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The influence of heat treatment on the microstructure of GA8 magnesium alloy

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Materials

ABSTRACT

Purpose: GA8 magnesium alloy is a general purpose gravity sand casting alloy containing aluminum, zinc and manganese. Typically, it is used in aerospace or commercial casting applications particularly where there is no high temperature requirement. The aim of this paper is to present the results of investigations on the microstructure of the GA8 magnesium alloy after heat treatment.

Design/methodology/approach: The study was conducted on GA8 magnesium alloys in as-cast condition and after heat treatment. The microstructure was characterized by optical microscopy (Olympus GX-70) and a scanning electron microscopy (Hitachi S3400) equipped with an electron dispersive detector EDS (VOYAGER of NORAN INSTRUMENTS). To measure the stereological parameters, an image analysis program "AnalysisPro®" was used.

Findings: The microstructure of GA8 magnesium alloy has a solid solution structure α with α + discontinuous ß areas and continuous ß ($Mg_{17}Al_{12}$) phase at grain boundaries. After solution treatment a reduction of the number of ß precipitations was observed. Application of ageing treatment caused precipitation of discontinuous ß phase.

Research limitations/implications: Future researches should involve investigations of the effect of heat treatment parameters on the mechanical properties of GA8 magnesium alloy.

Practical implications: The established heat treatment parameters can be useful for preparing heat treatment technology of the GA8 magnesium alloy.

Originality/value: The relationship between the initial structure, heat treatment parameters and $Mg_{17}Al_{12}$ phase morphology in GA8 magnesium alloy was specified.

Keywords: Metallic alloys; Manufacturing and processing; Heat treatment; GA8 magnesium alloy

1. Introduction

Magnesium alloys belong to the lightest structural alloys. They are characterised by low density: ~1,8 g/cm^3, tensile strength R_m=300÷350 MPa, and hardness ~100HB. Mainly for these reasons, magnesium alloys have a widespread application in the motor vehicle and aircraft industries as well as in household appliances and office machines [1÷3]. The basic magnesium alloys contain Mn, Al and Zn which allow obtaining suitable properties. Manganese doesn't have much effect on tensile strength, however, it does increase yield strength. It most important function is to improve the saltwater resistance of Mg-Al alloys by removing iron and other heavy metal elements into relatively harmless intermetallic compounds. Aluminium enhances both tensile strength and hardness, and improves casting properties of an alloy. The best ratio of mechanical to plastic properties is obtained with a 6% Al content. An addition of zinc in combination with Al aims at improving tensile strength at a room temperature, however 1% of Zn with a 7÷10% Al content in an alloy enhances hot cracking [4÷6]. In the microstructure of the Mg-Al casting alloys can observe: solid solution α with β ($Mg_{17}Al_{12}$) phase precipitations on grain boundaries and regions of lamellar mixture α+β [7÷9].

Solution treatment of magnesium alloys enhances their strength, with maximum ductility and resistance to dynamic loads. Ageing of solution heat treated alloys allows obtaining maximum hardness and yield point, with a decrease of ductility [10÷12]. After solution treatment a solid solution of aluminium is present in magnesium (α) and possibly, some regions of undissolved continuous β ($Mg_{17}Al_{12}$) phase [13]. After ageing, two types of β ($Mg_{17}Al_{12}$) precipitations occur in Mg-Al alloy: discontinuous and continuous. It has been found that the morphology of precipitations of the β phase in Mg-Al alloys depends on the chemical composition and temperature [14].

