THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^0. 3 – 2013, ISSN 1453 – 083X

THERMOMECHANICAL PROCESS SIMULATION TO PREDICT PROCESSING OF MECHANICAL PROPERTIES OF ALLOYS Al-Zn-Mg-Cu

Marian-Iulian NEACSU, Elisabeta VASILESCU, Doru HANGANU
email: uscaeni@yahoo.com

ABSTRACT

This paper presents how to perform simulation (prediction) mechanical properties of aluminum alloys of the system Al-Zn-Mg-Cu. Graphical interface that can predict the mechanical properties studied was performed using MATLAB software version 6.5 based on mathematical equations mathematical models obtained by the mathematical modeling of thermomechanical treatment process studied. This GUI can be established before the thermomechanical treatment parameters to achieve a favorable complex mechanical properties.

KEYWORDS: GUI, aluminum alloy thermomechanical treatment, mathematical modeling

1. Introduction

Due to special properties such as high strength, low specific gravity, chemical stability, good thermal conductivity, good to very good resistance to corrosion, etc. aluminum alloys find their application in almost all branches of modern industry and aviation implicitly. Close cooperation between aircraft manufacturers and metallurgical engineers led to obtaining material characteristics. Since the inception of building aircraft manufacturers have been clear that the materials were to be used for aircraft must be at the same time, strong and lightweight. In aeronautical engineering has had a rapid development that makes metallurgy strive to ensure performance materials to meet the requirements of the aviation industry. Alloy Al-Zn-Mg-Cu are part of deformable aluminum alloys and hardened by applying heat treatment and (or) Thermo.

Some of them have mechanical properties comparable to alloy with copper base with some steel grades, but have the advantage of much lower density. In this paper we present research conducted by the authors on thermomechanical processing of these alloys that leads to optimal complex materials properties such.

2. Experimental conditions

Tensile strength alloys Al-Zn-Mg-Cu is even greater as the precipitate formed, which is phase hardening precipitates, after aging, natural or artificial, are more numerous, finer and more dispersed in the solution table core (solid solution). Experiments were performed on samples from alloy chemical composition given in Table 1.

Table 1. *Chemical composition of alloys subjected to research*

Alloy \ Element	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

Alloys have been investigated alloys are the principal alloying element is zinc. As shown in Al-Zn equilibrium diagram in Figure 1., Zn content of the three alloys investigated were of 2.67, 4.5 and 5.76% Zn alloys are part of wrought alloys and hardened by treatment heat.

