

MICRO-MACRO SURFACE ASPECTS OF CORROSION RESISTANCE OF A STAINLESS STEEL IN SEA WATER

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Abstract: *In metallurgy, stainless steel, also known as inox steel or inox from French "inoxydable", is defined as a steel alloy with a minimum of 10.5% to 11% chromium content by mass. Stainless steel does not readily corrode, rust or stain with water as ordinary steel does, but despite the name it is not fully stain-proof, most notably under low oxygen, high salinity, or poor circulation environments. It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment the alloy must endure. Stainless steel is used where both the properties of steel and resistance to corrosion are required.*

A stainless steel material suffers a generalized corrosion after his immersion in sea water during 30 days. The environment is a closed considered space and do not consider the biological effects on the metallic material surface. The liquid influence on the metallic element surface was analyzed through scanning electrons microscopy (SEM) with 2D and 3D considerations and by energy dispersive X-ray analyze (EDAX) for chemical insights.

The nature of chemical compounds appeared on the surface was also established and considered for further corrosion effects investigations.

Keywords: *corrosion, SEM, metallic material surface.*

1. Introduction

Stainless steel differs from carbon steel by the amount of chromium present. Unprotected carbon steel rusts readily when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide, and due to the greater volume of the iron oxide this tends to flake and fall away. Stainless steels contain sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure, and due to the similar size of the steel and oxide ions they bond very strongly and remain attached to the surface [1].

Under action off different work environments (for example moist air, water and other liquids or aggressive gaseous) the structure surface and metallic pieces that came in contact during them function the materials suffer a faster or slower deterioration [2].

This deterioration by oxidation of the structures and pieces surface made of steel is called corrosion and it causes considerable immense losses each year, amounting to tangible assets, financial and human. This triggered an intense research activity, both in the direction of establishing some procedures to protect the pieces against surface destructive phenomenon and in the development of materials better able to resist, in good condition, to corrosion.

The ability of chromium to passive the steel against corrosion is due to the protecting action which provides under oxidizing conditions. When the chromium content is high enough, it turned out that this protective effect is the formation of a thin film, invisible oxide dense structure, which possesses a resistance to chemical attack [3].

The metal oxide film that forms on the surface of stainless steel protects them against an attack by corrosion initiation. If, under different conditions, the oxide coating is

damaged or removed, in contact with oxygen or another oxidizing substance, the film quickly recovers at the steel surface in question and the steel is again passivated. The presence of oxygen is necessary to keep the steel passive, and therefore to keep his capacity to not oxidize [4, 5].

2. Experimental details

The environment is a closed considered space and do not consider the biological effects on the metallic material surface. The liquid influence on the metallic element surface was analyzed through scanning electrons microscopy (SEM) with 2D and 3D considerations and by energy dispersive X-ray analyze (EDAX) for chemical insights.

3. Experimental results

In reference [1] it is shown the chemical composition of the electrolyte solution, the water of the Mediterranean, according to research conducted by Dr. J. Floor Antoni. From chemical composition it can be observed the different components of sea water, especially chlorine that can react with the surface of the alloy, even with the oxide layer formed, but in rare cases, the affected areas are actually inhomogeneous layers or external damaged.

It was analyzed the resistance of a stainless steel material in sea water for a holding period of 30 days. The sample subjected to direct contact with sea water was cubic form with 1 cm² area and immersing the material in corrosive solution has been achieved static without any mechanical implications of the environment or over the environment.

Figure 1 presents the general aspects, a) and c) also particular b) and d) of the metallic material surface immersed in sea water, in aggressive and corrosive environments at different magnification powers, 100x, 1000x, 350x and 500x showing the appearance on the surface of the reaction components and traces of corrosion of the surface. In Figure 1 B) it can be observed also small affected pitting type of the surface but occur at a very small scale size, in microns. The affected areas by

compounds reaction are relatively large between 50 and 250 μm without base material loss but in reacting with the material.

