RESEARCH ON THE INFLUENCE OF SECONDARY HEAT TREATMENT PARAMETERS ON THE MARTENSITIC STAINLESS STEEL PROPERTIES

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Abstract: *Heat treatments constitute an essential stage for the possibilities of improving the mechanical properties of metal materials, such as hardness, mechanical strength and corrosion resistance.*

Any change in the heat treatment parameters, such as temperature, holding time and cooling rate, can influence the structure of the steel and cause the formation of the martensitic phase, responsible for increasing the hardness. Moreover, if the temperature and time are correctly selected, they can help eliminate internal stresses and imperfections in the crystalline structure, thus improving the strength and ductility of the steel.

The hardness of martensitic stainless steel needs to be increased to meet the performance requirements for the applications in which it is used, such as the manufacture of knives, surgical instruments or components for the aerospace industry. Martensitic stainless steel is valued for its corrosion resistance and relatively low cost, and the hardness increase is essential to ensure proper operation and durability of products manufactured from this material.

Any change in the martensitic stainless steel heat treatment parameters has a significant impact on increasing the hardness and improving its mechanical properties, being essential for obtaining the desired performance in various industrial applications.

Keywords: *mechanical properties, heat treatment parameters, martensitic stainless steel*

1. INTRODUCTION

Stainless steels are metal alloys containing iron, chromium, nickel and other elements with chemical properties which make them resistant to corrosion and oxidation. These materials are durable and versatile, and they are used in a variety of industrial and commercial applications. In addition to corrosion resistance, stainless steels are also resistant to high temperatures and pressure, being thus ideal for use in aggressive environments. They can be processed into different shapes and sizes, giving them great flexibility in terms of their use in various applications [1, 5, 4]

Due to these properties, stainless steels are frequently used in the chemical, food, pharmaceutical, material processing and construction industries. They are also used in interior and exterior design, in the manufacture of kitchen tools and utensils, as well as in the construction of vessels and aircrafts.

Heat treatments give martensitic stainless steel excellent mechanical and chemical properties, such as high hardness, corrosion resistance and wear resistance [5].

Martensitic stainless steels are known for their high hardness, which is achieved using tempering heat treatments. A high hardness gives these materials an increased resistance to wear and cutting [3].

The good corrosion resistance specific to these alloys is due to the content of chromium and other alloying elements, forming a passive oxide layer on the surface. However, martensitic stainless steels are more susceptible to stress corrosion than other types of stainless steels due to their higher carbon content. Therefore, it is important that they are heat treated correctly to minimize this vulnerability [2, 5].

The results of different heat treatments may vary depending on parameters such as temperature, exposure time and the environment in which the treatment is performed. The interpretation of these results is crucial for understanding how material properties change depending on the treatment.

Temperature and exposure time can influence the degree of transformation of the material phase or the size and distribution of particles in the material. Moreover, the environment in which the heat treatment is performed can affect the chemical reactions taking place in the materials [1].

The heat treatment results must be interpreted taking into account these variables and providing detailed information on how they influence material properties. For example, an increase in hardness after a heat treatment may indicate an increase in internal stresses in the material or a change in the crystalline structure.

2. EXPERIMENTAL RESEARCH

The material used in the study is the martensitic stainless steel AISI 420, EN 1.4021, and its chemical composition is presented in Table 1.

Table 1. Chemical composition of the AISI 420 steel

C	Si	Mn	P	S	Cr
0.16 - 0.25	max 1	max 1.5	max 0.04	max 0,015	12 - 14

The material thus selected was cut and subjected to several heat treatment variants in order to analyse its properties (the hardness).

The parameters which were modified in the heat treatments were the tempering holding time and temperature, as follows:

- Sample 1, the material was annealed at 850 °C - initial state
- Sample 2 was heated to 1100 °C for 30 minutes and cooled in water.
- Sample 3 was heated to 1100 °C for 30 minutes and cooled in water, followed by tempering at 400 °C for 30 minutes and cooling in air.
- Sample 4 was heated to 1100 °C for 30 minutes and cooled in water, followed by tempering at 400 °C for one hour and cooling in air.
- Sample 5 was heated to 1100 °C for 30 minutes and cooled in water, followed by tempering at 500 °C for 30 minutes and cooling in air.
- Sample 6 was heated to 1100 °C for 30 minutes and cooled in water, followed by tempering at 500 °C for one hour and cooling in air.
- Sample 7 was heated to 1100 °C for 30 minutes and cooled in air.

Figures 1 - 7 show the structures obtained following the heat treatment applied.