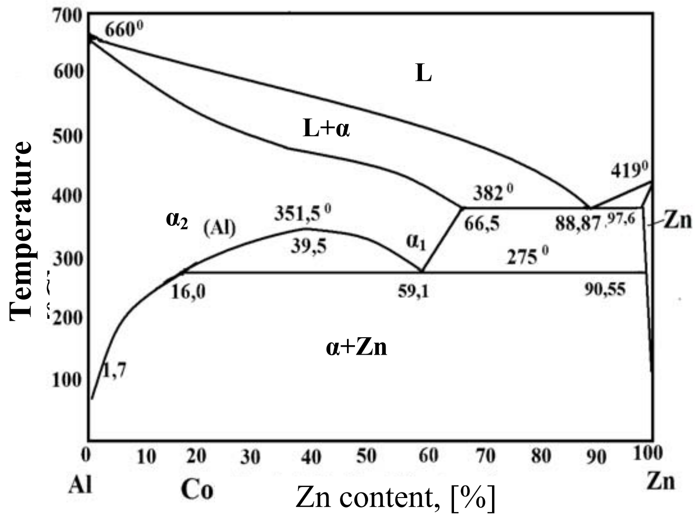

Fig.1. *Al-Zn equilibrium diagram [16]*

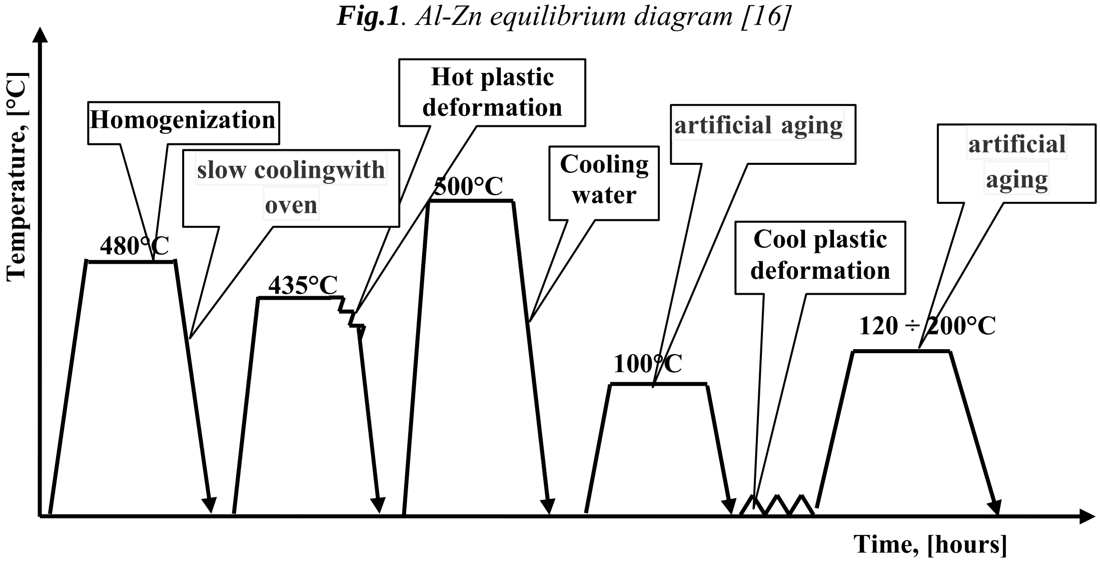

Fig. 2. *Schematic representation of thermal and thermomechanical processing*

Sequence of operations that have undergone three samples of three is shown in Figure 2.

As illustrated in Figure 2 samples of the three alloys considered were subjected to thermomechanical treatment with cold plastic deformation between two artificial aging. After implementing the solution hardening is performed at a temperature of 1000C aging for 1 hour to stabilize structural material. Further, the samples are subjected to cold plastic deformation, with three degrees of deformation, ε1 = 10%, ε2 = ε3 = 20% and 30%, to achieve set size.

Subsequently these distortions is achieved by artificial aging heat treatment at temperatures T1 = 120°C, T2 = 140°C, T3 = 160°C, T4 = T5 = 180°C and 200°C and time-keeping: τ1= 4hours, τ2=8hours, τ3 = 12hours = 16 hours τ4, τ5 = 20hours.

Among the aluminum alloys studied alloy (3) AlZn5.7Mg2.6 gathered the best physical and mechanical properties of resistance. Based on this consideration, in order to optimize the use of this alloy properties, we proceeded to develop mathematical model typical thermomechanical treatment process, based on the optimization process.

We considered that the main influencing factors (independent variables) thermomechanical treatment following technological parameters:

1 - artificial aging temperature - t [°C];

2 - while maintaining the temperature of artificial aging - τ [h];

3 - degree of plastic deformation - ε [%].

Optimized parameters are considered as the set of physical and mechanical properties: R_m, $R_{P0,\ 2}$, A_5, HB.

Given studies and experimental results obtained by some authors [141], [155], [156] on alloys with high strength aluminum base, we established experimental conditions as follows:

- aging temperature:
  - basic level: U_{01} = 160°C;
  - the range: Δu_1 = 40;
- the duration of aging:
  - basic level: U_{02} = 12 hours;
  - the range: Δu_2 = 8:00
- the degree of deformation:
  - basic level: U_{03} = 20%;
  - the range: Δu_3 = 10%

We used samples of the same thickness, and the total degree of strain variation was cold by maintaining a constant final thickness.

