THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^0. 1 – 2010, ISSN 1453 – 083X

INTERCRITICAL THERMOMECHANICAL TREATMENTS APPLIED TO THE STEEL HEAVY PLATES

Elisabeta VASILESCU
„Dunarea de Jos” University of Galati, Romania,
email: elisabeta.vasilescu@yahoo.com

ABSTRACT

This paperwork shows the laboratory experiments made on X60 and X65 steels with several intercritical thermomechanical treatment applications. Two variants were used: "down-up" thermomechanical treatment with heating and rolling in the intercritical range and "up-down" thermomechanical treatment with preliminary complete austenitizing and rolling in the intercritic interval. High values of the strength characteristics and a good plasticity were obtained. A comparison was made with the obtained results of the classical thermal treatment application (normalizing).

KEYWORDS: intercritical thermomechanical, microalloyed steel

1. Introduction

The present world conjuncture regarding the plate products offers and costs imposed (to keep the markets) the making of the new technologies of the processing and thermal treatments that lead to the diminution of the energy consumption. The siderurgy is placed among the industrial branches with high level energy consumption therefore, the aim of this paper-work is to settle the reduction solutions of the energy consumption in the final stage of the plate-products thermally treated. [3]

The study of the national and international standards, that establishes the manufacturing conditions, mechanical and technological characteristics of the siderurgical products made of the hypoeutectoid steels, showed that there are cases when the thermal treatment characteristics are not precised. In these cases first of all, and when the treatment characteristics are not precised, the researches could be achieved to settle the reducing ways of the energy consumption by temperature decrease or final thermal treatment elimination.

It is supposed a nonconventional approach of the thermal treatment process by thorough studies regarding transformation mechanism and kinetics in the intercritic field of the structural steels and a better correlation to the previous stage - plastic deformation.

In the practice of the thermal treatments, the conservative positions are shown that impose the hypoeutectoid steels to be completely austenitized to achieve the normalizing annealing or quenching.

It has been considered for a long time that the incomplete austenitizing to such steels leads to the fatigue strength worsening and to the increase of transition temperature at brittle fracture.

All national and foreign researches introduce the incomplete austenitizing for normalizing of the naval plates or some structural steels quenching and for normalizing of the welded joint thermal influence zones for some low Carbon Ni-Mo or Ni-Mo-V steels.

It was established that, by thermal treatment temperature reducing a certain values increase of the material strength and plasticity, and metal loss reduction due to oxidation during thermal treatment were gotten.

By a thorough study and systematisation of the results in this research field, a new orientation could be traced in the practice of the hypoeutectoid steels, the thermal treatment, which answers better to the purposes for which these siderurgical products are made.

The thermal treatment of the steels and cast-irons, based on the austenite getting and its subsequent transformation (annealing, quenching), is made traditionally, with complete austenitizing (for hypoeutectoide steels) or incomplete austenitizing (for eutectoide, hypereutectoide and ledeburite steels). [4]

From the austenitizing temperature point of view, the respective treatment of the hypoeutectoide steels could be considered as "overcritic" (above A_{C1}-A_{C3} interval), and for the other steels as "intercritic" (in Ac_1-$A_C$cem critic interval).

By heating, in the balance condition of a hypoeutectoide steel, in A_1-A_3 interval, its microstructure, pearlitic-ferrite initially, will become austenite-ferrite.

Carbon concentration of the austenite and austenite ratio, as well, will depend on steel carbon content and heating temperature.

The highest possibilities of controllable variation of such characteristics, the steels with an extend A1-A3 range present, those with 0,10 - 0,30%C, respectively. [2]

Moreover, the fact should be specified that the studies balance situation could be achieved on the other ways such as: by steel heating in the austenite field (total austenitizing) and by show cooling up to a temperature placed within the A_3-A_1 interval (Fig. 1)

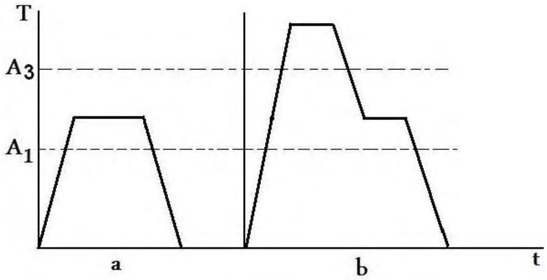


Fig. 1. *Practical ways of an intercritic treatment for a hypoeutectoide steel*
a) heating from the ambient temperature within the A_3-A_1 interval (down-up)
b) preliminary austenitizing and precooling within the A_3-A_1 interval (up-down)

This kind of the treatments were named intercritical thermal treatments and are used for thermal influenced zone recovery from electroslag welding of some Ni-Mo or Ni-Mo-V steels (with low carbon) and dual-phase steels, as well. The latest paper-works of specialty show that the intercritical thermal treatment could be used for some hypoeutectoide steel, as well, those with high Ni content, carbon-steel, and low alloyed steels for naval constructions. [1]

2. Laboratory experiments

Combining the thermal treatment with a plastic deformation in the intercritic field, an intercritic thermal mechanical treatment was achieved.

