisa – received: 2012-08-13; sprejem za objavo – accepted for publication: 2012-11-27

The effect of strontium additions in mass fractions of (0.05, 0.1, 0.2, 0.5 and 1) % to a magnesium alloy (Mg-3Sn) was investigated in this work. The alloys were gravity cast under a controlled atmosphere. The mechanical properties and the microstructures of the above alloys were examined and recorded. The results revealed that an addition of strontium to the above alloy had significantly affected its microstructure. The X-ray diffraction results showed that in all of the obtained alloys the main phases were α-Mg and Mg_2Sn, and that the strontium-based intermetallics were not detected. The hardness values increased with the increasing strontium content. The highest yield strength, tensile strength and elongation were exhibited by the Mg-%3Sn-%0.1Sr alloy.

Keywords: Mg-Sn alloy, Sr addition, mechanical properties

V tem delu je bil preiskovan učinek dodatka masnih deležev stroncija (0,05; 0,1; 0,2; 0,5 in 1) % magnezijevi zlitini (Mg-3Sn). Zlitine so bile gravitacijsko lite v kontrolirani atmosferi. Preiskane in ugotovljene so bile mehanske lastnosti in mikrostruture navedenih zlitin. Rezultati so pokazali, da dodatek stroncija pri tej zlitini močno vpliva na mikrostrukturo. Rezultati rentgenske difrakcije so pokazali, da so glavne faze α-Mg, Mg_2Sn v preiskovanih zlitinah, niso pa bile odkrite intermetalne faze na osnovi stroncija. Vrednosti trdote so naraščale z naraščajočo vsebnostjo stroncija. Najvišja meja plastičnosti, najvišja trdnost in največji raztezek se je pokazal pri zlitini Mg-%3Sn-%0,1Sr.

Ključne besede: zlitina Mg-Sn, dodatek Sr, mehanske lastnosti

1 INTRODUCTION

There have been various investigations to identify the properties of magnesium and its alloys with regard to their use in industrial applications due to their low density in comparison with the other commercial, low-density alloys such as aluminium.[1–5] Generally, magnesium alloys are based on the Mg–Al system. For example, aluminium-containing magnesium alloys will have an $Mg_{17}Al_{12}$ compound, which adversely influences the mechanical properties at high temperatures.[6,7] It is therefore important to add another alloying element to reverse such an effect. Such elements are strontium (Sr), calcium (Ca) and tin (Sn).[8,9] In this work aluminium-free magnesium alloys were used (Mg-3Sn).

2 EXPERIMENTAL WORK

The alloys were melted in a stainless-steel crucible using an electric-resistance furnace facilitated with a CO_2-0.2SF_6 atmosphere. Commercially pure magnesium, tin and Mg-%20Sr were used in this case as shown in **Table 1**. The melt was held at 760 °C for 10 min, then stirred to ensure a homogeneous distribution of all the alloying elements. The melts was then poured into a preheated steel die at 270 °C. Cross-sections were taken from similar areas of all the castings and ground down to 1200 grit using silicon carbide papers. The cross-sections were then polished down to 1 μm samples using abrasive diamond wheels. The specimens were chemically etched using an acetic picric acid compound (5 ml of acetic acid, 6 g of picric acid, 10 ml of distilled water, 100 ml of ethanol), then examined using a JOEL scanning electron microscope (SEM). The second lot of cross-sections were taken from similar areas of all the castings. The sections were ground using silicon carbide papers before examining them with an X-ray diffraction [(XRD) Rigaku D-Max 1000 X-ray diffractometer with Cu Kα radiation] machine to identify their compounds and phases.

Table 1: Chemical compositions of the investigated alloys (mass fraction, *w*/%)

Tabela 1: Kemijska sestava preiskovanih zlitin (masni deleži, *w*/%)

Alloys	Composition	Mg	Sn	Sr
1	Mg-3Sn	96.8	2.97	–
2	Mg-3Sn-0.05Sr	96.5	2.92	0.046
3	Mg-3Sn-0.1Sr	96.1	2.94	0.09
4	Mg-3Sn-0.2Sr	95.9	2.97	0.183
5	Mg-3Sn-0.5Sr	95.9	2.94	0.45
6	Mg-3Sn-1Sr	95.7	2.89	0.92

Brinell hardness tests were performed on all the cross-sections using a diameter ball 2.5 mm with an

