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BEHAVIOUR AT NITRIDING IN FLUIDIZED LAYER OF AUSTENITIC STAINLESS STEELS AT THE TEMPERATURE OF 1050°C

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ABSTRACT

Nitriding at low temperatures, 450-500^{o}C of austenic stainless steels lead to the obtaining of the tough layers over 1000 HV_{005} *but having thicknesses of tenths of microns. Moreover, nitriding at 500ºC has determined the obtaining of layers of combinations with carbonitrades that caused a severe decrease of corrosion resistance. Nitriding at 1050ºC with an enriched nitrogen austenitic diffusion structure. The nitrogen concentration ensures, by the increase of the diffusion speed, a high layer depth of millimeter tenths,under the saturation limit lead to a reduced strength down to 500* HV_{005}*. The nitrated layer has displayed good properties of corrosion resistance and a twofold increase of the abrasive wear strength, which recommend the treatment for numerous practical applications.*

KEYWORDS: Austenite, nitriding, corrosion, abrasion

1.Introduction

By nitriding we want to improve the strength properties, mainly the superficial strength in order to ensure an abrasion resistance of the austenitic stainless steels. Such steels are characterized by a good corrosion resistance but the strength during solution tempering, the usual delivery and usage condition is low, below 200 HV_5.

Nitriding must ensure the formation of an improved strength superficial layer but also of a structure that should ensure the conservation of the corrosion resistance properties.

Nitriding at low temperatures of 450-500ºC in fluidized layer has lead to the obtaining of superficial layers with strength over 1000 HV_{005}. Strength is higher in the case of nitriding at 500ºC and over this temperature due to the formation of the layer of combinations made of iron, chromium and other elements nitrates, with high strengths. In this case, yet, the corrosion resistance of the steels has been strongly affected. In the case of nitriding at 450ºC in fluidized layer and below this temperature there have been obtained strengths of somehow lower strengths, with a little over 1000 HV_{005}, the superficial layer being composed of solid austenite solution enriched with nitrogen and fine separations of chromium nitrates. In this case, the mono phase austenitic layer displays good corrosion resistance properties comparable with those of the original materials or even better. Yet, in the conditions of low temperature nitriding, the nitrated layer depth is very low, of only a couple of tenths of microns, the higher the treatment temperature is higher.

In order to obtain high depths nitrated layers in the conditions of treatment times of 3-4 hours as well as in the case of low temperature nitrading, we considered necessary the testing of the austenitic stainless steels at high temperature nitrading.

For the high temperature nitrading nitrogen was used as active atmosphere. Until 900ºC, the nitrogen atmosphere represents a neutral protection atmosphere. Over 900ºC, nitrogen becomes active due to the thermal dissociation. Envisaging fact that in the case of the austenitic stainless steels, the temperatures used for austenizing for the purpose of solution dipping tempering range between 1050-1150ºC, we opted for the temperature of 1050ºC. The temperature is on the lower side of the range and satisfies the condition of nitrogen dissociation and in the same time limits the tendency of excessive granulation increase, with effects on the mechanical properties but also corrosion resistance.

For a coherent and homogenous research, the treatment has been accomplished also in fluidized layer. The nitrogen fluidizing trial at high temperatures proved to be improper, experiencing swabbing and channel formation caused by the unfavourable thermal conditions of nitrogen and mainly due to the low fluidity of the same. The improvement of the fluidizing characteristics has been obtained by adding 30% of NH3, which, by dissociation, offers hydrogen to the atmosphere, a gas with proper thermophysical properties and good fluidification.

For the research we used samples of 6 austenitic stainless steel CrNi and CrNiMo whose chemistry is presented in Table 1.

