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Mechanical properties of magnesium casting alloys

L.A. Dobrzański [a,*], T. Tański [a], J. Domagała [a], L. Čížek [b]
[a] Division of Materials Processing Technology, Management and Computer Techniques in Materials Science, Institute of Engineering Materials and Biomaterials, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
[b] Faculty of Metallurgy and Materials Engineering, Technical University of Ostrava, Tř.17 Listopadu 15, 708 33 Ostrava, Czech Republic
* Corresponding author: E-mail address: leszek.dobrzanski@polsl.pl

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Properties

ABSTRACT

Purpose: In the following paper there have been the properties of the MCMgAl12Zn1, MCMgAl9Zn1, MCMgAl6Zn1, MCMgAl3Zn1 magnesium cast alloy as-cast state and after a heat treatment presented.
Design/methodology/approach: A casting cycle of alloys has been carried out in an induction crucible furnace using a protective salt bath Flux 12 equipped with two ceramic filters at the melting temperature of 750±10ºC, suitable for the manufactured material. The following results concern sliding friction, mechanical properties, scanning microscopy.
Findings: The different heat treatment kinds employed contributed to the improvement of mechanical properties of the alloy with the slight reduction of its plastic properties.
Research limitations/implications: According to the alloys characteristic, the applied cooling rate and alloy additions seems to be a good compromise for mechanical properties and microstructures, nevertheless further tests should be carried out in order to examine different cooling rates and parameters of solution treatment process and aging process.
Practical implications: The concrete examples of the employment of castings from magnesium alloys 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, etc.
Originality/value: Contemporary materials should possess high mechanical properties, physical and chemical, as well as technological ones, to ensure long and reliable use. The above mentioned requirements and expectations regarding the contemporary materials are met by the non-ferrous metals alloys used nowadays, including the magnesium alloys.
Keywords: Heat treatment; Mechanical properties; Fracture mechanics; Magnesium alloys

1. Introduction

The dynamic industrial development puts some higher and higher demands to the present elements and constructions. These demands belong production and research newer and newer materials for materials engineering materials with relation to predictable work conditions and arise needs [1-4, 10-15].

Magnesium alloys gets a huge importance with present demands for light and reliable construction. Magnesium alloys have low density and other benefits such as: a good vibration damping and the best from among all construction materials: high dimension stability, small casting shrinkage, connection of low density and huge strength with reference to small mass, possibility to have application in machines and with ease to put recycling process, which makes possibility to logging derivative alloys a very similar quality to original material [6-9].

Magnesium alloys, which are produced, often are fill in them, especially in fewer reliable construction [3-5].

Thanks to the progresses in the filed of magnesium alloys technology currently (alloys, which are received by cooling with a hige speed – Rapid Solidification Processing, composite material on magnesium fabric – MMCs that are – Meta-Matrix Composites, casting in constant-liquid condition, rheocasting**,** thixomoulding, thixoforming), forming, heat treatment, technological improvement and corrosion resistance, they find wide range of use in many fields [1-8]. 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.

The rising tendencies of magnesium alloy production, show increased need of their application in world industry and what follows the magnesium alloys become one of the most often apply construction material our century. Therefore it is extremely important to keep a high investigation development of a light alloy issue, furthermore performing in Institute of Material Processes and Computer Technology, Institute of Engineering Materials and Biomaterials, Silesian University of Technology.

2. Experimental procedure

The investigations were performed on experimental magnesium alloys MCMgA112Zn1,MCMgAL9z1, MCMgAl6Zn1, MCMgAl3Zn1 in stable state and after heat treatment (table 2). Chemical composition of this materials was conditioned by changeable concentration range of aluminium in accordance with different types of alloy, which changes in range from 3-12% (table 1).

Metallographic examinations of the investigated cast materials have been made on the light microscope LEICA MEF4A as well as on the electron scanning microscope Opton DSM-940 using a secondary electron detection.

Tensile strength tests were made using Zwick Z100 testing machine. The results in the work, were statistical worked out, for each measurement of the average value, standard deviation.

3. Discussion of experimental results

The results of the static tension test make it possible to determine and compare the mechanical and plastic properties of the examined magnesium cast alloys in as cast and after heat-treatment. On the basis of the tests done, one has stated that the biggest resistance to tension in as cast state show the MCMgAl6Zn1 and MCMgAl3Zn1 alloys which also posses the biggest state elongation. It has also been proved that the increase of the Al concentration from 6 to 12% reduces the resistance to tension in as cast state to 170,9+1,64 MPa. The heat-treatment i.e. the solution heat treatment with the furnace cooling and ageing, causes the increase of the resistance to tension. The maximum resistance to tension 294,8+3,31 MPa has been obtained after the ageing of the MCMgAl12Zn1 alloy; one has also observed a significant (by 50%) increase of the resistance to tension for the MCMgAl9Zn1 specimens after ageing (Fig. 2). The smallest growth of the resistance to tension after the heat-treatment has been gained for the MCMgAl6Zn1 and MCMgAl3Zn1 materials, 30,3 and 12,4 MPa respectively. The differences in values of the resistance to tension for the alloys subjected to solutioning with water and air cooling amount to 6 MPa maximum (Fig. 2).

