STUDY FOR THE VARIATION OF HARDNESS AND RESILIENCE CHARACTERISTICS AFTER HEAT TREATMENT FOR STAINLESS STEELS

Manuela Cristina Perju[1], Dragoş Cristian Achiței[1], Carmen Nejneru[1], Anca Elena Lărgeanu[1], Mihai Axinte[1], Ion Hopulele[1]

[1]*Technical University "Gheorghe Asachi" of Iaşi-România, E-mail address: cryss_ela@yahoo.com*

Abstract: The paper presents tests of the stainless steel. This material was subjected to heat treatments, afterwards conducted impact bend tests and hardness measurements. Using the data was drawn graphic variation of hardness and resilience depending on the condition of structural material (hardened, annealed, solution treated and aged).

Keywords: *hardness, resilience, heat treatment*

1. Introduction

Metallic materials structure researches are obvious by the fact that structure is very important determining the properties, the behavior of materials in service, and their use areas. In modern metallurgical technology, based on thorough knowledge of the structure, it can be obtained new metallic materials, with mechanical and chemical-physical features precise, requested the use of these materials [5].

Material behavior is determined by its reaction on stress. Material property is defined as measured behavior on given test. By the exterior stresses there are three properties categories:

- Mechanical properties, which reflects the material behavior on the mechanical forces.
- Physical properties which measures the material behavior, under the temperature field, electrical or magnetic field effect.
- chemical properties which characterizes the material behavior in an more or less aggressive environment [6].

The components behavior regarding mechanical stresses produced by the exterior forces depends on the certain specific material properties, called mechanical properties.

Usually, mechanical properties for a metallic material is determined by specific tests, that means sample testing (some parts with well defined configurations and dimensions), in adequate conditions for the needed properties, [8]. With mechanical test aid, qualitative data on the material behavior is obtained. Also with mechanical test aid we can obtain the physical quantities, called mechanical characteristics, which can be used as quantitative parameters for mechanical properties.

2. Experimental results

For the experiment stainless steel was used. Standard samples were heat treated to modify their properties. Afterwards the samples were tested by impact bending and hardness.

2.1 Austenitic stainless steel analysis

Austenitic stainless steel is used in different domains (fig.1), [10].

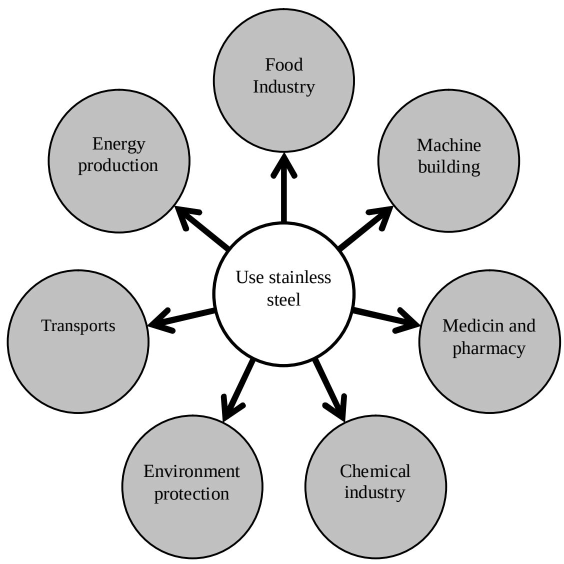

Figure 1: *The use of austenitic stainless steel.*

Austenitic stainless steel, X5CrNi18-10(AISI 304), STAS EN ISO 3651-2 was subject to chemical composition determination, presented in table 1.

Table 1: *Steel chemical composition, %*

C	Si	Mn	Cr	Mo	Cu	Ni
0,025	0,49	1,6	18,38	0.43	0.49	8.12

Foundry Master Spectrometer qualitative analysis was used.

2.1.1 Heat treatment application

In order to modify the resilience and hardness properties, a solution treatment was applied [3, 4], followed by aging heat treatment, using the Uttis heat treatment furnace.

