INFLUENCE OF HEAT TREATMENT ON MAGNESIUM ALLOYS MEANT TO AUTOMOTIVE INDUSTRY

Gabriela POPESCU[1], Petru MOLDOVAN[2], Dionezie BOJIN[3], Wim H. SILLEKENS[4]

Lucrarea prezintă un studiu privind tratamentul termic efectuat asupra aliajelor de magneziu deformabile, AZ80 şi ZK60, în tentativa de a înlocui aliajele feroase şi pe cele de aluminiu, în industria de autovehicule. S-a realizat tratamentul termic de îmbătrânire artificială T5 şi s-au determinat caracteristicle microstructurale şi mecanice ale probelor tratate termic. S-a pus în evidenţă faptul că tratamentul aplicat a fost benefic asupra caracteristicilor aliajelor AZ80 şi ZK60 studiate.

The paper presents a study concerning the heat treatment realized on magnesium alloys, from AZ80 and ZK60 class. These alloys are destined to replace the conventional ferrous and aluminum alloys in automotive industry. It was realized the heat treatment, T5 – artificially aging, and it were determined the microstructures and mechanical properties of the heat treated samples. It was put in evidence the fact that by applying T5 heat treatment the mechanical characteristics of AZ80 and ZK60 alloys were increased.

Keywords: magnesium alloys, heat treatment, microstructure, mechanical properties

1. Introduction

The study realized on this paper was done under the MagForge project [1]. This project [2] was conducted within the 6^{th} Framework Programme on the European Commision (EC) as a collective research project. The main target of the project was to forge magnesium components that fulfill all requirements of the same shaped aluminum components. The project addresses the need of European forging industry to meet customer demand for structural lightweight components. The issue of weight reduction of structural components for automotive industry

[1] Prof., Department of Engineering and Management of Metallic Materials Elaboration, University POLITEHNICA of Bucharest, Romania, gabriela81us@yahoo.com
[2] Prof., Department of Engineering and Management of Metallic Materials Elaboration, University POLITEHNICA of Bucharest, Romania
[3] Prof., Department of Engineering and Management of Metallic Materials Elaboration, University POLITEHNICA of Bucharest, Romania
[4] PhD eng., TNO Science and Industry, Eindhoven, The Nederland's

magnesium being 75% lighter than steel and 35% lighter than aluminum was one of the project target [3].

In order to substitute aluminum parts two types of magnesium alloys, AZ80 and ZK60, were selected because of their good forming behavior and mechanical properties. These alloys are similar to those of wrought aluminum alloy 6082 typically used for forged components. The advantages of using AZ alloys are: castability, high strength and corrosion resistance, low price. The disadvantage of this magnesium class is moderate formability. Regarding the ZK alloys their advantages are: good formability, high strength, low price, and like disadvantages we can remark their lower corrosion resistance and moderate castability.

Considering these aspects the team from University "POLITEHNICA" of Bucharest was involved with improving the magnesium properties by heat treating of magnesium alloys.

Magnesium alloys are heat treated in order to improve mechanical properties or conditioning for specific fabricating operations and depends on alloy composition and form (cast or wrought alloy) and on anticipated service conditions. Precipitation heat treatment or artificially aging gives maximum hardness and yield strength, shock resistance, but with some reduction of toughness.

Wrought alloys can be strengthened by heat treatment by grouping into three classes according with composition:

- Magnesium-aluminum-zinc (example AZ80A);
- Magnesium-zinc-zirconium (example ZK60A);
- Magnesium-zinc-copper (example ZC71A).

In most wrought magnesium alloys maximum mechanical properties are developed by strain hardening and these alloys are either used without subsequent heat treatment or merely aged to a T5 temper [4, 5]. Thus, was chose for treating of AZ80 and ZK60 alloys T5 treatment for the samples received from LEIBER and TNO [1]. For these alloys are recommended the following conditions:

- for AZ80: aging temperature 177 ^{0}C /16-24 h;
- for ZK60: aging temperature 150 ^{0}C/24 h.

AZ80 alloy may be fully aged by heating in furnace for 24 hours at 350 ^{0}C. AZ80 alloy T5 heat treated will have maximum tensile properties, compressive yield strength and hardness. Variations of properties can be obtained by different aging cycles starting with F (as-fabricated) or T4 (solution heat treated) material.

