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ANALYSIS OF THE POSSIBILITIES OF HEAT TREATING THE GA8 MAGNESIUM ALLOY

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The article presents the results of the preliminary analyses of the effect of T4 and T6 heat treatments on the structural changes in the GA8 magnesium alloy as compared to the as-cast condition, and sets the obtained results against the relevant literature data. Performed microstructural observations and HV microhardness and HB hardness examinations have made it possible to reveal substantial differences in the changes occurring in the material under study. A possibility of applying solution heat treatment in water and a favourable effect of this process on the post-ageing alloy structure have also been found.

1. Introduction

Casting alloys of magnesium with aluminium, zinc, or rare-earth metals owe their susceptibility to heat treatment to the variable solubility of the alloy components in solid state with temperature. The basic heat treatments are homogenizing and solutioning processes along with artificial ageing. In the literature, however, the heat treatment of magnesium alloys, similarly as most information on their subject, are covered in a very fragmentary and undefined manner [1-4]. For this reason, an attempt has been made in the study to analyze the possibility of applying basic heat treatments to magnesium alloys on the example of the GA8 alloy. The composition of the alloy under study was the following: 7.5÷9.0%Al; 0.2÷0.8%Zn; 0.15÷0.5%Mn and max. 0.5% of impurities (Si, Cu, Fe, Be, Zr).

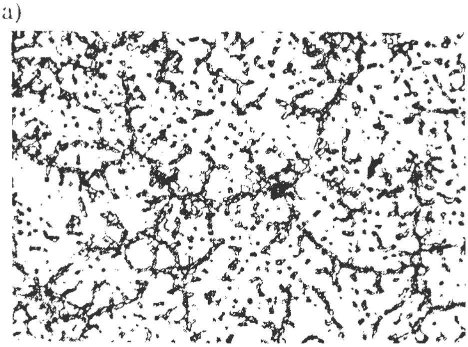
The literature describing the heat treatments of magnesium alloys [1,2] claims it necessary to use protective atmospheres, e.g. air with an admixture of 0.7÷1.0%SO_2. Because of the noxiousness of this type compounds, however, in tests carried within this study no protective atmospheres were used.

According to the literature data [1, 3], the process of the solution heat treatment of magnesium alloys should be conducted in air (because of the slow rate of diffusion processes). Even more categorical statements can also be found, that magnesium alloys should not be solution heat treated in water in view of the violent reaction occurring between the hot alloy and water [2, 4]. Nevertheless, solution heat treatments were carried out comparatively in this study, both in air and in water with a large amount of ice, respectively.

2. Structure of the Cast GA8 Alloy

The structure of the gravity cast GA8 alloy has a dendritic build, which is characterized by very heavy segregation of components (Fig. 1). Magnesium-aluminium alloys, like magnesium-zinc alloys, are prone to segregation due to the relatively broad temperature spans between the liquidus and the solidus curves. The equilibrium structure of the GA8 alloy should be composed of the solid solution, α, and the secondary precipitates, γ'. Non-equilibrium solidification conditions cause, however, the formation of large crystals of the phase α (depleted in aluminium) and pushing the Al admixture away into inter-dendrical spaces, where, at the final phase of solidification, primary γ precipitates form (Fig. 1b). With the further cooling of the casting, γ' secondary precipitates may form in solid state at the moment of transgressing the limiting solubility line, which have a characteristic flake-like build (Fig. 1c). Both the formation and the amount of those precipitates are dependent on the casting cooling rate. It should be noted that during the non-equilibrium solidification of the alloy traces of T phase might also occur.

a)



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c)

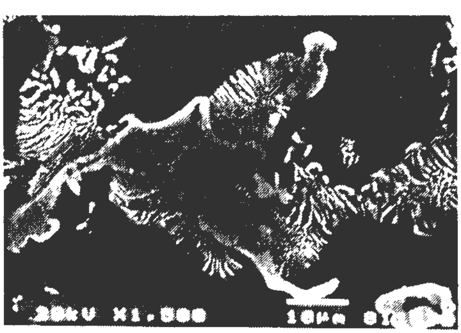

Fig. 1. Microstructure of the cast GA8 alloy
a) optical microscope, magn. 100x
b) optical microscope, magn. 1000x,
c) SEM, magn. 1000x

The observed structural inhomogeneity of the cast GA8 alloy was the cause of the non-uniformity in the properties of this material. Microhardness examinations performed by the Vickers method have enabled a very substantial difference in microhardness to be found between the α solid solution and the areas heavily enriched in aluminium (the γ areas). For the α phase, microhardness was around 64V01, while for the γ precipitates being approximately 190HV01. The average hardness of this alloy, as determined by the Brinell method (ball diameter 5 mm, load 2450 N, measurement time 20 s) was 70HB.

