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Influence of modification with chemical elements on structure of magnesium casting alloys

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Abstract: Results are presented in the paper of the chemical composition qualitative and quantitative examinations of the test pieces' microzones and of the observations of transverse fractures surfaces of the modified casting magnesium alloys based on the EN-MCMgAl9Zn1 alloy. Presence of the following casting alloys main elements was confirmed in the analysed test pieces: magnesium, aluminium, manganese, and zinc, constituting the structure of the α solid solution with the $Mg_{17}Al_{12}$ phases precipitations, as well as eutectics and most probably of the $MnAl_4$ phase. Fractures of the investigated alloys were of a mixed nature.

Keywords: Magnesium alloys, Heat treatment, Structure, Mechanical properties, Investigation

1. INTRODUCTION

Castings from magnesium alloys acquire bigger and bigger technological importance because of the introduction of the contemporary casting technologies, heat treatment, and plastic forming. Effectiveness and range of applications of these alloys are governed by the significant weight reduction of the final product, and consequently result in lowering costs and improvement of the conditions of their use. The dynamic development of engineering, as well as of the product technology itself, stimulated by the continuously growing consumer demand and progress in the area of the materials engineering science is more and more characteristics of the new trends and potential of the materials engineering, design, and manufacturing of products. Materials processing costs have been lowered, and first of all, casting methods have been improved thanks to introducing the state of the art technologies [4, 5]. Striving to decrease the weight of products becomes a big challenge on a worldwide scale for designers and process engineers. Products are preferred that will merge features of the material with the high strength and low mass density. The „deadweight" problem decides to a significant extent potential of the particular material groups. Material selection is preceded by analysis of many factors, including requirements from various areas of science: technology, environment, economy, geology, and chemistry, which change because of the existing conditions and emerging needs. Currently, big attention is paid to magnesium alloys and their derivatives, as materials from the lightweight and ultra-lightweight family, which are characteristic of low density (1.5-1.8 g/cm^3) and high strength (from 169 to 365 MPa) in relation to their weight [1, 2]. Moreover, the magnesium alloys demonstrate good corrosion resistance, no aggressiveness towards the mould material and low heat of fusion, which makes it possible to use pressure die casting with high shape reproducibility. Good capability of damping vibrations and low inertia make employment of magnesium alloys possible for the fast moving elements and in locations where rapid velocity changes occur, i.e., car wheels, combustion engine pistons, high-speed machine tools, aircraft equipment elements [Fig.1]. The concrete examples of employment of castings from magnesium alloys in batch production are also elements of the suspension of the front and rear axes of cars, propeller shaft tunnel and housings of the gearbox, and interior outfit [3, 6, 7]. Magnesium alloys have also found their application in manufacturing the hand operated equipment - mowers, saws, office equipment including computer hardware, sport and medical appliances [Fig.2]. Therefore, the magnesium alloys attract lastly more and more interest of the manufacturers and designers, which makes them also attractive from the research point of view.

The goal of this work is to determine the effect of the percentage of the alloying elements on structure of the casting magnesium alloys.

a)  b) c)

Figure 1. Part of cars from magnesium alloys a) car wheels, b) steering wheels, c) combustion engine pistons

a) b) c)

Figure 2. Different examples of magnesium alloys applications a) deck cleat, b) bicycle forks, c) bicycle brake shields

2. EXPERIMENTAL PROCEDURE

The investigations were made of the test pieces from the casting magnesium alloys with the lowered and increased aluminium content, compared to theEN-MCMgAl9Zn1 alloy*. Chemical compositions of the analysed materials are given in Table 1.

The castings in the form of cones and plates with the dimensions of 200x100x15 were melted in the Ema vacuum furnace with the maximum working temperature up to 2000° C. The device chamber was filled with argon after obtaining vacuum in the furnace. Fractures of the investigated materials were examined using the Philips Xl-30 scanning microscope.

The X-ray quantitative and qualitative analyses of the investigated alloy were carried out on the transverse microsections on the Philips scanning microscope with the EDX energy dispersive radiation spectrometer at the accelerating voltage of 20 kV. Observations of the investigated materials structure were made on the transverse metallographic microsections using the light microscope.

Table 1.
Chemical composition of investigation alloy

The mass concentration of main elements, %							
Kind of alloy	Al	Zn	Mn	Si	Fe	Mg	Rest
1	4	0,292	0,122	0,0280	0,0111	95,5	0,0469
2*	7,98	0,532	0,198	0,0403	0,00955	91,2	0,04015
3	16,1	0,617	0,174	0,0468	0,0130	83	0,0492

3. DISCUSSION OF EXPERIMENTAL RESULTS

Basing on examinations made on the scanning electron microscope, it was found out that the casting magnesium alloys with the varying percentages of chemical elements (Table 1) do not display any visible cracks. The cast magnesium alloys with the varying aluminium percentage (about 4%, 8%, and 16%) are characteristic of the α solid solution microstructure, featuring the matrix of the alloy and originating eutectics. Moreover, in the vicinity of the eutectics the presence of the β intermetallic phase of the $Mg_{17}Al_{12}$ type – dark phase - was revealed, mostly at grain boundaries. The distinct manganese and aluminium concentrations were revealed in the alloy structure, which indicates most probably to occurrence of the $MnAl_4$ type precipitations – bright phase (Fig.3) (Table 2). Phases containing Mn and Al are characteristic of the irregular shape.

