ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 7
Issue 1/2007
179 – 182

39/1

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Microstructure of MCMgAl12Zn1 magnesium alloy

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Received 08.02.2007; Approved for print on: 12.03.2007

Abstract

In this paper is presented the structure of the cast magnesium alloys as cast state and after heat treatment cooled with different cooling rate, depending on the cooling medium (furnace, water, air). For investigations samples in shape of 250x150x25 mm plates were used. The structure have been study in the light microscope, scanning electron microscope equipped with an electron back scattering facility. The effects of the addition of Al on the microstructure were also studied. In the analysed alloys a structure of α solid solution and fragile phase β ($Mg_{17}Al_{12}$) occurred mainly on grain borders as well as eutectic and phase with Mn, Fe and Si. Investigation are carried out for the reason of chemical composition influence and precipitation processes influence to the structure and mechanical properties of the magnesium cast alloys with different chemical composition in as cast alloys and after heat treatment.

Keywords: Heat Treatment; Manufacturing and processing; Mechanical Properties; Fracture Mechanics; Magnesium alloys

1. Introduction

At the contemporary stage of the development of the engineering thought, and the product technology itself, material engineering has entered the period of new possibilities of designing and manufacturing of elements, introducing new methods of melting, casting, forming, and heat treatment of the casting materials, finding wider and wider applications in many industry branches. Engineers whose employment calls for significant expenditure of labour and costs strive to reduce material consumption. Therefore the development of engineering aims at designs optimizing, reducing dimensions, weight, and extending the life of devices as well as improving their reliability [1, 2, 4].

The material selection is preceded by the analysis of many factors like: mechanical, design, environmental, urbanization, recycling, cost, availability, and weight related issues, which may change the existing conditions and emerge the needs resulting from the supplier-customer relation [5, 9, 10]. The strive to decrease the weight of products becomes an important challenge for designers and process engineers. The excessive weight verifies a significant extent the possibilities of employing particular material groups. Contemporary materials should possess high mechanical properties, physical and chemical, as well as technological ones, to ensure long and reliable use. The above requirements and expectations regarding the contemporary materials are met by the non-ferrous metals alloys used nowadays, including the magnesium alloys. Magnesium alloys and their derivatives, alike materials from the lightweight and ultra-lightweight family, characterize of low density (1.3-1.8 g/cm^3) and high strength in relation to their weight [1-4, 6-8]. Moreover, the magnesium alloys demonstrate good corrosion resistance, no aggressiveness towards the mould material and low heat of fusion, which make it possible to use pressure die casting that ensures good shape reproducibility.

The magnesium alloys are widely used in the automotive industry. The concrete examples of the employment of castings from magnesium alloys in batch production in the automotive industry are elements of the suspension of the front and rear axes of cars, propeller shaft tunnel, pedals, dashboards, elements of seats, steering wheels, elements of timer-distributors, air filters, wheel bands, oil sumps, elements and housings of the gearbox, framing of doors and sunroofs, and others [6-8]. Generally they are applied in motor industry and machine building, but they find application in a helicopter production, planes, disc scanners, a mobile telephony, computers, bicycle elements, household and office equipment, radio engineering and an air - navigation, in chemical, power, textile and nuclear industrial [1-15].

For the reason of growing requirements for materials made from light alloys concerning mechanical properties, corrosion resistance, manufacturing costs and the influence no the environment this efforts can be consider as very up-to-date from the scientistic view and very attractive for investigation.

The goal of this paper is to present of the investigation results of the casting magnesium alloy in its as-cast state and after heat treatment.

2. Experimental procedure

The investigations were carried out on test pieces from the casting magnesium alloy made by ČKD Motory a.s. Hradec Králové in the as-cast state and after heat treatment (Table 2) with the chemical composition given in Table 1.