3. Structure of the GA8 Alloy After Heat Treatment

3.1. T4 Treatment

The process of homogenizing the cast GA8 alloys was conducted at 400°C for 26 hours, followed by slow cooling (at a rate of approx. 5°C/h). The microstructure of the obtained material was characterized by a disappearance of the dendritic build and an occurrence of α-phase grains with a large amount of flake-like γ' secondary precipitates (Fig. 2). Microhardness measurements taken on this structure showed the value of 96HV01. The hardness of the homogenized alloy was approximately 85HB.

a) b)

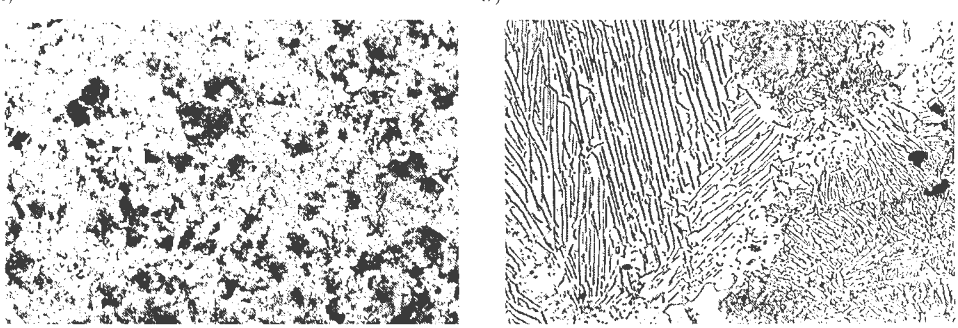

Fig. 2. Microstructure of the GA8 alloy in T4 condition, a) magn.100x, b) magn.500x

The examined alloy, with a relatively high aluminium content, is characterized by a rather narrow temperature span between the solidus and the solvus, which restricts operating with substantially different temperature ranges. Moreover, due to the highly non-equilibrium structures of the alloy after casting, there is a danger of occurring localized melting upon surpassing the eutectic temperature of 437°C. For this reason, the temperatures of homogenization of magnesium alloys range within 370÷425°C [1]. Because of the slow rate of diffusion processes in those alloys, on the other hand, the homogenization requires very long times, i.e. 6÷24 hours [1]. It should be noted, however, that the time necessary for the homogenization of the GA8 alloy can be longer than that given by the literature. Too short time of the process will lead to an incomplete dissolution of γ primary phases in the matrix, and will also result in areas free from γ′ precipitates being left in the structure, for which microhardness drops to the value of 81HV01 (Fig. 3).

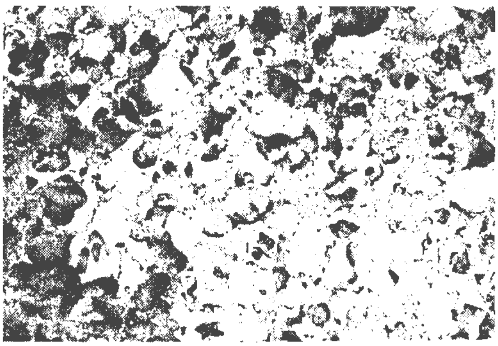

Fig. 3. Microstructure of the GA8 alloy in T4 condition, magn. 100x.

3.2. T6 Treatment

Homogenized specimens were subjected comparatively to two solution heat treatments: one in air, and the other one in water with a large amount of ice. The resulted supersaturated specimens were then subjected to the identical artificial ageing process at 150°C for 16 hours. After ageing, the specimens were cooled down in air.

The microstructure of the alloy solution heat treated in air and artificially aged was characterized by clearly finer (as compared to the T4 treatment) γ′ secondary precipitates (Fig. 4a-b). However, some differences in the amount of precipitates per individual grains were observed. In fact, a considerable amount of grains with either incomplete or missing γ′ precipitates had left in this alloy. These grains are visible in Figure 4a as the most bright ones. This caused differences in microhardness, ranging from 88HV01 for grains depleted in the secondary precipitates to 99HV01 for grains rich in the γ′ precipitates.

Applying solution heat treatment in water with ice, on the other hand, caused even greater size reduction of the flake-like γ′ precipitates, and in addition, it enabled a more uniform their distribution to be obtained within the alloy volume (Fig. 4c-d). The bright grains visible in Figure 4c are in this case grains with equally high amount of the γ′ precipitates, but these being fine and oriented at a different angle to the microsection surface. They can be recognized at high magnifications reached using an electron scanning microscope. For this reason, no differences in the microhardness of individual grains were observed, with microhardness being 110HV01 for this alloy. Brinell hardness, on the other hand, increased to 105HB.