Solution treatment temperature was 1000°C, heating the samples with the furnace, maintaining 30 minutes, and the cooling made in warm water at 60°C. Heating rate was 10°C/minute.

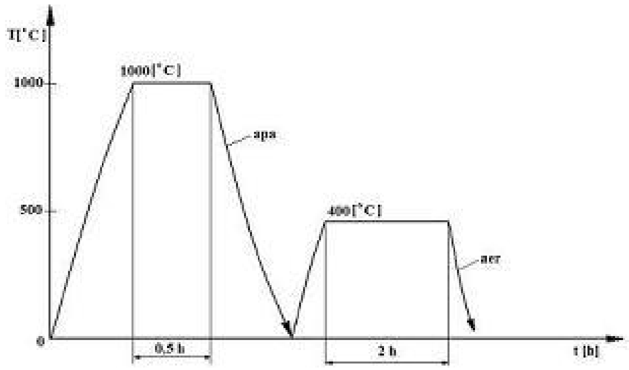

Figure 2: *Solution treatment and aging treatment diagram at 400°C.*

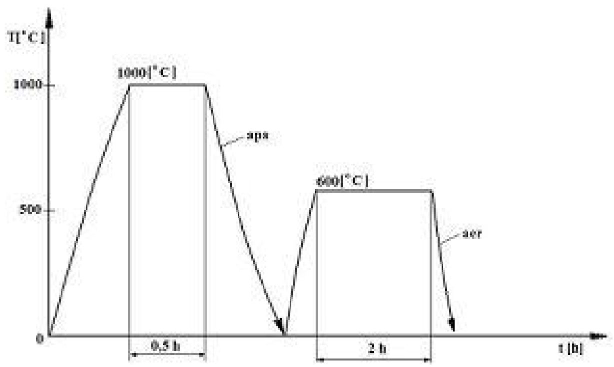

Figure 3: *Solution treatment and aging treatment diagram at 600°C.*

After the solution treatment, followed the aging heat treatment, at two temperatures:

- aging heat treatment, at 400°C, maintaining 2 hour, followed by air cooling. Aging heat treatment diagram in figure 2.
- aging heat treatment, at 600°C, maintaining 2 hour, followed by air cooling. Aging heat treatment diagram in figure 3.

2.1.2 Hardness testing

The tests for hardness were conducted on Wilson Wolpert hardness test instrument. The Brinell method was used. The pressing force was 187,5 daN, with steel ball 2,5 mm diameter.

The samples hardness was tested before the heat treatments; data in table 2. For a better precision on hardness values an arithmetical average for three tests was calculated.

Table 2: *Untreated and heat treated stainless steel hardness values*

Stainless steel Untreated	Hardness, HB		
	174,1	177,0	175,3
	Average: 175,46		
Stainless steel Solution treatment	Hardness, HB		
	163,3	164,9	161,5
	Average: 163,23		
Stainless steel Aging heat treatment at 400˚C	Hardness, HB		
	208,0	221,6	216,7
	Average: 215,43		
Stainless steel Aging heat treatment at 600˚C	Hardness, HB		
	188,2	193.4	191,6
	Average: 191,06		

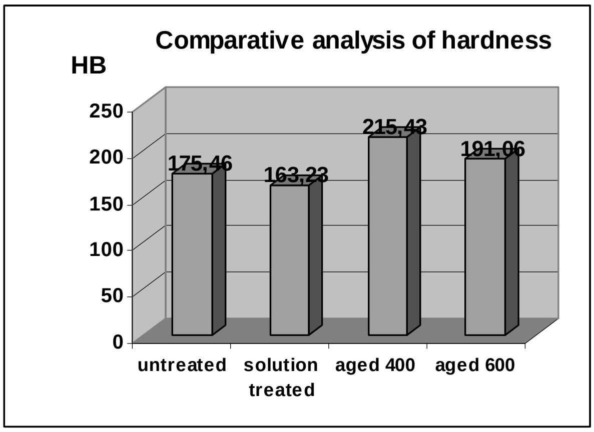

Figure 4: *Comparative analysis for stainless steel hardness untreated and heat treated.*

Comparative hardness analysis is presented in figure 4.