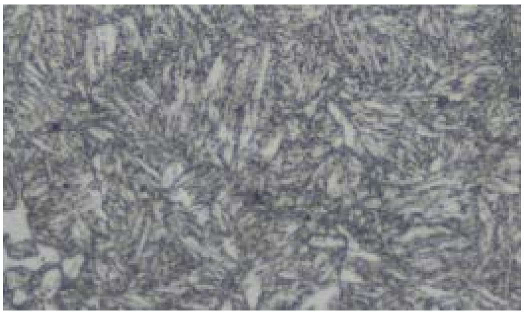

FIG. 1. Sample 1 - initial state. Aqua regia etching. 500:1

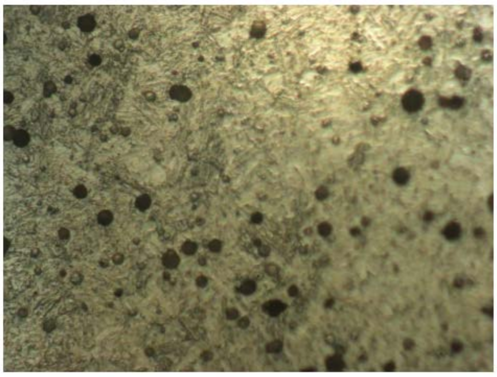

FIG. 2. Sample 2 - heating to 1100 °C for 30 minutes and cooling in water. Aqua regia etching, 500:1

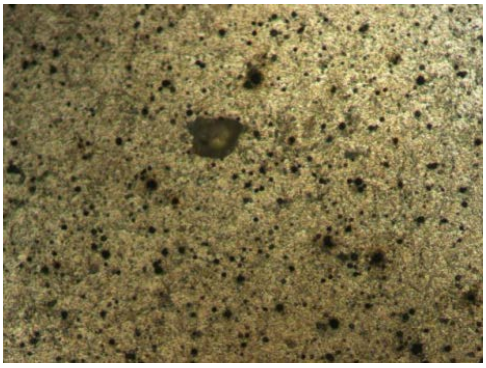

FIG. 3. Sample 3 - heating to 1100 °C for 30 minutes and cooling in water, followed by tempering at 400 °C for 30 minutes and cooling in air. Aqua regia etching. 500:1

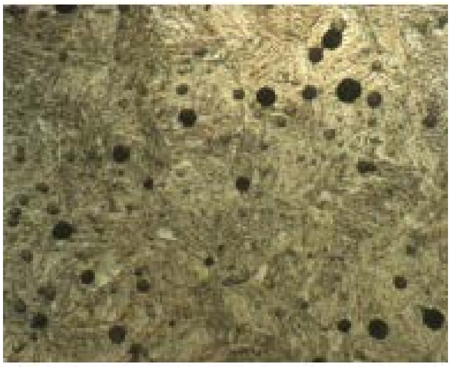

FIG. 4. Sample 4 - heating to 1100 °C for 30 minutes and cooling in water, followed by tempering at 400 °C for 1 hour and cooling in air. Aqua regia etching. 500:1

FIG. 5. Sample 5 - heating to 1100 °C for 30 minutes and cooling in water, followed by tempering at 500 °C for 30 minutes and cooling in air. Aqua regia etching. 500:1

FIG. 6. Sample 6 - heating to 1100°C for 30 minutes and cooling in water, followed by tempering at 500°C for one hour and cooling in air. Aqua regia etching. 500:1

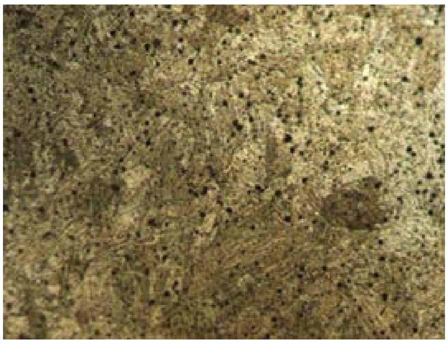

FIG. 7. - Sample 7 - heating to 1100 °C for 30 minutes and cooling in air. Aqua regia etching. 500:1

Table 2 shows the hardness values obtained after the different heat treatment procedures applied.

Table 2. The hardness values obtained following the heat treatments applied

Sample no.	Hardness values	
	Average [HV]	Average [HRC]
1	256	23.5
2	381.3	38.73
3	342.9	34.73
4	631.23	50.06
5	430.56	42.9
6	431.36	43.7
7	415.16	42.1

Steels with 12...13% Cr feature high resistance to tempering and do not soften at tempering temperatures up to 500°C, and those with average carbon (0.2...0.3% C) even give a secondary hardening effect around 500°C.

The (Fe, Cr)3 C carbide transforms into the (Fe, Cr)7 C3 dispersed and coherent carbide; the subsequent increase in temperature leads to the transformation into (Fe, Cr)23 C6 carbide and to rapid coalescence at tempering temperatures above 600°C.

In the case of the analysed steel, having regard to the fact that it is a low carbon content steel, the amount of carbides obtained - as it appears from the analysed structures - is also reduced. The heating to the tempering temperature of 1100°C led to the almost complete dissolution of the carbides. After tempering, there can be noted the occurrence of fine precipitates and of the bainitic appearance in the microstructure.

CONCLUSIONS

Heat treatments are essential to improve the properties of martensitic stainless steels, such as corrosion resistance and wear resistance.

The hardness and tensile strength of martensitic stainless steels can be improved by applying the correct heat treatment.

The crystalline structure of martensitic stainless steels can be improved by controlled heat treatments, which can help increase the hardness and strength of the materials.

The martensitic stainless steel properties can be improved by heat treatment by appropriately selecting the heat treatment parameters, such as temperature, cooling time and rate.

The maximum hardness values were obtained for the treatment in which a tempering the 400 °C for one hour was applied after quenching.

The increase of the holding time from 30 minutes to one hour for the tempering at 400°C for 30 minutes led to a significant increase in hardness.

The increase of the tempering temperature to 500°C led to a decrease in hardness regardless of the holding time.

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