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TECHNOLOGICAL PARAMETERS OPTIMIZATION OF THE AlZn5Mg3Cu ALLOY THERMOMECHANICAL TREATMENT PROCESS

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The paper presents the results of experimental research with a view to optimizing the thermo mechanical treatment process that has been applied to AlZn5Mg3Cu alloy used in the aviation industry. The research led to the conclusion that, for the alloy studied, the highest mechanical strength values were obtained for an artificial aging time of 16 hours at a temperature of 120 °C, while the lowest resistance values were obtained for an artificial aging time of 8 hours at 160 °C.

Keywords: AlZnMgCu-alloy, thermo mechanical treatments, energy, mechanical properties

INTRODUCTION

The alloy studied is part of the AlZnMgCu, series 7000. Due to their superior mechanical characteristics obtained through thermal and / or thermo mechanical processing, they are used with very good results in the aviation industry and machinery industry. These mechanical characteristics are obtained by controlling the precipitation hardening process [1, 2].

Thermo mechanical processing for AlZnMgCu alloys involves a combination of plastic deformation and artificial aging. Cold flow accelerates and intensifies the age-hardening process. This acceleration is closely related to the degree of plastic deformation. The experimental data presented in the literature reveal that the acceleration of the precipitation process is mainly determined by an accumulation of dislocations up to saturation during plastic deformation. This increases the efficiency of diffusion phenomena in artificial aging, subsequent to plastic deformation [3, 4].

By using modern techniques of investigating materials such as atomic probe, tomography researchers systematically managed to see the microstructure of the precipitates resulted (obtained) after applying some regimes of heat treatment (aging or artificial re-aging) and thermo mechanical treatments for AlZnMgCu alloys.

The parameters of the thermo mechanical treatment regime influence the achievement and evolution mechanisms of the precipitates during the recovery and re-aging stages [5].

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The AlZn5Mg3Cu alloy is deformable and hardenable and after the application of some heat treatment and / or thermo mechanical treatments, the values obtained in the mechanical characteristics recommend it to be used in the aviation industry. The technical and economic performances of a metallurgical process depend on the process parameters and on the conditions and mode of operating the system as a whole. [6, 7].

Determining the optimal solution is made by determining the values of the independent variables so as to obtain the best value for the objective -function (the optimized function). In the case of optimizing the thermo mechanical processing parameters of the alloy studied, the objective function is represented by the consumption of energy "$Q = f(T, \tau, \varepsilon)$", where T and τ are the temperature, respectively the time for the final artificial aging, in this case, and ε is the degree of plastic deformation, given the restrictions on the values of the mechanical properties investigated.

In this work, the mathematical model is given by the equations for calculating the energy Q consumed with heat treatment furnace and the mini rolling mill where the plastic deformation of the studied alloy samples was performed.

The model equations express the relationships between the process parameters and are deducted either by theoretical analysis or based on experimental observations (empirical) [8].

MATERIALS AND METHODS

The materials for experimental research are samples made of AlZn5Mg3Cu aluminum alloy whose chemical composition is shown in Table 1, and which fall within the requirements of EN 573-3-2013.

Table 1 **Chemical composition of the AlZn5Mg3Cu research / mas. % / [9]**

Zn	Mg	Cu	Si	Fe	Cr	Mn	Al
5	3	0,75	0,5	0,5	0,2	0,25	Remainder

Table 2 **Mechanical properties of AlZn5Mg3Cu / [10]**

R_m / MPa	$R_{p0,2}$ / MPa	A_5/ %	HB
450	370	8	133

According to EN 485-2-2013[10] after thermo mechanical processing, the values obtained for the main mechanical characteristics must be at least equal to those shown in Table 2.

Figure 1 shows schematically thermo mechanical processing that the samples studied have undergone.

The thermo mechanical processing consisted of the following technology sequence:

- solution quenching at 500 °C for 2 hours;
- preliminary artificial aging at a temperature of 100 °C for 1 hour to stabilize the structure of the material;

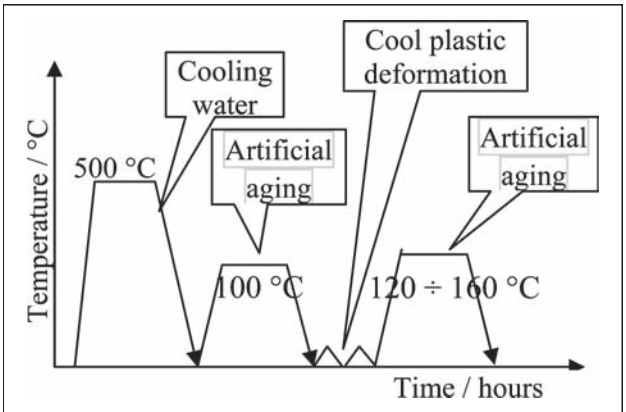

Figure 1 Schematic representation of thermo mechanical processing

- cold plastic deformation with three degrees of deformation ε_1 = 10%, ε_2 = 20% and ε_3 = 30% to achieve the set dimensions;
- after having performed these deformations, a final artificial aging heat treatment is made at the following temperatures: T_1 = 120 °C, T_2 = 140 °C, T_3 = 160 °C with the holding time: τ_1 = 8 hour, τ_2 = 12 hour, τ_3 = 16 hour for each temperature.

