

CORROSION OCCURRENCE DUE TO MICROSTRUCTURE CHANGE IN COLD DEFORMED X5CrNi18-10 STEEL

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Abstract Corrosion resistance of stainless steels depends on metallurgical and production variables. Corrosion is highly unwanted in stainless steels because of their purpose, to have high corrosion resistance and high mechanical properties. In this paper, one example of corrosion occurrence in X5CrNi18-10 stainless steel will be analyzed. Samples were taken from two different cold deformed sheets that had porosity on similar places. Chemical analysis and metallography were done in laboratory in order to determine the reason for corrosion occurrence.

Keywords: Corrosion; metallography; stainless steel.

1. INTRODUCTION

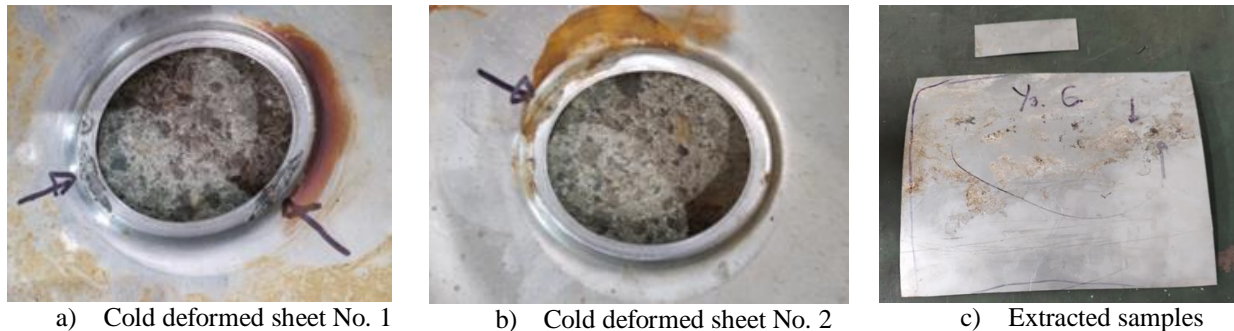
Consequence of corrosion is loss of essential properties in a material due to reactions with its surroundings. Millions are lost each year worldwide because of corrosion. Much of this loss is due to the corrosion of iron and steel, although other metals may corrode as well. The problem with iron as is that the oxide formed by oxidation does not firmly adhere to the surface of the metal and flakes off easily causing "pitting". Extensive pitting eventually causes structural failure [1]. Although one of the main reasons why stainless steels are used is corrosion resistance, they do in fact suffer from certain types of corrosion in some environments and care must be taken to select a grade which will be suitable for the application. Corrosion can cause a variety of problems.

Methodology of the analysis of corrosion occurrence in cold deformed sheets made from X5CrNi18-10 stainless steel is presented in this paper. Photographs of samples and results of analysis will be presented in order to compare how different deformation ϵ influences on the microstructure of the samples with metallography and chemical composition of non-deformed steel sheet.

2. TESTING METHODOLOGY AND RESULTS

2.1. Sampling

Two cold deformed X5CrNi18-10 steel sheets that had porosity were analyzed in this paper. On Figure 1. a), b), it can be clearly seen that the errors (porosity, i.e., pitting corrosion) on the material are of a systemic nature, i.e., on both visually inspected samples, there are defects (porosity, i.e., pitting corrosion) in the same zone.



a) Cold deformed sheet No. 1 b) Cold deformed sheet No. 2 c) Extracted samples

Figure 1. Photo of two cold deformed sheets a), b) and extracted samples c).

All the errors shown (porosity, i.e. pitting corrosion) are in the same zone, i.e. in the rim area at the hole. This is the place where the steel sheet was exposed to the greatest plastic deformation during processing. By visual inspection, it is easy to see that the error actually represents a surface defect in the form of perforation, i.e., a hole in a steel sheet as a result of metal corrosion (porosity, i.e., pitting corrosion). These errors may be the result of various influences, e.g., material structure, mechanical damage, influence of non-metallic materials in the joint, consequences of pressure and temperature in the container, as well as a combination of the above and various other factors. The laboratory tests were performed in the accredited Laboratory for Metal Testing, accreditation number 01-104, IMS Institute, Belgrade.

2.2. Chemical Analysis

The results of chemical analysis compared to nominal values according to a referent standard is presented in this part [2]. Results are presented in Table 1. */For sheet metal to be welded, sulfur is recommended in the range of 0.015% to 0.030%. **/ Allowed deviation of nickel is $\pm 0.10\%$.

Table 1. Chemical composition analysis results [2].