Coded to represent the experiment, we used the following notations and symbols:

Independent variables:

- x1 - artificial aging temperature, t, °C;
- x2 - retention time, τ [h];
- x3-degree strain, ε [%];

Dependent variables (parameters optimized)

- Y1 - tensile strength, Rm [MPa];
- Y2 - yield, R_{p02} [MPa];
- Y3 - Specific elongation at break, A_5 [%];
- Y4 - hardness, HB;

Between natural and coded values of the factors are the following relations xi link:

$$x_1 = \frac{t - t_0}{\Delta t};\ x_2 = \frac{\tau - \tau_0}{\Delta \tau};\ x_3 = \frac{\varepsilon - \varepsilon_0}{\Delta \varepsilon};$$

Yi values are expressed in natural units.As we study the influence of three factors on process performance (Y) has conducted a full factorial experiment type 23. Complete factorial experiment based matrix coefficients are calculated regression equation (mathematical model).

The specific calculations to obtain the final form of mathematical models, corresponding to the four properties studied:

$$Y_1(t,\tau,\varepsilon) = 592{,}1339 - 1{,}0766 \cdot t + 7{,}6406 \cdot \tau + 3{,}6063 \cdot \varepsilon - 0{,}0293 \cdot t \cdot \tau - 0{,}0059 \cdot t \cdot \varepsilon - 0{,}0016 \cdot \tau \cdot \varepsilon$$
$$Y_2(t,\tau,\varepsilon) = 536{,}621 - 0{,}8375 \cdot t + 7{,}0625 \cdot \tau + 4{,}5375 \cdot \varepsilon - 0{,}0328 \cdot t \cdot \tau - 0{,}0213 \cdot t \cdot \varepsilon + 0{,}0594 \cdot \tau \cdot \varepsilon$$
$$Y_3(t,\tau,\varepsilon) = 8{,}125 + 0{,}0219 \cdot t - 0{,}1063 \cdot \tau - 0{,}0438 \cdot \varepsilon + 0{,}0003 \cdot t \cdot \tau - 0{,}0004 \cdot t \cdot \varepsilon + 0{,}0003 \cdot \tau \cdot \varepsilon$$
$$Y_4(t,\tau,\varepsilon) = 137{,}5357 - 0{,}1906 \cdot t + 4{,}5625 \cdot \tau + 1{,}6 \cdot \varepsilon - 0{,}0195 \cdot t \cdot \tau - 0{,}005 \cdot t \cdot \varepsilon + 0{,}0063 \cdot \tau \cdot \varepsilon$$

After verifying the adequacy of mathematical models based on Fisher criterion shows that all models are consistent with experimental data and can be used to optimize the thermomechanical processing.

With MATLAB software version 6.5 and based on the mathematical model obtained was made a prediction program (simulation) values of mechanical properties investigated.

3. Results and discussion

The simulation values of mechanical properties studied is shown with graphical interfaces and usable parameter values within experimental thermomechanical treatment.