At the end of the thermo-mechanical processing, the dimensions of the samples are: length L = 200 mm, width l = 60 mm, thickness h = 5 mm.

RESULTS AND DISCUSSIONS

After the thermo mechanical treatment, the samples were subjected to mechanical tests, after which the values of the R_m, $R_{p0.2}$, A_5, HB properties were determined as shown in Tables 3. The values listed in the Tables represent the average of 5 measurements.

The mechanical properties were considered as functions of three variables of the thermo mechanical treatment, namely: $R_m = R_m\ (T, \tau, \varepsilon)$, $R_{p0.2} = R_{p0.2}\ (T, \tau, \varepsilon)$ $A_5 = A_5\ (T, \tau, \varepsilon)$, HB = HB (T, τ, ε).

The optimization of the thermo-mechanical treatment was carried out by calculating the total energy consumption Q_{total} and choosing the mechanical treatment variant for which Q_{total} is minimal in terms of obtaining values in accordance with EN-485-2-2013 for the mechanical characteristics studied.

These calculations were performed using the following relationship:

$$Q_{total} = Q_{total\ oven} + Q_{lam},\ [11] \tag{1}$$

where: $Q_{total\ oven}$ - the amount of heat necessary to attain and maintain the treatment temperature throughout performing the heat treatment;

Q_{lam} - the amount of energy consumed for rolling samples.

Table 3 **The values of the mechanical properties after applying thermo mechanical treatment with high plastic deformation degree ε = 10; 20; 30 %**

The time for the artificial aging / hours	Artificial aging temperature / °C											
	120				140				160			
	R_m / MPa	R_{p02} / MPa	HB	A_5 / %	R_m / MPa	R_{p02} / MPa	HB	A_5 / %	R_m / MPa	R_{p02} / MPa	HB	A_5 / %
ε = 10 / %												
8	402	316	123	9,2	394	318	118	10	364	305	115	10,4
12	424	345	131	8,8	412	329	129	9,7	380	325	121	10,3
16	461	371	148	8,6	441	367	137	9,1	394	341	132	9,5
ε = 20 / %												
8	466	429	134	8,6	433	391	130	9	426	374	119	9,2
12	481	436	147	8	462	398	143	8,7	456	385	135	9
16	492	453	159	7,6	477	416	153	8.2	465	403	142	8,5
ε = 30 / %												
8	485	430	153	8,3	454	392	141	8,6	429	363	132	8,7
12	498	450	164	8,1	473	420	154	8,4	462	385	144	8,5
16	523	465	170	8,0	505	440	162	8,1	484	417	155	8,3

