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INFLUENCE OF AGING HEAT TREATEMENT ON SOME MECHANICAL PROPERTIES OF THE AlZn5.7MgCu ALLOY THROUGH EXPERIMENTAL RESEARCHES

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Abstract: The paper presents the results of experimental research at laboratory scale on the influence of AlZn5.7MgCu alloy thermal processing mode. Two types of aging heat treatment were studied, namely: a natural aging and an artificial aging treatment. For each of the two types of technological heat treatment, the change of the mechanical properties was monitored according to the parameters of the aging procedure. The experimental research of this paper highlights the advantage of artificial aging as compared to natural aging, but this advantage must also be seen in terms of the costs implied by the two types of treatment.
Keywords: aluminium alloy, heat treatment, mechanical characteristics

INTRODUCTION

There is a close relationship between the development of the aviation industry and the evolution of the materials it uses. It is well known that this top area of the technique requires advanced materials with special physical and mechanical properties.

AlZn5.7MgCu alloy is part of special aluminium alloys from Al-Zn-Mg-Cu system, of zicral type. These alloys have high mechanical characteristics and low density, which is why they are interesting for the aviation industry and automotive industry [1-6].

In the raw molded state in general, these alloys have a low mechanical strength and deformability which modifies very much by applying heat treatments [6].

Al-Zn-Mg-Cu alloys have a tensile strength which becomes greater as the precipitates formed after the aging process, natural or artificial, are more numerous, finer and more dispersed in the mass of the base solution (solid solution).

The phase transformations in the solid state occurring during thermal processing, if they are allowed in the alloy equilibrium diagram, represent an essential condition for making a heat treatment, by quenching, putting it in solution and artificial or natural aging, of an aluminium alloy. An alloy of this type can support an order-disorder reaction.

In the case of aluminium alloys with structural hardening, the increase of mechanical characteristics occurs on account of the complex interactions between the dislocations of the basic matrix and the precipitate particles arising in the alloys structure following aging.

The high strength of Al-Zn-Mg-Cu alloys is directly proportional to the increase of the amount of Zn or Zn + Mg content, thus generating metastable fine precipitates zones, rich in Zn and Mg, which represent the so-called GP zones [1].

The stages of the structure hardening mechanism after applying aging heat treatments are: forming the supersaturated solid solution through quenching by putting it in solution, forming Guinier - Preston areas during the aging process; first precipitates form a metastable zone (η'), then, as the temperature gradient is higher, these areas become stable (η), i.e. the formation of $MgZn_2$ precipitates [2].

MATERIAL AND METHOD

The materials for the experimental research are samples of the Al-Zn-Mg-Cu system alloy, whose chemical composition is shown in Table 1. The chemical composition of the alloy studied falls within the EN 573-3-2013 requirements [10].

Table 1. Chemical composition of the researched alloy [10]

Alloy / Element	Zn	Mg	Cu	Si	Fe
AlZn5,7MgCu	5.76	2.61	1.55	0.15	0.19
Alloy / Element	Pb	Cr	Mn	Al	
AlZn5,7MgCu	0.021	0.19	0.10	rest	

In order to be used in the aviation industry or in the automotive industry, this alloy must acquire, after applying thermal processing regimes (natural or artificial aging), the mechanical properties stipulated in EN 485-2-2013 [11], which are shown in table 2.

Table 2. Alloys properties [11]

Element / Alloy	Rm / MPa	$Rp_{0,2}$ / MPa	A_5 / %	HB
AlZn5,7MgCu	540	470	7	161

In this paper, the influence of some heat treatment regimens on the mechanical properties of the AlZn5.7MgCu alloy was experimentally researched.

Experiments have been conducted in two thermal processing technological variants: variant I, which is represented by the natural aging, and variant II, which is the artificial aging regime.

Ingots casting was performed on the casting system of SC Wagstaff from Alro Slatina S.A., Romania. Also at SC Alro S.A. was performed the ingots homogenization treatment at a temperature of 480/°C in an Olivotto semi-continuous furnace operating within the 460-610/°C temperature range.