There is no rule for estimating time of heating for magnesium alloys. Also, protective atmosphere is required if the treatment is realized above 400 ^{0}C, in order to prevent surface oxidation. As gases used for this purpose are sulfur hexafluoride, sulfur dioxide and carbon dioxide. Usually heat treatment in a controlled atmosphere contain about 0.5 to 1.5 SF_6 in CO_2 or in an inert gas atmosphere. After heat treatment, magnesium alloys are normally quenched in air. Forced-air cooling is recommended for dense loads or for parts that have very thick sections.

The alloys responsive to heat treatments are those in which the solid solubility of the principal alloying constituents shows a marked increase at elevated temperature [6]. For current wrought magnesium compositions only AZ80 and ZK60 are to be so classed.

2. Experimental procedure

Samples used in heat treatment experiments were forged bicycle parts (fig.1) received from the LEIBER partner and rings, forged in severe and moderate conditions, received from the TNO partner. Chemical composition of the alloys is presented in table 1.

Fig. 1. Forged LEIBER bicycle part

Table 1

Chemical composition of magnesium alloys

Type alloy	Mg	Al	Zn	Zr	Mn	Cu	Fe	Ni	Si	Other elem.
AZ80A	bal.	7.8-7.9	0.2-0.8	-	0.15-0.50	max 0.05	max 0.005	max 0.005	max 0.05	max 0.3
ZK60A	bal	-	4.8-6.2	min 0.45	-	-	-	-	-	max 0.3

It were realized a great number of experiments in order to establish the hard intermetallic phases presented in AZ80 and ZK60 alloys, phases that can lead to decrease of forgeability properties and material fracture. Thus, AZ80 alloy was treated at 180 ^{0}C for 18, 21 and respectively 24 hours, and ZK60 alloy was treated at 150 ^{0}C for the same periods of time. After treatment were take samples from each treated part and was investigate using optical microscopy (OMNIMET Image Analysis System) and electron microscopy (XL30ESEM). The samples were etched with 5% Nital solution in order to put in evidence the magnesium compounds.

From the mechanical properties were tested only hardness and microhardness of the treated samples using HARDCHECK 3000 and LECO micro-hardness testers.

3. Results and discussion

The samples from AZ80 forged bicycle part, treated at three different time of exposure put in evidence the presence of MgMnAl precipitates, as can be observed from fig. 2.

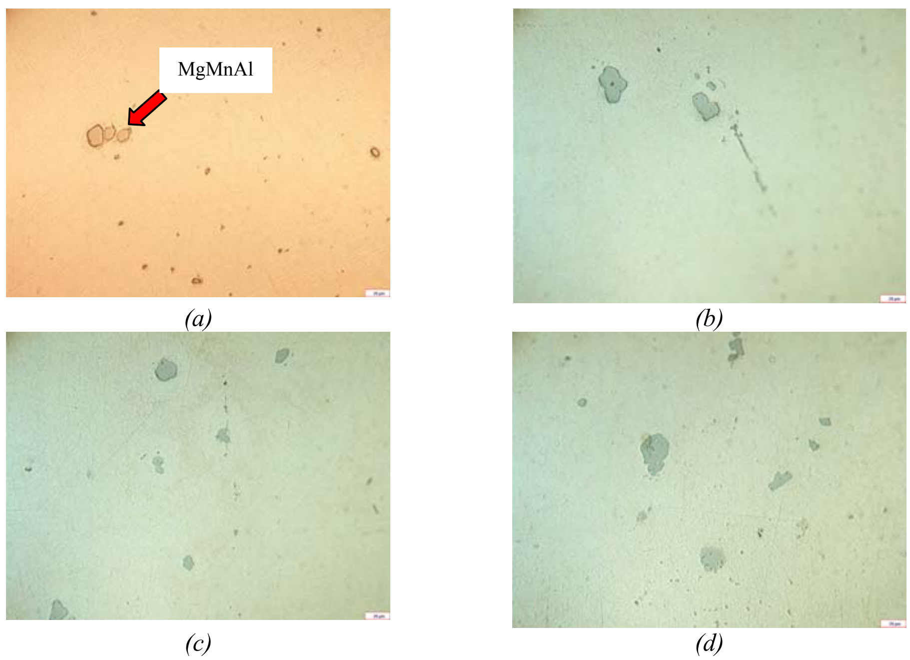


Fig. 2. Optical microstructures of forged and heat treated, at 180 ^{0}C, AZ80 alloy - Leiber part: (a) forged sample; (b) maintain for 18 h; (c) 21 h; (d) 24 h; unetched samples.

The same phases precipitates were noticed in the forged ring samples, as can be observed from fig. 3.