For experiments, X65 steel test pieces were used having the following characteristics (mentioned in Tables 1 and 2).

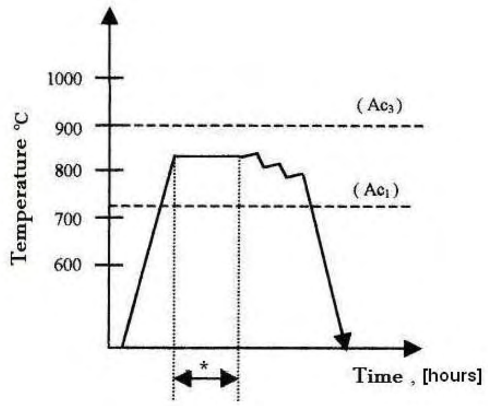
Table 1. *Chemical characteristics of X65 steel*

C	Mn	Si	V	Al	Ni	Mo	Ti	Nb
0.1	1.5	0.2	0.03	0.07	0.01	0.003	0.02	0.04

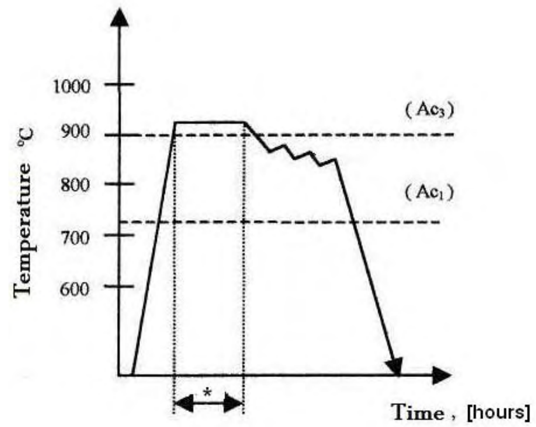
Table 2. *The imposed mechanical characteristics steel grade*

Steel grade	Rm, min [N/mm^2]	Rp $_{0,2}$ min [N/m^2]	A min [%]	KV min [J]
X65	413	331	22	27

The intercritic thermo-mechanical treatment was used by the direct heating in the intercritic deformation field (down-up) and deformation in intercritic condition after a preliminary austenitizing (up-down) Fig. 2.



a



b

Fig.2. *Intercritical thermomechanical treatments: a) down-up; b) up-down, *1/2 hour.*

In the laboratory conditions, the thermomechanic treatment consisted of:

- heating in the austenitic or intercritic conditions;
- one passing rolling with a e = 30% and 20% reduction degree on the laboratory rolling mill having barrel diameter of D = 129mm;

- the rolling was achieved in the intercritic field (temperature of 850°C and 800°C) for both treatments: "down-up" and "up-down";
- the cooling after rolling was made in air or water.

On the test specimen, thus obtained, the mechanical characteristics and structure were determined. The results are shown in Table 3.

Table 3. *The experimental conditions of intercritical treatments*

No exp	Experimental variants	Mechanical caracteristics				
		ε %	Rm N/mm^2	Rp$_{0,2}$ N/mm^2	A 5 %	HB
1	Heating to 920ºC + cooling air(normalizing)	30	546	368	29	278
2	Heating to 920ºC →cooling 850 ºC → rolling →water	30	804	764	22	292
3	Heating to 920ºC→ cooling 850 ºC → rolling → air	30	637	579	29	191
4	Heating to 920ºC→ cooling 800 ºC → rolling → water	30	803	753	20	285
5	Heating to 920ºC→ cooling 800 ºC → rolling → air	30	577	412	26	174
6	Heating to 850ºC→ rolling →water	20	834	685	26	292
7	Heating to 850ºC→ rolling → air	20	686	566	32	202
8	Heating to 800ºC→ rolling →water	30	1027	852	20	329
9	Heating to 800ºC→ rolling → air	30	651	498	20	215
10	Heating to 800ºC→ rolling →water	20	933	756	20	315
11	Heating to 800ºC→ rolling → air	20	651	498	20	215
12	Heating to 920ºC →cooling 850 ºC → rolling →water	20	880	696	20	301
13	Heating to 920ºC→ cooling 850 ºC → rolling → air	20	636	526	26	148

3. Results and discussions

First experiment consisted in a classic normalizing treatment for results comparison (Table 1).