Table 1
Chemical composition of investigated alloys

The mass concentration of main elements, %						
Al.	Zn	Mn	Si	Fe	Mg	Rest
12,1	0,617	0,174	0,0468	0,0130	86,9507	0,0985
9,09	0,77	0,21	0,037	0,011	89,7905	0,0915
5,92	0,49	0,15	0,037	0,007	93,3347	0,0613
2,96	0,23	0,09	0,029	0,006	96,6489	0,0361

Table 2
Parameters of heat treatment of investigated alloys

Sing the state of heat treatment	Solution treatment			Aging treatment		
	Temperature	Time	Cooling	Temperature	Time	Cooling
0	As-cast					
1	430	10	air	-	-	-
2	430	10	water	-	-	-
3	430	10	furnace	-	-	-
4	430	10	water	190	15	air

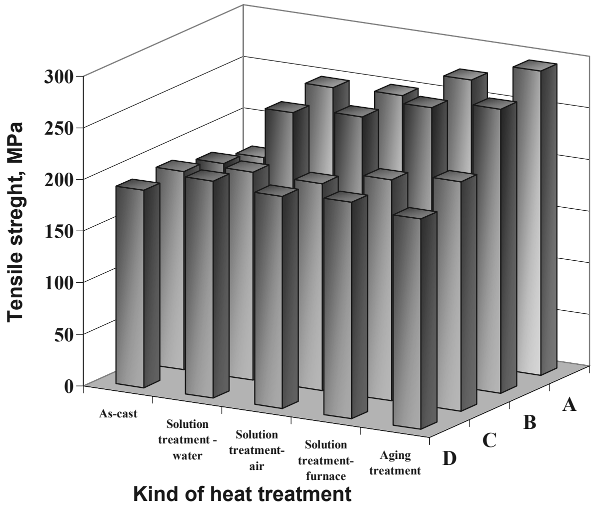

Fig. 2. The results of Tensile strength magnesium casting alloys: A) MCMgAl12Zn1, B) MCMgAl9Zn1, C) MCMgAl6Zn1, D) MCMgAl3Zn1

Specimens with 12% concentration of aluminum–MCMgAl12Zn1 show a maximum yield point in as cast state. The biggest value of the yield point after the heat treatment show the MCMgAl12Zn1, MCMgAl9Zn1 and MCMgAl6Zn1 alloys after the solutioning with furnace cooling, insignificantly higher than in the case of the aged materials. The increase of the aluminum concentration to 12% diminishes the elongation of the examined alloys to the value of 2,97%+0,07, five times lower in comparison to the elongation of the MCMgAl3Zn cast alloys. The solution heat treatment with water and air cooling causes the increase of the value of elongation even by 100% for MCMgAl12Zn1 and MCMgAl9Zn1 alloys. The alloys after the solution heat treatment with furnace cooling and ageing are characterized by an insignificant fall of the elongation in relation to the as cast state.

For fuller characteristics of the influence of the heat treatment and the aluminum concentration on the properties of the magnesium cast alloys, the pictures of the structures of factures after a static test of elongation, have been presented in Figures 4 (Fig. 3).

