THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^0. 4 – 2013, ISSN 1453 – 083X

OPTIMIZATION OF THERMOMECHANICAL PROCESSING OF SOME ALUMINUM ALLOYS BY DIMENSIONAL INTERPOLATION METHOD USING THE MATLAB

Marian NEACSU, Doru HANGANU,
Elisabeta VASILESCU
“Dunărea de Jos” University of Galaţi, 111, Domnească Street, 800201, Galaţi, Romania
email: uscaeni@yahoo.com

ABSTRACT

This paper presents results of research on optimization of thermomechanical treatment applied to an alloy of the Al-Zn-Mg-Cu system, used in the aviation industry.Optimizing thermomechanical treatment process is based on a mathematical model that establishes the relationships between the main technological parameters of thermomechanical processing and association of physical and mechanical properties of the alloy used. Findings are based on an laborious experimental program to elaborate the mathematical model, an essential element of thermomechanical treatment process optimization applied to the alloy studied for obtaining the required values of mechanical properties with the minimal cost.

KEYWORDS: optimization, mathematical model, aluminum alloy thermomechanical treatments, properties

1. Introduction

Alloys of the system Al-Zn-Mg-Cu 7000 series because they have special characteristics are used first in the aviation industry and engineering.

Are part of wrought aluminum alloys and hardened by the application of heat treatment and (or) Thermo. Some of them have mechanical properties comparable copper-based alloys or steel grades, and even some with titanium, but has the advantage that it has a much lower density [2].

For the aviation industry where alloys are subjected to stresses multidirectional operation alloys must provide an optimal combination of strength, plasticity, toughness, fatigue strength and good resistance to stress corrosion. To achieve this optimum is necessary to replace the coarse grain structure obtained in the process of casting alloys and semi-finished laminated fibrous structure, they are decisive factors to achieve an optimal properties [2].

Like any technical system, metallurgical processes have certain technical performance and economic performance parameters that depend on the conditions and mode of operation of the system. So, the choice of these parameters and conditions at any given time, you select those that will provide the best technical and economic performance of the process (choosing optimal parameters) "[13].

Optimization of the technological process is based on a mathematical model must accurately describe how that process, the mathematical model is the main element in the management process. It follows immense importance to obtain a mathematical model that describes how closely that process, ie between model and describe the process you must be a line as high [14].

Determination of the optimal solution is done by determining the values of the independent variables so as to obtain the best value for the function - objective function (optimized).

The objective function when optimizing thermomechanical processing parameters of the alloy studied is the energy "$Q = f(t, \tau, \varepsilon)$" subject to certain restrictions in respect of the mechanical properties investigated.

2. Experimental conditions

Table 1 shows the chemical composition of the alloy from which the samples were made under experimental regimes thermomechanical processing.

***Table1.** Chemical composition*

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

Table 2. Properties of alloys according to EN 485-2-2007

Properties / Alloy	Rm, [Mpa]	$Rp_{0,2}$ [Mpa]	A_5 [%]	HB
3 (AlZn5,7MgCu)	540	470	7	161

In table 2 are listed the mechanical properties required by EURONORMA EN 485-2-2007.

Figure 1 shows the schematic thermomechanical processing which were subjected to the aluminum alloy samples studied.