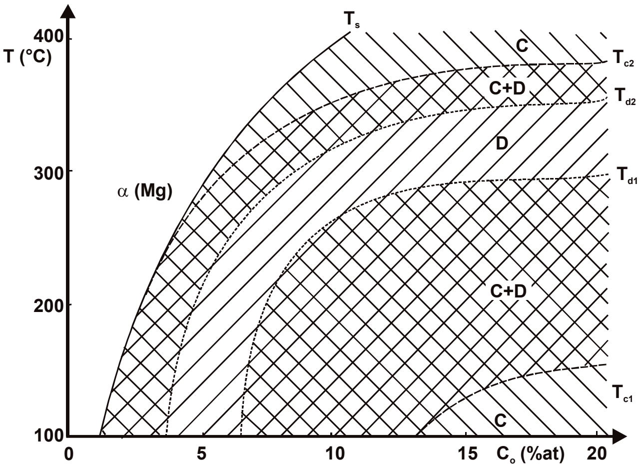

Fig. 1. Influence of Al content and temperature on the morphology of $Mg_{17}Al_{12}$ phase [13]

It has been shown that when (Fig. 1):

- at $T<T_{c1}$ temperature – only continuous precipitations of phase $Mg_{17}Al_{12}$ occur in the alloy;
- in the temperature range of $T_{c1}<T<T_{d1}$ – both continuous and discontinuous precipitations of the $Mg_{17}Al_{12}$ phase occur in the alloy;
- in the temperature range of $T_{d1}<T<T_{d2}$ – only discontinuous precipitations of phase $Mg_{17}Al_{12}$ occur in the alloy;
- in the temperature range of $T_{d2}<T<T_{c2}$ – again, both continuous and discontinuous precipitations of the $Mg_{17}Al_{12}$ phase occur in the alloy;
- in the temperature range of $T_{c2}<T<T_s$ (solubility limit temperature – solvus) – only continuous precipitations of phase $Mg_{17}Al_{12}$ occur in the alloy.

2. Description of the work methodology and material for research

The material for the research was a GA8 magnesium alloy in as-cast condition and after heat treatment. The chemical composition of the alloy is shown in Table 1. The solution and ageing treatment parameters are presented in Table 2. The quantitative evaluation of phases detected in the GA8 alloy after heat treatment was performed using a light microscope, OLYMPUS GX-71, equipped with an AnalySIS Pro® software as well as MetIlo® software [15].

Table 1.
Chemical composition of the GA8 magnesium alloy in wt.-%

Al	Zn	Mn	Si	Fe	Ni	Mg
8,7	0,7	0,23	0,04	0,006	0,001	balance

Table 2.
Parameters of the heat treatment

Design.	Solution treatment			Ageing treatment		
	Tem. [°C]	Time [h]	Cooling	Temp. [°C]	Time [h]	Cooling
N	As-cast					
N1	360	3	air	-	-	-
N2	N1+415	24	air	-	-	-
N3	N1+N2			170	8	air
N4	360+415	3+24	air	-	-	-
N5	N4			170	8	air

3. Description of achieved results of own researches

3.1. Microstructure of the GA8 magnesium alloy in as-cast condition

The microstructure of GA8 magnesium alloy has a solid solution structure α with α + discontinuous β areas and continuous β ($Mg_{17}Al_{12}$) phase at grain boundaries (Fig2). Moreover, the occurrence of Mg_2Si and Mn_5Al_8 phases has been provided. The average area fraction of continuous β phase was A_A=6.65% and discontinuous (α+β areas) was A_A=19.99%.

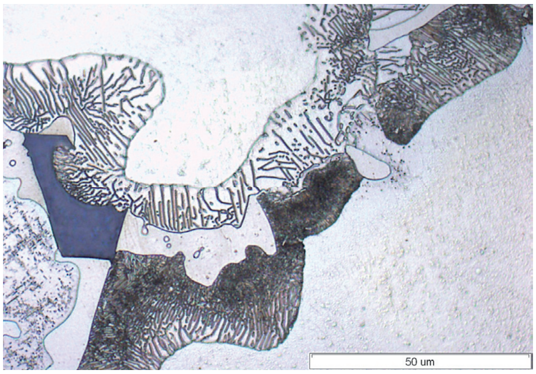

Fig. 2. Microstructure of the as-cast GA8 alloy (sample N)

3.2. Microstructure of the GA8 magnesium alloy after solution treatment

Solution treatment at 360°C/3h with air cooling led to reduction of discontinuous β phase area fraction to A_A=5.55% and continuous β phase area fraction to A_A=3.44% (Fig.3). Solution treatment at a temperature of 415°C, after treatment at 360°C caused a considerable (4-times) decrease of the β phase quantity compared to the state after treatment at 360°C. The area fraction of continuous β phase decrease to A_A=1.2%. The precipitates of discontinuous β phase weren't observed (Fig.4).

