Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 20 ISSUES 1-2 January-February 2007

Microstructure of AE44 magnesium alloy before and after hot-chamber die casting

A. Kiełbus *
Department of Materials Science, Silesian University of Technology, ul. Krasińskiego 8, 40-019 Katowice, Poland
* Corresponding author: E-mail address: andrzej.kielbus@polsl.pl

Received 19.10.2006; accepted in revised form 15.11.2006

Manufacturing and processing

ABSTRACT

Purpose: AE44 magnesium alloy allows attractive high temperature mechanical properties, as well as die-castability and good corrosion resistance. It contains magnesium, aluminum, cerium and lanthanum. Typically, it is used in automotive industry for structural components working at elevated temperature (150÷175°C). The aim of this paper is to present the results of investigations on the microstructure of the AE44 magnesium alloy before and after hot chamber die casting.

Design/methodology/approach: Die casting was carried out on 280 tone locking force hot-chamber die casting machine. For the microstructure observation, a Olympus GX+70 metallographic microscope and a HITACHI S-3400N scanning electron microscope with a Thermo Noran EDS spectrometer equipped with SYSTEM SIX were used.

Findings: Based on the investigation carried out it was found that the AE44 magnesium alloy before die casting is characterized by α-Mg solid solution with globular, lamellar and acicular precipitations of Al11RE3 and Al_3RE phases. Moreover, there was found globular Mn-rich phase existence (probably Al_8CeMn_4 phase). After hot-chamber die casting the microstructure of AE44 alloys consist of equiaxed dendrites of α-Mg with precipitates of $Al_{11}RE_3$ and probably Al_2RE phase.

Research limitations/implications: Future researches should contain investigations of the influence of the hot chamber die casting process parameters on the microstructure and mechanical properties of AE44 magnesium alloy.

Practical implications: AE44 magnesium alloy can be cast with cold- and hot-chamber die casting machine. Results of investigation may be useful for preparing die casting technology of this alloy.

Originality/value: The results of the researches make up a basis for the investigations of new magnesium alloys containing rare earth elements for hot chamber die casting designed to service in elevated temperature.

Keywords: Metallic alloys; Manufacturing and processing; Casting; AE44 magnesium alloy

1. Introduction

Magnesium alloys belong to the lightest structural alloys. The most popular process for the manufacture of magnesium alloys casts is cold or hot chamber die casting [1]. The process, due to economic reasons, should provide for automatic delivery of a liquid material to a mould. It is much easier in the case of hot chamber casting [2,3]. The cold chamber process consists of two stages. At the first stage, liquid metal is fed into an injection chamber and then (stage two) it is injected into a mould. Moreover, during this process, neither the chamber nor the piston are heated, which makes it difficult to ensure an appropriate casting temperature. Such problems are not experienced while applying the hot chamber method. During the process, the siphon is immersed in a liquid metal bath, as the result of which it is constantly filled with metal, which ensures the obtaining of the required casting temperature. Due to placing the injection mechanism directly in the bath, the casting process is faster and, consequently, more efficient [4,5].

Die cast magnesium alloys applications can be grouped into three main areas: safety parts (high ductility and energy absorption), structural parts (high strength) and elevated temperature parts with good creep strength [6]. The Mg-Al-RE creep resistant alloys have good ambient and elevated temperature properties (high yield strength, good tensile strength and fatigue) up to 175°C [7]. The strength and castability of these alloys can be improved by increasing the Al content but this is generally at the expense of their creep resistance [8]. An addition of rare-earth elements enhances magnesium alloys strength at a room temperature, increase creep resistance and what is more, it reduces porosity of casts [9]. These alloys were targeted for automotive applications such as oil pans and automatic transmission housings [10,11]. Microstructural stability and creep strength remain major challenges in the development of these alloys [12]. AE44 is a new high pressure die casting magnesium alloy, which has attractive high temperature mechanical properties, as well as die castability and corrosion resistance [13]. HPDC AE44 magnesium alloy is being considered for structural components such as automotive front engine cradle [14].

2. Description of the work methodology and material for research

2.1. Material for research

The material for the research was the AE44 alloy in ingot condition and after hot chamber die casting. The chemical composition of the AE44 alloy is provided in Table 1.

Table 1.
Chemical composition of the AE44 alloy in wt.-%

Al	Mn	Zn	RE	Mg
3,98	0,35	0,2	3,95	balance

2.2. Research methodology

Die casting was carried out on 280 tone locking force hot-chamber die casting machine. Table 2 lists the process parameters used for this work. Casting was undertaken at the NTP firm in Kędzierzyn-Koźle, Poland.

