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Heat and thermochemical treatments of austenitic steels and their influence on corrosion resistance

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Abstract

A structure with good corrosion resistance mainly characterized by a largely austenitic metal mass, is contained in chromium and nickel high alloyed steels. Surface and heat treatments can possibly influence this quality to a great extent. In the paper, steel samples with high content of chromium and nickel were subjected to several different technologies, from which some are using temperature.

Heat and thermochemical treatments of austenitic steels and their influence on corrosion resistance include a treatments' spectrum of hardening by putting into solutions, cold plastic deformation, nitriding, carbonitriding, etc., effectuated on 316L steel samples, with the working parameters being indicated in the paper for each individual process. The changes made in the mechanical properties and structure were studied for each lot of specimens.

Taking into account that for parts of this category of steel it is required a good resistance to oxidation and corrosion, besides a certain ensemble of mechanical characteristics, this was also studied.

In order to determine the corrosion resistance, the most reliable approach is to use a potentiostatic technique to determine a series of characteristic parameters. They emphasize significant differences in treatments occurred. Concluding, surface treatments generally lead to a decrease in corrosion resistance.

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Keywords: heat and thermochemical treatments; austenitic steels; corrosion resistance.

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1. General considerations

Corrosion resistance represents an essential property of pieces working in aggressive environments, such as saline or other dissolved solvents, acid solutions, bases, gas mixtures, etc. [1, 2, 8, 10]. In these cases, high alloyed steels

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with chromium or chromium and nickel are used, having a predominantly austenitic structure; highly alloyed austenite which is stable at ambient temperature, behaves accordingly at the action of the chemical agents mentioned above [3, 4].

For improving or stabilizing of this characteristic in chemical composition of austenitic steels, some other alloying elements are added such as Si, Mo, Mn and other. Besides stability at chemical agents it is often required an appreciable mechanical resistance, so these additions are provided. Various heat and thermochemical treatments are also applied to corrosion resistant steels for improving their behaviour at mechanical, volumetric or surface stress. Hardening, tempering, nitriding in gas and plasma, carbonitriding, cold plastic deformations are some of these [1, 5, 6, 7, 9, 11].

For various concrete cases, it is applied an ensemble of technologies with and without using the heat corresponding to exploitation necessities. From the practical point of view, the optimal variant must be chosen, taking into account the type of the alloy, its chemical composition, the target marks, functional conditions, etc.

2. Working mode and obtained results

The 316 L stainless steel from the austenitic class was chosen for experimental attempts. It is highly alloyed with chromium and nickel, at a low content of carbon; in this way the base mass structure of γ solid solution is ensured. The chemical composition of the given steel is presented in table 1. By using a Spectomax XF-BT spectrometer, we experimentally determined the chemical composition for alloy.

Table 1. The chemical composition of 316L steel.

316L steel	Chemical composition [%]								
	C	Cr	Ni	Mn	Si	P	S	Mo	B
	0.062	17.73	10.33	0.89	0.494	0.0077	0.0041	1.84	0.0017

The chemical composition fits within the limits indicated by the producer's standard. The samples for the experimental attempts have cylindrical shape with ϕ=20x10 mm. For dissolving possible secondary carbides and for stabilizing the base structure, the samples were subjected to heat treatment of putting into solution, and plus an tempering for some of them according to table 2.

Table 2. The heat treatment parameters.

Steel type	Hardened in vacuum			Tempering		
	Temp. [°]	Time [min]	Cooling	Temp. [°]	Time [min]	Cooling
316L	1050	40	Nitrogen	520	60	Nitrogen

The resulted structures from these heat processes are shown in figures 1, 2 and 3. The metallographic structures were performed with Nikon microscope (with resolution up to 1000 x). There is also presented the structural aspect of the samples which were cold plastic deformed (30%) after hardening.

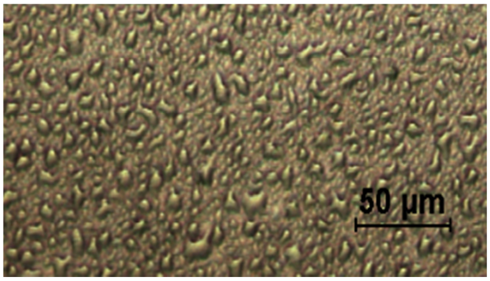

Fig. 1. 316 L steel hardened in vacuum from 1050°C. Royal water attack.

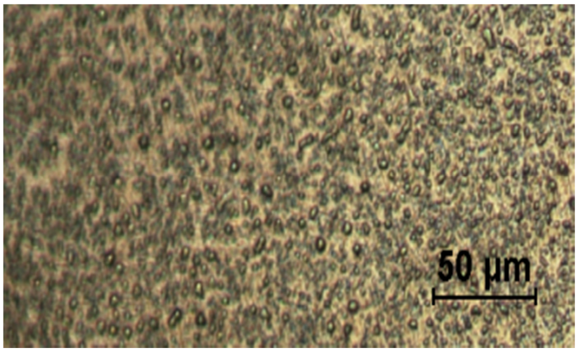

Fig. 2. 316 L steel hardened in vacuum from 1050°C and tempering at 540°C. Royal water attack.