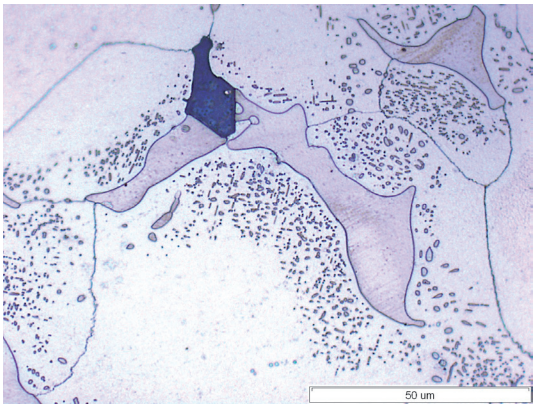

Fig. 3. Microstructure of the GA8 alloy after solution treatment 360°C/3h/air (sample N1)

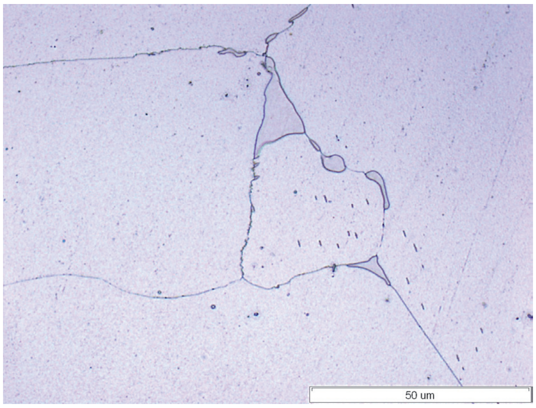

Fig. 4. Microstructure of the GA8 alloy after solution treatment 360°C/3h/air+415/24/air (sample N2)

After solution treatment at 360°C/3h/without air cooling and 415/24/air also a reduction of the number of β phase precipitations was observed. This treatment led to reduction of discontinuous β phase area fraction to A_A=0,82% and continuous β phase area fraction to A_A=0,46% (Fig.5).

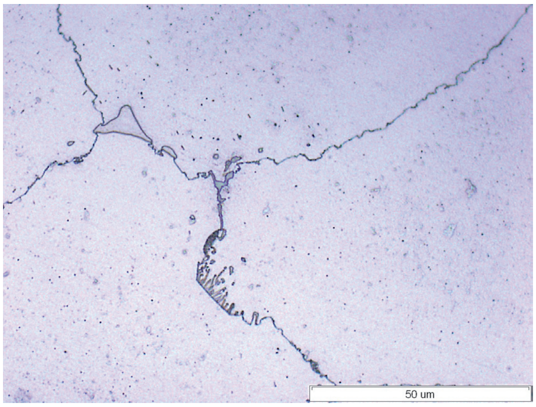

Fig. 5. Microstructure of the GA8 alloy after solution treatment 360°C/3h+415/24air (sample N4)

3.3. Microstructure of the GA8 magnesium alloy after ageing treatment

The ageing treatment 170°C/8h/air applied after solution treatment 360°C/3h/air+415/24/air caused increase of discontinuous β phase area fraction to A_A=11,03%, but did not influence to the number of continuous β phase precipitates (A_A=1,07%) compared to the state after solution treatment (Fig.6).

The ageing treatment applied after solution treatment 360°C/3h/without cooling + 415/24/cooling in air also caused increase of discontinuous β phase area fraction (A_A=2,72%), but this increase was very small. The area fraction of continuous β phase was slightly higher (A_A=2.55%) compared to the state after solution treatment (Fig.7).

