

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

A. Kielbus*

Department of Materials Science, Silesian University of Technology,
ul. Krasińskiego 8, 40-019 Katowice, Poland

* Corresponding author: E-mail address: andrzej.kielbus@polsl.pl

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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 Al₃RE phases. Moreover, there was found globular Mn-rich phase existence (probably Al₈CeMn₄ phase). After hot-chamber die casting the microstructure of AE44 alloys consist of equiaxed dendrites of α -Mg with precipitates of Al₁₁RE₃ and probably Al₂RE 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).

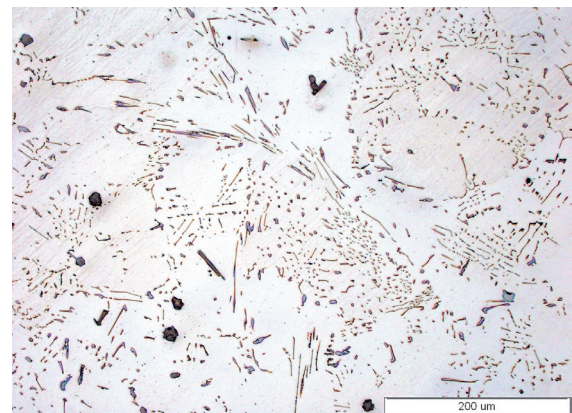


Fig. 1. LM microstructure of as-cast AE44 alloy

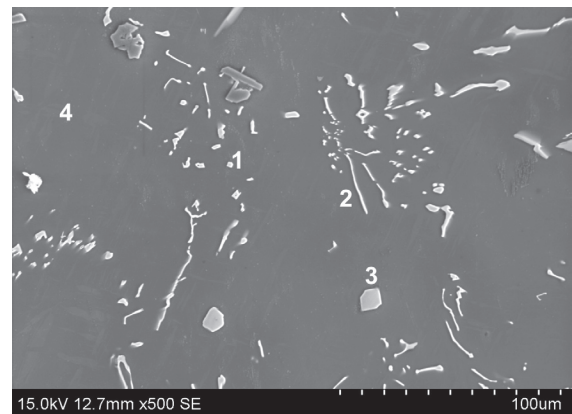


Fig. 2. SEM microstructure of AE44 ingot

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

Are	Element [at.-%]							Likely phase
	Mg	Al	Ce	La	Nd	Mn	Σ RE	
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

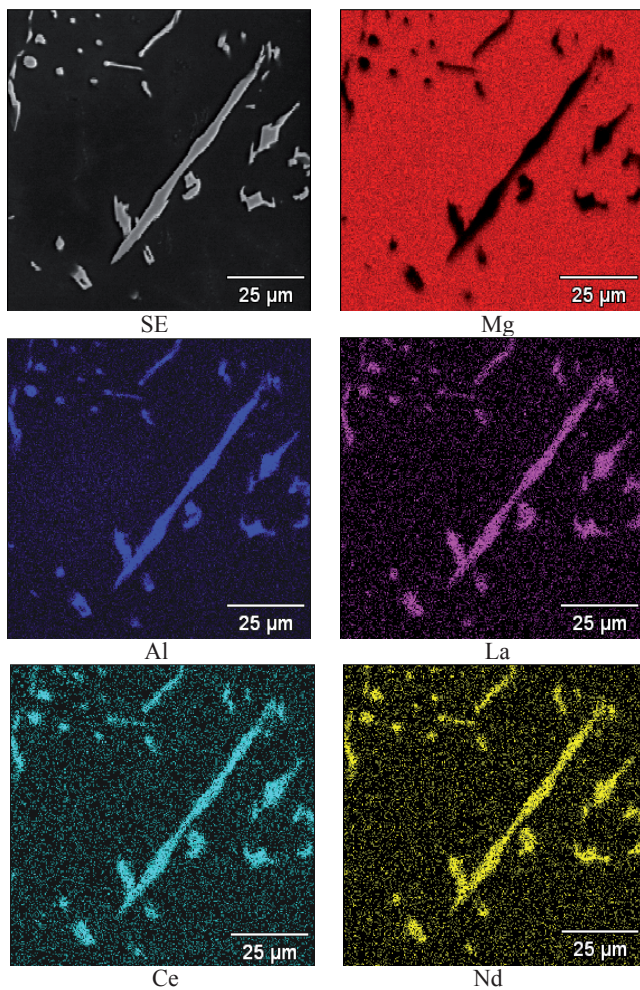


Fig. 3. The SE image and the distribution of Mg, Al, La, Ce and Nd in microareas of AE44 alloy

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.

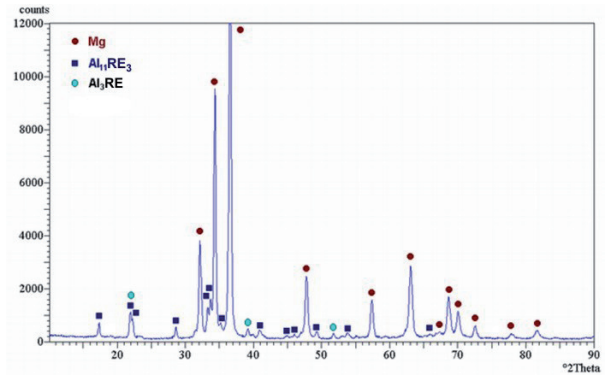


Fig. 4. X-ray diffraction pattern of AE44 alloy

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).

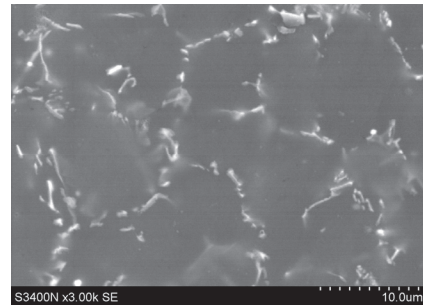


Fig. 5. SEM microstructure of AE44 after hot chamber die casting

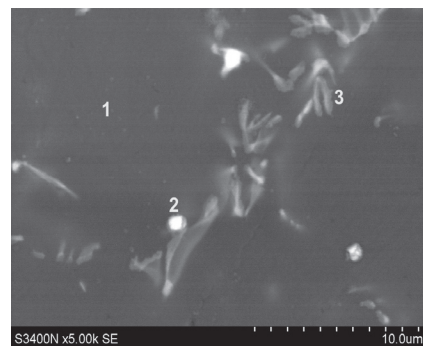


Fig. 6. Microareas of the chemical composition analysis in the AE44 alloy after hot chamber die casting

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.

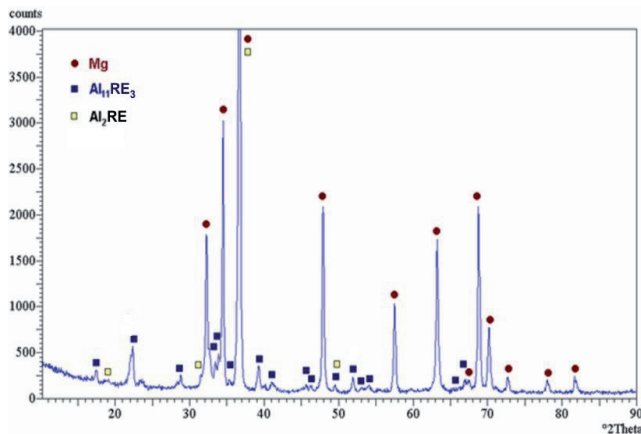


Fig. 7. X-ray diffraction pattern of AE44 alloy after die casting

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

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