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THE INFLUENCE OF THERMOMECHANICAL TREATMENTS ON THE MECHANICAL PROPERTIES OF SOME AL-Zn-Mg-Cu ALLOYS

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ABSTRACT

In this paper, the variation of some mechanical properties was studied according to the values of the thermomechanical processing parameters to which an aluminium alloy of the Al-Zn-Mg-Cu series was subjected.

Thermomechanical processing consisted of a cold plastic deformation followed by an artificial aging performed at various treatment temperature values and various maintenance time values.

Following the application of this thermomechanical processing variant, it can be concluded that the values obtained for the studied mechanical characteristics are closely related to the values of the thermomechanical processing parameters.

KEYWORDS: aluminium alloys, thermomechanical treatment, artificial aging, temperature, holding time

1. Introduction

Al-Zn-Mg-Cu alloys belong to the category of deformable and hardened aluminium alloys. Alloys in the Al-Zn-Mg-Cu system depending on the chemical composition may end up having outstanding mechanical properties, being comparable to Cu alloys or even some steel brands, however, they have the advantage of having a lower density [1].

The presence of alloying elements influences the technological and operational characteristics of Al-Zn-Mg-Cu alloys. Thus, silicon contributes to the increase of mechanical strength, reduces ductility as well as fatigue resistance and influences the behaviour to heat and thermomechanical treatment; magnesium also increases, mechanical strength and hardness but also influence the behaviour to heat treatment. In alloys where Si and Mg are also present, the behaviour to heat treatment depends on the Mg/Si ratio, thus, if this ratio has a high value, then by natural aging the best properties of strength and plasticity are obtained, at a lower ratio artificial aging is required. If iron is also present in the composition of the alloy, at contents below 0.7%, it increases hot stability, in some alloys, producing fragility due to the appearance of its compounds in other alloys [2].

The presence of manganese in these alloys has a hardening effect (each percentage of manganese increases the hardness by 2-3 daN/mm^2) and reduces the brittle effect of iron and finishes the grain. Nickel like manganese has a hardening effect, but more limited and reduces the brittle effect of iron. The main effect of nickel alloying is manifested by increased high temperature resistance, fatigue resistance and creep. Titanium finishes the grain by increasing the tenacity, lithium has a similar effect to magnesium, zinc increases the mechanical strength but decreases the plasticity and chromium increases the resistance to high temperatures [2, 3].

From the experiments made, thermomechanical processing was found to lead to obtaining superior values of the main mechanical properties, and so this method of processing these alloys should be used in practice more than conventional methods [4, 5].

The metallurgical technologies used for special alloys of Al in terms of the size of the finished grain and achieving medium or high strength are of two kinds [6-8]:

1. technological processing that acts on the size of the crystallized grain of some aluminium alloys during the first phases of processing at high temperatures by partially eliminating the structural heterogeneity, by controlling the chemical composition, the casting and homogenization cycles of these alloys. Next, the hot plastic deformation is applied, finally obtaining a recrystallized structure with fine and uniform grains in size.

2. technological processing applied to high-strength alloys, especially those used in the aviation industry. It consists of several stages of plastic deformation and heat treatment, which is

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thermomechanical processing. In the practice of metallurgical processing, it is found intermediate thermomechanical processing and final thermomechanical processing [9-11].

Generally, intermediate thermomechanical processing is used internationally to improve the plasticity, hardness and corrosion resistance of special aluminium alloys without reducing mechanical strength compared to conventional processing.

The final thermomechanical processing is used to obtain the final strength characteristics combined with good plasticity, corrosion resistance and fatigue resistance.

Alloys in this system are divided into [10]:

1. high-strength alloys, for which the amount (Zn + Mg + Cu) is more than 10%.

2. medium-strength alloys with amount (Zn + Mg + Cu) = 7-9%.

3. alloys with low resistance, for which the amount (Zn + Mg + Cu) is less than 6%.

The high strength of these alloys is achieved after a heat treatment of natural or artificial hardening [11-13].

2. Conditions of experimental research

Experiments were carried out on alloy samples with the chemical composition indicated in Table 1, alloy of the alloy family: Al-Zn-Mg-Cu.

The mechanical properties of the alloy according to EN 485-2-2007 are shown in Table 2.