The group of second experiments consisted of "up-down" treatments where working conditions were different by the cooling way and deformation degree:
- austenitizing temperature T = 920°C;
- cooling at 850°C;
- rolling with ε_1 = 30% and ε_2 = 20%;
- cooling water and air.

It is noticed that Rm and Rpo,2 mechanical characteristics values exceed the values provided by the norms (Table 2). In turn, the elongation is not framing, in all cases, in the values required by the norms.

Deformation degree did not influence appreciably the mechanical characteristics.

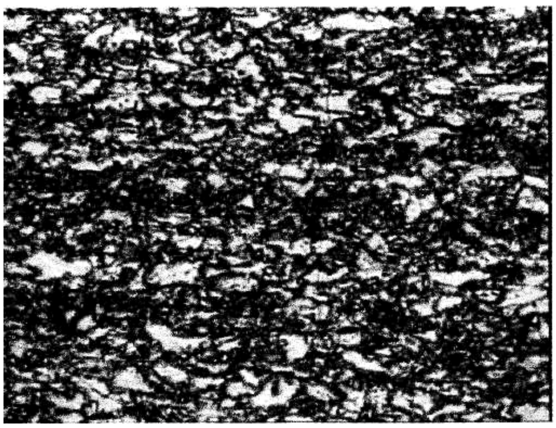
In case of such treatment, the best results are obtained in domains 3 and 5 with austenitizing temperature T = 920°C, cooling 850°C, rolling 8i = 30% and air cooling. Water cooling brings about low elongation values. The structure is shown in Figs. 3a and 3b.

The third group of experiments consisted of "down-up" treatment thus:
- heating at 850°C and 800°C;
- rolling at these temperatures;
- air or water cooling;
- deformation degree ε_1= 30% and ε_2 = 20%.

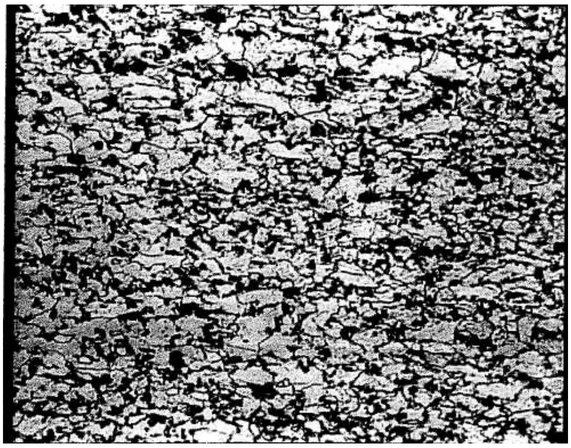
The best results were obtained in the domains 6 and 7 with heating at 850°C, rolling with ε_2 = 20% and air / water cooling.

High values are obtained for both Rm and Rp$_{o,2}$ and elongation as well (32% to the min 22% provided by norms).

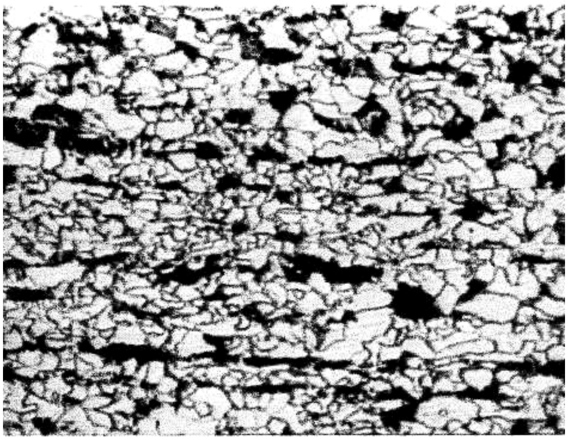
The structures are shown in Figs. 3c and 3d.