Chemical element	C %	Si %	Mn %	P %	S* %	Cr %	Ni** %
Sample No. 1	0,017	0,588	1,787	0,003	0,016	18,27	7,93
Sample No. 2	0,052	0,644	1,443	0,006	0,021	18,48	8,28
X5CrNi18-10	$\leq 0,07$	$\leq 1,00$	$\leq 2,00$	max 0,045	$\leq 0,15$	17.5 - 19.5	8,0 - 10.5

Both samples meet the chemical composition criteria for steel quality mark X5CrNi18-10, compared to a referent standard.

2.3. Metallographic Analysis

According to the findings of the report, the microstructure of samples no. 1 and no. 2, is similar, consists of austenite and martensite formed in austenite grains [2]. Also, in the microstructure of these samples, the presence of carbides/partially agglomerated carbides along the grain boundaries and inside the grains was observed. Austenitic steels are particularly sensitive to deformation-induced phase transformation. Cold plastic processing, by cold deformation, initiated change in the

microstructure of the steel itself. Cold deformation caused the transformation of metastable austenite into deformation martensite. With an increase in the degree of deformation ε , the degree of transformation of austenite into deformation martensite α' also increased, as well as the appearance of carbides in bands. For example, the microstructure consists of austenite and martensite formed in austenite grains [3]. As an example of this transformation, Figure 2: the evolution of the microstructure from austenitic to austenitic-martensitic after different levels of plastic deformation (a) $\varepsilon = 5\%$, (b) $\varepsilon = 25\%$, (c) $\varepsilon = 35\%$, (d) $\varepsilon = 45\%$, (e) $\varepsilon = 55\%$, (f) $\varepsilon = 60\%$ is presented [3]. Plastic deformation leads to a distinct elongation of the grains in the direction of rolling and to the formation of numerous slide bands and shear bands, in which probably the martensite α' is localized [4].

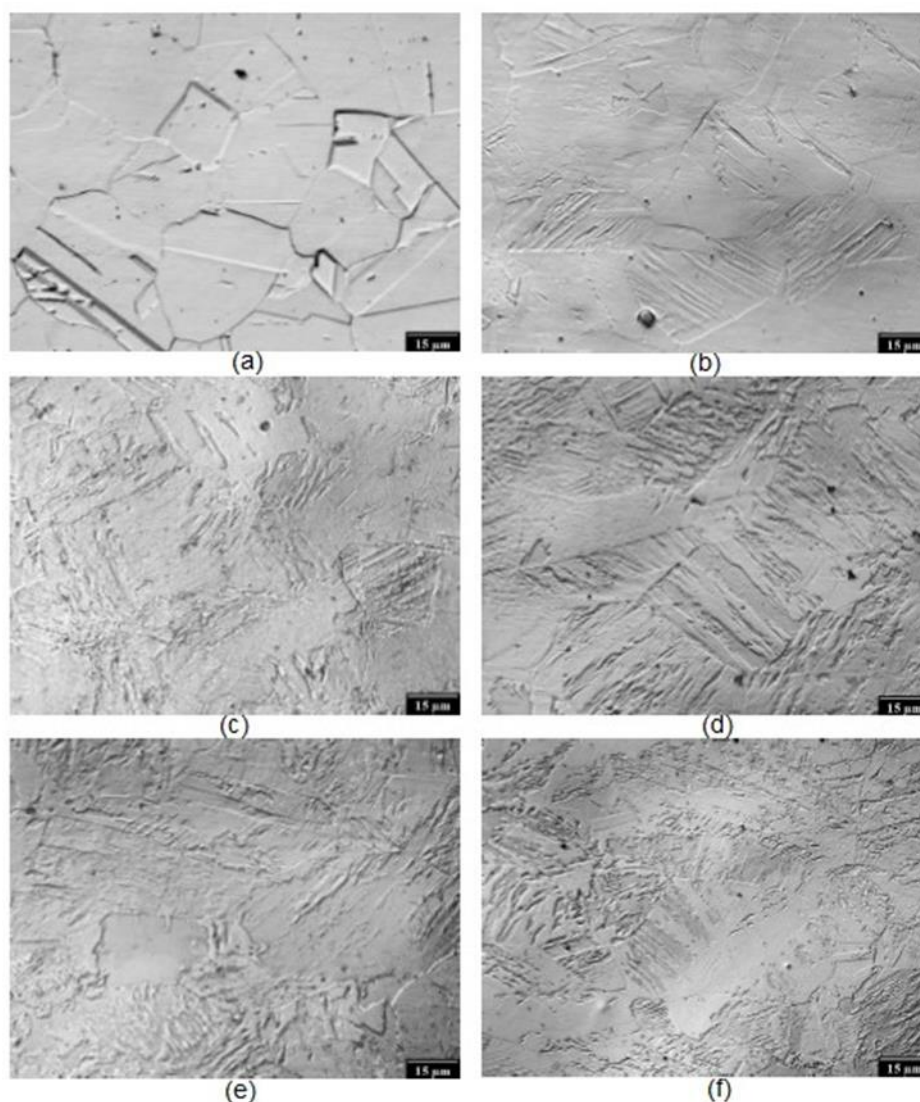


Figure 2. The evolution of the microstructure from austenitic to austenitic-martensitic after different levels of plastic deformation. (a) $\varepsilon = 5\%$, (b) $\varepsilon = 25\%$, (c) $\varepsilon = 35\%$, (d) $\varepsilon = 45\%$, (e) $\varepsilon = 55\%$, (f) $\varepsilon = 60\%$ [3].