Table 1

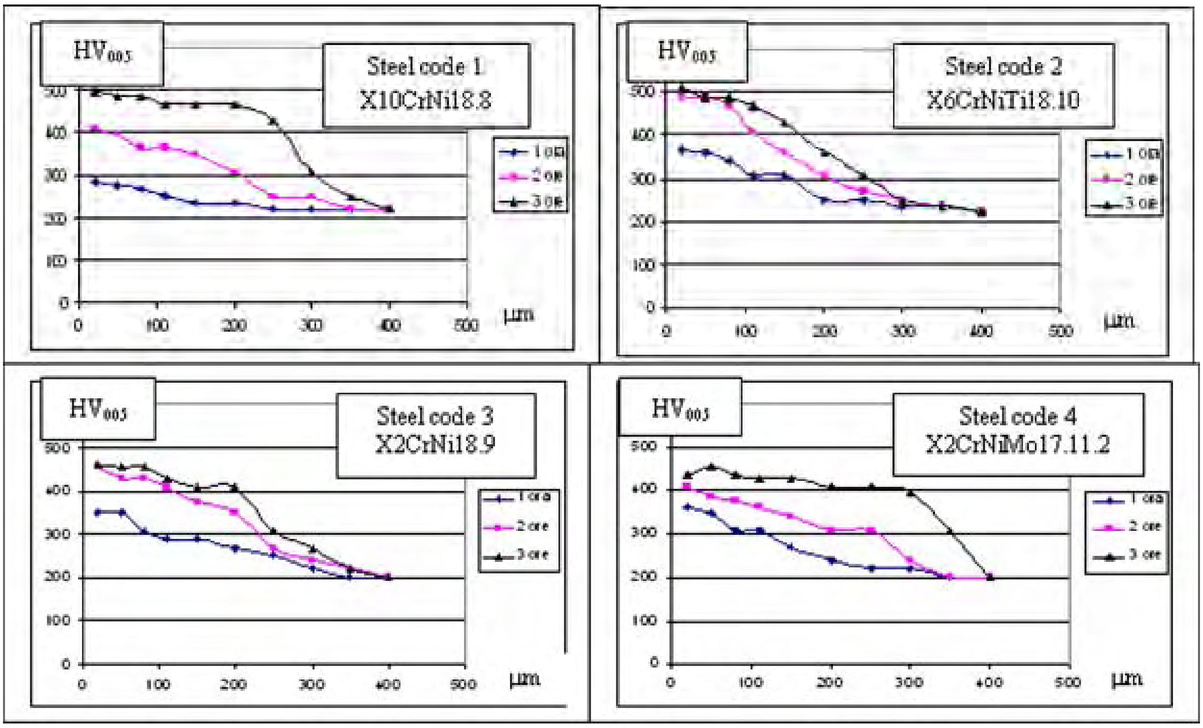
Steel code	Related mark SR:EN 10283-98	% C	% Mn	% Si	% Cu	% Cr	% Ni	% Mo	% Ti	% V
1	X2CrNi18.8	0,12	1,24	1,64	0,06	23,2	9,8	0,11	0,01	0,02
2	X6CrNi18.10	0,06	1,55	0,65	0,08	17,1	9,3	0,05	0,60	
3	X2CrNi18.9	0,03	1,27	0,42	0,19	18,9	8,95	0,15	0,01	0,02
4	X2CrNiMo17.11.2	0,02	2,06	0,78	0,27	20,0	8,8	2,7	0,03	0,03
5	X6CrNiMoTi17.12.2	0,045	0,96	0,54	0,16	18,1	11,6	2,04	0,32	
6	X1CrNiMoCu20.18.7	0,02	1,12	0,41	0,70	20,1	18,1	6,1		0,2

The samples were prepared from sheets having the dimensions of 60x20x3mm, adjusted by grinding for the rounding of the edges and then with abrasive paper with 400 granulation pointage on all surfaces. Before treatment, the samples have been washed, degreased and dried, then nitraded in fluidized layer at the temperature of 1050ºC, being maintained for 1, 2, 3 hours.

From the nitrated samples have been cut for the strength trials and structure analysis. These have been embedded in resin, adjusted, grinded on metallographic paper and polished with diamond paste.

2. Analysis of the samples nitrated at 1050ºC

For the highlighting of the nitrated layer, layer depth and nitriding process intensity Vickers HV_{005} strength trials have been done, with a pressure load of 0.50N. The results of the trials, strength variation on the nitrated layer depth are presented in figures 1.