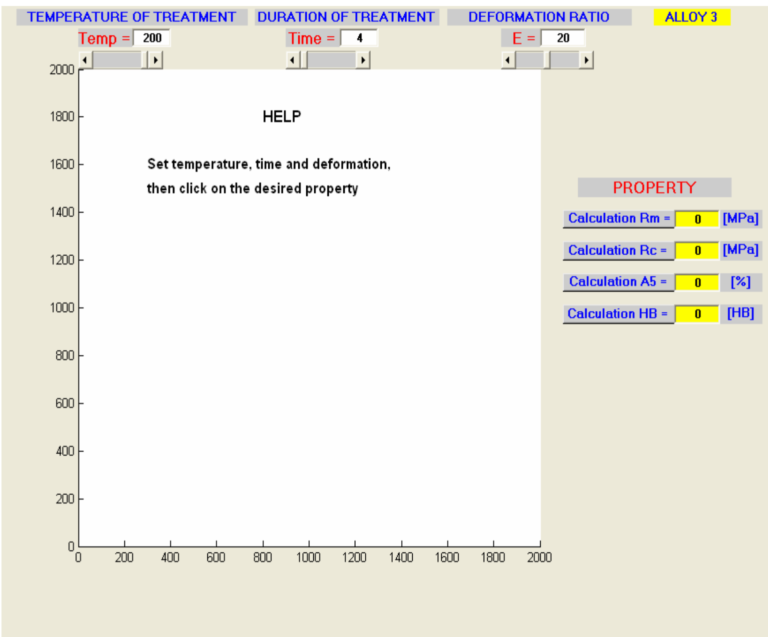

Fig. 3. *The picture began to run simulation program based on the property values of parameters thermomechanical treatment*

The input parameters (thermomechanical treatment parameters) Remove the period studied, based on which the range of values were obtained mathematical equations, the simulation accuracy is lower. Figure 3 presents the picture began to run simulation program based on the values of properties in thermomechanical treatment parameters.

Figure 4 shows the simulation of the mechanical strength of the alloy value (3) that was subjected to thermomechanical treatment which consisted of cold plastic deformation with a degree of deformation of 25% followed by artificial aging at 170°C with a time of maintenance 5 hours.

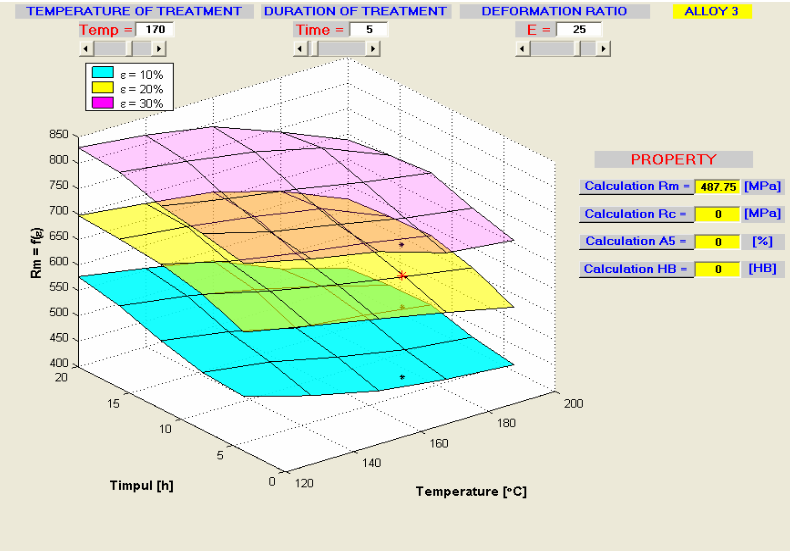

Fig. 4. Prediction value of R_m for alloy 3 to artificial aging temperature of 170ºC for 5 hours and cold deformation degree ε=25%

