A. NIOAȚĂ

ISSN 0543-5846
METABK 52(2) 231-234 (2013)
UDC – UDK 669.11:620.178:620.193=111

RESEARCHES REGARDING THE OPTIMIZATION OF THERMAL TREATMENT DEPENDING ON HARDNESS FOR MARAGING 300 STEEL

Received – Prispjelo: 2012-05-25
Accepted – Prihvaćeno: 2012-10-05
Preliminary Note – Prethodno priopćenje

The paper presents researches regarding the optimization of aging thermal treatment and solution heat treatment for MARAGING 300, in order to get a certain hardness value. Experimental data processing resulted from the study of MARAGING 300 steel hardness dependence on the temperature and aging maintenance time and solution heat treatment was made using Statistica pr ogram. Results ha ve allowed to determine some mathematic patt erns for determining heating temperature, maintenance time respectively in order to get a certain steel hardness.

Key words: maraging steel, aging thermal treatment, solution heat treatment, material hardness, mathematic pattern.

INTRODUCTION

MARAGING steel has very good usage properties in fields where usage phenomena are very present. These usage properties depend on the steel chemical composition very much, and also on the thermal treatment parameters applied. Thermal treatments that influence these usage properties very much is the aging thermal treatment and solution heat treatment characterized by the two parameters: heating temperature, maintenance time respectively [1-3]. The process for achieving alloy hardness is called structural hardening or aging.

If hardening takes place at surrounding temperature natural aging occurs, and if it takes place at various temperatures, artificial aging takes place [4].

Solution heat treatment consists of solubilisation, dissolution thermal treatment that is precipitates phases treatment in the structured followed by cooling [5].

MATERIAL AND METHOD

Maraging steel (a combination “martensite” and “aging”) are types of steel known for having higher resistance and tenacity without losing malleability [6,7]. The main alloy element is nickel in composition from 15 to 25 %. Secondary alloy elements are added in order to produce inter-metallic precipitates which comprise cobalt 8 - 12 %, molybdenum 3 - 5 %, and titan 0,2 - 1,6 %.

These types of steel, despite having low content of carbon, are steel with a god processing rate.

In order to optimize heat treatment parameters on hardness, samples were made from MARAGING 300 steel under cylindrical form having the diameter of φ 20x30 undergoing aging thermal treatment and solution heat treatment. MIC 10 device was used for measuring hardness by using ultrasounds method, with a Vickers diamond (136 ^{o}). For aging thermal treatment and solution heat treatment Therma 80 CHT oven was used with the following characteristics: 85 litres capacity; maximum heating temperature of 1280 ^{o}C.

A. Nioață, Engineering Faculty, University “Constantin Brâncuși” of Târgu-Jiu, Romania

RESULTS AND DISCUSSIONS

Researches have comprised several variants of heat treatment used for aging thermal treatment and solution heat treatment. Therefore, for aging thermal treatment, temperature varied between 430 ^{o}C and 550 ^{o}C, and maintenance time between 60 min. and 300 min. For solution heat treatment, temperature varied between 820 ^{o}C and 860 ^{o}C, and maintenance time between 20 min. and 100 min. For an adequate processing of the experimental data used, several elements were considered for adequate statistic processing. Statistic processing of experimental data has meant to achieve conclusive results regarding the evolution of various answer measures (steel hardness) consisting in dependant variables, depending on independent variables (aging temperature and solution heat treatment and solution heat treatment maintenance time).

In order to achieve statistic processing of experimental data, related technique and software program have been developed. The software program used for experimental data statistic processing was **STATISTICA** running on a computer. Experimental data collected through measurements were the input values for the software program used. One of the main objectives of experimental data statistic processing was to achieve regression equations that describe the studied phenomenon as good as possible. For the regression analysis, more specifically for checking the meaning of regression coefficients, independent and dependent variables had to be dimensioned using the same measure units scale. This dimensioning, that is passing from various natural measurement units (°C, min.) to the same software measurement unit (a-dimensional) – established conventionally.

For independent variables aging temperature and solution heat treatment – X_1, aging maintenance time and solution heat treatment time – X_2) the problem was for the values of heating temperature introduced in the software program after the measured value was divided by 10 therefore (°C/10).