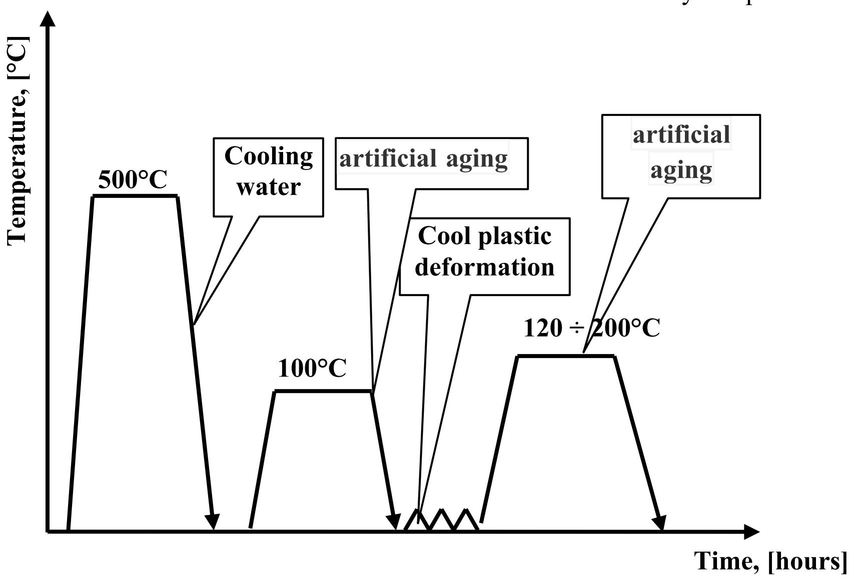

***Fig. 1.** Schematic representation of thermal and thermomechanical processing*

After placing the solution annealing at 500 ° C aging is carried out at a temperature of 1000C for 1 hour for structural stabilization of the material. Further samples are subjected to a cold plastic deformation, with three degrees of deformation ε1 = 10%, 20% and ε2 = ε3 = 30% to achieve the set size.

Following this deformation is achieved by artificial aging heat treatment at the following temperatures: T1 = 120°C, T2 = 140°C, T3 = 160°C, T4 = 180°C and T5 = 200°C with the retention times: = 4:00 τ1, τ2 = 8:00, τ3 = 12:00, τ4 = 16 hours τ5 = 20 hours.

For optimization of thermomechanical processing described above we used three-dimensional interpolation using MATLAB software package.

MATLAB software package interpolation function of three variables through the use of specific functions such as ***interp3***.

The interpolation functions interp3 three variables by different laws and calling syntax: vi = interp3 (x, y, z, v, xi, yi, day, 'method') (1) where 'method' may be one of the key words:

- 'Nearest' - for interpolation type nearest neighbor;
- 'linear' - for bilinear interpolation;
- 'cubic' - for Bicubic interpolation;
- 'spline' - for cubic spline interpolation;

The function returns the matrix vi interpolated values corresponding to xi, yi day. Arrays x, y, and z specific data points which are the values of v. If x, y and z are vectors, their values have to be monotonic, equally spaced [1].

vi = interp3(v, xi, yi, zi) (2)

interp3 function implies that x = 1: n, y = 1: m, Z = 1: p where [m, n, p] = size (v) and returns an array with the size you mxnxp, which is data interpolation matrix v [1], [15].

Interpolating through all four mechanical properties studied by three parameters final thermomechanical treatment (t - artificial aging

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{0}. 4 – 2013, ISSN 1453 – 083X

temperature, τ - ε during artificial aging - the degree of plastic deformation) resulted in a data volume 6069 interpolated values for each property.

Since aluminum alloys are "sensitive" to variations of the temperature of the treatment was determined a change in the temperature of treatment every five degrees, resulting in a total of 17 temperature between 120 ° C and 200 ° C. Artificial aging time was discretized at 4:00 to 8:00 p.m. by step for an hour, resulting 17 values of interpolation. The degree of deformation has been required a total of 21 values increasing with step of 1% in the range of 10-30%.

3. Experimental results and conclusions

After interpolation using the program, resulting 6069 values for each of the four mechanical properties. In these circumstances, the stakes optimization translates into finding of these data, only those that comply with the restrictions simultaneously EN_485-2-2007 regarding property values.

The calculations made in 1648 resulted in a number of cases (combinations of process parameters thermomechanical treatment) for each property in the 6069 possible cases, while fulfilling the requirements for the four mechanical properties:

- mechanical resistance, Rm ≥ 540MPa
- yield, RP0, 2 ≥ 470 MPa;
- elongation at fracture A5 ≥ 7%;
- Brinell hardness, HB ≥.

For each of the 1648 combinations of energy required to calculate the thermomechanical processing.