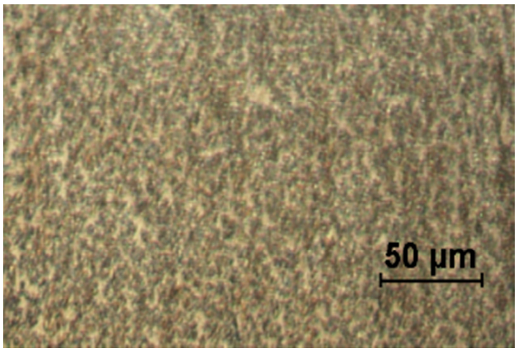

Fig. 3. 316 L steel hardened in vacuum from 1050°C and cold plastic deformed (30%). Royal water attack.

In all cases, the structure consists of austenite with traces of precipitated phases. In the cold deformed samples a slight orientation of the grains is observed.

The thermochemical treatments applied were plasma nitriding and carbonitriding, with the working regimes shown in tables 3 and 4.

Table 3. The thermochemical treatment of nitriding.

Steel type	Temp [°]	Time [h]	Degree of dissociation [%]	Cooling	
				up to 100°C	100°C - 200°C
316L	530	12	1.5	in oven, 3h	air

Table 4. The thermochemical treatment of carbonitriding.

Steel type	Temp [°]	Time [h]	Hardening		Tempering	
			Temp [°]	Environment	Temp [°]	Time [h]
316L	840	2	840	oil	400	1

The superficial layers obtained at the above described thermochemical treatments are shown in figures 4 and 5.

Fig. 4. Nitrided 316L steel. Superficial layer. Royal water attack.

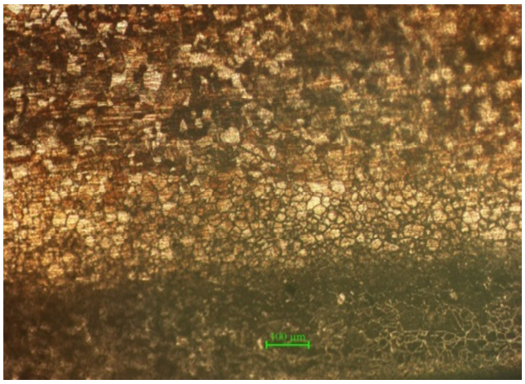

Fig. 5. Carbonitrided 316L steel. Superficial layer. Royal water attack.

Following these heat and thermochemical treatment operations, hardness in the layer, respectively in the metallic mass were obtained as shown in table 5.

Table 5. After treatment hardness.

Steel type	Hardness $HV_{0.1}$ for different state of heat treatment and surface				
	Hardening	Hardening and tempering	After plastic deformation	Nitriding	Carbonitriding
316L	151	171,8	287	454,6	497

It has to be mentioned that hardness in the diffusion layers were measured on specimens divided by the diameter; the hardness was measured at half the layer thickness. Examples of pictures with HV positioning are presented in figure 6.

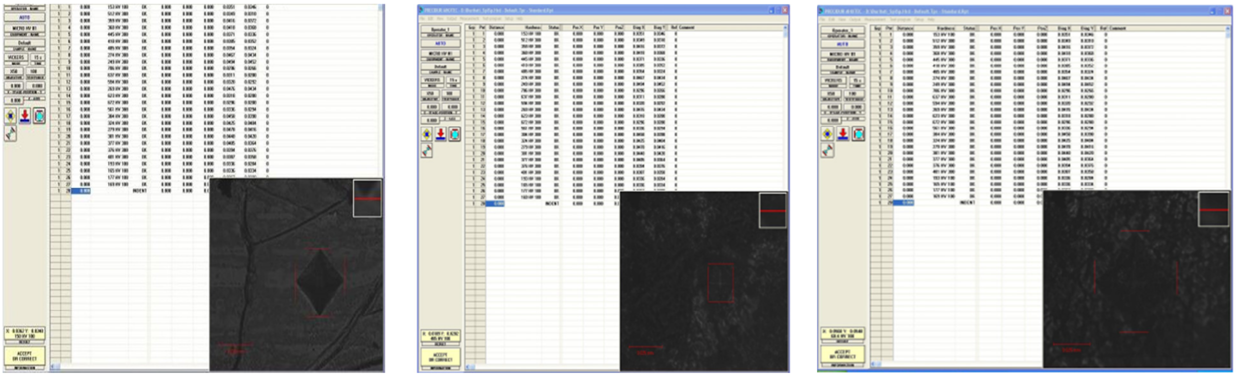
Hardening and tempering Carbonitriding Nitriding

Fig. 6 Picture with positioning of HV.

Corrosion resistance was determined using a galvanic potentiometer as shown in figure 7.

