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THE ANALYSIS OF THE BREAKING SUSCEPTIBILITY OF SOME FERITIC STAINLESS STEEL

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ABSTRACT

The growth of the world stainless steel conumption was the result of some new domains development, of some demands and special conditions undercooling not only the adaptability of this alloy but also the remarcable range of some important properties. It has a high resistance – weight proportion, is extremely resistant at corrosion, usage and heating and it can be, relativelly, easily malleable or welded.

The stainless steel are, also, excelent materials from point a view of the environment protection. The special characteristics of the stainless steel create sometimes during the working process some difficulties that can lead to the rise of the working costs. In this paper it is made an analisys of the causes of breakage of the strip made of feritic stainless steel during the preparing operation for cold rolling and solutions are suggested for eliminating the deficiency.

KEYWORDS: cold rolling, breaking susceptibility, ferritic stainless steel

1. Introduction

The stailess steel is succesful used in the products used in the chemical industry, in the alimentary industry, in construction domain, machine construction industry, medical domain, environment and transport.

The stainless steel tends to replace, in a serious of products, the charbon steels, aluminum, brass or bronze. The succes of the stainless steel has following major advantage: the chrome, which is part of the steel composition has a good affinity whith the oxygen, forming in its present, protection film of chrome oxyde.

All the alloyed elements which form the stainless steel, especially the nickel, contribute to the significant growth of the mechanical resistance and hardness values.

The stainless steel is superior to the carbon steels from many point of view and it is preferable in manufacturing of the finishing profiles, in the first place, owing to its superior resistance to corrosion, the aesthetic qualities of this material are not neglectable – satinized or shiny, particulary elegant.

Under the conditions when the maintenance costs are low, the life span is comprised between 10 and 20 years and the influence over the environment is not harmful, the stainless steel market has an encreasing trend. If we take into account the total costs along the life span of the material, the stainless steel proves sometimes to be the most convenient as a price.

Therefore an object made of stainless steel can be bought with 25% cheaper than a chrome plated one, but with a bigger life span, to the prejudice of a chaper chrome plated object, but with smaller life span.

2. Experiments

During the preparation for the cold rolling process of the strip coils made of ferritic stainless steel X6Cr17 (according to EN), respectivelly, W4016, with 0.06 %C and 17% Cr, it was remarked a high breakage susceptibility in various states (at the pickling, before the thermal treatment process, during the rolling process).

That is way, the results obtained in various states, in industrial conditions were analysed; the results are compared with those obtained in laboratory onditions (table 1).

The coils, after thermal treatment were analysed made in industrial conditions:

a. annealing treatment: maintaining 2 hours at 810^{0}C, furnace cooling;

b. annealing treatment: maintaining 1 hour at 840^{0}C, furnace cooling

Tabel 1. *The coils o fhot rolling strips with cold breakage susceptibility*

Nr. crt.	Coil No.	The state in which cold breakage susceptibility was noticed
1	265.065	while pickling
2	273.555	while pickling
3	228.290	before the thermal treatment
4	215.664	while pickling
5	265.058	while pickling
6	321.667	before the thermal treatment

The chemical composition of the ferritic stainless steel 10Cr170, show that the analyzed coils is placed in the limits of the prescribed chemical composition through standards for this steel mark.

The values of the hardness for the analyzed coils are presented in table 2 and the chemical composition in table 3. Measurements on groups of three coils were made for each coil. In the table being presented the medium values of three measurements made on every coil.

Table 2. *The hardness of the analysed coils*

Coil No.	Hardness, HV		
	Initial state	After the thermal treatment type A	After the thermal treatment type B
265065	375; 386; 388	213; 216; 216	215; 216; 218
273555	264; 255; 256	172; 172; 170	172; 173; 170
228290	394; 407; 388	158; 180; 184	179; 178; 150
215664	390; 247; 322	184; 184; 184	133; 144; 143
265058	295; 265; 288	173; 165; 164	184; 177; 175
321667	277; 267; 284	171; 168; 167	180; 188; 189

2.1. Bending behaviour

The bending was made on punch of 10mm at an angle of 90^{0} (fig.1), on coil under thermal treatment in laboratory furnace at the temperatures and maintenance period previously presented. The results of bending test are presented in table 2.

Fig.1. *Aspects of breakage at the bending stress for the tests prelevated from coils without thermal treatment; (the punch diameter– 10mm).*

Tabel 3. *Chemical composition*

Coil no.	State	C	Mn	Si	S	P	Ni	Cr	Mo
265065	lich.	0,05	0,50	0,15	0,015	0,025	0,34	17,40	-
	prod.	0,07	0,82	0,24	0,015	0,027	0,70	17,10	-
273555	lich.	0,06	0,93	0,55	0,013	0,023	-	16,60	-
	prod.	0,08	0,77	0,36	0,017	0,024	0,26	17,00	0,110
228290	lich.	0,04	0,85	0,27	0,014	0,022	-	17,00	-
	prod.	0,08	0,87	0,30	0,016	0,024	0,33	13,95	0,011
321667	lich.	0,07	0,33	0,46	0,016	0,023	0,10	16,25	-
	prod.	0,07	0,67	0,74	0,016	0,027	0,24	16,80	-
215664	lich.	0,04	0,56	0,81	0,013	0,022	-	16,88	-
	prod.	0,07	0,76	0,36	0,017	0,023	0,27	17,10	0,11
265058	lich.	0,07	0,50	0,33	0,012	0,024	-	17,75	-
	prod.	0,08	0,76	0,36	0,017	0,023	0,27	16,80	0,4

