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EXPERIMENTAL STUDIES AND RESEARCH DURING HEAT TREATMENT ON THE BEHAVIOUR/AGING OF Al-Zn ALLOY SYSTEM WITH DIFFERENT Zn CONTENTS

Marian NEACSU, Elena DRUGESCU, Elisabeta VASILESCU
„Dunarea de Jos” University of Galati
email: uscaeni@yahoo.com

ABSTRACT

The paper presents the results of a research on the behavior at artificial aging heat treatment carried out on three different chemical compositions of the alloys belonging to Al-Zn system.

We studied the behavior of the three alloys after applying more thermal regimes during artificial aging. Following the experiments conducted, we can notice an increase in strength properties with increasing zinc content of the alloys investigated.

KEYWORDS: aluminum alloy, heat treatment, Zn content, microstructures

1. Introduction

The alloys studied in the Al-Zn system are aluminum alloys in the 7000 series, which, due to their special characteristics are used mainly in the aviation industry and machine building [7]. The alloys are deformable and hardenable by applying heat treatment and/or thermo-mechanical treatment. Some of them have mechanical properties comparable to copper-based alloys or to some brands of steels and even metallic titanium, but have the advantage that they have a much lower density.

For Aeronautical industry where alloys are subject to multidirectional service requests, they must provide an optimal combination of mechanical strength, plasticity, toughness, fatigue resistance and good resistance to stress corrosion.

To achieve this optimum level, it is necessary to replace the coarse grain structure obtained in the process of casting alloys and to amend fiber structure of semi-finished rolled products; they are decisive factors in order to achieve optimal properties.

Therefore the aim of the experimental research in this work was to obtain semi-finished products with a structure able to give the desired properties to the material.

Basic requirements for an aluminum alloy to be heat treated by quenching and artificial aging implementing solution are that they should allow in the equilibrium diagram phase transformations in solid state. Such a type of alloy is the one able to support an order-disorder reaction; the hardening which accompanies this process (similar to the precipitation hardening) is determined by the order-hardening reaction.

However, for this form of hardening conditions are quite strict so that the most important methods often used for alloys are based on precipitation from supersaturated solid solution and by eutectic decomposition. Precipitation reaction occurs following a decrease in solubility with temperature of solid solutions when there is a line of variation of solubility in the equilibrium phase diagram of the system [6], [7].

The breaking strength of Al-Zn-Mg alloy-Cu is even greater as the precipitates formed, which represent the hardening stage in the process of natural or artificial aging, are more numerous, finer and more dispersed in the basic solution mass (solid solution).

2. Experimental conditions

Experimental researches were conducted on samples of Al-Zn alloy, three chemical compositions shown in Table 1 and physical-mechanical characteristics in Table 2. Samples were processed in accordance with the technological scheme shown in Figure 1, showing the sequence of technological operations in the experimental variants adopted.

Table 1. *Chemical composition of researched alloys*

Element / Alloy	Zn	Mg	Cu	Si	Fe	Pb	Cr	Mn	Al
1 AlZn2.6Mg2	2.67	2.06	1.22	0.31	0.29	0.0025	0.06	0.47	rest
2 AlZn4.5Mg1	4.5	1.4	0.2	0.35	0.4	-	0.35	0.5	rest
3 AlZn5.7MgCu	5.76	2.61	1.55	0.15	0.19	0.021	0.19	0.10	rest

Table 2. *Physico-mechanical properties imposed by European norm EN 485-2-2007*

Element / Aliajul	**Rm.** [MPa]	**$Rp_{0.2}$** [MPa]	**A_5** [%]	**HB**
1 AlZn2.6Mg2	160	130	16	45
2 AlZn4.5Mg1	350	280	11	104
3 AlZn5.7MgCu	470	395	7	135