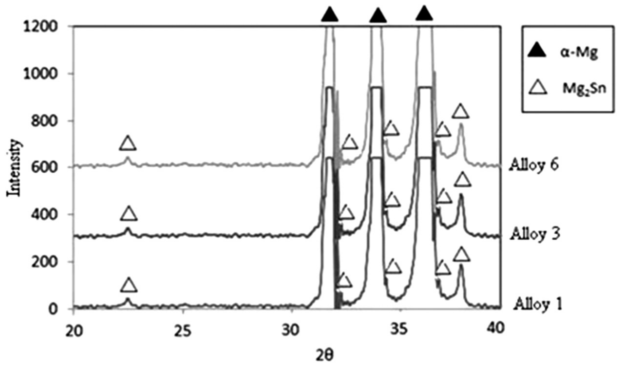


Figure 1: XRD spectrums of selected alloys
Slika 1: XRD-spektri izbranih zlitin

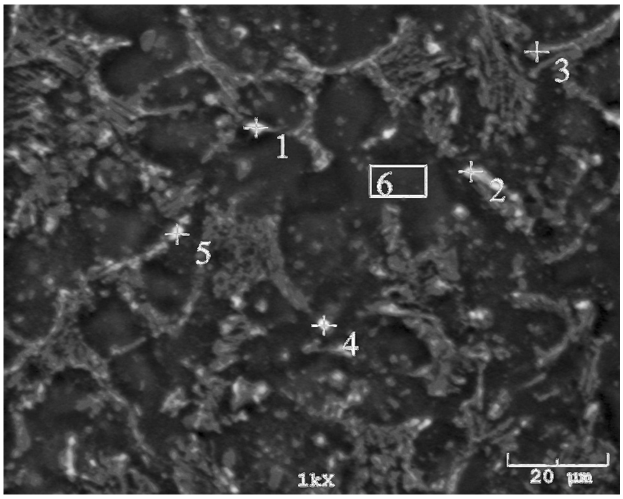
applied load of 31.25 kg. Tensile tests were carried out using an Instron 3367 universal testing machine with a fixed ram speed of 0.2 mm/s at ambient temperature.

3 RESULTS AND DISCUSSION

The XRD results shown in **Figure 1** revealed that the main phases were α-Mg and Mg_2Sn. The XRD results, on the other hand, failed to show any Mg-Sr- and Sn-Sr-based intermetallics in any of the tested castings. Here the results are in agreement with the study made by Hongmei Liu.[9]

The SEM images shown in **Figure 2** revealed that the microstructures of these alloys mainly consisted of the primary α-Mg surrounded by the boundary of the Mg_2Sn phase. It is very clear that the primary α-Mg in the strontium-free alloy 1 is much bigger than those seen in alloys 2, 3, 4, 5 and 6. The intermetallics (Mg_2Sn), on the other hand, appear to be smaller and more nodular than those of 2, 3, 4, 5 and 6. The increase in the strontium content influenced the formation of a large Mg_2Sn phase, which also influenced the mechanical properties. **Figure 3** shows the results of the energy-dispersive spectrometer (EDS) obtained for alloy 6. The figure shows that strontium was completely dissolved in the Mg_2Sn intermetallic, which influenced its final shape.

The hardness increased and was directly proportional to the increase in the strontium content as shown in



	Mg	Sn	Sr	O
1	79.266	9.935	0.961	9.837
2	80.628	8.260	0.699	10,412
3	84.764	4.952	2.634	7.649
4	75.648	11.145	0.438	12.770
5	71.894	11.235	2.091	14.780
6	98.733	1.267	–	–

Figure 3: EDS analysis of alloy 6
Slika 3: EDS-analiza zlitine 6

Figure 4. The tensile and the yield strengths increased only up to alloy 3, then they decreased for alloys 4, 5 and 6. The elongation results showed a similar manner as seen in the cases of the tensile and yield strengths. It is clear from **Figure 4** that the yield and tensile strengths reached their maximum of about 78 MPa and 157 MPa when 0.1 % Sr was used. The hardness, on the other hand, reached a maximum of 40 BH when 1 % Sr was used.

The reason for the increase in the tensile and yield properties in the case of alloy 3 can be clearly attributed to its microstructure. It is very clear from the microstructure that the longitudinal shape of the Mg_2Sn intermetallic has influenced the increase in its tensile and yield strengths.