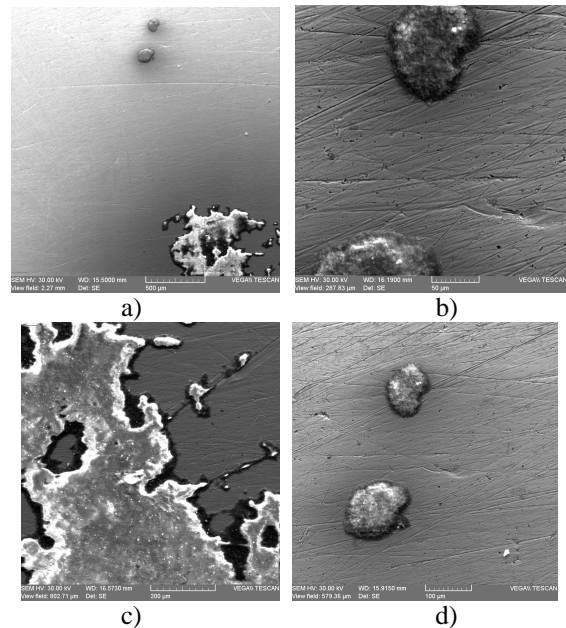


Figure 1 SEM microscopy of the surface of stainless steel by immersing the material in sea water for 30 days for different power amplifier) 100x, b) 1000x, c) 350x also d) 500x

Table 1 show the atomic also the mass percentage of chemical composition of the stainless steel surface after the immersing test of this material in solution in sea water for 30 days.

The analysis was performed using EDAX equipment (Bruker AES device), which uses a Xflash detector on surface in Figure 1) and it is observed a high content of oxides, the presence of calcium on the surface of Sodium salt in the solution and iron in the base material. Carbon atom is in a higher proportion on the etched surface than typically found in a stainless steel.

Table 1 Chemical composition of the steel material surface after immersion in seawater solution

Element	[norm. wt.%]	[norm. at.%]	Error in %
Oxygen	65,97	80,48	1,72
Calcium	29,73	14,48	0,94
Carbon	2,47	4,02	0,44
Iron	1,04	0,36	0,06
Sodium	0,782289	0,66	0,09

In order to determine the chemical nature of the compounds from the material surface it was carried out an analysis of the distribution of chemical elements in a selected line in Figure 2 a). The analysis was carried out on a distance of 350 μm , the monitored chemical elements belonging to the base material, such stainless steel iron, chromium, manganese and the carbon, as well as corroded solution, or sea water by the analysis of oxygen, chlorine and sulfur on the surface. Although it appears relatively in small quantities, sodium hasn't been pursued in the analysis having a very low signal in the films formed on the material surface.

It is noted from the variations figure 2 b) and c) that the surface of stainless steel is covered with a thick layer, which shields the components signal of the base material from reaction of compounds of chlorine, oxygen, carbon and sodium.

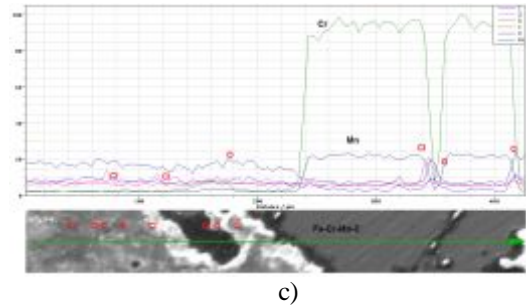
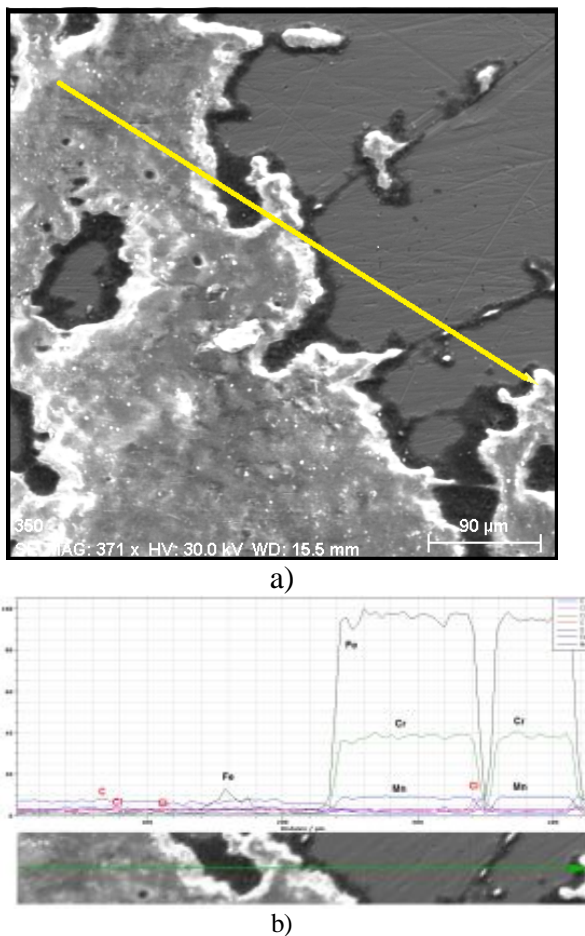