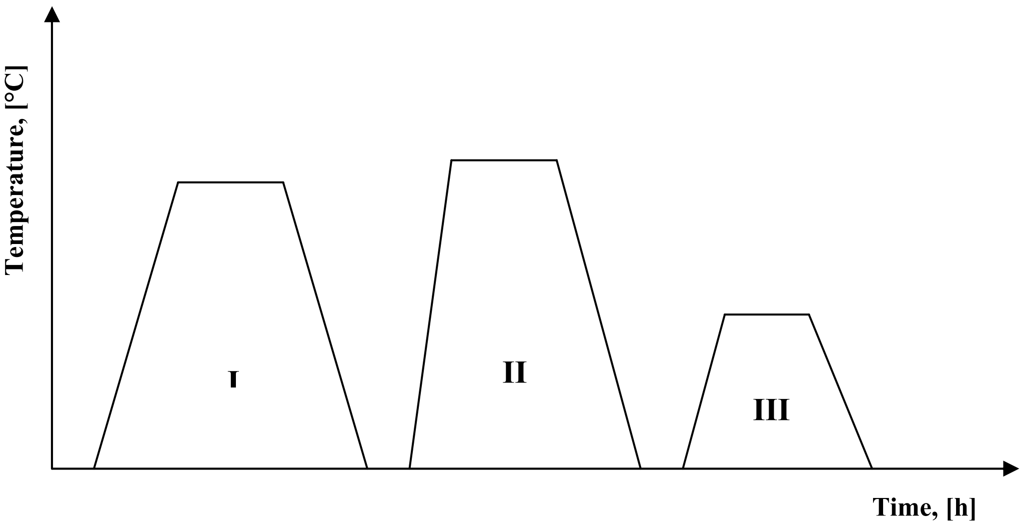

Fig. 1. *Technological scheme of realization of experiments*
I- homogenization; II- Solution quenching; III – artificial aging.

After the homogenization of ingots, corresponding to the three chemical compositions at a temperature of 480 °C and slow cooling in the oven, samples were cut from them which were heated to 500 C, maintained at this temperature for 120 minutes followed by cooling in water solution for implementing quenching in solution. As a result of structural changes, homogenization, improves alloys plasticity and unifies their final properties, leads to reduction of internal tensions and to changes in microstructure. In the first phase of homogenization some part of the $MgZn_2$ becomes Al_2CuMg while the other, unchanged, is dissolved in the mass of solid solution. The phase containing AlFeSi is partially transformed into Al_7Cu_2Fe. Mg_2Si compound undergoes small changes and slow cooling from homogenization temperature to room temperature leads to precipitation of $MgZn_2$

Solution quenching is intended to get the solid solution with maximum amount of alloying elements dissolved and to maintain this structure of homogeneous solution to the ordinary temperature. Aging of hardened alloys leads to decomposition of oversaturated solid solution with the appearance of secondary phases in a controlled dispersion and solid solution near the equilibrium. Type, size, distribution and amount of precipitates particles in an alloy depend on temperature, aging time and the initial state of microstructure. [6], [7]

Artificial aging was performed at the following temperatures:120 C, 140°C, 160°C,180 C and 200 C and duration of maintenance: 4 hours, 8 hours, 12 hours, 16 hours and 20 hours for each temperature of aging.

3. Experimental results

The variation of some mechanical properties achieved after thermal /thermo-mechanical processing, according to the diagram in Figure 1 is illustrated in figures 2, 3, and 4 for alloy composition 1 (Table 1).

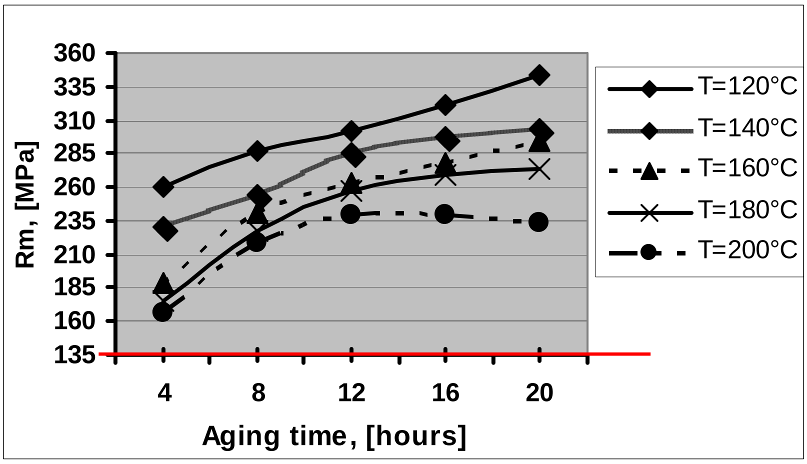

Fig.2. *Variation of mechanical resistance for an alloy based on the time of artificial aging.*