2.1.3 Impact bending test

To achieve impact bending tests were used standardized samples, parallelepiped shape dimensions: 100x100x550 mm: samples with “V” shape indentation.

Testing instrument is Charpy-type pendulum hammer. The test is conducted as follows:

- positioning the sample on the fixed bearing device, so as to be hit right behind the indentation;

-hammer rises releasing its action space;

-positioning the pointer at its maximum value;

-fall firing;

-after sample breakdown the hammer is stopped with a computer command;

-analyzing the samples.

After the impact bending, the untreated stainless steel and the heat treated one were subject to macroscopic analyses; this is for highlighting the fracture character. The fracture character could be brittle or ductile [1, 7, 9]:

-the brittle section looks crystalline grain and bright.

-the ductile fracture section (tenacious), looking fibrous, mat.

Austenitic steel, beside the corrosion resistance, is characterized by high resilience, tenacity and strength.

The untreated stainless steel, X5CrNi18-10 (AISI 304), was called group 1 (the group represents the average from three samples tests, at impact bending test) (figure 5), and the average for the two tests gives a high value for resilience KV=357,81 J.

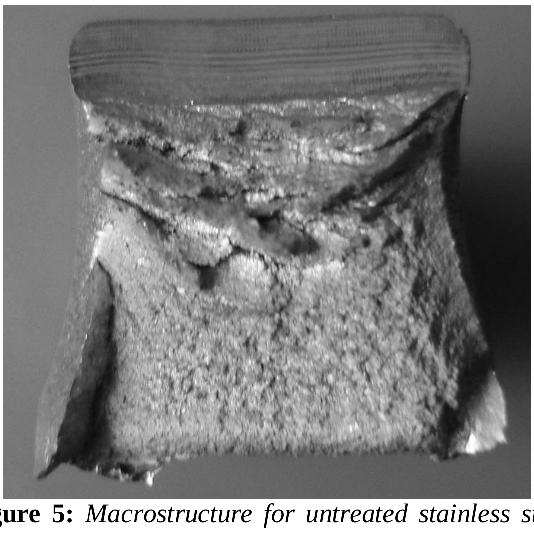

Figure 5: *Macrostructure for untreated stainless steel tested at impact bending.*

Austenitic stainless steels are generally characterized by low yield and good cold plastic deformation properties. They present a stronger stress hardening on cold plastic deformation due to martensite formation in metastable austenite [7].

The fracture structure is determined by the existence of hollows or indentations. They characterize the material ductile fracture and they have a concave structure resulted from vacancies fracture, which are initiated and grows during the plastic deformation process. From a structural point of view is presented as a solid solution with precipitates, chemical compounds like complex carbides, and intermetallic compounds.

According to the corresponding ternary diagrams Cr carbides are of the form: Cr_3C_2, Cr_7C_3, $Cr_{23}C_6$, Mo compounds like: Fe_2MoC, Fe_2Mo, Mo_2C, and Mn compounds like: Mn_3C, Mn_5C, Mn_7Cr_3.

In figure 6 is presented the group 2 fracture. Group 2 represents the solution treated material followed by artificial aging, at 400˚C. This material was subject to impact bending test, obtaining a lower value for the resilience KV=193,84 J.

Solution treatment generally seeks plasticity values needed for processing by cold forming and aims at removing the secondary phase crystal structure (complex carbides of complex elements). Resilience decreasing is possible by increasing hardness from aging treatment.