In case of ZK60 alloy was notice the presence of MgZnZr phases, aligned and relatively uniform distributed in the sample, phenomena put in evidence in fig. 4.

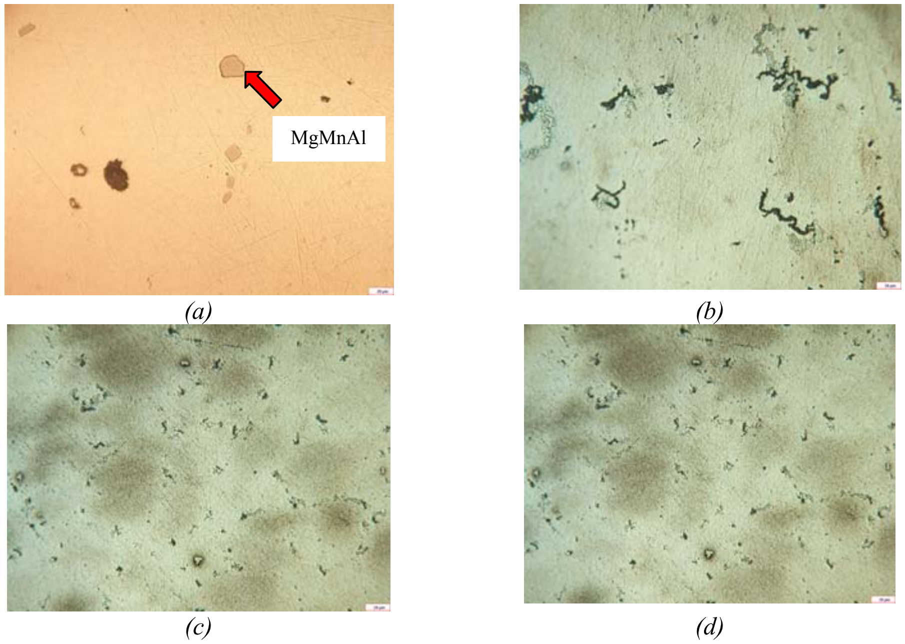


Fig. 3. Optical microstructures of forged and heat treated, at 180 ^{0}C, AZ80 alloy, TNO ring: (a) forged sample; (b) maintain for 18 h; (c) 21 h; (d) 24 h; unetched samples.

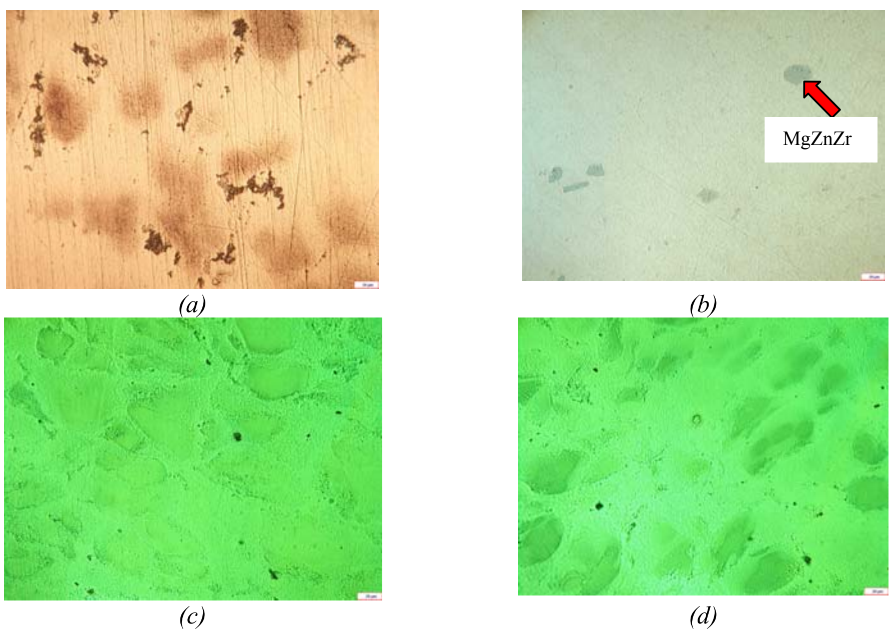
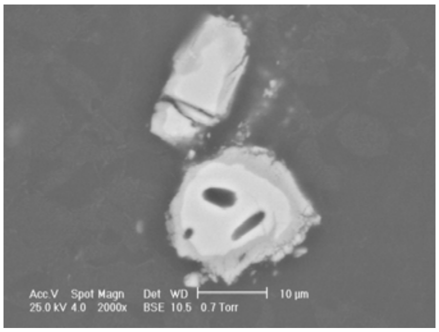
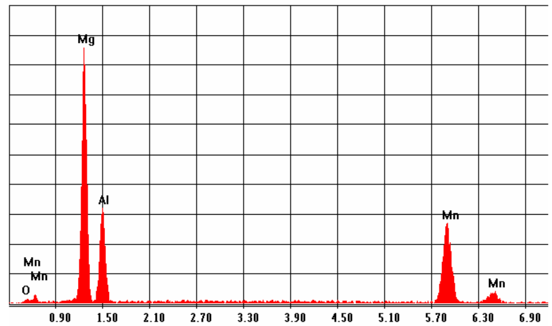