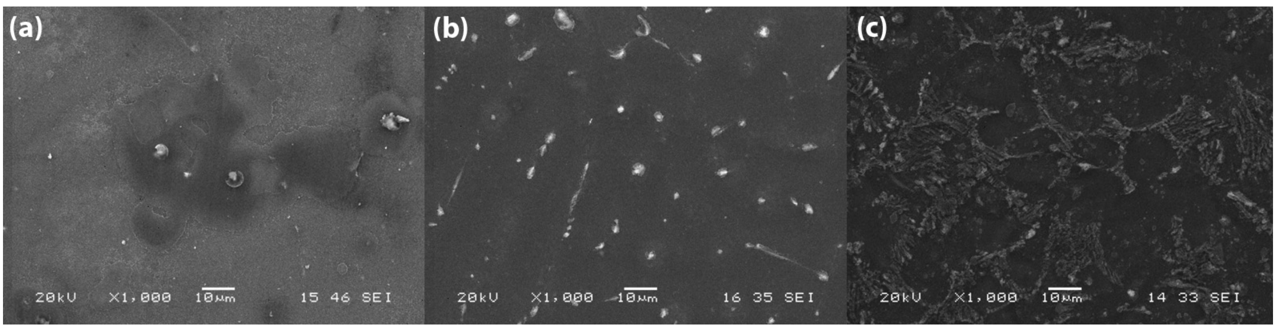


Figure 2: SEM micrographs showing microstructures of: a) alloy 1, b) alloy 3 and c) alloy 6
Slika 2: SEM-posnetki mikrostrukture: a) zlitina 1, b) zlitina 3 in c) zlitina 6

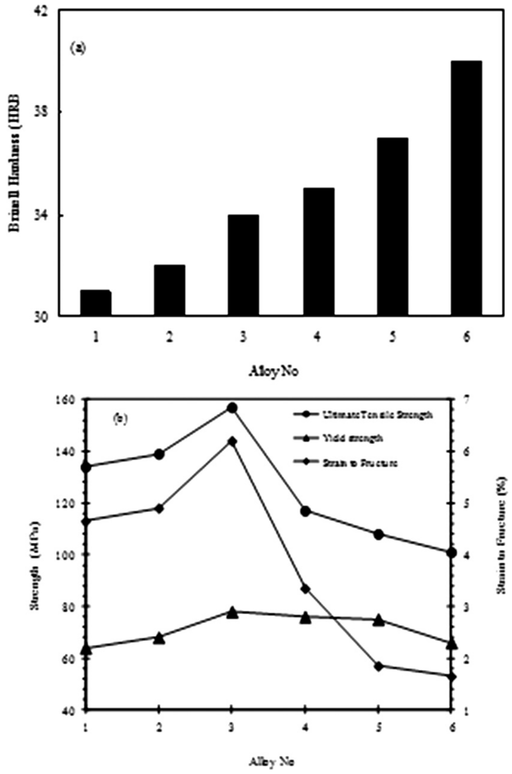


Figure 4: Mechanical test results for the alloys: a) hardness and b) strength and strain

Slika 4: Rezultati mehanskih preizkusov zlitin: a) trdota in b) trdnost in deformacija

4 CONCLUSIONS

1. The microstructures of all the above alloys consisted of the α-Mg and Mg_2Sn phases.
2. The strontium addition modified the microstructural shapes of the intermetallics.
3. The addition of Sr affected the UTS, yield and elongation only to a certain extent.
4. The hardness increase was directly proportional to the increase in strontium.

5 REFERENCES

[1] A. Yu, S. Wang, N. Li, H. Hu, Journal of Materials Processing Technology, 191 (**2007**), 247–250

[2] H. Hu, Journal of Materials Science, 33 (**1998**), 1579–1589

[3] H. Q. Sun, Y. N. Shi, M. X. Zhang, Surface and Coating Technology, 202 (**2008**), 2859–2864

[4] W. Huang, B. Hou, Y. Pang, Z. Zhou, Wear, 260 (**2006**), 1173–1178

[5] T. A. Leil, N. Hort, W. Dietzel, C. Blawert, Y. Huang, K. U. Kainer, K. P. Rao, Transactions of Nonferrous Metals Society of China, 19 (**2009**), 40–44

[6] S. Kleiner, O. Beffort, A. Wahlen, P. J. Uggowitzer, Journal of Light Metals, 2 (**2002**), 277–280

[7] H. Liu, Y. Chen, H. Zhao, S. Wei, W. Gao, Journal of Alloys and Compounds, 504 (**2010**), 345–350

[8] S. Li, B. Tang, D. Zeng, Journal of Alloys and Compounds, 437 (**2007**), 317–332

[9] H. Liu, Y. Chena, Y. Tang, S. Wei, G. Niu, Journal of Alloys and Compounds, 440 (**2007**), 122–126