From the analysis of the data presented in table 3, we have drawn the following conclusions:

a. in initial state the coils present an accentuated susceptibility at bending only coil 2 being unbroken from three tests;

b. after annealing at 840^{0}C (with maintenance of 1-12 hours) or at 810^{0}C (for 2-12 hours) the tests from all the 6 coils analysed have not presented sensibility of the breakage of the bending test;

c. after annealing at 810^{0}C with maintenance period of 4 or 8 hours – three coils presented a greater susceptibility by a rise of the hardness (table 4).

Table 4. *The hardness variation function of annealing thermal treatment parameters*

Coil no.	**The value of the hardness after the annealing effectuated in mentioned conditions** [HB]							
	810^{0}C 2h	810^{0}C 4h	810^{0}C 8h	810^{0}C 12h	840^{0}C 1h	840^{0}C 4h	840^{0}C 8h	840^{0}C 12h
265.065	216	333	376	287	218	-	234	244
273.555	171	166	184	204	173	-	165	166
228.290	176	184	246	200	173	164	187	193
215.664	184	180	173	166	156	159	167	183
265.058	167	167	165	166	181	-	172	169
321.667	169	165	167	178	189	-	-	169

2.2. Metallographic analysis

1. The coils in the thermal treatment in industrial furnace state

The coils from the coils in rolling state, respectivelly, 228290 coil no. and 231667 coil no present a great quantity of ferite with scale pitted, resulting from the austenite transformation at the cooling of the strip during the rolling process or after quantity of ferite with smooth surface (fig. 2 - 228290 coil no. and fig. 2 - 231667 coil no.).

The carbure quantity is relativelly small in 228290 coil no. (fig. 2), fact that proves on the one hand heating for the rolling process at temperature high enough for the dissolving of the carbide (1050^{0}C-1100^{0}C) and, on the other hand, at the cooling process, the crossing with a high rate of the temperatures domain where the carbides precipitate intensly. In 231667 coil no. (fig. 3) the quantity of precipitated carbides is bigger, fact that shows that in case of this coil, the cooling rate during and after rolling was smaller.

Fig.2. *Microstructure 228290 coil no. (rolling state). Attack: oxalic acid 10% magnify: 500:1.*

Fig.3. *Microstructure 231667 coil no. (rolling state). Attack: oxalic acid 10%; magnify: 500:1.*

2. The coils in the thermal treatment in laboratory furnace state

a. The coils 3 and 6 have, after annealing at 810^{0}C or 840^{0}C with maintaining period for 2-12 hours, presents, also, a microstructure with elongated and very fine grains (size 10-11) and a great quantity of precipitated carbides, both on the grain limit, and in side them (fig.4 – 228290 coil no.) and fig. 5.a, b –

231667 coil no.). But, it has been found that inside the ferrite grains with smooth surface (initial ferrite not turned into austenite during the heaqting for the rolling process) the quantity of precipitated carbide is smaller in ferrite grains with scale-pitted surface (ferrite resulted from the transformation of the austenite during the cooling process) explainable by the fact that the austenite, at the heating temperature for the rolling process (1050-1100^{0}C) has dissolved in itself a much more content of carbon (about 0.12%) than the ferrite not turned into austenite (about 0,12%). In this case, substantial structural modifications were not found, at the same time with the variation of the annealing temperature from 810 to 840^{0}C or at the same time with the growth of the maintenance period from 2 hours to 12 hours (comparatively, fig.4.a and 4.b).

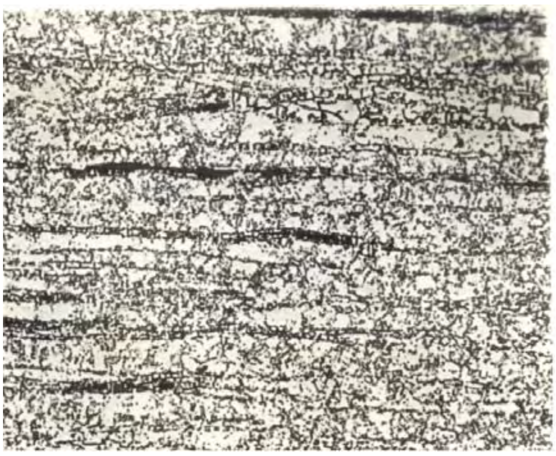

***Fig.4**. Microstructure 228290, coil no. (laboratory thermal treated: annealing 2 hours at 810^{0}C). Attack: oxalic acid 10%, magnify: 500:1.*

a **b**

***Fig.5.** Microstructure 231667 coil no. (laboratory thermal treated):*
***a.** annealing 2 hours at 810^{0}C, **b.** annealing 12 hours at 810^{0}C.*
Attack: oxalic acid 10%, magnify: 500:1.