Calculation of energy as heat (thermal energy) means calculating the total energy consumed to heat treatment furnace that final artificial aging is done according to Figure 1 for mill use, according to the equation below:

Qtotal = Qtotal oven + Qlam, where: Qtotal oven - the amount of heat necessary to achieve and maintain temperature treatment throughout the performing heat treatment; Qlam - the amount of energy consumed for rolling sample.

The program developed in MATLAB shows that any value we impose the limits of the possible in 1648, any property of the four studies, we get a number of options which can be determined by calculating the optimal in terms of energy consumption.

The graphical interface made with the program allows viewing of those possible situations and the choice of a large number of values for each of the four properties as shown in the figure: 2, 3, 4, 5.

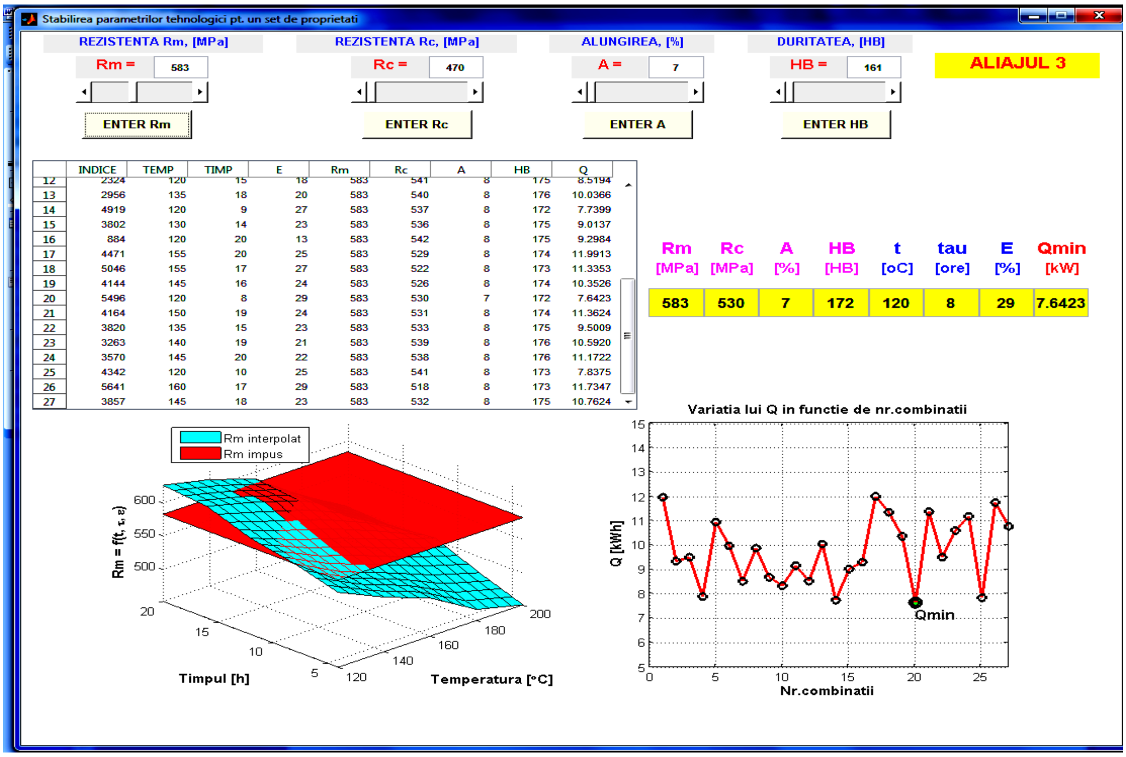

Fig. 2. The values of thermomechanical treatment to obtain Rm = 583MPa

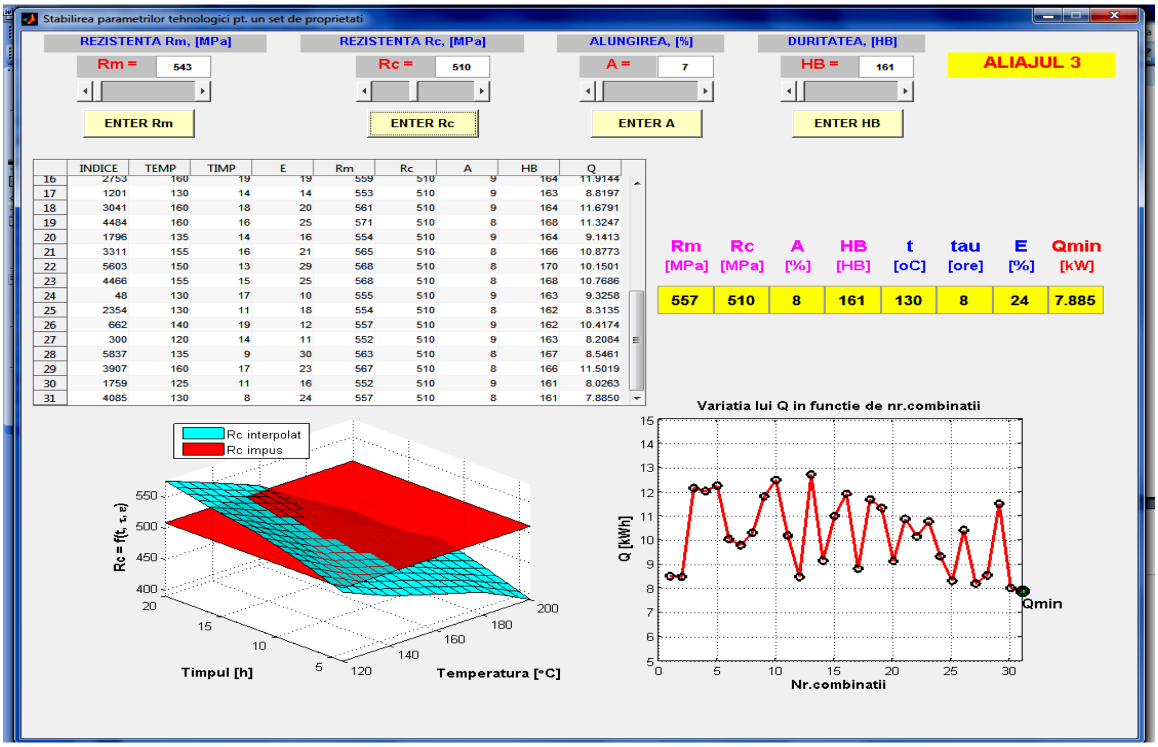