Fig. 4. Optical microstructures of forged and heat treated, at 150 ^{0}C, from ZK60 alloy: (a) forged part; (b) maintain for 18 h; (c) 21 h; (d) 24 h; *a* and *b* not etched samples, and *c* and *d* etched with 5%Nital solution.

The same phases observed with optical microscopy were put in evidence by the electron microscopy. Thus, in fig. 5 are presented SEM microscopy and EDS analysis of the main phases noticed in LEIBER sample, and in fig. 6 are presented the results obtained for TNO sample.



(a)



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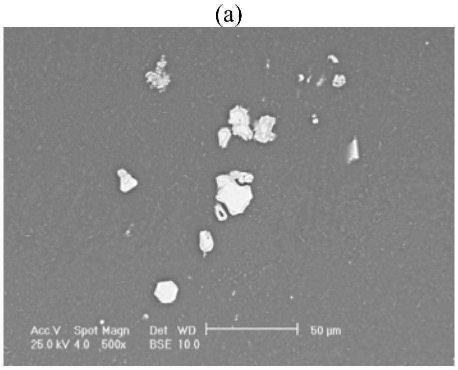
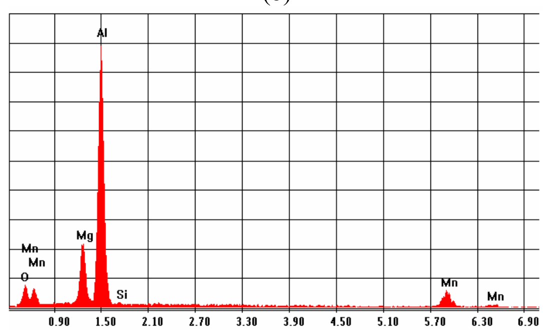
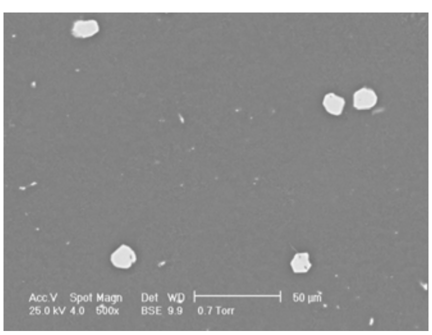


(c)

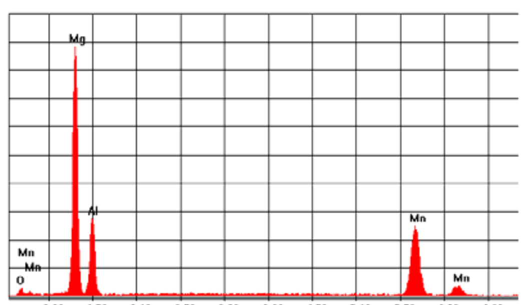


(d)

Fig. 5. SEM microstructure and EDS analysis of AZ80 alloy treated at 180 ^{0}C for 18 hours (a, b) and treated for 24 hours (c,d) from Leiber part sample



(a)



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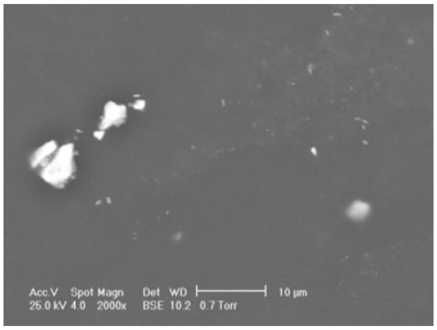
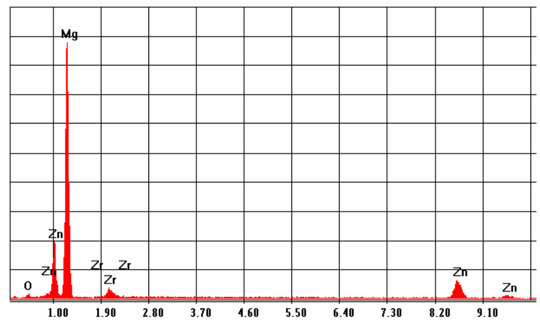
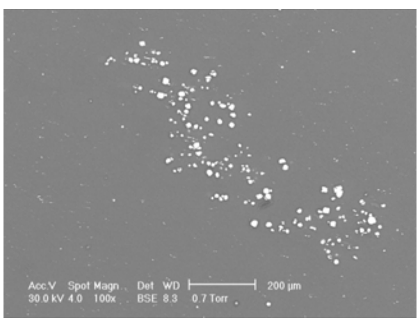