3. *Results and discussions*

The analysis of the test results correlated with some data from the specialise literature concerning the phase transformations at the heating and cooling processes of the ferrite stainless steels with 17%Cr, allow to be made the following findings regarding the causes that provoke the encreased breakage susceptibility of the hot rolled strips during the preparation operations for the cold rolling:

3.1. The high hardness of the rolled state steels (320-420 HB), determined by the high hardness of the ferrite obtained from the austenite transformed during the cooling process (about 480 HV, compared with about 260-280 HV on the ferrite not turned into austenite at the heating for the rolling process).

Connected with these things, the following aspects are mentioned:

a. The quantity of austenite obtained at the heating for the rolling depends on the contact in alphagen elements (Cr, Si) and gamagene (Ni, C, N, Mn) and the heating temperature. At the heating temperature, at which the maximum quantity of austenite (cca. 1100^{0}C) is obtained, the austenite quantity can vary, for the ferrite steels with 17%Cr, between about 30% (the case of maximum content in alfagene elements Cr and Si) and about 60% (the case of minimum content in gamagene elements C şi Mn). In the case of the coils analysed, the echivalent content in Cr is, as a rule, over 17%, fact that ensures the premise of forming of a maximum 30-40% austenite at the heating for the rolling process. With the exception of 228290 coil no., where, the content of Cr echivalent of only 14.40% determined the appearance in the microstructure of a quantity of about 90-95% austenite formed at the heating for the rolling process varies relatively with the variation of the temperature between 1000-1150^{0}C, , in such a way that there is no practical possibility of decreasing the quantity of austenite through the variation of this technological parametre. It follows that, in order to obtain a smaller quantity of austenite at heating (with unfavourable consequences by the harness of the cold rolling stip) the steel must be elaborated with content in Cr of 17-17,5% and in Si of 0,40-0,60% and, respectivelly, C of 0,04-0,07% and in Mn of 0,4-0,6%, reducing at the same time the content in N at minimum possible.

b. The austenite obtained at the heating from the rolling process is transformed at the cooling during the rolling process and after cooling in scale-pitted ferrite with massive precipitation of carbides and the formation of eutectoid. But if the cooling during the rolling process and after the rolling process is achieved with high speed (intense spraying with water during the rolling process finishing the rolling process at the low temperature, tranformed partially in ferrite and partially in martensite, the respectiv steel belonging to the ferrito-martensite steel class (diagrama Schaeffer). The fact that at the hot rolling strip process of the steel with 17% Cr the partially transformation of the austenite in martensite is produced, this fact is demonstated by the big hardness of the so called „scale-pitted" ferrite; the ferrit had micro-hardness of 48HV. The high rate of hot rolling strip is proved, supplimentary, by the absence of the precipitated carbides in big quantity (fig.1), and by the fact that the ferrite grains remain strongly lengthened (unrecristallised) and size 10-11 (very fine). Technologically, it is necessary to finish the rolling process at a high temperature, in the limits recomanded for this class (730-770^{0}C), the rolling process at a higher temperature (1100^{0}C) can, also, start taking into account that in the specialised reference materials for similar steel (AISI 340) it is prescribed as an interval for deformation temperature 1125-815^{0}C. At the same time it is necessary to avoid the cooling of the strip during the rolling process diminishing as much is possible the water flow capacity for cooling the rolls and, respectivelly, of the unscaling.

c. Fact that, in the hot rolling strip practice it is possible to obtain some strips with relatovelly low hardness (240-260 HB, in comparison with the hardness of 320-420 HB of analised rolling strips) and with smallsensibility at the strip breakage during at uncoiling process, fact that was stated at the analysis of the rolled strips (without annealing treatment).

3.2. The very fine grained (size 10-11) and the absence, in majority of cases, of the recrystallisation, and the precipitated carbures show that the final rolling temperature it too low and the cooling rate during the rolling process and after coiling is relativelly high. It results that from this point of view it is necessary previously mentioned in order to avoid the partial transformation of the austenite in martensite (higher temperature of begining of rolling and final rolling temperature, lower cooling rate).

3.3. The inadequate behaviour of the bending test of the coils drawen from some coils thermal treated in the industrial furnaces as well as strip breakage during their uncoiling in the technological operation are determined by the incomplete efectuation of the annealing process in addition to some technological aspects (mentioned at the 3.1. and 3.2. points). This fact was aproved by diminishing hardness from about 260-420 HB, on coils from the coils industrially, thermal treated to 165-220HB on coil.s thermal treated in laboratory furnaces (table 2 – annealig 2 hours at 810^{0}C). Efectuation of annealing process in laboratory furnaces at 810-840^{0}C, for a maintance period of 2 hours, ensured a sensible diminishing of the hardness and an inadequate behaviour at bending test fact that leads to the adoption of necessary measures for achieving a full annealing in the industrial furnaces.

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