Fig. 3. *The valuesof thermomechanical treatment to obtain $Rp_{0,2}$ = 583 MPa*

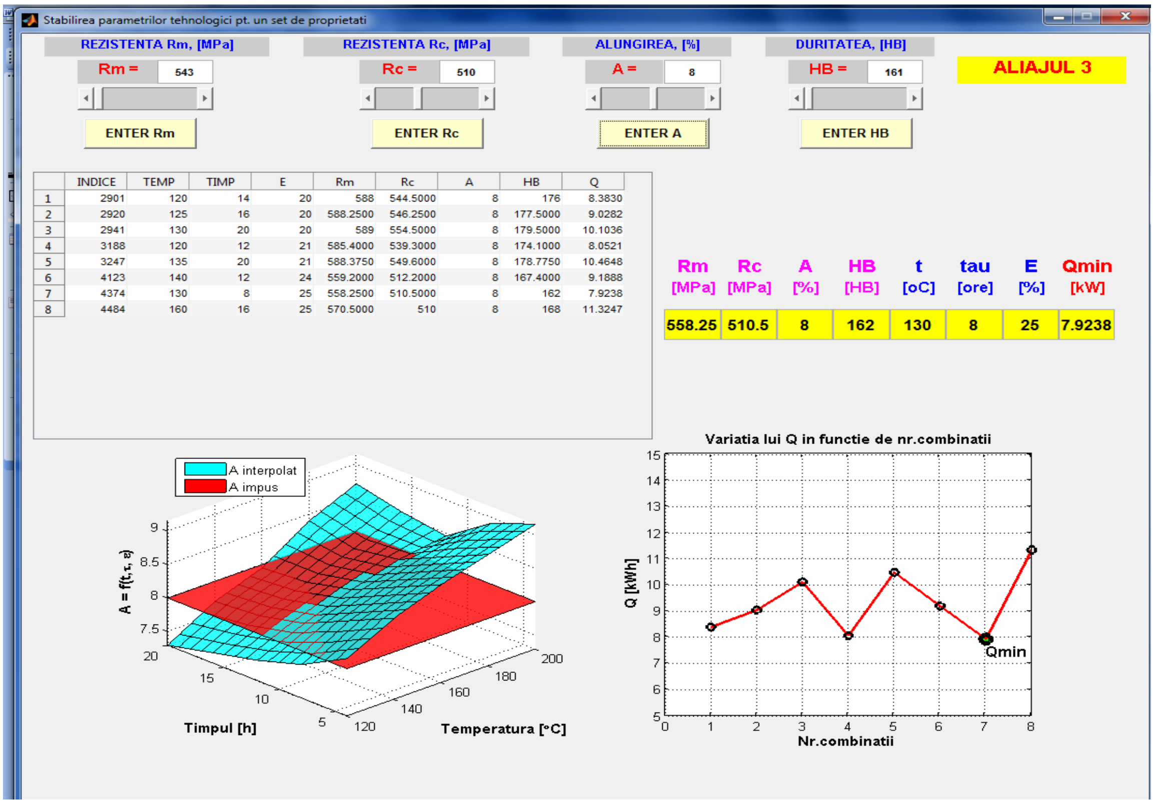

Fig. 4. *The values of thermomechanical treatment to obtain A_5 = 8 %*

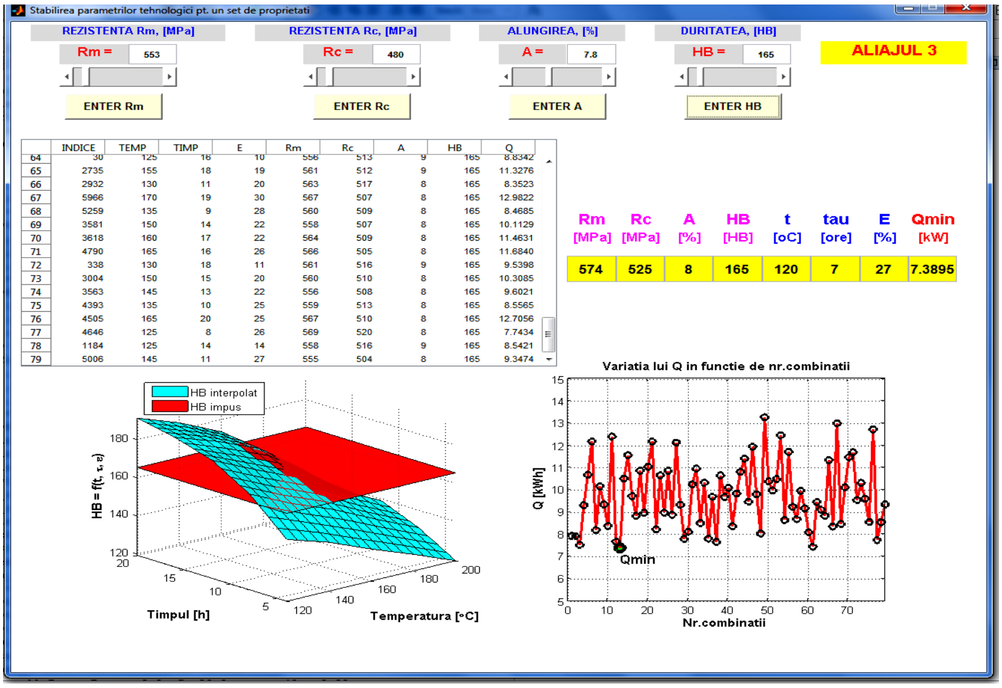

Fig. 5. The values of thermomechanical treatment to obtain HB = 165

With the help of the graphical user interfaces can be distinguished, in tabular form, the values of the parameters of thermomechanical processing for those situations where it is desired to obtain a certain amount of one or more of the properties of the study.