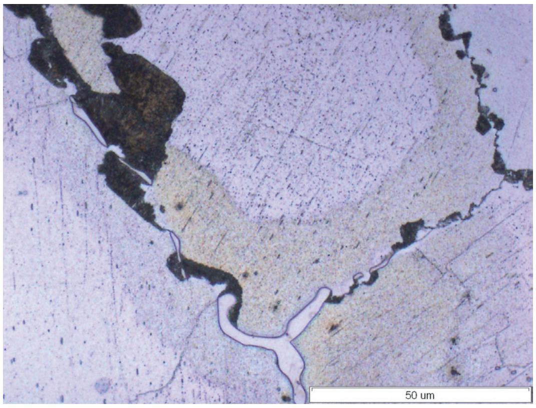

Fig. 6. Microstructure of the GA8 alloy after solutioning 360°C/3h/air+415/24/air and ageing 170°C/8h/air (sample N3)

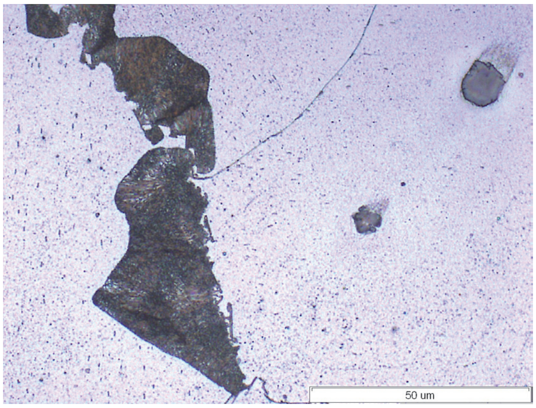

Fig. 7. Microstructure of the GA8 alloy after solution treatment 360°C/3h+415/24/air and ageing 170°C/8h/air (sample N5)

4. Conclusions

The subject of the research carried out was an evaluation of the effect of heat treatment parameters on the microstructure of the GA8 magnesium alloy. It was found that in as cast condition, the GA8 alloy had a solid solution α structure with

α + discontinuous β areas and continuous β ($Mg_{17}Al_{12}$) phase at grain boundaries.

After solution treatment a reduction of the number of continuous and discontinuous β ($Mg_{17}Al_{12}$) phase precipitates was observed. Solution treatment at 360°C/3h/air led to significant decrease of the discontinuous β phase area fraction from A_A=19.99% to A_A=5.55% and continuous β phase area fraction from A_A=6,65% to A_A=3.44% (Fig.8). Both solution treatments (samples N2 and N4) at 415°C/24h/air led to fully reduction of discontinuous β phase area fraction to A_A=0% and A_A=0.82%, respectively and significant reduction of continuous β phase area fraction to A_A=1.2% and A_A=0.46%, respectively (Fig.8).

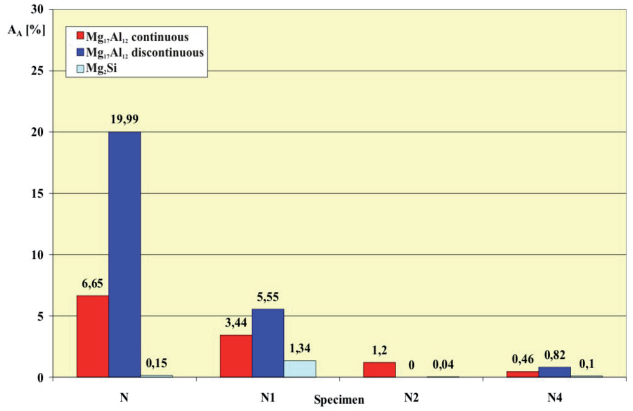

Fig. 8. Influence of the solution treatment on the β phase quantity

Application of the ageing treatment caused precipitation of discontinuous β phase along the solid solution grain boundaries. Ageing after solution treatment designated N2 caused increase of the discontinuous β phase area fraction from A_A=0% to A_A=11.03%. The area fraction of the continuous β phase did not change (Fig.9). Ageing after solution treatment designated N4 caused slightly increase of the discontinuous and continuous β phase area fraction to A_A=2.72% and A_A=2.55%, respectively (Fig.9).