Table 2.
Hot chamber die-casting process parameters

Parameter	Value
Piston speed	3,0 m/s
Pressure	100 bar
Casting temperature	680 °C
Die temperature	200 °C

The samples for structural examination were ground, mechanically polished and finally etched in a 5% acetic acid. For the microstructure observation, a Olympus GX+70 metallographic microscope and a HITACHI S-3400N scanning electron microscope with a Thermo Noran EDS spectrometer equipped with SYSTEM SIX were used.

3. Description of achieved results of own researches

3.1. Microstructure of AE44 ingot

The AE44 magnesium alloy in ingot condition is characterized by a solid solution structure α with acicular and irregular precipitations (fig. 1) [15]. These second phases were composed mainly of Al, Ce, La and Nd (fig. 2 and 3).

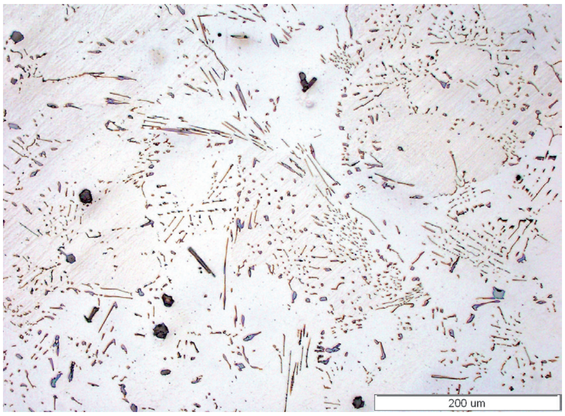

Fig. 1. LM microstructure of as-cast AE44 alloy

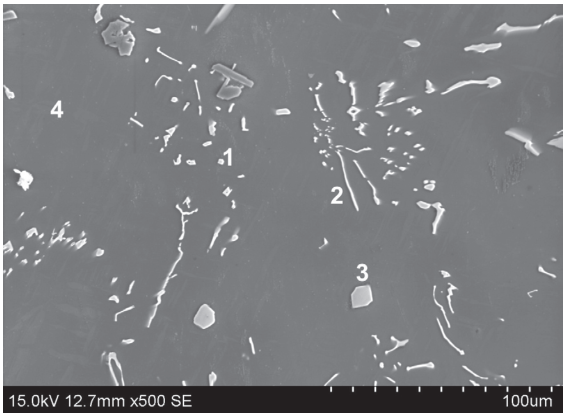

Fig. 2. SEM microstructure of AE44 ingot

EDS analysis also show that globular particles (point 1, fig. 2, table 3) have higher content of cerium than other constituents of the Ce-rich mischmetal, while the acicular compounds (point 2, fig. 2, table 3) have higher content lanthanum and neodymium than the others. Moreover, in microstructure are Mn-rich particles with cerium and aluminum (point 3, fig. 2, table 3), but the amount Mn-rich phase is too small to be detected by X-ray diffraction. The aluminum dissolved in α-Mg is lower than its maximal solid solubility at room temperature (point 4, fig. 2, table 3).

Table 3.
Chemical composition of phases identified in AE44 ingot

Area	Element [at.- %]							Likely phase
	Mg	Al	Ce	La	Nd	Mn	ΣRE	
1	11.12	71.26	15.54	2.08	-	-	17.62	$Al_{11}RE_3$
2	11.74	64.01	16.17	4.55	3.53	-	24.24	Al_3RE
3	10.46	53.47	5.25	-	-	30.83	5.25	Al_8CeMn_4
4	99.57	0.43	-	-	-	-	-	α