Along with calculating these values of thermomechanical treatment process parameters is calculated and the energy needed for these variations. Among them is selected and highlighted one which has the lowest energy consumption, that works best.

In Figures 2, 3, 4, 5 are shown a few examples. Figure 2 shows the situation when the required mechanical strength of 583 MPa, it is apparent that optimal way from the point of view of energy consumption, varying the parameters of thermo-mechanical treatment are the following: T = 120°C, τ = 8:00, ε = 29% with an energy consumption of 7.64kW. Figure 3 shows the situation in which, for a yield strength of 510 MPa, there are 31 possible cases, but of which the most economical is the treatment that has the following parameters: T = 130°C, τ = 8:00, ε = 24%, giving a power consumption of Qtot = 7.88kW.

Elongation 8% is obtained for the optimal parameters shown in Figure 4, with values T = 130°C, τ = 8:00, ε = 25%, leading to a minimum energy Qtot = 7.9kW.

Hardness HB = 165 is obtained for T = 120°C, τ = 7 hours, ε = 27%, as shown in Figure 5, and the minimum value of Qtot = 7.39kW.

References

[1]. Ghinea M., Fireţeanu V. – *MATLAB – calcul numeric – grafică – aplicaţii,* Editura Teora, ISBN 973-601-275-1, Bucureşti, 1998;

[2]. Giacomelli I. – *Aspecte privind unele procedee de îmbătrânire accelerată a aliajelor de aluminiu pentru turnare,* revista Construcţia de Maşini, nr.8/1992

[3]. Ciucă I. Dumitriu S. - *Modelarea şi optimizarea proceselor metalurgice de deformare plastică şi tratamente termice,* Editura Didactică şi Pedagogică, Bucureşti, 1998;

[4]. Banabic D., Dorr I. R. - *Modelarea proceselor de deformare plastică a tablelor metalice*, Editura Transilvania Press, Cluj-Napoca, 1995

[5]. Baron T., ş.a., - *Statistică teoretică şi economică,* Editura Didactică şi Pedagogică. Bucureşti, 1995;

[6]. Cazimirovici E. – *Bazele teoretice ale deformării plastice* – Editura Bren Bucureşti, 1999;

[7]. Cănănău N., Tănase D. – *Tehnologia deformării plastice,* Galaţi University Press, 2010;

[8]. Moldovan, P. - *Alliages nonferreux*, Ed. Matrix Rom Bucureşti, 2003;

[9]. Neacşu M., Hanganu D., Vasilescu E. - *Mathematical modeling of thermomechanical treatment process applied to aluminum base alloys for aeronautics,* Analele Universitatii „Dunarea de Jos" din Galati, Fascicula IX Metalurgie şi Ştiinţa Materialelor, nr.4/2011, pag. 70 – 76;

[10]. Popa B., Man E., Popa M. – *Termotehnică, agregate şi instalaţii termice,* Editura tehnică, Bucureşti, 1979;

[11]. Popescu O., ş.a. – *Matematici aplicate în economie,* vol.1 şi vol. II, Editura Didactică şi Pedagogică, Bucureşti, 1993;

[12]. Şerban R., Dumitrescu T. – *Metode de optimizare*, Editura Matrix Rom, Bucureşti, 1998;

[13]. Taloi D. ş.a. – *Optimizarea proceselor metalurgice*, Editura Didactică şi Pedagogică, Bucureşti, 1983;

[14]. Neacşu M. – *Influenţa compoziţiei chimice, a tratamentelor termice şi termomecanice asupra proprietăţilor mecanice ale aliajelor din sistemul Al-Zn utilizate în aeronautică,* Teză de doctorat, Galaţi 2012.