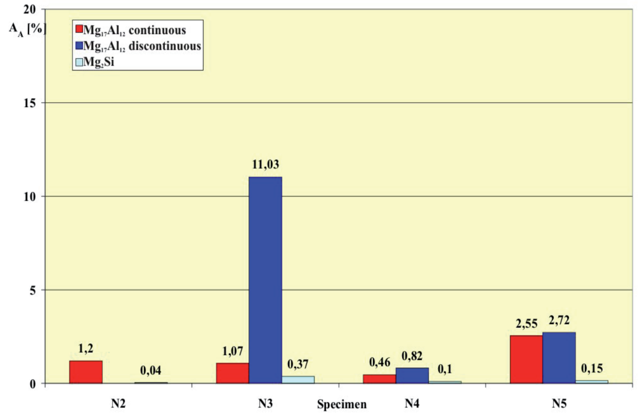

Fig. 9. Influence of the ageing treatment on the β phase quantity

Acknowledgements

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References

[1] H. Friedrich, S. Schumann, Research for a “new age of magnesium” in the automotive industry, Journal of Material Processing Technology 117 (2001) 276-281.

[2] L. Cizek, M. Greger, L. Pawlica, L.A. Dobrzański, T. Tański, Study of selected properties of magnesium alloy AZ91 after heat treatment and forming, Journal of Materials Processing Technology, 157-158 (2004) 466-471.

[3] E. Aghion, B. Bronfin, D. Eliezer, The role of magnesium industry in protecting the environment, Journal of Material Processing Technology 117 (2001) 381-385.

[4] A.A. Luo, Magnesium: current and potential automotive applications, JOM, 54, No.1 (2002) 42-47.

[5] A. Dahle, Y. Lee, M. Nave, P. Schaffer, D. StJohn, Development of the as-cast microstructure in magnesium-aluminium alloys, Journal of Light Metals 1 (2001) 61-72.

[6] L.A. Dobrzański, T.Tański, L. Čížek, Influence of Al addition on structure of magnesium casting alloys, Journal of Achievements in Materials and Manufacturing Engineering, 17, Issue 1-2, (2006) 221-224.

[7] J.Adamiec, A.Kiełbus, J.Cwajna, Microstructure of the GA8 casting magnesium alloy, Archives of Foundry no 18 (2006) 203÷208.

[8] A.Kiełbus, M.Sozańska, L.Cizek, Microstructural behavior of AZ91D magnesium alloy during heat treatment, Materials Engineering No 3 (2004) 364-367.

[9] A. Kiełbus, T. Rzychoń, R. Cibis, Microstructure of AM50 die casting magnesium alloy, Journal of Achievements in Materials and Manufacturing Engineering, 18, Issue 1-2, (2006) 135-138.

[10] C.H. Caceres, C.J. Davidson, J.R. Griffiths, C.L. Newton, Effects of solidification rate and ageing on the microstructure and mechanical properties of AZ91 alloy, Materials Science and Engineering A325 (2002) 344-355.

[11] P.F. Stratton, E.K. Chamg, Protective atmospheres for the heat treatment of magnesium alloys, TMS Annual Meeting, Symposium: Magnesium Technology 2000.

[12] E. Cerri, M. Cabobbo, E. Evangelista, Microstructural evolution during high-temperature exposure in a thixocast magnesium alloy, Materials Science and Engineering A333 (2002) 208-217.

[13] M. Zhang, P.M. Kelly, Crystallography of $Mg_{17}Al_{12}$ precipitates in AZ91D alloy, Scripta Materialia 48 (2003) 647-652.

[14] D. Duly, J.P. Simon, Y. Brechet, On the competition between continuous and discontinuous precipitations in binary Mg-Al alloys. Acta Meta. Mater. Vol. 43, No. 1,m pp. 101-106, 1995.

[15] J. Adamiec, A. Kiełbus, J. Cwajna, J. Paśko, Procedure of Quantitative Description of Mg-Al Alloy Structure After Heat Treatment, Magnesium alloys and their applications, Dresden, 2006.