From Figures 2 and 3 we can see that for all times and all artificial aging temperatures studied, the values required by the Euronorm (160 MPa for Rm and 45HB) are met.

Mechanical resistance values as well as those of Brinell hardness increase as artificial aging temperature decreases and the maintaining time at these temperatures increases. For the temperature of 200 C it can be seen that the value of properties (Rm, HB) reaches a maximum for a maintaining time of 12 hours, after which both mechanical strength and hardness begin to decline.

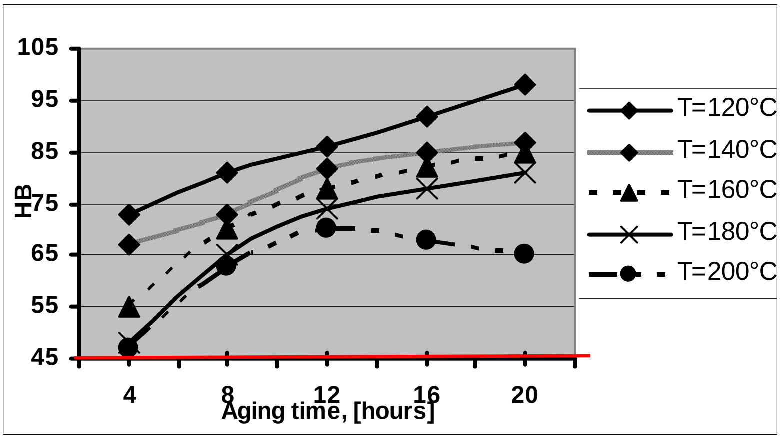

Fig.3. *HB hardness variation for alloy 1 according to artificial aging time.*

As Figure 3 shows, breaking elongation records values greater than or equal to the value required only for some artificial aging temperatures and times. For maintenance during 4 hours, only 160 °C, 180 C and 200 C lead to elongation values which satisfy the requirements. For maintenance times of 8, 12 and 20 hours, only the temperature of 200°C provides the samples with an elongation greater than 16% (fig. 4). For the retention time of 16 hours none of aging temperatures leads to an elongation of at least 16%.

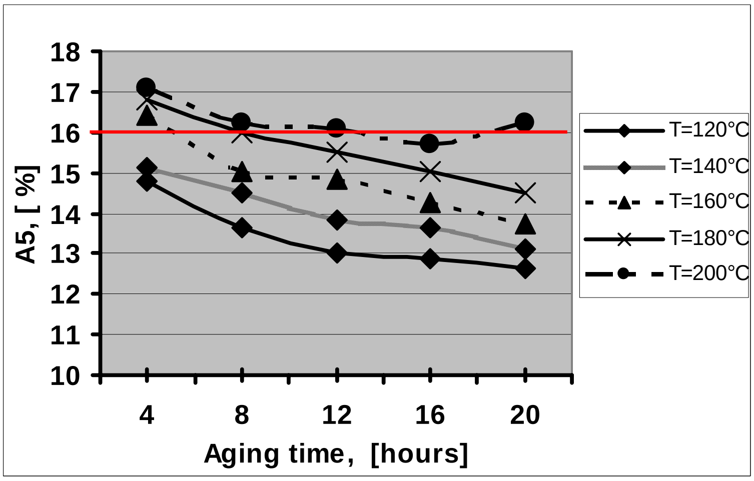

Fig.4 *Change in elongation at break for alloy 1 according to artificial aging time.*

For alloy 2, as shown in Figure 5, the strength as imposed minimum value is obtained for aging temperatures of 120°C and 140°C with maintenance times higher than 8 hours and at a temperature of 16°C with maintaining times higher than 16 hours. The minimum value required for strength is not achieved for temperatures of treatment of 180 and 200°C regardless of the maintenance time considered in these experiments. Figure 6 illustrates the results obtained for Brinell hardness in the case of alloy 2. For the temperature of 120 C at maintaining times of more than 8 hours, it is obtained the value imposed for the alloy to be used.