Table 1. *Chemical composition of the alloy studied*

Alloy	Cu	Zn	Cr	Fe	Mn	Si	Mg	Al
	0.75	4.3	0.25	0.5	0.17	0.5	2.6	Rest

Table 2. *Alloy properties according to EN 485-2-2007*

Elemental / Alloy	Rm, [MPa]	$Rp_{0,2}$ [MPa]	A_5 [%]	HB
AlZn4.3Mg2.6Cu	430	370	8	130

Figure 1 shows the sequence of heat and thermomechanical treatment operations, to which the samples from the alloy studied have been subjected. Specific to this variant is the thermomechanical treatment with cold plastic deformation performed between the two artificial aging [14].

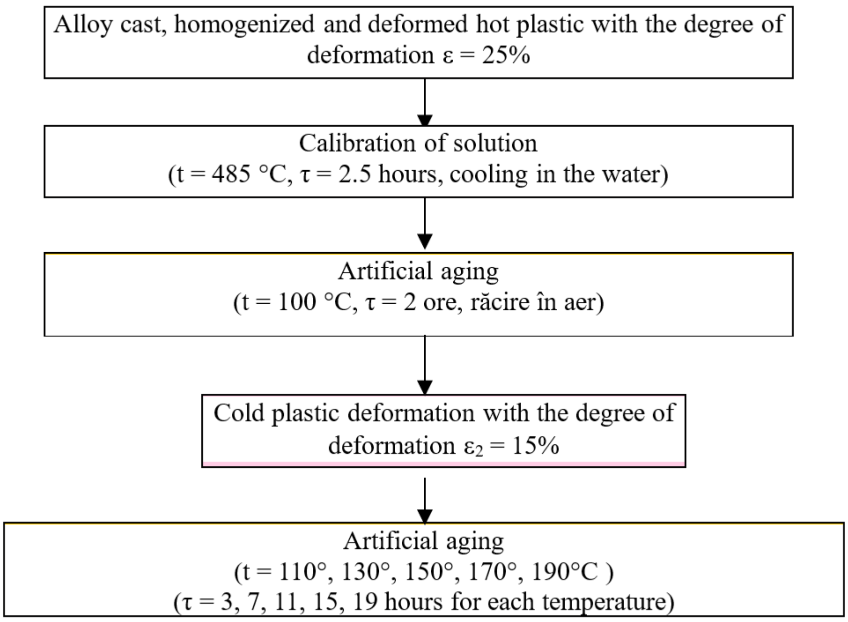

Fig. 1. *Experimental conditions of thermomechanical treatments* [14]

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For structural stabilization of the material, after quenching the solution, an artificial aging with a one-hour maintenance time at 100 °C is carried out. Further, a cold plastic deformation takes place where the samples are deformed with a degree of plastic deformation 15%, in order to reach the established dimensions.

After plastic deformation, an artificial aging is performed at the following temperatures: T_1 = 110 °C, T_2 = 130 °C, T_3 = 150 °C, T_4 = 170 °C and T_5 = 190 °C having these temperatures: τ_1 = 3 hours, τ_2 = 7 hours, τ_3 = 11 hours, τ_4 = 15 hours, τ_5 = 19 hours.

After performing thermomechanical processing, the samples from the alloy studied were subjected to tensile and hardness tests for finding out the values of the mechanical properties (mechanical resistance, flow limit, elongation at breaking and hardness).

Cold plastic deformation accelerates and intensifies the processes of hardening by aging. Cold rolling is aimed on the one hand at increasing the hardness of the material as well as creating favourable conditions for the occurrence of precipitation around dislocations at the next artificial aging. At the same time, this deformation brings the blank to the final size [10, 14].

3. Experimental results

For the analysis of the results and the formulation of conclusions, graphical representations were used that mainly illustrate the influence of technological parameters of aging (age temperature and maintenance time) on the main mechanical properties of the alloy studied belonging to the Al-Zn-Mg-Cu system.

Putting into practice the technological operations according to the processing variant of the alloy investigated, a series of values of the mechanical properties whose values vary depending on the time and temperature of the treatment were obtained.