Samples heating for hot-rolling at a temperature of 435/°C, hot plastic deformation with a reduction rate of 25/%, heating the samples at 500/°C for quenching through putting in solution as well as warming the samples to artificial aging temperatures were conducted in the Laboratory of Plastic Deformation and Heat Treatment of the Faculty of Engineering with "Lower Danube" University of Galati. These technological operations are common for both variant I and II.

The temperatures of artificial aging are: T_1 = 120C, T_2 = 140/°C, T_3 = 160/°C, T_4 = 180/°C, T_5 = 200/°C with the resistance time of: τ_1 = 4/hours, τ_2 = 8/hours τ_3 = 12/hours, τ_4 = 16/hours, τ_5 = 20/hours for each temperature.

Research variant I studied, for a degree of hot plastic deformation ε = 25%, the influence of the resistance duration in the case of natural aging for τ_1 = 24/hours, τ_2 = 72/hours τ_3 = 168 / hours τ_4 = 360/hours, τ_5 = 720/hours τ_6 = 1080/hours, τ_7 = 1440/hours, on the mechanical properties studied.

Research variant II studied, for a degree of hot plastic deformation ε = 25%, the influence of temperature and resistance time in the case of artificial aging, on the mechanical properties studied.

The manufacturing from the homogenized ingots of the samples (test pieces) for carrying out the experiments, according to variants I and II, was made after metal cutting to the dimensions: length = 105/mm, height = 7/mm, width = 55/mm. After the hot plastic deformation, the sample dimensions had the following values: length = 150/mm; height = 5/mm; width = 60/mm.

RESULTS

After thermo-mechanical treatment, the samples were subjected to thermo mechanical testing and the mechanical characteristics were determined: Rm, $R_{p0.2}$, A_5 and HB. On the basis of these results, there have been made the graphs of mechanical properties variation depending on the temperature and aging time.

The graphical representation of mechanical properties variation with natural aging time, according to variant I, is shown in Figures 1 and 2.

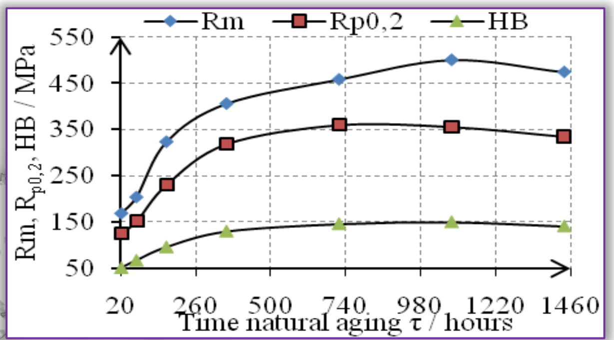

Figure 1 - Variation of Rm, Rp0.2 and HB during natural aging

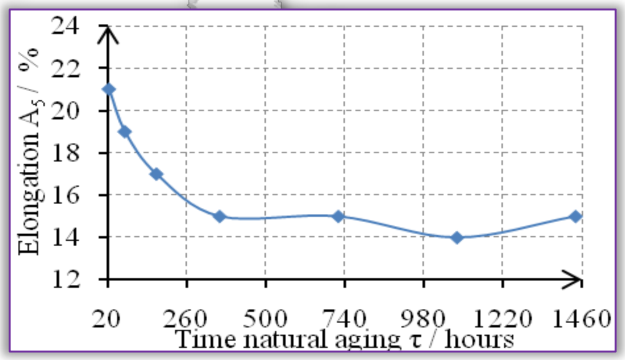

Figure 2 - Variation of elongation at break with natural aging time

Figure 1 shows resistance properties variation according to natural aging time and it can be noticed that these mechanical characteristics increase as the natural aging time increases, up to a maximum value corresponding to a time of 1080 hours.

The graph in Figure 2 shows that the elongation at break decreases as the natural aging time increases and records a minimum at the time of 1,080 hours, followed by a slight increase.

For the tensile properties, as well as for elongation, this variation can be explained by the fact that the precipitates formed during the natural aging process reached a critical value of their size, after which their growth by coalescence followed.