Experimental data statistic processing followed the determination of mathematic patterns which give HV30 hardness dependence depending on one or two independent variables. The two independent variables that hardness depend on are: aging temperature and solution heat treatment (X_1) and aging maintenance time and solution heat treatment maintenance time (X_2).

Expressing steel hardness by using mathematic patterns allows to determine its values for the steel studied through analytical software without requiring other experimental researches. Therefore, by using these mathematic patterns, steel hardness values can be determined for any value of independent variables comprised between their minimal and maximal variation limit. Analytical determination of hardness values by using mathematic patterns cancels experimental researches necessary for determining it for various values of independent variables. Steel hardness values can be determined by using mathematic patterns without the results be different by using them to a large extent in comparison to the ones resulted from experimental researches.

In case of big differences between the analytically determined values for the response measure steel hardness) and experimental ones the conclusion is that mathematic patterns are not adequate for the description of the phenomenon. For this case, it is necessary to determine other mathematic patterns of resume experimental researches by thoroughly detailing them. Hardness values dependence of the steel on every independent variable, expressed analytically, is given by the mathematic patterns presented in Table 1 for the aging thermal treatment and in Table 2 for the solution heat treatment.

Table 1 **Mathematic patterns describing steel hardness dependence for every independent variable (aging).**

No.	Mathematic patterns
1	HV30 = -211,095 + 443,816*log10(X_1)
2	HV30 = 421,819 + 53,775*log10(X_2)

Table 2 **Mathematic patterns describing steel hardness dependence for every independent variable (solution heat treatment).**

No.	Mathematic patterns
1	HV30 = 2,428e3 – 983,25*log10(X_1)
2	HV30 = 596,034 – 34,856*log10(X_2)

In order to develop an adequate analysis of the influence of every independent variable on steel hardness, graphic representation of experimental researches results was made. Graphic dependence of hardness on every independent variable is presented in Figures 1 - 4. Graphic dependences presented in Figures 1, 2 correspond to the mathematic patterns presented in Table 1. Graphic dependences presented in Figures 3, 4 correspond to the mathematic patterns presented in Table 2.