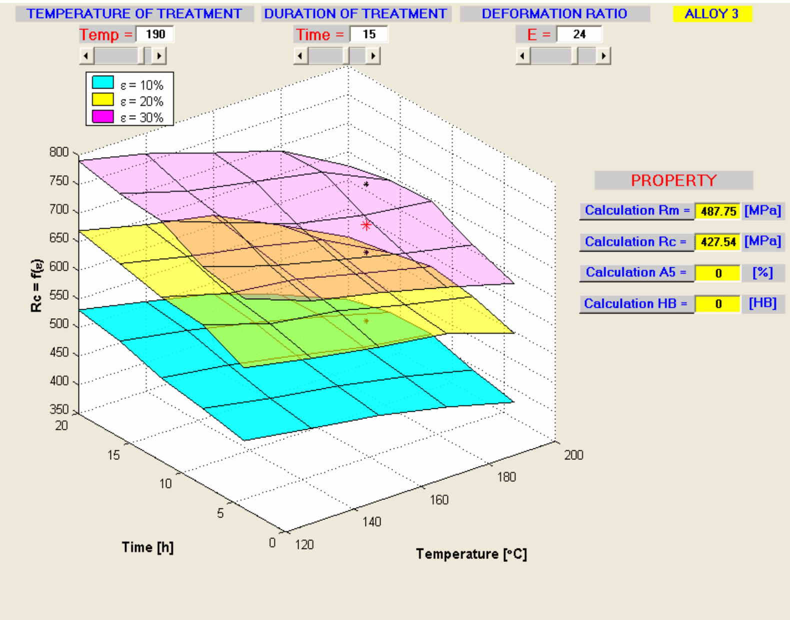

Fig. 5. *Prediction for Alloy 3 of the value of $R_{p0,\,2}$ artificial aging temperature of 190ºC for 15 hours and the degree of plastic deformation ε = 24%*

Proceed similarly to find any of the 4 studied mechanical properties (Rm, RP0, 2, HB, A5) to any value within the thermomechanical processing parameters studied, temperature: 120°C to 200°C for retention time τ = 4 ÷ 20 hours and the degree of deformation ε = 10 ÷ 30%.

Conclusions

Mathematical modeling of thermomechanical treatment processes performed, led to mathematical models that express the connection / correlation between the overall mechanical properties of strength and plasticity and main influence factors, ie the main parameters of thermomechanical treatment.

Equations of the mathematical model allowed and highlighting technological parameters with the greatest influence on the mechanical properties, but also the order in which parameters influence these properties. A GUI was made based on mathematical models and equations using MATLAB program. This interface can predict mechanical properties so you can know in advance what values should have thermomechanical treatment parameters to achieve a complex anumoit property of a certain value to them.

References

[1]. Alexandru I. – *Ştiinţa materialelor metalice*, Editura Didactică şi Pedagogică, Bucureşti, (1996)

[2]. Aloman A. – *Fazele şi compoziţia chimică a materialelor*; Editura Bren Bucureşti, (2001)

[3]. Aloman A. – *Structura materialelor*, Editura AGIR Bucureşti, (2000)

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

[5]. Askeland D. R .– *The Science & Engineering of Metals*, 3-rd edition, (1994)

[6]. *** – *ASTM Handbok vol. I – X*, (1999)

[7]. Bunea D., Şaban R., Vasile T., Gheorghe D., Brânzei M. – *Alegerea şi tratamentele termice ale materialelor metalice,* Editura Didactică şi Pedagogică. Bucureşti, (1996)

[8]. Bunea D., ş. a. – Studiul materialelor, Editura Universităţii Politehnica Bucureşti, (1993)

[9]. Cazimirovici E. – *Bazele teoretice ale deformării plastice*, Editura Bren Bucureşti, (1999)

[10]. Cănănău N., Tănase D. – *Tehnologia deformării plastice,* Galaţi University Press, (2010)

[11]. Ciucă I. Dumitriu S. – *Modelarea şi optimizarea proceselor metalurgice de deformare plastică şi tratamente termice*, Editura Didactică şi Pedagogică, Bucureşti, (1998)

[12]. Taloi D. – *Optimizarea proceselor tehnologice – aplicaţii în metalurgie*, Editura Academiei, Bucureşti, (1987)

[13]. 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

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

[15]. Popescu D; Ionescu F, Dobrescu R. Ştefanoiu D, - *Modelare în ingineria proceselor industriale,* Editura AGIR, Bucuresti (2011)

[11]. Ienciu, M. ş.a. - *Elaborarea şi turnarea aliajelor neferoase speciale.* Editura Didactică şi Pedagogică, Bucureşti (1985).