More specifically, the growth of the large ones occurs at the expense of the small ones, and structurally is recorded a decrease of grain limits, which lowers the mechanical strength at the expense of plasticity. In Figures 3-6 are shown the properties variations of the studied alloy, according to experimental research variant II.

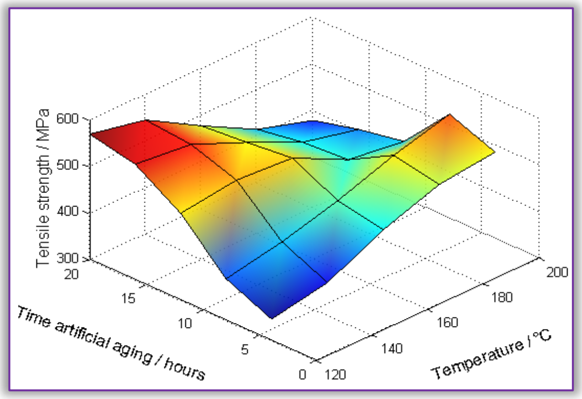

Figure 3 - Mechanical resistance variation with artificial aging time and temperature

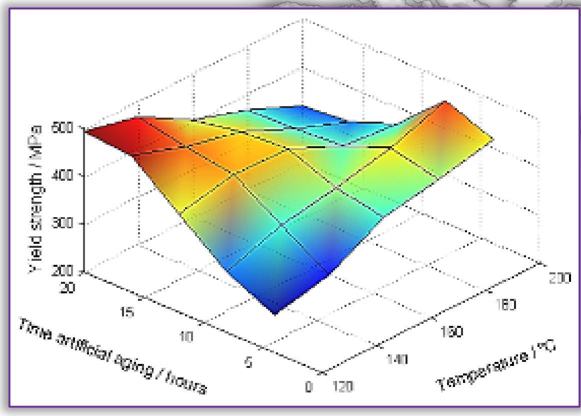

Figure 4 - The variation in yield strength with artificial aging time and temperature

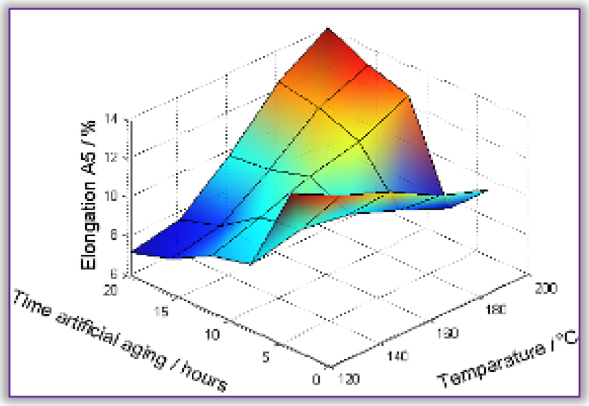

Figure 5 -Variation of elongation at break with artificial aging time and temperature

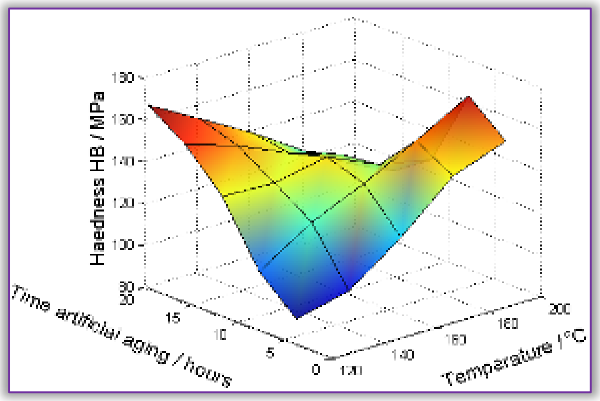

Figure 6- HB hardness variation with artificial aging time and temperature

For properties Rm, $R_{p0.2}$, HB was found a growth of their values with the increasing of the duration of treatment at temperatures of 120 and 140/°C.

The thermal regime with temperatures of 180 to 200/°C and duration of 8 hours, led to maximum values of the mechanical characteristics.