Table 1.
Chemical composition of investigation alloy

The mass concentration of main elements, %						
Al	Zn	Mn	Si	Fe	Mg	Rest
12,1	0,62	0,17	0,047	0,013	86,96	0,098

Table 2.
Parameters of heat treatment of investigation alloy

Sing the state of heat treatment	Conditions of solution heat treatment		
	Temperature , °C	Time of warming, h	Way coolings
0	As-cast		
	Solution treatment		
1	430	10	Water
2	430	10	Air
3	430	10	With furnace
	Aging treatment		
4	190	15	Air

Castings in the form of Ø42xØ56xh120 cones and 200x100x15 mm plates were melted in a resistance furnace using a protective salt bad Flux 12 equipped with two ceramic filters by the applied melting temperature of 750±10°C (according to the manufactured alloy). Caused trough the metallurgical casting quality efforts of the manufactured alloy a refining with a neutral gas wit the industry name Emgesalem Flux 12 was carried on. Castings were made in dies with betonite binder. The caste material was heated in an electrical resistance furnace in protective argon atmosphere. The heat treatment involve the solution heat treatment and cooling in different cooling mediums as well water, air and furnace.

Metallographic examinations have been made on magnesium cast alloy specimens mounted in thermohardening resins. In order to disclose grain boundaries and the structure and to distinguish precisely the particular precipitations in magnesium alloys as an etching reagent a 5% molybdenic acid has been used. The time of the etching for each specimen was between 5-10 s. The observations of the investigated materials structure were made on the transverse metallographic microsections using the light microscope LEICA MEF4A. The X-ray quantitative analyses of the investigated alloy were carried out on the transverse microsections on the Philips scanning microscope with the EDS energy dispersive radiation spectrometer at the accelerating voltage of 20 kV.

3. Discussion of experimental results

Examinations of the chemical composition of the casting magnesium alloys using the EDS spectrometer confirmed the presence of the main alloying elements: magnesium, aluminium, manganese, and zinc. It was found out that the cast magnesium alloys were characteristic of the α solid solution microstructure featuring the alloy matrix and the β $Mg_{17}Al_{12}$ intermetallic phase was located mostly at grain boundaries (Fig. 1-3, 6-10). Moreover, in the surroundings of the β intermetallic phase precipitations the presence of the (α+β) eutectics was revealed (Fig. 1, 4, 8). One can clearly observe in the structure of the casting magnesium alloys, not only the $Mg_{17}Al_{12}$ phase precipitations, the distinct aluminium, manganese, iron and silicon concentrations, which indicate the presence of the AlMnFe and Mg_2Si type precipitations in the alloy structure (Fig. 10). Phases with high Mn concentration (are colored red) are irregular with a non plain surface, they often occur in the form of blocks or needles (Fig. 10). After water cooling, the alloy precipitations in the α phase structure were revealed ($Mg_{17}Al_{12}$, AlMnFe and Mg_2Si). After the air-cooling of the alloy the remainder amounts of the β – $Mg_{17}Al_{12}$ and AlMnFe, Mg_2Si phases were identified in the alloy structure in the α solid solution. After cooling the alloy in the furnace the α structure was revealed and moreover locations of the α + β eutectic occurrences, precipitations of the β – $Mg_{17}Al_{12}$ phases were located at the grain boundaries and AlMnFe, Mg_2Si precipitation. Structure of this alloy is similar to the as-cast alloy structure. The aging treatment applied after solution treatment with water cooling caused β phase precipitation was located mostly at grain boundaries, moreover it was found pseudoeutectic regions.