In the color Figure 3, for a better overview, the transformation of austenite into martensite is also shown depending on the degree of plastic deformation ε , austenite - green color, martensite - red color. (a) $\varepsilon = 35\%$, (b) $\varepsilon = 60\%$.

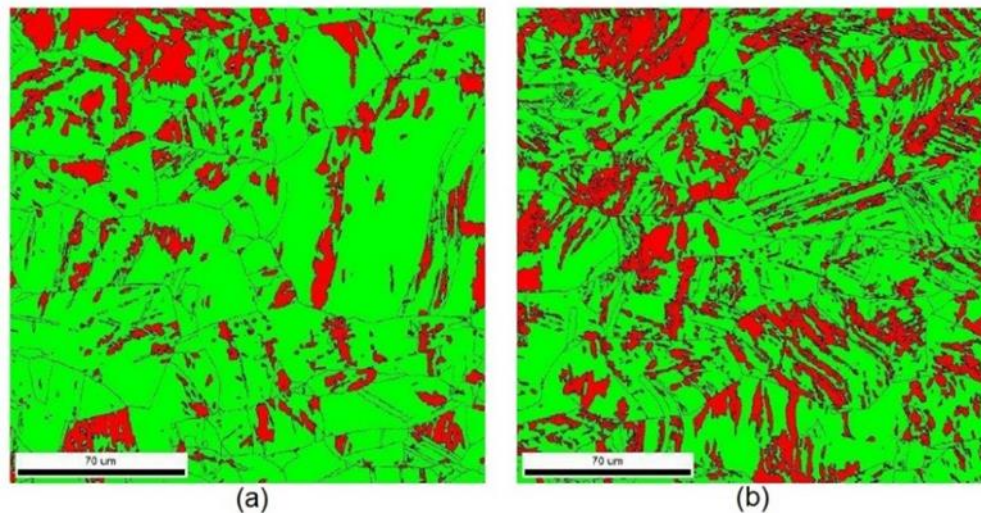


Figure 3. The transformation of austenite into martensite is also shown depending on the degree of plastic deformation ϵ , austenite - green color, martensite – red color. (a) $\epsilon = 35\%$, (b) $\epsilon = 60\%$ [3].

In short, the volume of martensite increases progressively with increasing plastic strain ϵ . In addition, the number and size of martensitic localized islands increase steadily with increasing plastic strain ϵ [3, 4]. In Figure 4 example of the appearance of carbide bands in deformation martensite α' is presented [5].

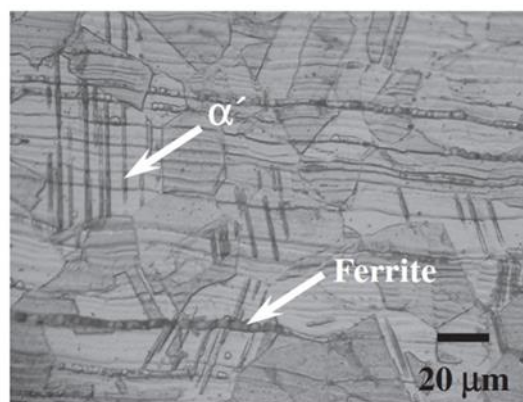


Figure 4. An example of the appearance of carbide bands in deformation martensite α' [5].

Carbide deposition is a temperature-dependent process with slow kinetics that can occur during welding. Cold deformation before exposure to heat during welding has a combined effect. According to data from the available literature, the reversion of martensite to austenite could be performed by annealing heat treatment, to the initial state, which would reduce the hardness of the metal and significantly increase the resistance to corrosion [6].

3. CONCLUSION

The increasing number of martensite localized regions is a consequence of the increasing density. This clearly indicates that the non-ferromagnetic austenite phase can be easily transformed into ferromagnetic martensite. On the other hand, with the transformation of austenite into martensite (thanks to the increase in hard martensite fractions and the increase in the density of dislocations in

austenite), the hardness of the matrix gradually increases, i.e., the hardness of the steel increases. The transition of metastable austenite to martensite, and the appearance of carbides, significantly reduces the corrosion resistance of steel. According to data from the available literature, the reversion of martensite to austenite could be performed by annealing heat treatment, to the initial state, which would reduce the hardness of the metal and significantly increase the resistance to corrosion.

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