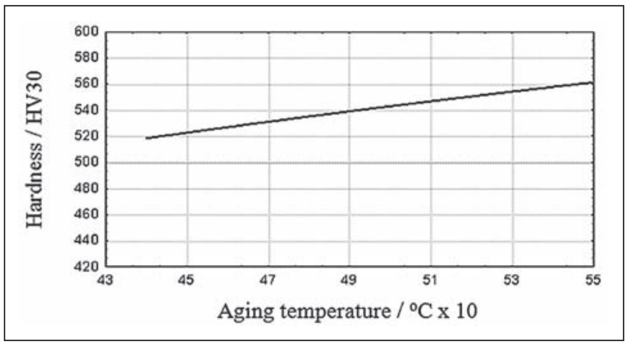

Figure 1 Hardness dependence on aging temperature

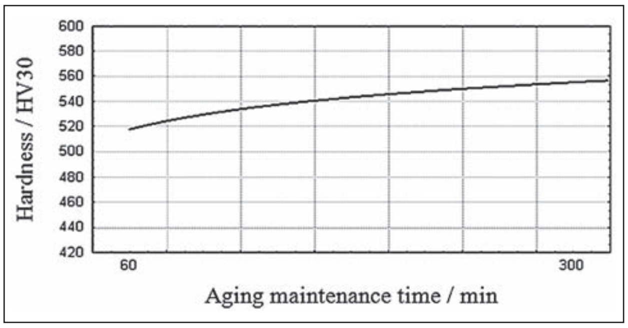

Figure 2 Hardness dependence on aging maintenance time

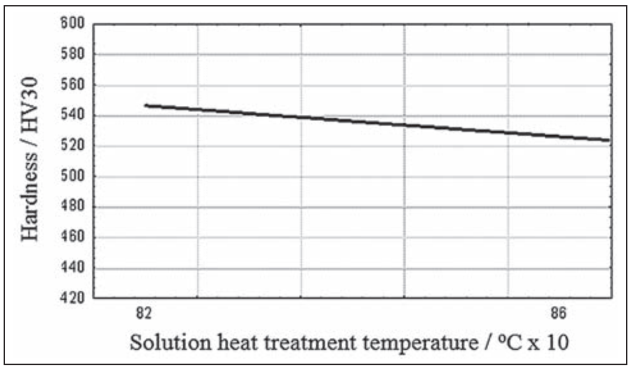

Figure 3 Hardness dependence on solution heat treatment

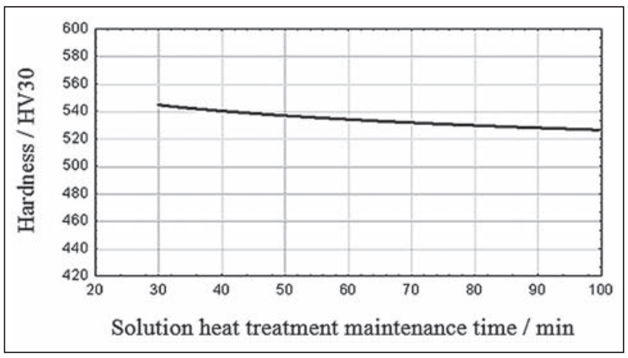

Figure 4 Hardness dependence on solution heat treatment maintenance time

It is very important to continue determining the dependence of the studied steel hardness for every two independent variables separately by using analytical and graphic methods. Analytical dependence of steel hardness on every two independent variables is presented in Table 3, 4.

Table 3 **Mathematic patterns describing steel hardness dependence on aging temperature and maintenance time**

No.	Mathematic patterns
1	$HV30=145,728-2,057X_1+5,948 X_2+0,085 X_1^2-0,013X_1X_2 - 0,014 X_2^2$

Table 4 **Mathematic patterns describing steel hardness dependence on solution heat treatment temperature and maintenance time**

No.	Mathematic patterns
1	$HV30=-131,217+25,991X_1-8,98 X_2 - 0,184X_1^2-0,004X_1X_2 +0,075 X_2^2$

This expression of steel hardness dependence of every two independent variables by using mathematic patterns does not always provide a conclusive image, this is why a graphic analysis was made presented in Figure 5 for the aging thermal treatment and Figure 6 for solution heat treatment. The graphic analysis creates a more conclusive image of phenomena development for the entire duration of the process.

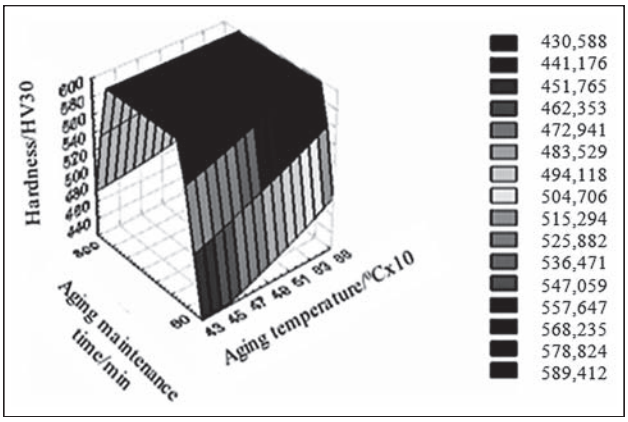

Figure 5 Hardness dependence / HV30 on temperature / °C x 10 and aging maintenance time / min

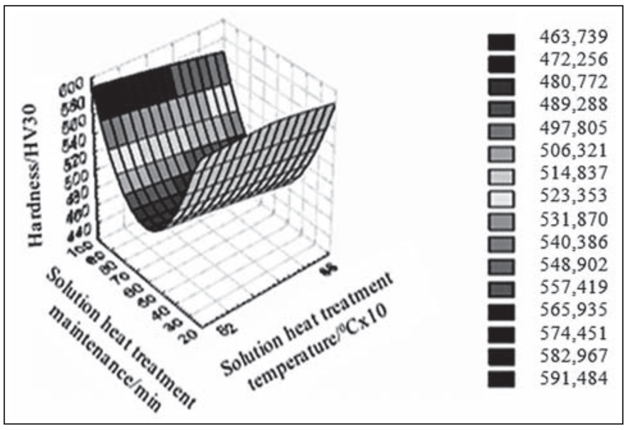

Figure 6 Hardness dependence / HV30 on temperature / °C x 10 and solution heat treatment time and maintenance / min.