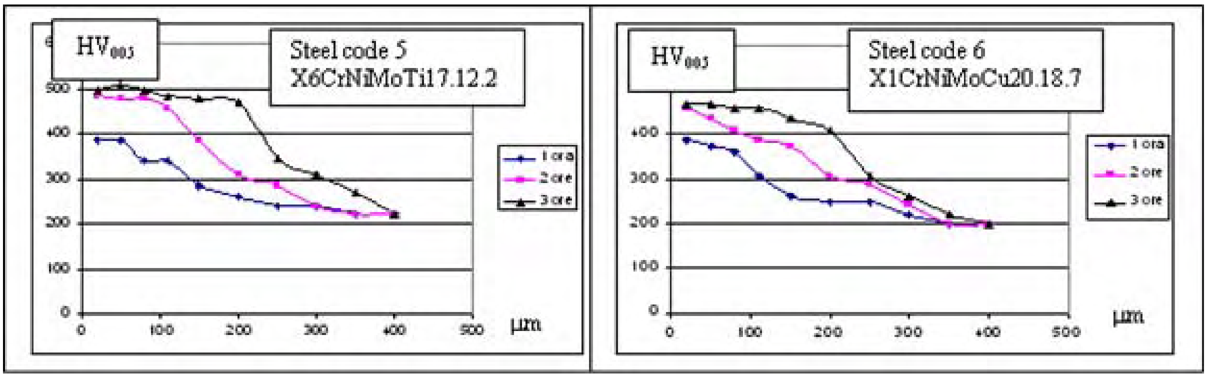


Fig. 1. *Strength variation over the nitrogen enriched layer*

The analysis of the strength trials show that the maximum strengths registered after the nitriding treatment at high temperature for 3 hours, range between 450HV$_{005}$ and 500HV$_{005}$

Higher values, even over 500 HV$_{005}$ occur in the case of high carbon steels, with or without stabilizing elements, titan and niobium, namely the steels coded 1, 2 and 5 and a little bit lower in the case of steels coded 2, 3 and 6. Also, the depth of the nitrated layer estimated on the basis of the strength variation curves is presented in table 2 for each material. The analysis of the values show that the highest depth is recorded at the steel code 4, where the ratio E_{Cr}/E_{Ni} has the highest value. One cannot say that this rule is valid for all materials as the process is influenced by many factors. The values of the nitrated layer depths are up to 10 times higher than in the case of low temperature nitrated steels.

Table 2

Steel code	E_{Cr}/E_{Ni}	Layer thickness [µm]	Hardness HV$_{005}$ [x10 MPa]
1-X2CrNi18.8	1,78	275	498
2-X6CrNi18.10	1,26	190	508
3-X2CrNi18.9	1,95	250	458
4-X2CrNiMo17.11.2	2,23	340	435
5-X6CrNiMoTi17.12.2	1,48	250	498
6-X1CrNiMoCu20.18.7	1,40	240	468

3. Analysis of the samples nitrated at 1050ºC

The analysis of the samples nitrated at 1050ºC does not show the presence of any distinct presence superficial layer, figure 2. The lower strength recorded indicates a lower nitrogen concentration, far from the saturation limit.

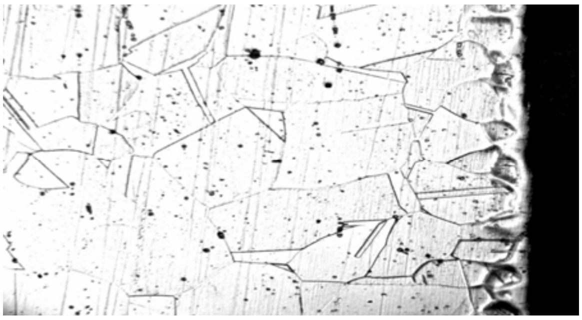


Fig. 2. *Microstructure of steel code 4 X2CrNiMo17.11.2. nitrated at 1050ºC.x400*

X-ray analysis indicates in the diffractogram from figure 3 the presence of the droplets for the diffraction angles of the γ_N phase – austenite enriched in nitrogen and γ_{Fe}– the original austenitic solid solution.

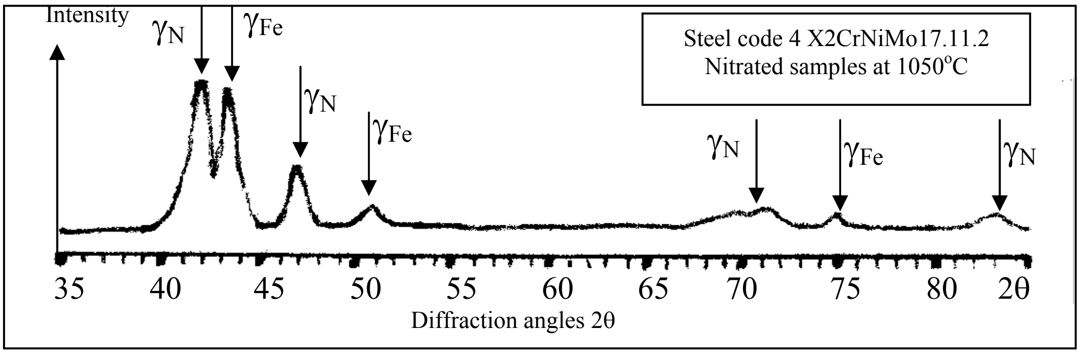


***Fig. 3.** Diffractogram of the nitrated samples at 1050 ºC, code 4 X2CrNiMo17.11.2.*

4. The analysis of corrosion behaviour in saline mist of the nitrated steel at 1050ºC

In figure 4 there are presented comparatively the results of the corrosion resistance in saline mist STAS 9229-95 for the samples nitrated at 1050ºC and the initial samples over 300 hours of weighing every 100 hours.