As the aging time increases above this value, the mechanical properties decrease.

The temperature of 160/°C leads to mechanical resistance values that increase with the increasing of the treatment time, up to a period of 12 hours, after which a decrease in mechanical properties can be seen.

The variation of the elongation at break is inversely proportional to that of the strength properties. The highest value for A5 is obtained at 200/°C and a treatment time of 20/hours.

Figure 7 shows the microstructure of the alloy that was submitted to natural aging for 729 hours, and where the formed precipitates on the basis of Al, Zn and Mg, leading to material hardening, are noticed.

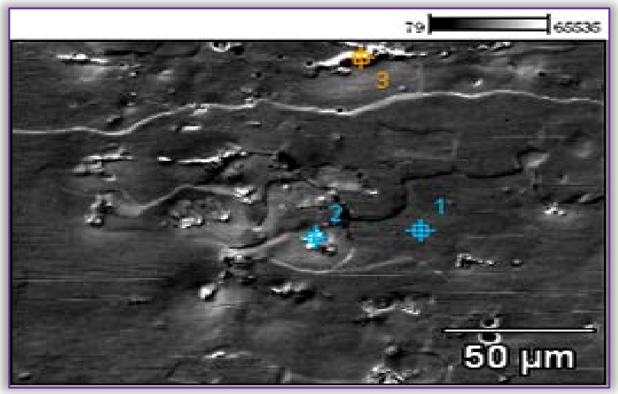

Figure 7 - Natural aging microstructure (τ =720 / hours), 1509: 1 zoom

Figure 8 shows the microstructure of the alloy after having been artificially aged at 140/°C for 8/h. By comparing the two images, it can be seen that after artificial aging, the number of precipitates is bigger and they are more finely dispersed in the base matrix of solid solution α, as compared to those formed by natural aging.

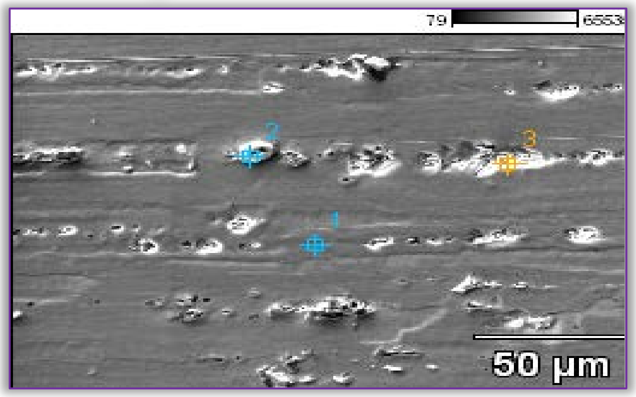

Figure 8 - SEM electron microscopy of the studied material subjected to treatment variant II at 140/°C and a time of 8/h, 1448: 1 zoom

This also explains the high values of the mechanical characteristics that were obtained from thermal processing according to variant II.

CONCLUSIONS

After conducting experimental research the following conclusions can be drawn:

- the aging of quenched alloys leads to supersaturated solid solution decomposition with the emergence of secondary phases in a controlled dispersion and the solid solution getting closer to equilibrium;
- the type, size, distribution and amount of the precipitated particles in an alloy depend on the temperature, duration of aging and initial state of the microstructure;
- the mechanical properties of the alloy continuously vary with the temperature and duration of aging;
- increasing the temperature of aging or extending durations over a certain value decreases the resistance properties, but gives good dimensional and properties stability (over aging with precipitates coagulation);
- the allure of the properties variation curves at aging shows that the maximum values of one of the followed properties decreases as the temperature or duration rise above the optimum value; approximately the same values of a feature can be obtained either at higher temperatures and shorter durations, or at lower temperatures and longer durations);
- mechanical resistance varies inversely with elongation at break, so that to achieve high strength while maintaining a sufficient plasticity, moderate temperatures and extended durations are selected;
- of the two types of heat treatment researched, the best mechanical resistance properties were obtained after the artificial aging regime;
- the properties required by EN 485-2-2013 for the studied alloy are met for only some thermal processing parameter values in the variant II.

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