For the temperature of 140 C at maintenance times higher than 16 hours, it is ensured an HB value greater than the one imposed. This value, in case of artificial aging at a temperature of 160 C, is performed only during a maintenance time of 20 hours while for the other treatment temperatures studied we can see that it is not done.

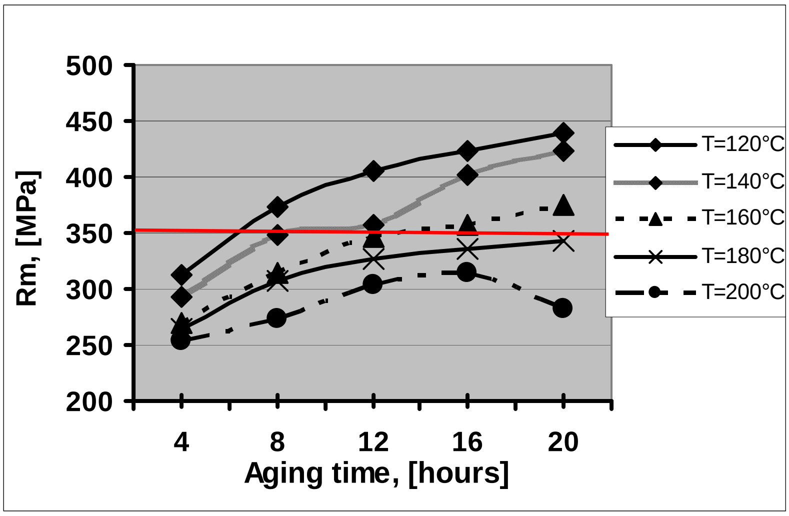

Fig.5. *Variation of mechanical resistance for alloy 2 depending on the time of artificial aging.*

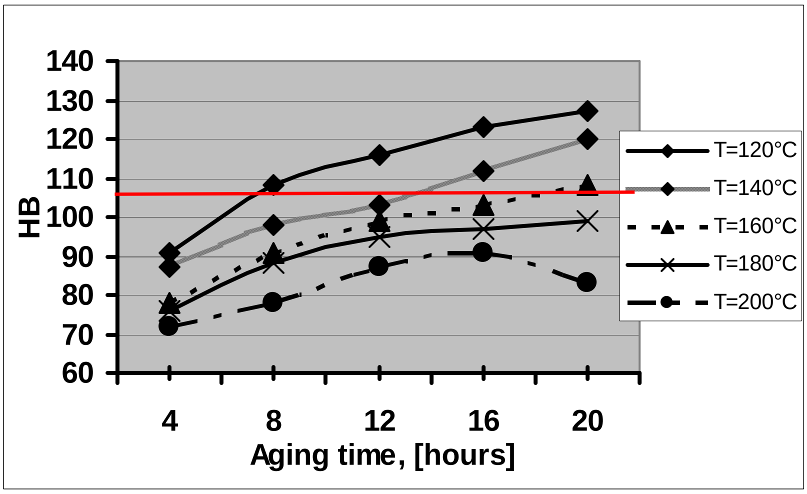

Fig.6. *HB for two alloy hardness variation depending on the time of artificial aging.*

From Figure 7, we can see that for elongation at break the value imposed by Euronorm is not made only for the temperature of 120°C during the maintenance of 16 to 20 hours. For alloy 3 experimental research results are shown in Figure 9 for strength, in figure 10HB hardness and in Figure 11 for elongation at break. Tensile strength has values over the rules imposed after artificial aging at a temperature of 120°C for all treatment times. For a temperature of 140°C, the limit value is exceeded for maintenance times higher than 8 hours, and for the temperature of 160°C this minimum value imposed is achieved only for maintaining times exceeding 16 hours. For other aging temperatures, regardless of the maintaining time, the value required by Euronorm is not obtained.