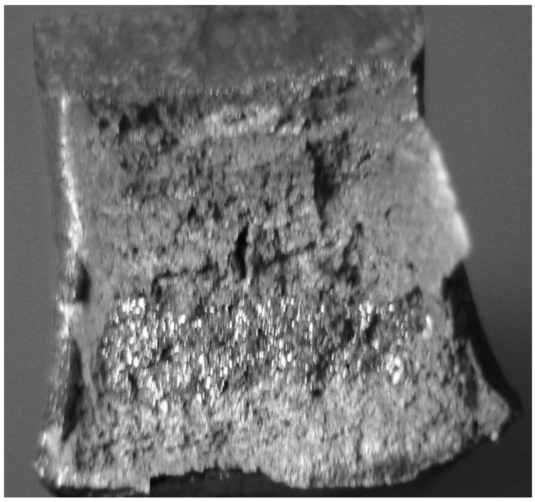

Figure 6: *The heat treated stainless steel macrostructure – solution treatment 400˚C aging subjected to resilience test.*

The stainless steel samples, solution heat treated and aged at 600˚C resulted with a very high toughness, (group 3), having a maximum resilience at 375 J. Samples were partially fractured (figure 7) when hitting with the force of 300 daN.

The reason for this is given by artificially aging at 600˚C, when the temperature exceeds the solubility variation line, so that the precipitates remain dissolved in material, even on cooling in air. The obtained structure will be a supersaturated solid solution, soft and plastic, with a very high resilience.

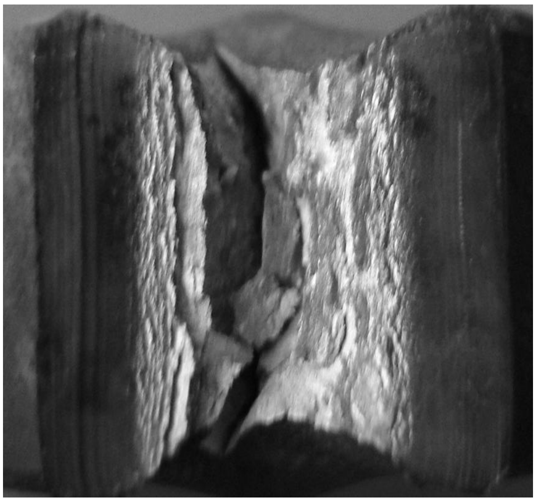

Figure 7: *The heat treated stainless steel macrostructure – solution treatment 600˚C aging subjected to resilience test.*

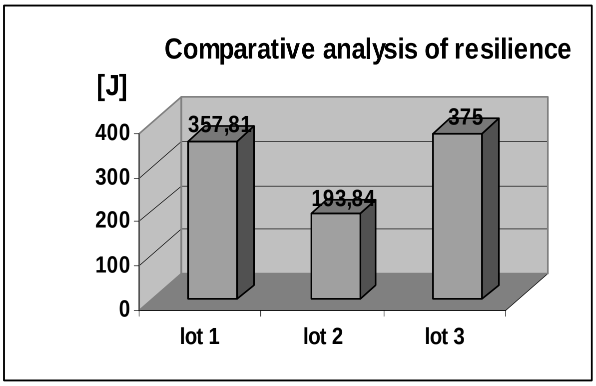

Figure 8: *Comparative analysis of resilience.*

Comparative analysis of resilience is presented in figure 8.

3. Conclusions

1) The heat treatment importance is given through their application.

A structural transformation occurs in materials, which alters the properties and gives them opportunities for rational use. Metallic materials subjected to a correct heat treatment have a relative low cost and higher durability.

2) After the hardness testing it was found that the hardness value for austenitic stainless steel is 175,46 HB, and after the solution treatment the hardness value decreased (163,23 HB), corresponding to this treatment. Because the supersaturated solution decomposition occurs during maintaining, at the beginning the hardness grows gradually, as the precipitation of crystals related to the matrix. Since the consistency fracture between the precipitates and the matrix, and the extent of their growth by coalescence, the hardness decreases.

3) The stainless steel hardness values, artificially aged, are: at 400°C, 215,43 HB, and 600°C, 191,6 HB, thus obtaining a major cases difference.

4) The impact bending test, on austenitic stainless steel gives a resilience value KV=193,84 J for the heat treated group, followed by aged treatment at 400°C. The conclusion was that samples from this group have a much better value than other groups from this class of steel.

4. References

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