The presented examination results, as opposed to the literature data, enable one to state that the solution heat treatment process as conducted in water with ice prior to ageing is possible to be run safely, and also it permits a favourable, homogeneous and finely dispersed alloy structure and an increased hardness to be obtained. It can be assumed on the basis of the known theory of supersaturating solid solutions that this is probably the result of reaching an increased (non-equilibrium) concentration of point defects being favourable nucleation centres for secondary precipitates.

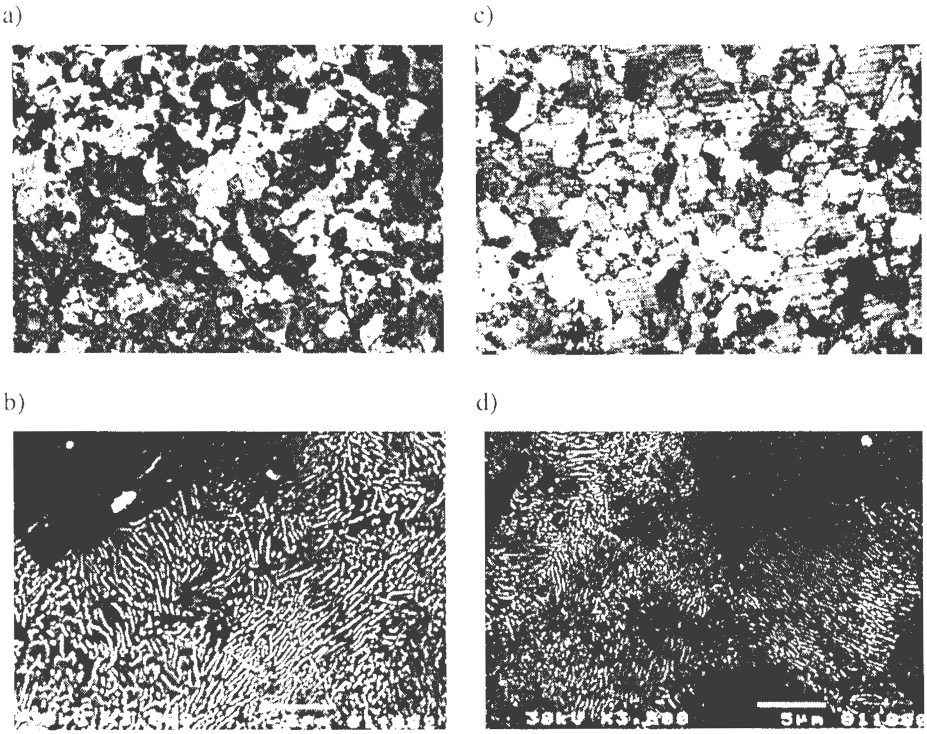

Fig. 4. Microstructure of the GA8 alloy in T6 condition;
a-b) supersaturation in air, a – optical microscope, magn. 100x, b – SEM, magn. 3500x,
c-d) supersaturation in water with ice, c – optical microscope, magn.100x, d – SEM, magn. 3500x

4. Summary

The performed preliminary analysis of the heat treatment of the GA8 alloy provides capabilities for further creating its structure and properties. It has been found from the tests carried out that the use of non-ecological protective atmospheres is unnecessary during heating the elements of the GA8 alloy. In addition to the oxide film on the surfaces of the elements being treated (which is formed also at ambient temperatures), no other harmful effects associated with such conducted processes were found. Moreover, it is possible to solution heat treat the alloy in water. No unfavourable phenomena were observed in this treatment, such as cracking of the treated elements, violent reactions between the hot alloy and water, or any other signs indicating that this might be a dangerous treatment. What has been found is that this treatment enables us to obtain the most favourable structure and a uniform distribution of the highest reached microhardness values within the specimen volume. The presented analysis requires, however, further investigations to be carried out into both the structural and mechanical properties.

Literature:

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List of Designations:

α – solid solution of aluminium and zinc in magnesium (A3 lattice)
γ – $Al_{12}Mg_{17}$ alloy-based solid solution (A12 lattice)
γ' – secondary precipitates of the $Al_{12}Mg_{17}$ compound
T – $Al_2Mg_3Zn_3$ compound based solid solution (multiple cubic lattice)
T4 – homogenizing
T6 – hyperquenching and artificial ageing

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ANALIZA MOŻLIWOŚCI OBRÓBKI CIEPLNEJ STOPU MAGNEZU GA8

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1. Wprowadzenie

W pracy podjęto próbę analizy możliwości stosowania podstawowych zabiegów obróbki cieplnej stopów magnezu na przykładzie, odlewniczego stopu magnezu GA8. Skład badanego stopu wynosił: 7,5÷9,0% Al, 0,2÷0,8% Zn, 0,15÷0,5% Mn oraz max.0,5%