THERMOMECHANICAL PROCESSING OF MICROALLOYED STEELS USED FOR NAVAL AND OIL INDUSTRIES

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ABSTRACT

This paperwork shows the laboratory experiments made on X60 and X65 steels with several intercritical thermomechanical treatment application.

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 gotten. A comparison was made with gotten results of the classical thermal treatment application (normalizing).

KEYWORDS: thermomechanical treatment, rolling, intercritic interval.

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 between 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 thermal-treated.[1]

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 supposing a nonconventional approaching of the thermal treatment process by studies thoroughly regarding transformation mechanism and kinetics in the intercritic field of the structural steels and a better correlation to the previously stage – plastic deformation.[2]

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

Long time it was considered that the incomplete austenitizing to such steels leads to the fatigue strength worsening and to the transition temperature increase at brittle fracture.

For all that some domestic and abroad researches introduce the incomplete austenitizing for normalizing of the naval plates or some structural steels quenching and 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 study thoroughly and systematisation of this field research-results, a new orientation could be traced in the practice of the hypoeutectoid steels, thermal treatment, and 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, subsequent, transformation (annealing, quenching), are made traditionally, with complete austenitizing (for hypoeutectoide steels) or incomplete austenitizing (for eutectoide, hypereutectoide and ledeburite steels).[3]

From austenitizing temperature point of view, the respective treatment of the hypoeutectoide steels could be considered "overcritic" (above Ac_1-

Ac_3 interval), and for the other steels “intercritic” (in Ac_1-Ac_{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 possibiliyties of controlable variation of such characteristics, the steels with extend A_1-A_3 range present, those with 0,10 – 0,30%C, respectively. [4]

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

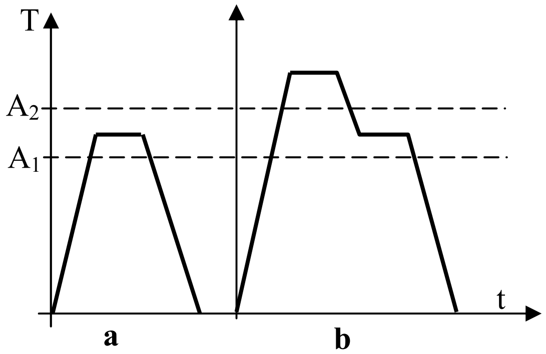

Figure 1. *Practical ways of an intercritic treatment for an hypoeutectoide steel:*

a) heating from the ambient temperature in A_3-A_1 interval (down-up)

b) preliminary austenitizing and precooling in 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 speciality 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.[5]

2. Laboratory experiments

Having in view the importance of the naval-plates from the total production of S.C.ISPAT-SIDEX Galati, it is considered that the reduction of the energy consumption will be important using the intercritic conditions. 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 table no.1 and 2)

Table 1. *Chemical characteristics of X65 steel (%).*

C	Mn	Si	V	Al	Ni	Mo	Ti	Nb
0,1	1,53	0,26	0,03	0,07	0,01	0,003	0,02	0,04

Table 2. *The imposed mechanical characteristics steel grade.*

Steel	R_m,min [N/mm^2]	$R_{p0.2}$,min [N/mm^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.

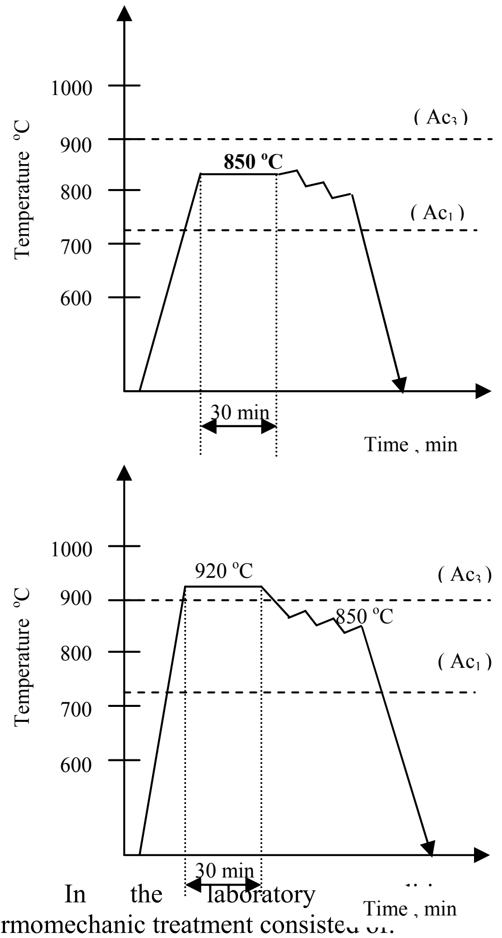

Figure 2. *Intercritical thermo-mechanical treatments*

a – down-up;

b – up-down

In the laboratory the thermomechanic treatment consisted of:

- heating in the austenitic or intercritic conditions;

- one passing rolling with a ε = 30% and 20% reduction degree on the laboratory rolling mill having barrell diameter of D = 129mm;

- the rolling was achieved in the intercritic field (temperature of 850^{0}C and 800^{0}C) for both treatments: “down-up” and “up-down”;

- the cooling after rolling was made in air or water.

On the test specimen, thus gotten, the mechanical characteristics and structure was determined. The results are shown in table 3.

Table 3. *The experimental conditions of the intercritical treatments*

No. exp.	**Experimental variants of TT/TTM**	**Mechanical characteristics**				
		ε [%]	**Rm** $[N/mm^2]$	**Rp$_{0,2}$** $[N/mm^2]$	**A5** [%]	**HB**
1	Heating to 920° C + cooling air (normalizing)	30	546	368	29	278
2	Heating to 920°→cooling 850°+ rolling→ water	30	804	764	22	292
3	Heating to 920°→ cooling 850°+ rolling → air	30	637	579	29	191
4	Heating to 920°→ cooling 800° + rolling → water	30	803	753	20	285
5	Heating to 920°→ cooling 800°+ rolling → air	30	577	412	26	174
6	Heating to 850°→rolling→ water	20	834	685	26	292
7	Heating to 850°→rolling → air	20	686	566	32	202
8	Heating to 800°→rolling→ water	30	1027	852	20	329
9	Heating to 800°→rolling → air	30	651	498	20	215
10	Heating to 800°→rolling→ water	20	933	756	20	315
11	Heating to 800°→rolling → air	20	651	498	20	215
12	Heating to 920°→cooling 850°+ rolling→ water	20	880	696	20	301
13	Heating to 920°→ cooling 850°+ rolling → air	20	636	526	26	148

3. Results and discussions

First experiment consisted in a clasic normalizing treatment for results comparison (table 3, regime 1).

Second experiments group consisted of “up-down” treatments where working conditions were different by the cooling way and deformation degree:

- austenitizing temperature T = 920^{0}C;
- cooling at 850^{0}C;
- rolling with ε_1 = 30% and ε_2 = 20%;
- cooling water and air.

It is remarked that Rm and $Rp_{0,2}$ mechanical characteristics values exceded 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 didn’t influence appreciably the mechanical characteristics.

In case of such treatment the best results are gotten in domains 3 and 5 (table 3) with austenitizing temperature T = 920^{0}C, cooling 850^{0}C, rolling ε_1 = 30% and air cooling. The water cooling results the low elongation values. The structure are shown in fig.3a and 3b.

The third group of the experiments consisted of “down-up” treatment thus:

- heating at 850^{0}C and 800^{0}C;
- rolling at these temperature;
- air or water cooling;
- deformation degree ε_1 = 30% and ε_2 = 20%.

The best results were gotten in the domains 6 and 7 (table 3) with heating at 850^{0}C, rolling with ε_2 = 20% and air / water cooling.

High values are gotten for both Rm and $Rp_{0,2}$ and elongation as well (32% to the min 22% provided by norms).

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

4. Conclusions

- All the experiment variants of the thermomechanical treatment lead to the increase of the mechanical characteristics values of the strength (Rm, $Rp_{0,2}$) and some of them to the improvement of the plasticity characteristics (Ar %);

- The experiments variants of the thermomechanical treatment with water cooling after deformation result the high values for strength characteristics (over 2 times higher than “rolled” condition) but determinate the elongation decrease even under 20% (smaller than “rolled” condition);

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

R_m = 577 ÷ 686 N/mm^2;
$Rp_{0.2}$ = 412 ÷ 566 N/mm^2;
A_5 = 20 ÷ 29 %, frecvent 26 %.