In order to make an adequate analysis of mathematic patterns, a further residue analysis was made for every mathematic pattern which gives the dependence of steel hardness on every two independent variables. Residue analysis is very important because it provides information on the error that may occur for hardness values by using a mathematic pattern instead of experimental researches. This residue analysis is presented in Table 5 for the aging thermal treatment and in Table 6 for the solution heat treatment.

Table 5 **Residue analysis of the mathematic pattern that gives the dependence of steel hardness aging temperature and maintenance time.**

No.	Observed value	Predicted value	Residual
1.	550,5	561,925	-11,425
2.	607,0	561,925	45,075
3.	500,5	561,925	-61,425
4.	609,5	561,925	47,5749
5.	434,7	472,0	-37,3
6.	499,4	472,0	27,4
7.	459,7	472,0	-12,3
8.	474,4	472,0	2,4
9.	684,4	708,125	-23,725
10.	659,5	708,125	-48,625
11.	644,7	708,125	-63,425
12.	824,1	708,125	115,975

Table 6 **Residue analysis of the mathematic pattern that gives the dependence of steel hardness on solution heat treatment maintenance time and temperature**

No.	Observed value	Predicted value	Residual
1.	550,5	549,6251	0,8745
2.	607,0	623,9501	-16,95
3.	500,5	556,175	-55,675
4.	609,5	630,5	-21,0
5.	434,7	549,6251	-114,925
6.	499,4	623,9501	-124,55
7.	459,7	556,175	-96,475
8.	474,4	630,5	-156,1
9.	684,4	549,6251	134,775
10.	659,5	623,9501	35,55
11.	644,7	556,175	88,525
12.	824,1	630,5	193,200

CONCLUSIONS

The main conclusions that may result from this analysis are:

– mathematic patterns describe the real phenomena very well because the errors introduced by using them are very low;
– maximum hardness for steel is achieved for aging temperature of 520 °C and aging maintenance time of 100 - 200 min;
– maximum hardness (HV30) for steel is achieved for solution heat treatment temperature of 820 °C and solution heat treatment maintenance time of 100 min;

– minimum hardness for steel is achieved for aging temperature of 440 °C and aging maintenance time of 60 min;
– minimum hardness (HV30) for steel is achieved for the case in which solution heat treatment maintenance time is of 60 min, and solution heat treatment temperature is 860 °C;
– residue analysis allows to notice that the differences between the measured values and those that can be determined by analytical software with mathematic patterns for hardness are small enough being generally included within the admitted error which is 5 %.

REFERENCES

[1] Wei Wang, Wei Yan, Qiqiang Duan, Yiyin Shan, Zhefeng Zhang, Ke Yang, Materials Science and Engineering A 527 (2010), 3057–3063.

[2] Muktinutalapati Nageswara Rao, Krishnan Sivasubramanian, Materials Sciences and Application, (2011) 2, 1116-1120.

[3] T. Poornima, Jagannath Nayak and A. Nityananda Shetty, International Journal of ELECTROCHEMICAL SCIENCE 5 (2010), 56 – 71.

[4] S.J. Pawlak, W. Zalecki , Journal of Achievements in Materials and Manufacturing Engineering, 29 (2008) 1, 31-38.

[5] M. N. Rao, International Journal of Materials Research, 97 (2006) 11, 1594-1607.

[6] D. Dobrotă, Annals of the Faculty of Engineering of Hunedoara, Year 3, Fascicle 1, (2001), 44-47.

[7] D. Dobrotă, Bulletin of the National Scientific Session of Scientific Communications, Henri Coandă Air Force Academy, Brasov, November, (2000), 205-210.

Note: The responsible translator for English language is S.C. OMNI-TRAD S.R.L., Craiova, Romania