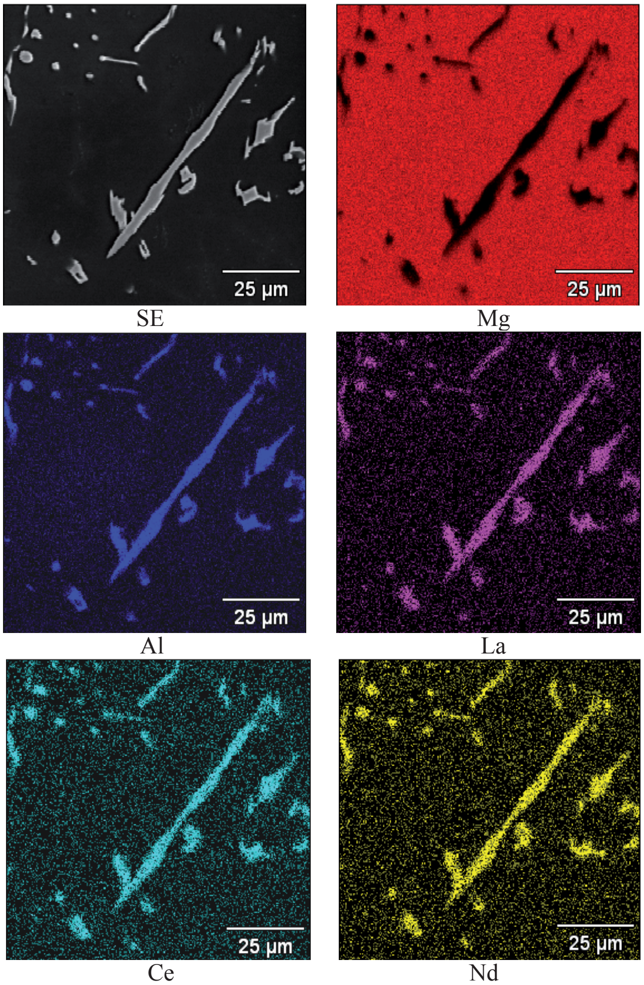

Fig. 3. The SE image and the distribution of Mg, Al, La, Ce and Nd in microareas of AE44 alloy

Results of XRD analysis (fig. 4) show the main intermetallic phases in AE44 alloys were $Al_{11}RE_3$ and probably Al_3RE but its diffraction lines are very weak.

Based on the XRD pattern and results of microanalysis particles in this alloy can be identified as $Al_{11}RE_3$ phase. Al_3RE particles can be identified with some lanthanum and neodymium substituting cerium and Mn-rich particles, containing aluminium and cerium can be identified as Al_8CeMn_4 phase.

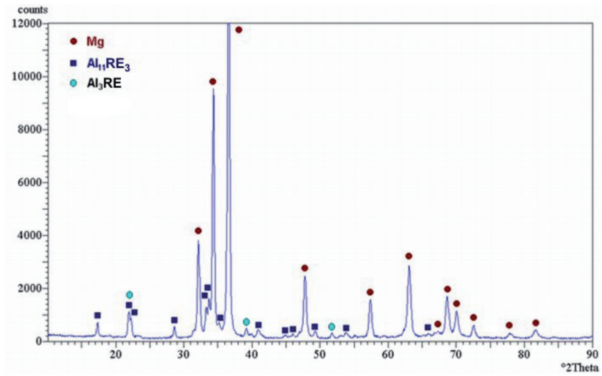

Fig. 4. X-ray diffraction pattern of AE44 alloy

3.2. Microstructure of the AE44 alloy after hot chamber die casting

The AE44 magnesium alloy after hot chamber die casting is characterized by a solid solution structure α with small particles of intermetallic phases on grain boundaries. The solid solution is characterized by very small grains due to fast cooling rate (fig.5).

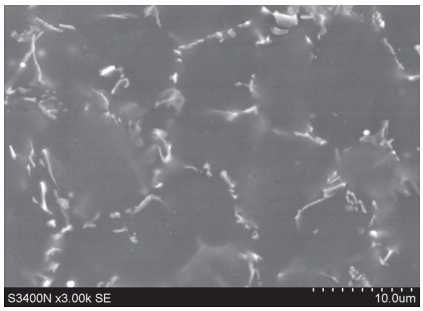

Fig. 5. SEM microstructure of AE44 after hot chamber die casting

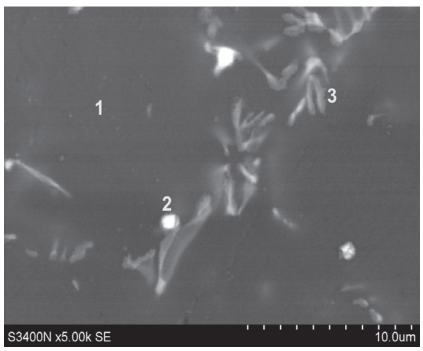

Fig. 6. Microareas of the chemical composition analysis in the AE44 alloy after hot chamber die casting

SEM-EDS and XRD analysis indicated that in AE44 alloy after hot chamber die casting the grain boundary phase formed are mainly $AL_{11}RE_3$ and Al_2RE (fig. 6, table 4). The phases Al_3RE and Al_8CeMn_4 were not observed. The results of microanalysis showed a relatively high aluminum content in the matrix of die-cast alloy compare to standard ingot.

Table 4.
Chemical compositions of identified phases in AE44 alloy after hot chamber die casting

Area	Element [at.- %]						Likely phase
	Mg	Al	Ce	La	Nd	ΣRE	
1	98.56	1.44	-	-	-	-	α
2	87.71	7.88	1.29	2.53	0.59	4,35	Al_2RE
3	84.90	10.93	1.71	1.96	0.25		$Al_{11}RE_3$

In order to identify the existing phases in the alloy, XRD analysis was performed (fig. 7). The XRD indicates the die-cast microstructure of AE44 alloy is mainly composed of α-Mg phase with $Al_{11}RE_3$ and probably Al_2RE phase but its diffraction lines are very weak. The peak positions for magnesium, the major phase, are shifted to higher angles, a shift that is consistent with dissolved aluminum in this phase.