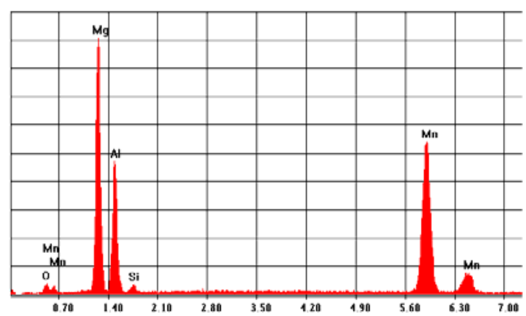


(c) (d)

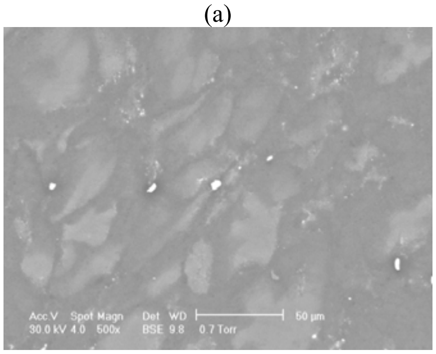
Fig. 6. SEM microstructure and EDS analysis of AZ80 alloy treated at 180 ^{0}C for 18 hours (a, b) and treated for 24 hours (c, d) from TNO ring sample

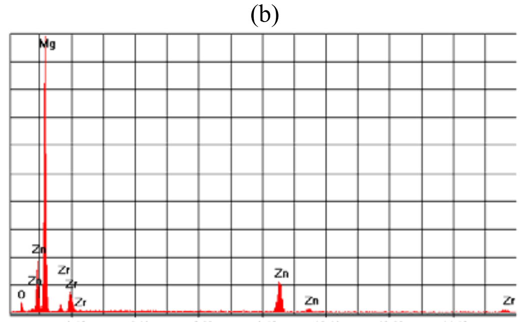
Electron microscopy was realized on ZK60 alloy too, and the results are presented in fig. 7. Can be noticed the tendency of phases alignment and small agglomeration of magnesium phases.





(a) (b)





(c) (d)

Fig. 7. SEM microstructure and EDS analysis of ZK60 alloy treated at 150 ^{0}C for 24 hours for LEIBER part (a, b) and (c,d) TNO ring

From mechanical characteristics were determined hardness and microhardness of the heat treated samples. The obtained results are presented in table 2. We can notice a significant increase of microhardenss for samples after applying the T5 heat treatment.

Table 2

Hardness and microhardness of magnesium alloys

Alloy	State of sample	Hardness	Microhardness	
			Transversal	Longitudinal
AZ80 LEIBER part	Untreated	-	33.1	32.5
	180 ^{0}C, 18 h	-	110	114
	180 ^{0}C, 21 h	-	112	110
	180 ^{0}C, 24 h	-	109	111
AZ80 TNO ring	Untreated	258	82.5	96.1
	180 ^{0}C, 18 h	270	112	98.4
	180 ^{0}C, 21 h	258	114	98.4
	180 ^{0}C, 24 h	219	95	98
ZK60 TNO ring	Untreated	212	67	71
	150 ^{0}C, 18 h	223	104	101
	150 ^{0}C, 21 h	228	89	107
	150 ^{0}C, 24 h	232	-	-

4. Conclusion

It was realized T5 heat treatment of two types of magnesium alloys, AZ80 and respectively ZK60 in order to improve mechanical characteristics. Were analyzed these improvements by studying the optical and electronically microstructures, as well as by analyzing EDS results. It was put in evidence the presence of MgMnAl and MgZnZr phases that lead to improvement of mechanical properties. By applying T5 heat treatment hardness and microhardness of both types of alloys were improved.

R E F E R E N C E S

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