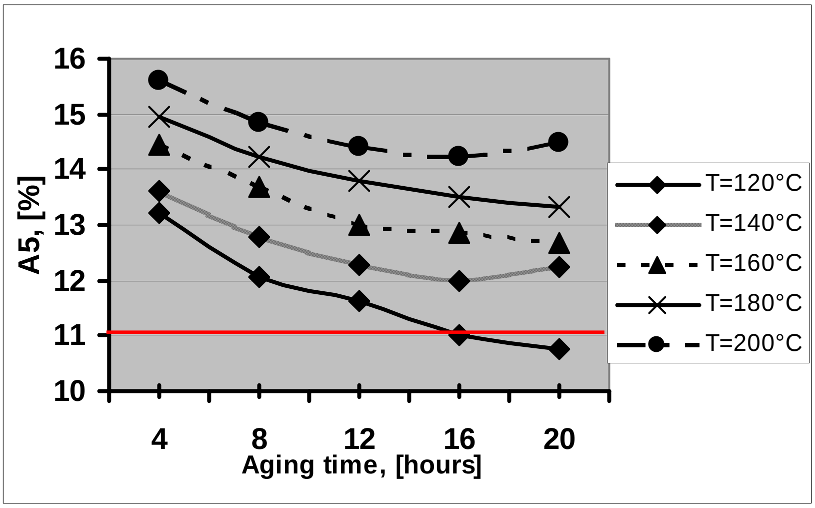

Fig. 7. *Change in elongation at break for alloy 2 depending on artificial aging time.*

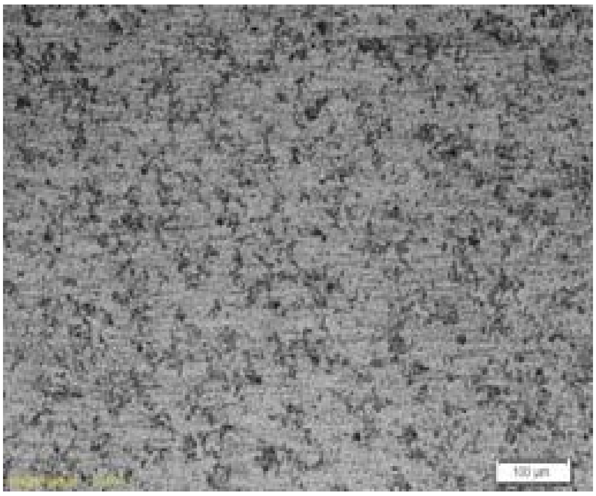

Fig.8. *Microstructure of alloy 2 aged artificially at a temperature of 120°C with a retention time of 12 hours (X100).*

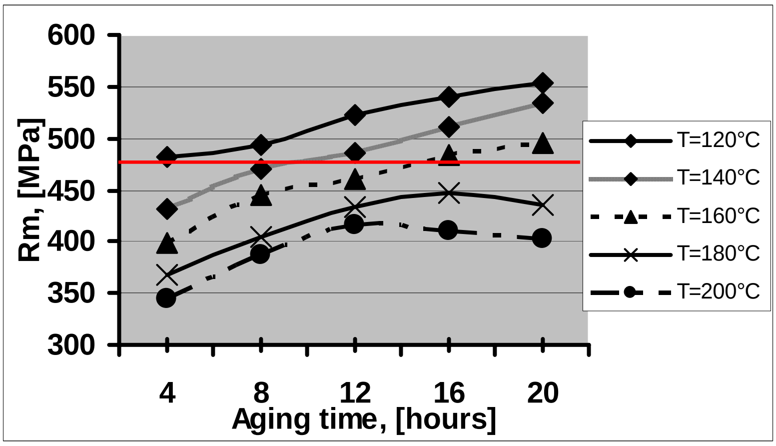

Fig.9. *Variation of mechanical resistance for alloy 3 according to the time of artificial aging.*