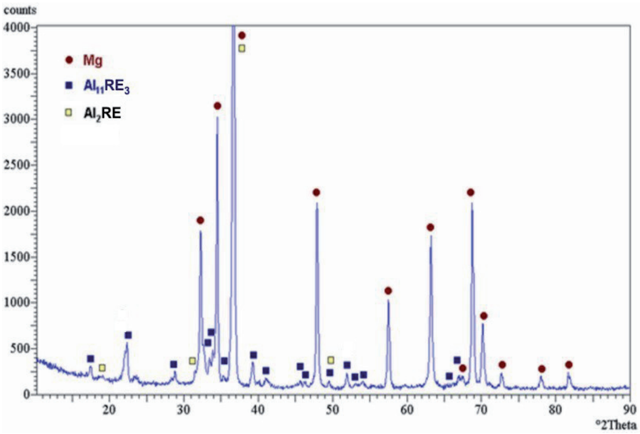

Fig. 7. X-ray diffraction pattern of AE44 alloy after die casting

4. Conclusions

Based on the research results obtained, it has been found that:

1. The AE44 magnesium alloy in as ingot condition is characterized by a solid solution structure α with acicular and irregular precipitations of $Al_{11}RE_3$ and probably Al_3RE and Al_8CeMn_4 phases.
2. The AE44 magnesium alloy after hot chamber die casting is characterized by a solid solution structure α with small precipitations of $Al_{11}RE_3$ and probably Al_2RE. The solid solution is characterized by very small grains due to fastest cooling rate. The Al_3RE and Al_8CeMn_4 phases were not observed.

Acknowledgements

The present work was supported by the Polish Ministry of Education and Science under the research project No PBZ-KBN-114/T08/2004.

References

[1] N. Moscovitch, D. Elezier, E. Aghion, The effect of high pressure die casting process characteristic on the properties and performance of advanced Mg alloys, Magnesium Technology 2005, 357-363.
[2] Magnesium Die Casting Handbook (201), NADCA, Illinois, 1998.
[3] A. Nahed, El-Mahallawy, A. Mohamed. Taha, E. Pokora, F. Klein, On the influence of process variables on the thermal conditions and properties of high pressure die-cast magnesium alloys, Journal of Materials Processing Technology, Vol. 73, Issues 1-3, 1998, 125-138.
[4] M. Avedesian, H. Baker, editors, Magnesium and Magnesium Alloys, ASM Speciality Handbook, ASM International, The Materials Information Society, 1999.
[5] A.Kiełbus, T. Rzychoń, R. Cibis, Microstructure of AM50 die casting magnesium alloy, Journal of Achievements in Materials and Manufacturing Engineering, Vol. 18, 2006, 135-138.
[6] P. Bakke, K. Pettersen, H. Westengen, Improving the strength and ductility of magnesium die casting alloys via rare earth addition, JOM, 2003, 46-51.
[7] B. Mordike, Development of highly creep resistant magnesium alloys, Journal of Materials Processing Technology, Vol. 117, Issue 3, 2001, 391-394.
[8] L.Y. Wei, G.L. Dunlop, The solidification behaviour of Mg-Al-rare earth alloys, Journal of Alloys and Compounds, 232, 1996, 264-268.
[9] I.A. Anyanwu, Y. Gokan, A. Suzuki, S. Kamado, Y. Kojima, S. Takeda, T. Ishida, Effect of substituting cerium rich mischmetal with lanthanum on high temperature properties of die-cast Mg-Zn-Al-Ca-RE alloys, Materials Science and Engineering, A 380, 2004, 93-99.
[10] M.O. Pekguleryuz, E. Baril, Creep resistant magnesium diecasting alloys based an alkaline earth elements, Materials Transactions, Vol. 42, No. 7, 2001, 1258-1267.
[11] H. Friedrich, S. Schumann, Research for a "new age of magnesium" in the automotive industry, Journal of Materials Processing Technology, Vol. 117, Issue 3, 2001, 276-281.
[12] I.P. Moreno, T.K. Nandy, J.W. Jones, J.E. Allison, T.M. Pollock, Microstructural characterization of a die cast magnesium-rare earth alloy, Scripta Materialia 45, 2001, 1423-1429.
[13] P. Bakke, H. Westengen, The role of rare earth elements in structure and property control of magnesium die casting alloys, Magnesium Technology 2005, 291-296.
[14] S.G. Lee, G.R. Patel, A.M. Gokhale, S. Sreerangenthan, M.F. Horstemeyer, Quantitative fractografic analysis of variability in the tensile ductility of high-pressure die-cast AE44 Mg-alloy, Materials Science and Engineering, A 427, 2006, 255-262.
[15] T. Rzychoń, A. Kiełbus, Effect of rare earth elements on the microstructure of Mg-Al alloys, Journal of Achievements in Materials and Manufacturing Engineering, Vol. 17, 2006, 149-152.