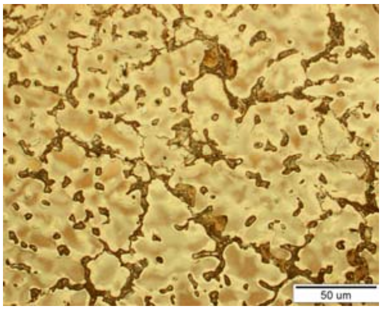

Fig 1. Microstructure alloy with 12 % Al without heat treatment- 0

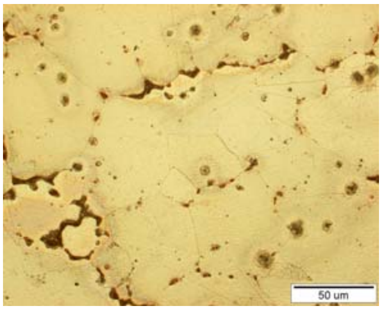

Fig. 2. Microstructure alloy with 12 % Al after cooling in the water

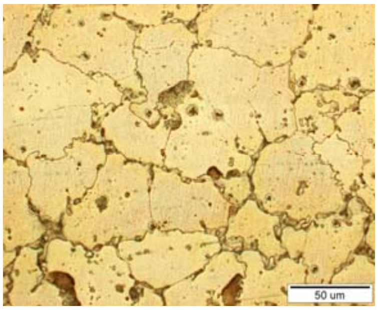

Fig. 3. Microstructure alloy with 12 % Al after cooling in the air

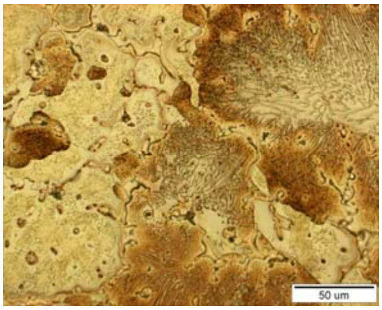

Fig. 4. Microstructure alloy with 12% Al after cooling with the furnace

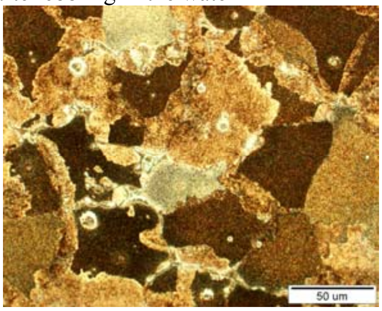

Fig. 5. Microstructure alloy with 12% Al after aging treatment

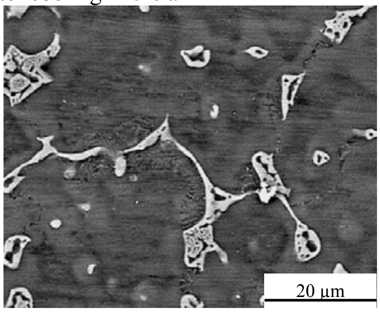

Fig. 6. Microstructure alloy with 12 % Al without heat treatment- 0

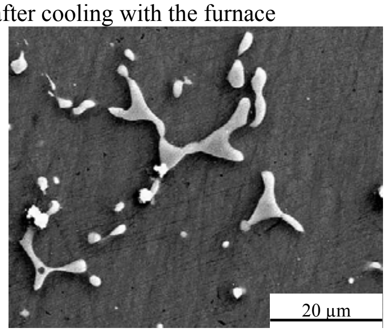

Fig. 7. Microstructure alloy with 12 % Al after cooling in the water

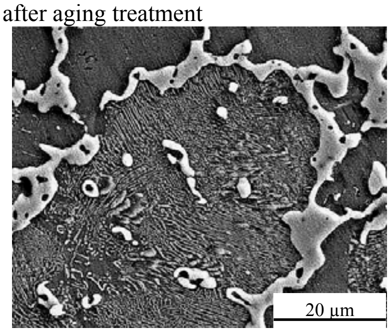

Fig. 8. Microstructure alloy with 12% Al after cooling in the furnace

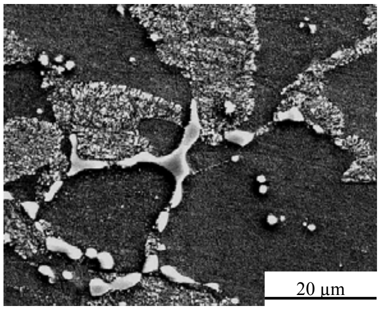

Fig. 9. Microstructure alloy with 12% Al after aging treatment

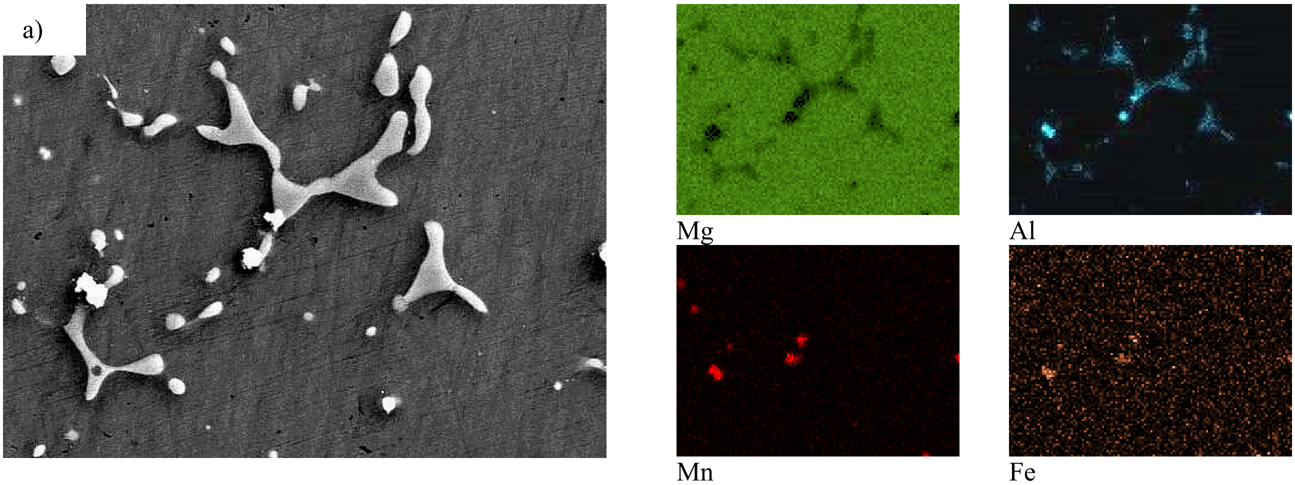

Fig. 10. The area analysis of chemical elements alloy MCMgAl12Zn1 after cooling in the water: image of secondary electrons (a) and maps of elements' distribution

4. Summary

The results of the metallographic examinations made on the light and scanning microscopes confirm the fact that the magnesium cast alloy MCMgAl12Zn1 is characterized by a microstructure of the solid solution α constituting the alloy matrix as well as the $\beta - Mg_{17}Al_{12}$ discontinuous intermetallic phase in the forms of plates located mostly at grain boundaries (Fig. 1-3, 6-9). Moreover, in the vicinity of the β intermetallic phase precipitations the presence of the needle eutectics $(\alpha + \beta)$ has been revealed (Fig. 4, 8). The applied ageing process after the solution heat treatment has caused the release of the β phase at grain boundaries as well as in the form of pseudo eutectic locations. (Fig. 9).

The results of the analysis of the EDS chemical composition confirm the presence of the main alloy additions Mg, Al, Mn, Zn in the magnesium cast alloys in as-cast and after the heat treatment (Fig. 10). The chemical analysis of the surface element decomposition and the quantitative micro analysis made on the transverse microsections have also confirmed the evident concentrations of magnesium, silicon, aluminium, manganese and iron what suggests the occurrence of precipitations containing Mg and Si with angular contours, as well as phases with high Mn and Al concentrations that are irregular, with a non plain surface, often occurring in the forms of blocks or needles (Fig. 10).

Acknowledgments

This scientific work is fragmentary financed within the framework of scientific financial resources in the period 2007-2008 as a research and development project R15 0702 headed by Prof. L.A. Dobrzański

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