Studying the possibility of the thermomechanical treatment with air cooling after plastic deformation the following remarks are mode:

- regarding the heating way: “up-down” or “down-up”, the variants with preliminary austenitizing result the highest values of the plasticity characteristics A_5 = 26 – 29% when mechanical characteristics are kept at high values: (Rm = 577 ÷ 637 N/mm^2; $Rp_{0.2}$ = 412 ÷ 579 N/mm^2). In the frame of these experiment variants 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”) determinate a decrease of the elongation from 26% to 20% even though the mechanical characteristics of strength are high, with remark that the deformation degree from 20% to 30% doesn't influence meaning fully:

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

a) in the experiment variant with preliminary austenitizing and deformation at 850^{0}C having deformation degree ε = 30%, a good assembly of mechanical characteristics is achieved (Rm = 637 N/mm^2; $Rp_{0.2}$ = 579 N/mm^2; A_5 = 29%) in comparaison to the temperature of 800^{0}C (Rm = 577 N/mm^2; $Rp_{0.2}$ = 412 N/mm^2; A_5 = 26%);

b) the experiment variant without preliminary austenitizing (“down-up”), also, demonstrated that temperature of 850^{0}C leads to the good results of the characteristics indifferent to the deformation degree.

In conclusion, the experiment results show that X65 microalloyed steel is sensitive to the mechanical processing and the value 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:

1) preliminary austenitizing at 920^{0}C;
2) plastic deformation temperature 850^{0}C;
3) deformation degree about 30%;
4) air cooling after deformation.

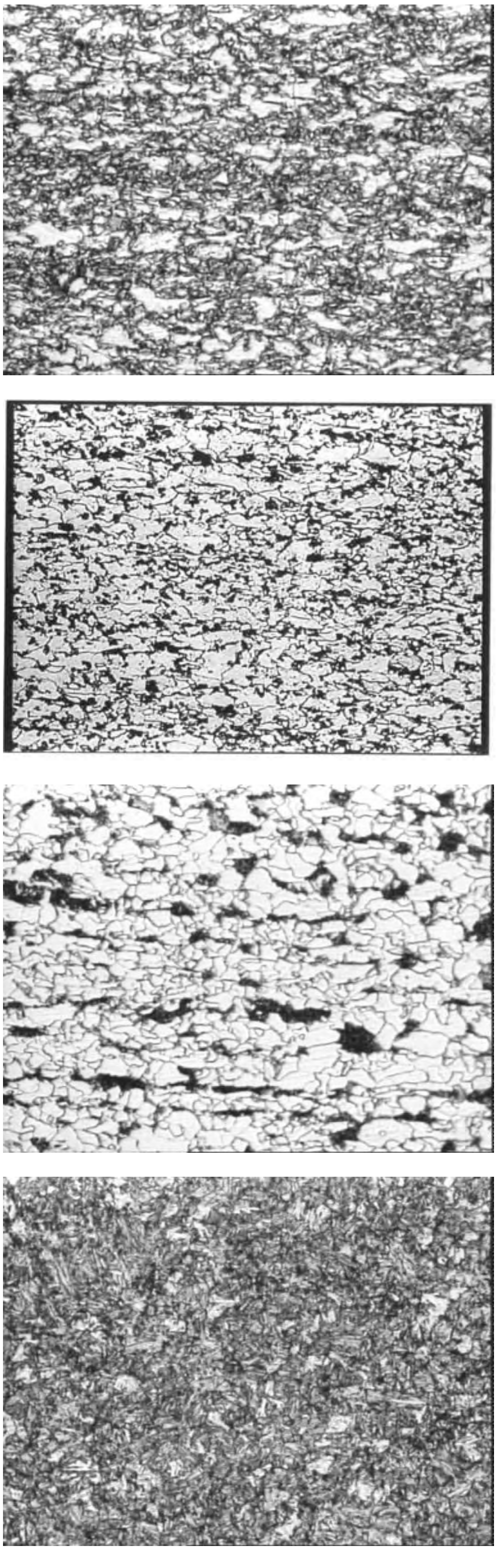

Figure 3. *Specimen microstructure with intercritic thermomechanical treatment* (table 3) *(x 500 magn., Nital etch 2%)*

a) regime 3;

b) regime 5

c) regime 6

d) regime 7

References

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