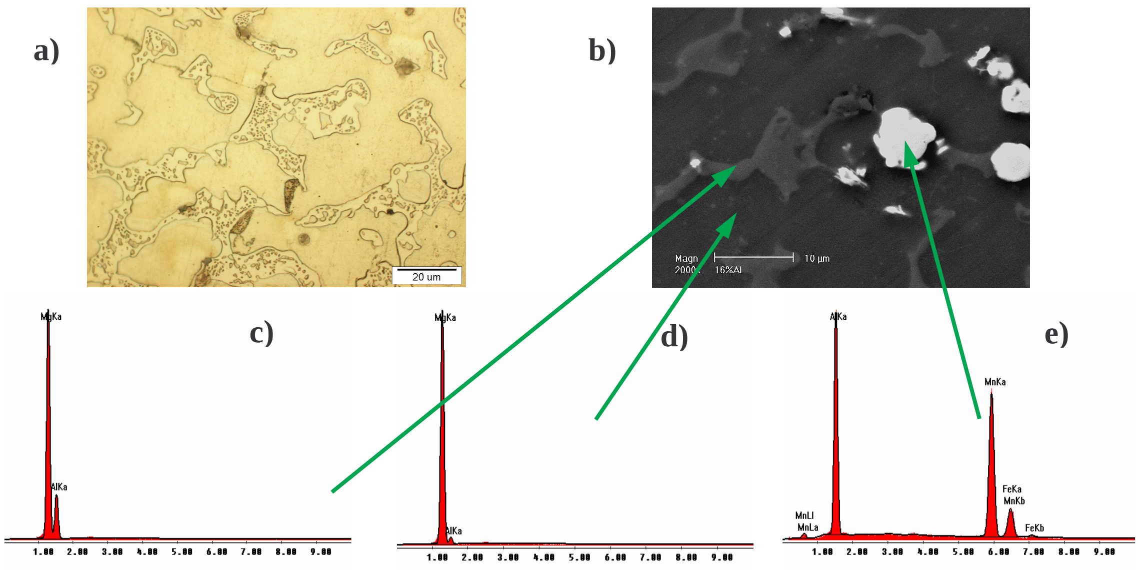

Figure 3. Microstrukture magnesium castin alloys with 16% Al; a) Light microscope mag. 1000x; b) Scanning microscope mag. 2000×; c) X-ray energy dispersive plot from the $Mg_{17}Al_{12}$ phase precipitation microzone; d) X-ray energy dispersive plot from the $MnAl_4$ phase precipitation microzone; e) X-ray energy dispersive plot from the α solid solution.

Fractographic observations of the analysed test pieces revealed that in most cases the fractures of the mixed nature occur with the visible brittle areas (locations with the precipitations) and ductile ones (matrix) (Fig.4).

Table 2.
Chemical composition of identified magnesium alloy phases

Phase	Chemical element, [wt.-%]			
	Mg	Al	Mn	Rest
α phase	82,67	17,33	-	-
β $Mg_{17}Al_{12}$ phase	65,74	34,26	-	-
$MnAl_4$ phase	-	41,68	51,83	6,49

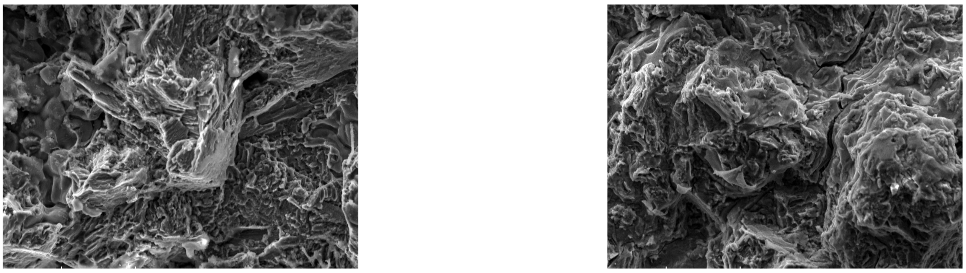

Figure 4. The fracture surface of magnesium casting alloys (16% Al), mag. 200x

4. SUMMARY

Basing on the investigations carried out it was revealed that the casting magnesium alloys cast to metal moulds display the microstructure of the α solid solution with the visible $Mg_{17}Al_{12}$ and $MnAl_4$ phases precipitations. The acquired results are comparable to results obtained by other authors [1, 2]. Presence of magnesium, aluminium, manganese, and zinc, whose occurrence has been expected, was confirmed with the EDX energy dispersive X-ray spectrometer. Fractures were of a mixed nature in most cases.

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