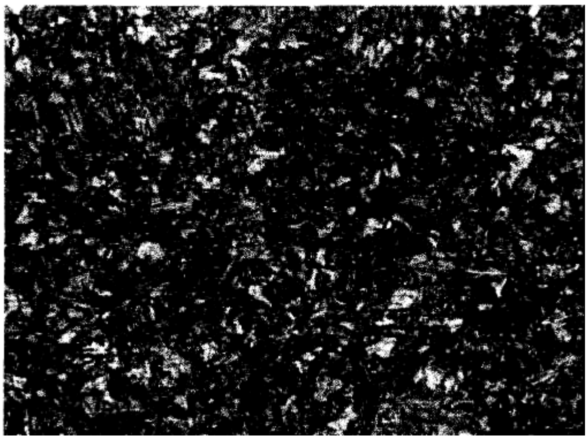
a)



b)



c)



d)

Fig.3. *Specimen microstructure with intercritic thermomechanical treatment (x 500 magn., Nital etch 2%)*
a) regime no.3; b) regime no.5;
c) regime no.6; d) regime no.7.

4. Conclusions

-all the experiment variants of the thermomechanical treatment lead to the increase of the mechanical characteristics values of the strength (Rm, $R_{p0.2}$) and some of them to the improvement of the plasticity characteristics (A_5 %);

-the experiment variants of the thermomechanical treatment with water cooling after deformation bring about high values for strength characteristics (over 2 times higher than in the "rolled" condition) but determine the elongation decrease even under 20% (smaller than in the "rolled" condition);

-the experiment variants of the thermomechanical treatment with air cooling after plastic deformation bring about mechanical characteristics improvement regarding both: strength and plasticity:

Rm = 577-686N/mm^2; Rp_{02} = 412-566N/mm^2; A_5 = 20-29 %, frecvently 26%. Studying the possibility of the thermomechanical treatment with air cooling after plastic deformation the following remarks are made:

-regarding the heating way: "up-down" or "down-up", the variants with preliminary austenitizing have the highest values of the plasticity characteristics A5 = 26-29%, when mechanical characteristics are kept at high values: (Rm = 577-637 N/mm^2; $Rpo._2$= 412-579 N/mm^2).

In the frame of these experiment variants it could be seen that the deformation degree, ε, in limits of 20-30% hasn't an important influence on the characteristics.

-the experiment variants of the thermomechanical treatment without preliminary austenitizing ("down-up") determine a decrease of the elongation from 26% to 20% even though the mechanical characteristics of strength are high, with the remark that the deformation degree from 20% to 30% does not influence meaning fully:

- regarding the plastic deformation temperature established between intercritic interval of the studied steel it could be noticed:

a) in the experiment variant with preliminary austenitizing and deformation at 850°C having deformation degree e - 30%, a good assembly of mechanical characteristics is achieved (Rm = 637 N/mm^2; Rpo.2 = 579 N/mm^2; A5 = 29%) in comparison to the temperature of 800°C (Rm = 577 N/mm^2; $Rpo._2$ = 412 N/mm^2; A_5 = 26%);

b) the experiment variant without preliminary austenitizing ("down-up"), also demonstrated that temperature of 850°C leads to the good results of the characteristics no matter to the deformation degree.

In conclusion, the experiment results show that X65 microalloyed steel is sensitive to the mechanical processing and the values of the mechanical characteristics are modified to the rolled condition or to the conventional thermal treatment but the optimum experiment variants that lead to the establishing of the technological conditions in keeping with the studied steel grade are characterized by the following parameters: *preliminary austenitizing at 920°C; plastic deformation temperature of 850°C; deformation degree of about 30%; air cooling after deformation.*

References

[1]. Doniga A., Vasilescu E., *Bazele tratamentelor termomecanice* E.D.P., Bucuresti 2004
[2]. Gadea S. si Petrescu M, *Metalurgie fizica si studiul metalelor* E.D.P , Bucuresti,. 1983
[3]. Leger J., *Etudes des traitements intercritiques* (A_1-A_3) des aciers hypoeutectoides Mem. Scient. Met LXVII, nr. 5 , 1971
[4]. Popescu N. s.a. ,*Tratamente termice neconvemionale* Editura Tehnica, Bucuresti, 1990
[5]. Kula, E, Radeliffe, S. Thermomechanical treatments of Steel, Journal of Metals no.10/1963
[6]. Komoda, A. Effect of Austenite Grain Size and C content on the Substructure and Toughness of Tempered Martensite and Bainite, Transaction ISIJ no.5/1974
[7]. Tamura, I. Some Fundamental Steps in Thermomechanical Processing of Steels, Transaction ISIJ, vol.27/1987
[8]. Elwazri, A. M.,s.a. Methadynamic and Static recrystallisation of Hypereutectoid Steel, ISIJ International, vol.43/1982
[9]. Proc. Int.Conf.on the Thermomechanical Treatments of Steels, Padua Italy, 2008.