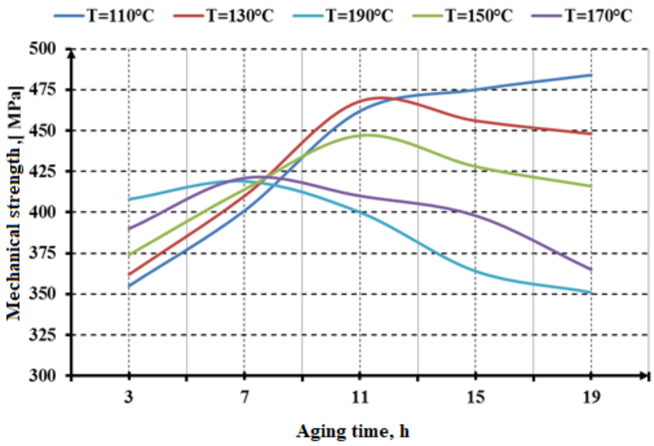

Fig. 2. *The influence of maintenance time on artificial ageing mechanical strength for the alloy studied*

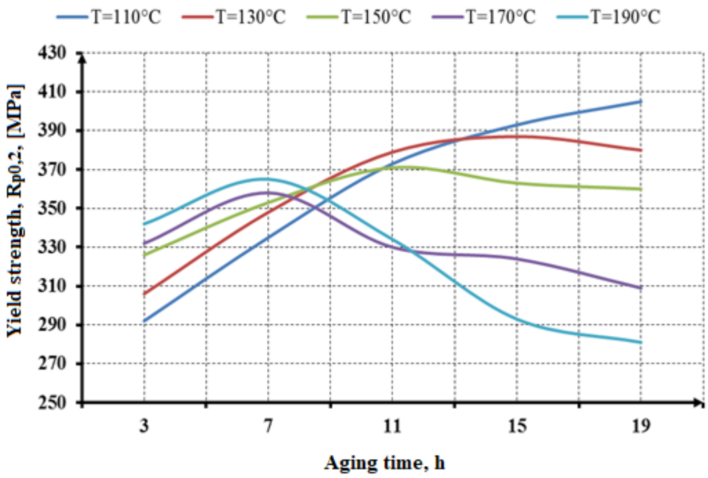

Fig. 3. *The influence of maintenance time on artificial ageing flow limit for the alloy studied*