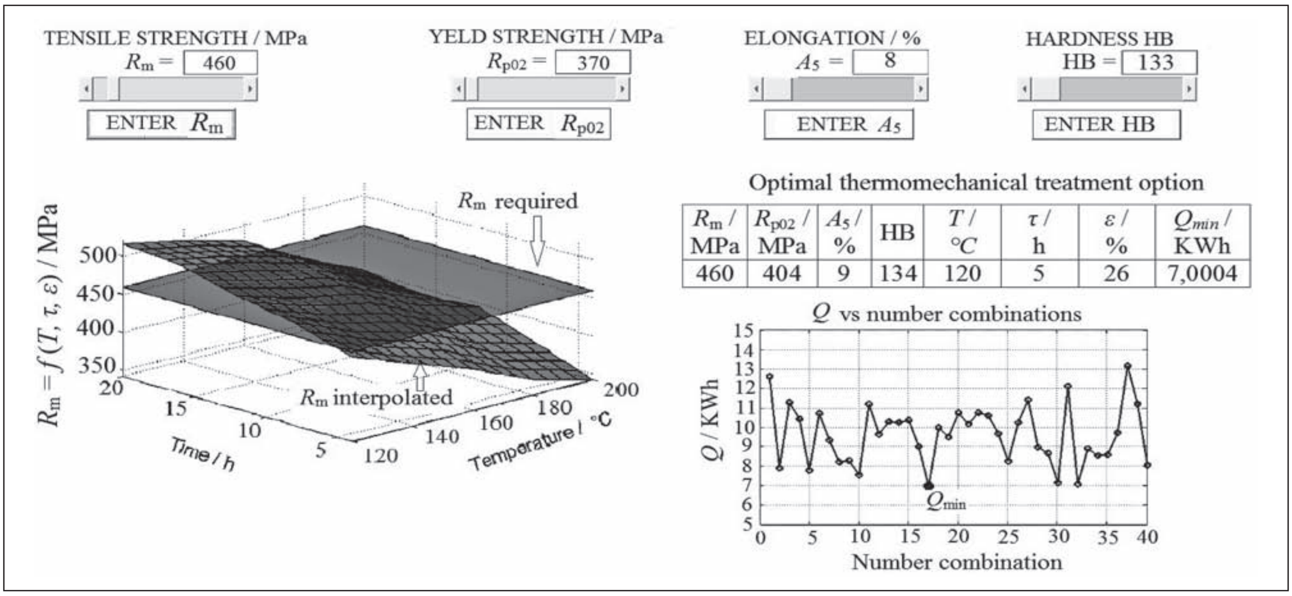

Figure 2 Values of thermo mechanical treatment parameters to achieve R_m = 460 MPa

Using the software package MATLAB interpolation functions of three variables and heat balance equation (1), was performed a graphical interface that allows viewing (simulation) by calculation of Q_{total} minimum.

An example of such a simulation is shown in Figure 2.

CONCLUSIONS

After conducting the research described in this paper, the following conclusions were drawn:

- the thermo mechanical processing carried highlighted the dependence of the level of resistance mechanical properties values on the degree of cold plastic deformation preceding the final artificial aging;

- the resistance mechanical properties values are directly proportional to the values of aging time and inversely proportional to the heat treatment temperature;

- the mechanical strength of the alloy processed has the highest values during artificial aging of 16 hours and a temperature of 120 ºC, and the lowest resistance values in the case of thermal processing are for the aging time of 8 hours and the temperature of 160ºC;

- the value of the alloy elongation at break is decreasing with increasing final aging time and decreasing final artificial aging temperature, as well as with increasing plastic deformation degree;

- the graphic interface created using MATLAB enables simulation and identification based on mathematical calculation, of the minimum amount of Q_{total}, which means finding the optimum of the thermo mechanical processing;

- with the help of the graphical user interfaces, there can be distinguished, in tabular form, the values of the thermo mechanical processing parameters for those situations where it is desired to obtain a particular value of one or more properties of the studied ones.

REFERENCES

[1] Z. W. Du, Z. M. Sun, B. L. Shao, T. T. Zhou b, C. Q. Chen, Quantitative evaluation of precipitates in an Al–Zn–Mg–Cu alloy after isothermal aging, Materials Characterization 56 (2006) 121–128.

[2] J. C. Werenskiold, A. Deschamps, Characterization and modeling of precipitation kinetics in an Al–Zn–Mg alloy, Materials Science and Engineering: A, Structural Materials: Properties, Microstructure and Processing, 2000; 293, 67–74.

[3] A. Deschamps, G. Fribourg, Y. Brechet, J. L. Chemin, C. R. Hutchinson, In situ evaluation of dynamic precipitation during plastic straining of an Al–Zn–Mg–Cu alloy, Acta Materialia 60 (2012) 5, 1905–1916.

[4] C. R. Hutchinson, F. de Geuser, Y. Chen, A. Deschamps, Quantitative measurements of dynamic precipitation during fatigue of an Al–Zn–Mg–(Cu) alloy using small-angle X-ray scattering, Acta Materialia 74 (2014), 96–109.

[5] T. Marluad, A. Deschamps, F. Bley, W. Lefebvre, B. Baroux, Acta Materialia 58 (2010)14, 4814–4826.

[6] D. Taloi, E. Florian, C. Bratu, E. Berceanu – Optimizarea proceselor metalurgice, Editura Didactică şi Pedagogică, Bucureşti, 1983, 11 – 13.

[7] A. Kawalek, J. Rapalska-Nowakowska, H. Dyja, B. Koczurkiewicz, Physical and numerical modeling of heat treatment the precipitation-hardening complex-phase steel, Metalurgija 52 (2013) 1, 23-26.

[8] I. Ciucă, S. Dumitriu - Modeling and optimization metallurgical processes of plastic deformation and heat treatments, Didactic and Pedagogic, Bucharest, 1998, 57-68.

[9] www.en-standard.eu/csn-en-573-3-alumi- nium-and-aluminium-alloys chemical-composition-and-form-of-wrought-pro- ducts-part-3-chemical-composition-and-form-of-products.

[10] www.din.de.

[11] B. Popa, E. Man, M. Popa – Thermo technology and heating units, Technical Publishing House, Bucharest, 1979, pp: 103-126.

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