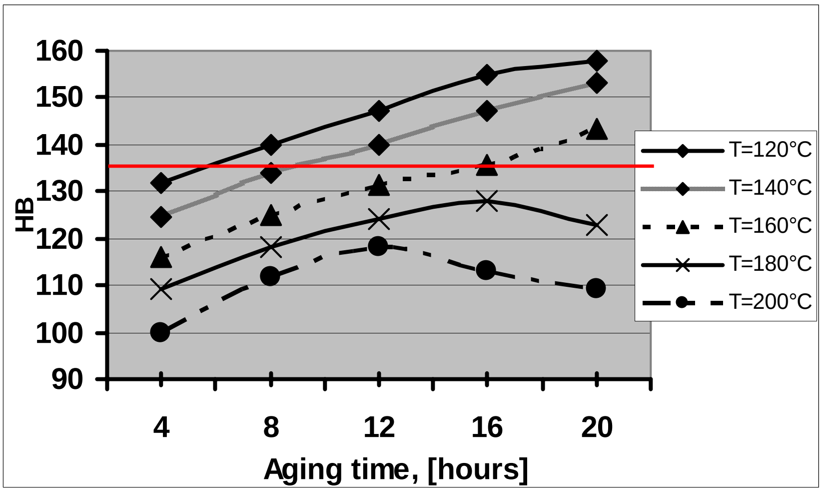

Fig.10. *Change in hardness for alloy HB 3 depending on the time of artificial aging.*

By analyzing the variation of HB in Figure 10, it can be seen that hardness varies similarly to tensile strength. The required value for hardness is not achieved at the artificial aging temperatures of 180 C and 200 C regardless of the maintaining time at these temperatures. The highest values were obtained for a temperature of 120°C for 20 hours. Elongation at break for alloy 3 obtained after artificial aging heat treatment (fig.11) was higher than the value imposed for any of the variants investigated.

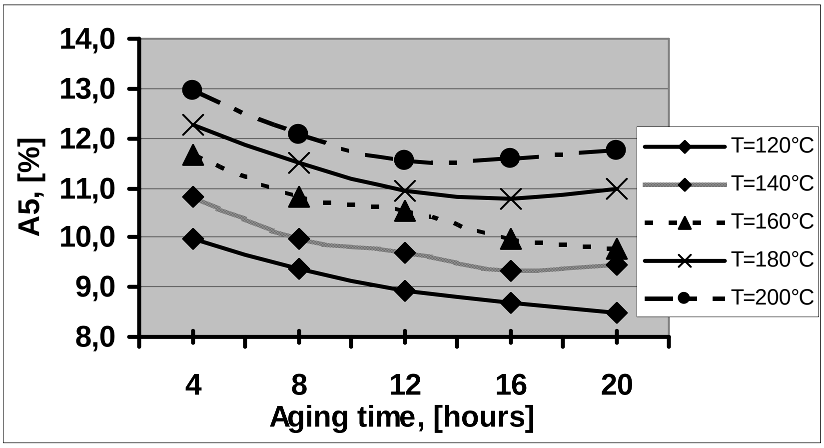

***Fig.11**. Change in elongation at break for alloy 3 according to the time of artificial aging.*

4. Conclusions

Mechanical properties of alloys vary continuously with temperature and aging time. Mechanical strength and hardness increase as the artificial aging temperature drops and artificial aging time increases, except for the temperature of 200^0C that records a maximum for 12 hours after which the values of Rm and HB decrease for retention times higher than 12 hours. Elongation at break increases as heat treatment temperature increases and decreases with increasing treatment time.

The highest values of properties were registered for alloy 3 which has the highest content of Zn and the lowest for alloy 1 where the Zn content is the lowest.

Therefore it can be concluded from the research that for the studied alloys of Al-Zn system, mechanical strength properties after artificial aging heat treatment, increase as the Zn content increases. As far as elongation is concerned, it decreases with increasing Zn content. Increasing the aging temperature or extending duration decrease resistance properties, but this gives a good dimensional and properties stability (overaging with precipitate coagulation).

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