Figure 2. The distribution of elements Fe, Cr, Mn, Cl, O, C and S on the surface of a stainless steel material maintained in seawater for 30 days a) the selected area, b) the distribution of the main elements selected and c) the signal distribution of the main elements selected without iron element

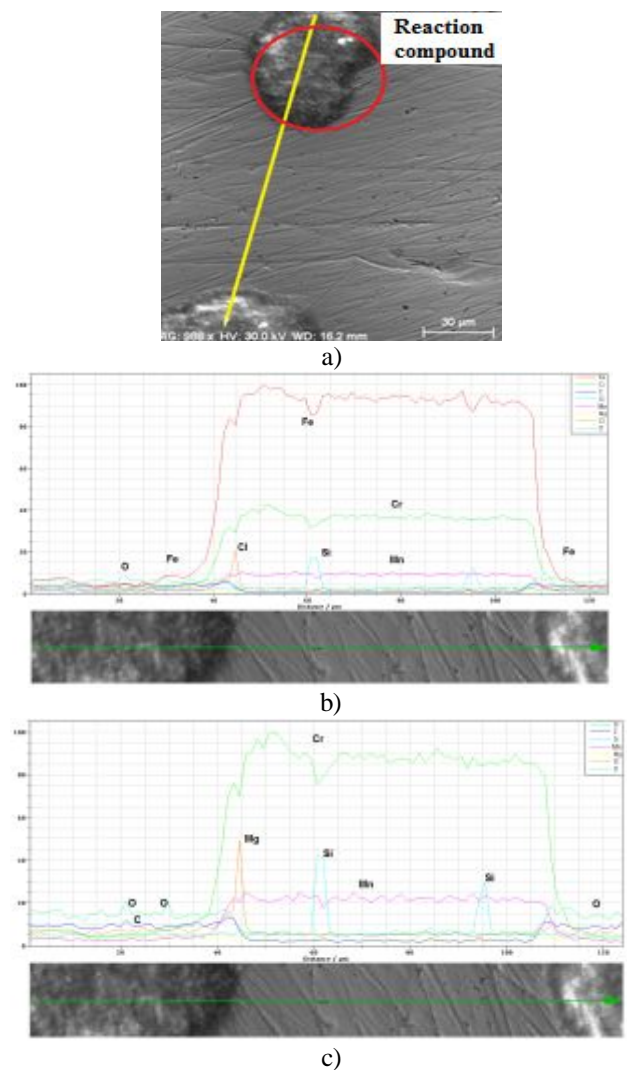


Figure 3 Distribution of the elements Fe, Cr, Mn, Cl, O, C and S on the surface of a stainless steel material maintained in seawater for 30 days showing another type of compound formed on the surface of stainless steel a) selected area, b) the distribution of the main elements selected and c) the distribution of main selected elements without the iron element signal.

The compound layers formed are non-homogeneous; forming preferentially on the material surface features such as larger scratching, surface defects or different types obtained by machining the surface.

Using the same method of analysis of the software Line equipment EDAX - Bruker another kind of compound on the surface of stainless steel was further analyzed. The selected area is shown in Figure 3) and involves for the test two new compounds, in terms of structure, and in the middle area, a base material easily affected by immersion in sea water.

From the distributions shown in Figure 3 it is noted that these compounds are generally based on oxygen (oxides), but it is observed a more intense signal carbon from the affected area compared with the received signal from the base material surface.

4. Conclusions

Stainless steels are becoming more useful because they possess special properties. One of these properties is a resistance to corrosion regardless of the environment in which it operates. The purpose of this paper is to summarize the characteristics of these materials, classification and their standardization and the behavior of stainless steel in corrosive environments such as sea water.

As a result of a stainless steel immersion in sea water for a period of 30 days it is observed a very good behavior of the surface of the metallic material without aggressive corrosion trace but with the formation and growth of chalk deposits on the surface of the material based on carbonate calcium and magnesium as well as the growth these deposits of salts from sea water. The surfaces on which appear these formations are selectively determined by the shape and appearance of the material surface, otherwise it appears a free clean zone and free of chemical formations, being noticed at high amplifier power a slight sub micron pitting effect.

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