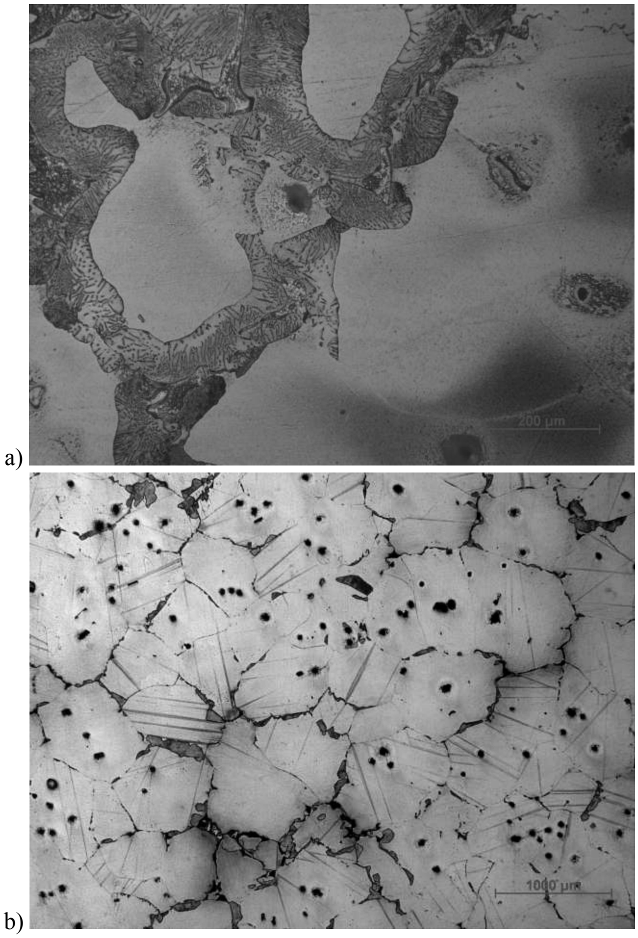

Fig 3. Microstructure alloy MCMgAl9Zn1: a) without heat treatment – as-cast, b) after aging treatment

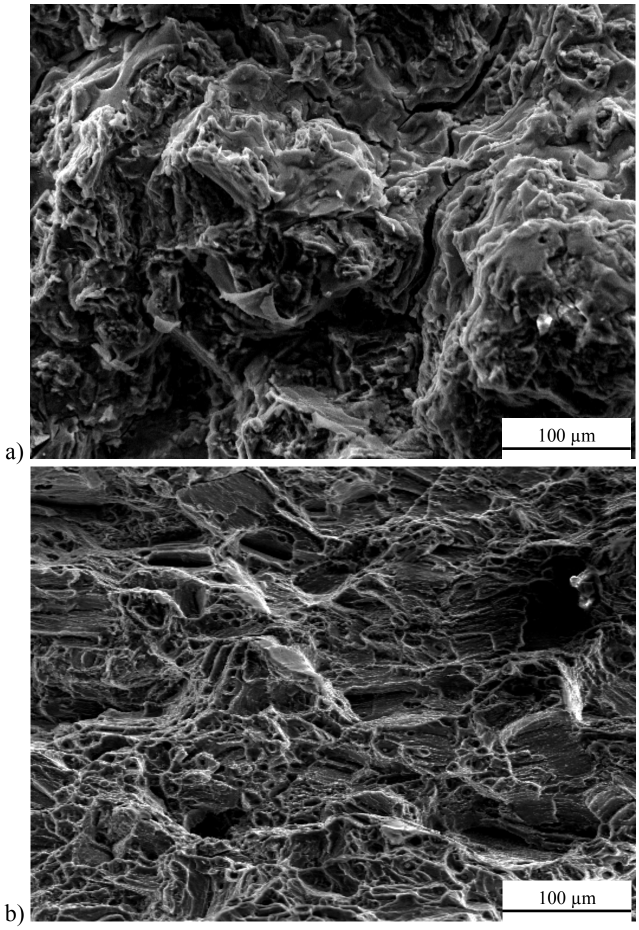

Fig.4. The fracture surface of tensile test alloy MCMgAl9Zn1: a) without heat treatment – as-cast, b) after aging treatment

One of the results of the carried out investigations is the fact that MCMgAl12Zn1, MCMgAl9Zn1 and MCMgAl6Zn1 alloys in as cast state are characterized by a mixed fracture, whereas in the case of the MCMgAl3Zn alloys one can observe a ductile fracture. Subjecting the alloys to the heat treatment consisting in solutioning with water and air cooling, has increased the plasticity of the alloys, which may prove the ductile, in most cases, character of the fracture, and the increase of the contraction and elongation values. The MCMgAl12Zn1 and MCMgAl9Zn1 alloys, in turn, heated and cooled with furnace as well as subjected to ageing, in which a significant increase of hardness in comparison with the initial state and an insignificant lowering of the contraction and elongation values took place, show a brittle fracture character; in the MCMgAl6Zn1 and MCMgAl3Zn alloys the mixed fracture has been observed.

4. Conclusions

Precipitation hardening causes some changes in the resistance properties. The biggest resistance to elongation in as cast state show the MCMgAl6Zn1 and MCMgAl3Zn alloys, 192,1+1,95 and 191,3+1,6 MPa respectively. It has also been proved that the increase of the Al concentration from 6 to 12% lowers the resistance to elongation in as cast state to 170,9+1,64 MPa. The maximum plasticity border has been obtained for the MCMgAl12Zn1 alloy, insignificantly higher than in the case of the MCMgAl9Zn1alloy. After the ageing with air cooling, the maximum increase of the resistance to elongation and the plasticity border has been gained for the MCMgAl12Zn1 alloy.

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