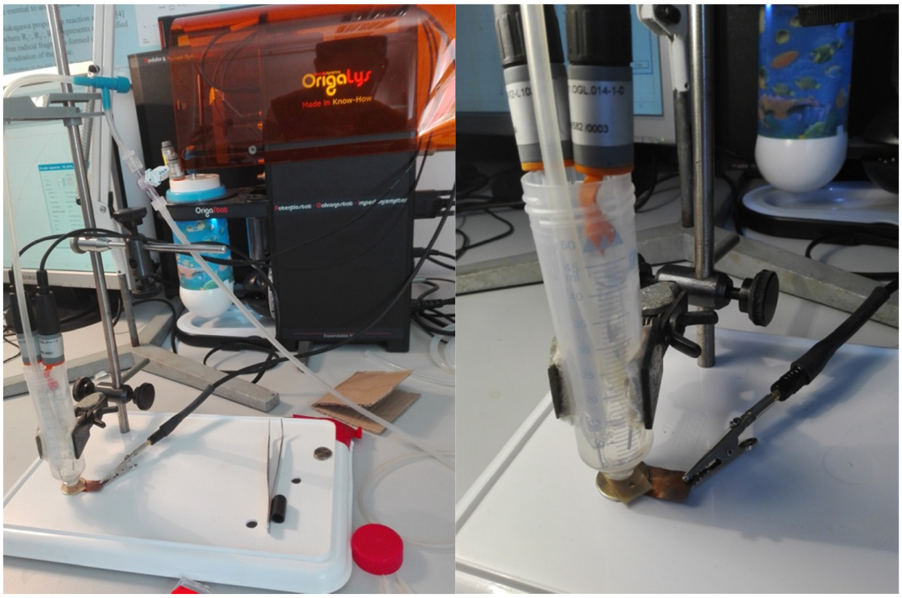

Fig. 7. Galvanic potentiostat.

Using this apparatus, a series of characteristics was emphasized, shown in table 6, as well as in the polarization curve in figure 8.

Table 6. The characteristics of polarization.

Size / Type of treatment	Hardening in vacuum	Hardening in vacuum and cold deformed	Nitriding	Carbonitriding
		Resistance to polarization		
Rp(multiscan), [kΩ/cm^2]	140	111	16	6.3
		Polarization curve		
Resistance to polarization Rp [kΩ/cm^2]	58	62	66	-
Potential for corrosion Ecor [mV]	-514	-510	-502	-345
Corrosion current Icor [μA/cm^2]	0.21	0.22	0.28	6.9
β cathode [mV/dec]	-68	-73	-88	-124
β anode [mV/dec]	68	80	207	127
Corrosion speed [μm/ Y]	2.4	5.3	3.2	80

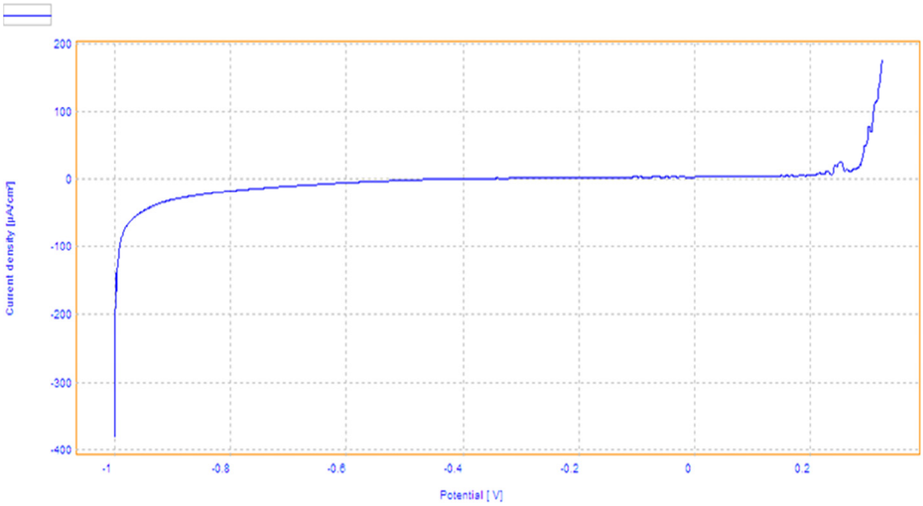

Fig. 8. The polarization curve.

From the above, significant differences regarding the corrosion resistance of the material in different states are remarked.

The best results are offered by the hardened state. This can be explained by austenitic structure, soft and plastic, with a tension free matrix.

By introducing of internal stresses through cold plastic deformation, as well as through surface treatments, the corrosion resistance decreases sensitively. However, the thermochemical treatments are applied, obtaining the mechanical characteristics required for operation.

3. Conclusions

Stainless steels are high alloyed steels, expensive, from which are required distinguished mechanical, physical and chemical characteristics. A remarkable corrosion resistance can be achieved by chemical composition, but because of the low carbon content, the mechanical resistance is relatively reduced. This is the reason why various technologies occur for the improvement of mechanical properties; but they affect the corrosion resistance in a way of another.

As a result of the performed experiments, it is found that all technological operations subsequent to hardening affect the corrosion comportment of the austenitic stainless steel. To a relatively small extent it influences the cold deformation, but the thermochemical treatments - nitriding and especially carbonitriding - have more important effects.

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