The analysis of the results shows a similar behaviour of the materials at the corrosion in saline mist, mass losses and average corrosion speeds calculated being very close. In figure 5 there are presented comparatively the average corrosion speeds in saline mist for all six materials tested.

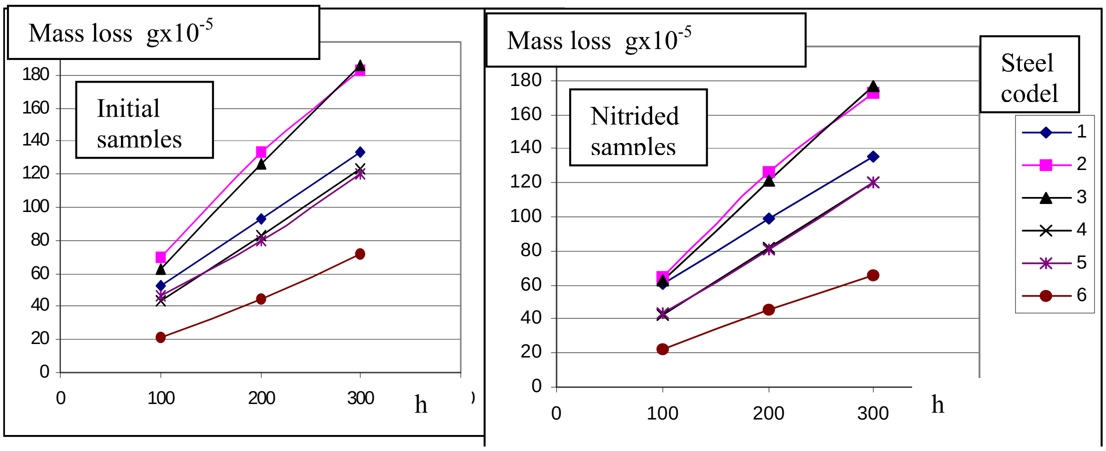


***Fig. 4.** Variation of mass losses in time at the corrosion in saline mist for the original samples and those nitrated at 1050ºC.*

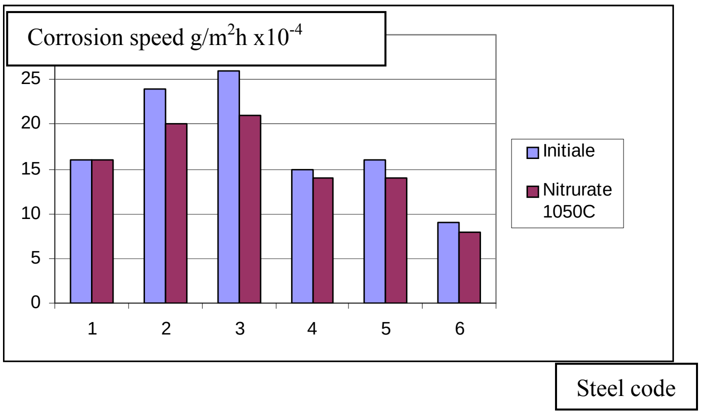


***Fig. 5.** Average corrosion speeds in saline mist for the original materials and those nitrated at 1050ºC*

As expected, having in view the fact that the structure of the material after treatment remained mono phase, austenitic, the corrosion strength has maintained, the materials matching the *Perfectly resistant* material group, namely: steels code 1, 2, 3, 4, 5 class two with merit note 1.2 and steel code 6 class one with merit note 1.1. Even a slight decrease of the average corrosion speed is manifest.The high potential dynamic curves for these materials nitrated at 1050ºC, in comparison with the original materials confirms the maintaining and even the improvement of the corrosion behaviour by this nitrating. In figure 6 we present comparatively the polarization curves for the steel code 4 - X2CrNiMo17.11.2 in the initial stage and after nitrading at 1050ºC.

The analysis of these polarization curves sow a slight extension of the passive domain and its shifting towards more electropositive values, and also a slight reduction of the corrosion current in the passive domain.