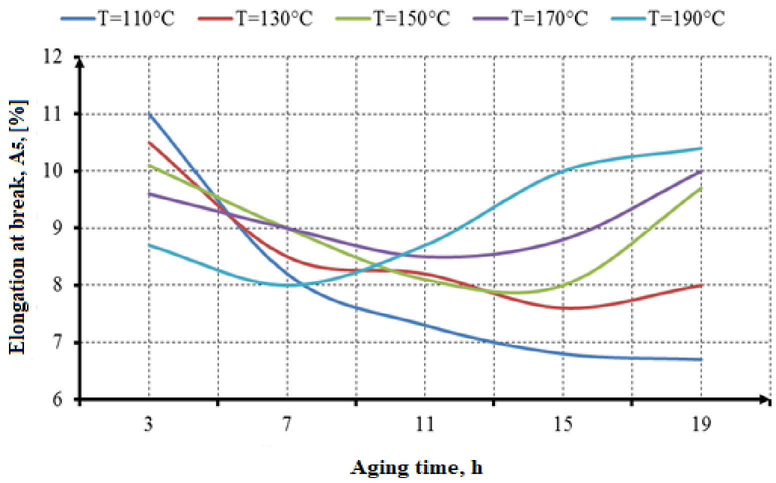

***Fig. 4.** The influence of maintenance time on artificial ageing elongation at break for the alloy studied*

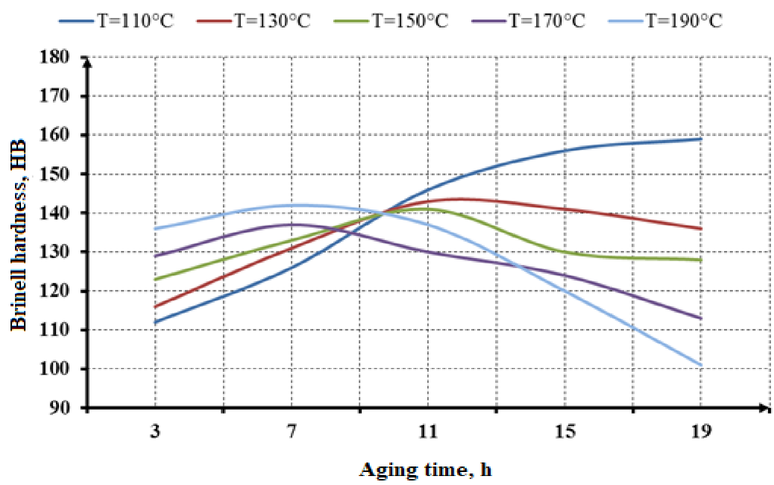

***Fig. 5.** The influence of maintenance time on artificial ageing Brinell hardness for alloy studied*

Figure 2 illustrates that as the aging temperature rises, for maintenance times of 3 and 7 hours, an increase in the value of mechanical strength also occurs. For temperatures of 110 °C, 130 °C and 150 °C, mechanical strength values increase only up to and including 11 hours of maintenance. For temperatures of 170 °C and 190 °C, a decrease in strength is observed.

At 110 °C the maximum resistance value shall be recorded for the holding time of 19 hours. Thermal processing at temperatures of 130 °C and 150 °C, leads to a maximum of strength values for a time of 11 hours of aging. For temperatures of 170 °C and 190 °C the mechanical strength has a maximum at a time of 7 hours of treatment.

The process of hardening these structures, according to the literature, is, it occurs by the occurrence of the phenomenon of precipitation and consists in the formation of chemical compounds between the chemical elements that are present and dissolved in the composition of the alloy being studied. After the quenching stage of putting into solution when a solid aluminium solution is obtained, which is supersaturated by dissolving as many alloying elements as possible, aging occurs by precipitation of new formed chemical compounds, which have as activation energy, as the driving force of their formation, the heat from the temperature of artificial aging treatment.

Once these compounds have formed, the phenomenon of their coalescence occurs, if the alloy is kept for too long at the temperature of aging. The coalescence of these compounds has the effect of a decrease in the mechanical strength properties of the alloy that has undergone these thermal processing. This explains the decrease in the strength properties of the alloy studied as the artificial aging temperature rises above 150 °C and for holding times of more than 7 hours.

For the flow limit and for the hardness things are mostly the same as for the mechanical strength.

The elongation at breaking has a minimum and a maximum at the temperature of 110 °C, the minimum is obtained for the 19-hour aging time and the maximum for the 3-hour aging time. In the case of the other values of the considered thermomechanical processing parameters, the elongation is inversely proportional to the mechanical resistance.

Following the processing of the alloy, the values obtained for the mechanical strength are higher values or at least equal to those imposed by the euro norm EN 485-2-2007, which is, for variants where the treatment temperature was 110 °C, 130 °C and 150 °C with artificial aging times of 11 hours, 15 hours and 19 hours, respectively, last less for the temperature of 150 °C. Similarly, the situation is also presented for the hardness and flow limit of the alloy studied.

The elongation at breaking was higher or equal to those prescribed by the euro norm EN 485-2-2007, for most experimental variants, except for the following combinations of treatment time and temperature:

- for the temperature of 110 °C at times of 11 hours, 15 hours and 19 hours;
- for the temperature of 130 °C on 15 hours and 19 hours;
- for the temperature of 150 °C at the time of 19 hours.

4. Conclusions

The study of the influence of thermal processing on the most important mechanical properties of aluminium-based alloy in the Al-Zn-Mg-Cu system studied in this paper led to the following conclusions:

1. Since the alloys of the Al-Mg-Zn-Cu system are alloys sensitive to thermomechanical treatments, superior values of mechanical strength result with the preservation at a convenient level of plasticity characteristics.

2. For the alloy studied, the maximum value of the mechanical properties is recorded when the final artificial aging treatment is carried out at a holding time equal to 19 hours at a temperature of 110 °C.

3. Cold plastic deformation between the two applied artificial aging causes a sharp increase in the values of mechanical characteristics (hardness and mechanical strength).

4. At ageing temperatures below 190 °C and for ageing times less than or equal to 11 hours, the increase in the duration of maintenance on ageing results in increased hardness for the alloy studied.

5. For the alloy studied, at the aging temperature of 170 °C and for ageing times longer than 7 hours, the increase in the maintenance time to aging causes the hardness to decrease.

6. The alloy under investigation records an increase in hardness directly proportional to the final artificial aging time for the treatment temperature of 110 °C.

7. By applying the thermomechanical treatment scheme of this paper, the obtained values for mechanical strength were higher or at least equal to those imposed by the euro norm EN 485-2-2007, for situations where the treatment temperature was 110 °C, 130 °C and 150 °C with aging times of 11 hours, 15 hours and 19 hours.

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