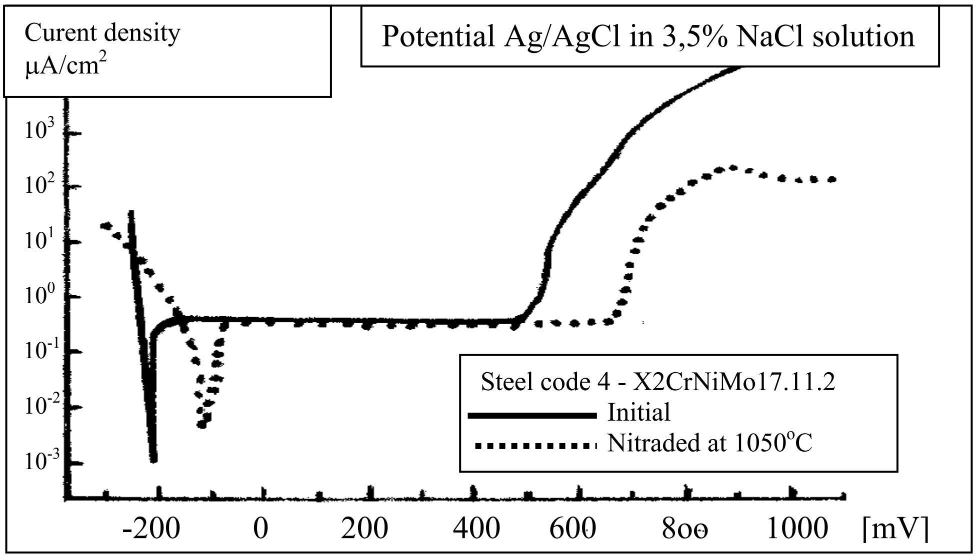


Fig. 6. *The potential dynamic curves traced for the original materials and those nitrated at 1050ºC of steel code 4 - X2CrNiMo17.11.2*

5. Analysis of the abrasive wearing strength of the steels nitrated at 1050ºC

The results of the abrasive wearing tests STAS 9639-81, using a friction coupling abrasive disk-pin, are presented in tab. 3. We mention that the working parameters of the trial remained the same as in the case of the trials performed before.

Tabelul 3

Steel code	**Initial samples**		**Nitraded samples at 1050°C**		
	Hardness HV$_{005}$	**Abrasive wear**	**Layer depth**	**Hardness HV$_{005}$**	**Abrasive wear**
	x10 MPa	g	µm	x10 MPa	g
1-X2CrNi18.8	198	0,0062	275	498	0,0031
2-X6CrNi18.10	202	0,0065	190	508	0,0030
3-X2CrNi18.9	188	0,0065	250	458	0,0036
4-X2CrNiMo17.11.2	180	0,0069	340	435	0,0039
5-X6CrNiMoTi17.12.2	204	0,0064	250	498	0,0032
6-X1CrNiMoCu20.18.7	182	0,0071	240	468	0,0035

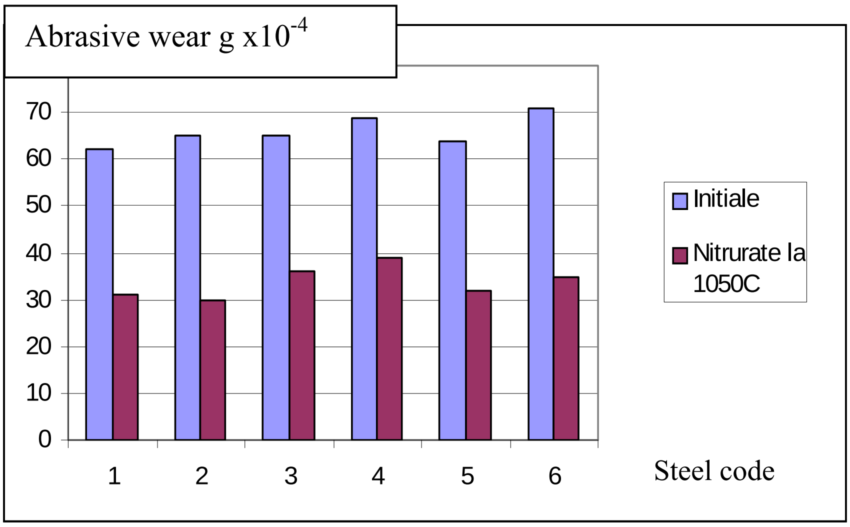


Fig. 7. *Behaviour at wearing of the samples nitrated at 1050ºC comparatively with the initial ones.*

In figure 7 there are presented comparatively the mass losses due to abrasion for all six materials both in initial state as well as nitrated at 1050ºC in fluidized layer. From the analysis of the results an increase of the wearing strength of almost 2 times for all analyzed materials.

6. Conclusions

Nitrading in fluidized layer at high temperature of 1050ºC leads to the obtaining of layers with strength of around 500HV$_{005}$ with a fairly big thickness of tenths of millimeters in 3 hours of treatment. The layer has a good corrosion resistance comparable to that of the initial materials and twofold abrasion strength.

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