[1.]Zoran KARASTOJKOVIĆ, [2.]Jasmina PEKEZ, [3.]Milan MILADINOV

# MAIN WAYS ON WHICH STAINLESS STEELS COULD CORRODE

[1.]Society for Ethics and Evaluation in the Arts and Sciences, 11000, Belgrade, SERBIA
[2.]University Novi Sad, Technical faculty „Mihajlo Pupin", 23000, Zrenjanin, SERBIA
[3.]"Sanacija i ispitivanje metala", d.o,o, 11060, Belgrade, SERBIA

**Abstract:** The monitoring of corrosion in common structural steels is present in every day practice and/or activities, while the same processes are less present at stainless steels. It does not mean that corrosion of stainless steels not exists anyway, but could be found, however, not at the same intensity or rate as in structural steels. Stainless contain chromium, in some kinds of them the presence of nickel is avoided mainly from economical reasons. Stainless steels are exposed to various working conditions and/or environmental media, so the different corrosion attacks will took place. Here will be analyzed some of the most frequently corrosion processes and types which may be appeared at stainless steels.
**Keywords:** stainless steels, corrosion ways, surface changes, structural changes

## 1. INTRODUCTION

Stainless steels often are classified as *noble* metals, but it is evident that many of them may corrode. The corrosion processes, however, depend from the environmental surroundings, but also from the chemical composition of used stainless steel. The fabricating methods during stainless steel production (as shaping, welding or heat treatment) also may have the influence on the final corrosion appearance/result.

Stainless steels with nickel contest (above 8%) posses pretty well corrosion resistance, but from economic reasons frequently are used nickel–free steels, neither the chosen steel is corroded and degraded. Corrosion attacks at stainless steels roughly may be registered (sometimes by naked eye) at or near the surface, or inside the product (when the changes of steel micro–structure might be registered microscopically). For both approaches, the corrosion revealing at surface or inside, the solid knowledge both from chemistry and metallurgy is needed. The appearance of mixed types of corrosion may not be excluded, indeed.

Almost stainless steels are passivated, but some of them may corrode. The corrosion rate at stainless steels commonly is, however, lesser than at usual structural steels. For all metals, the tendency corrosion is determined by (electro) chemical reactions when anode and cathode exist. The corrosion will took place every time when two metals with different electrochemical potentials are in contact, which is known as "contact" corrosion. But, other types of corrosion are pretty complex and need further considerations, sometimes by using electrochemical and thermodynamical approaches. The evaluation of kinetics (for determination of corrosion rate) always is an important task for choosing and applying a kind of steel. Many (standard) laboratory tests are available, but service conditions & results are irreplaceable.

## 2. MAIN GRUOPS OF STAINLESS STEELS

Stainless steels frequently are classified according to their chemical composition and/or stracture(s). The main alloying elements at those steels are chromium and nickel, Figure 1, while the stainless steels with nickel as a dominant alloying element are pretty less known, the main reason for that is only a high price of nickel.

| STAINLESS STEELS | | |
|---|---|---|
| Fe – Cr | Fe – Cr – Ni | Fe – Ni – Cr |
| corrosion resistant, contain carbon resistant to wear, impact and abrasion | more corrosion resistant, multialloyed, soft and tough | corrosion stable at acids and elevated temperatures |

Figure 1. Main large groups of stainless steels

All of those steels may be immune, corrosion active or might be passivizated, Figure 2.

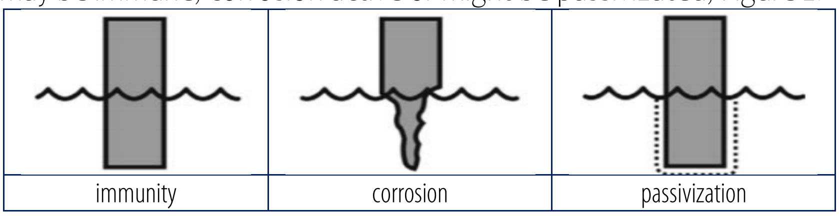



Figure 2. Typical reactions of immersed metal into liquid media


ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

These regions are well visible at Pourbaix diagrams, for some metals shown in Figure 3.

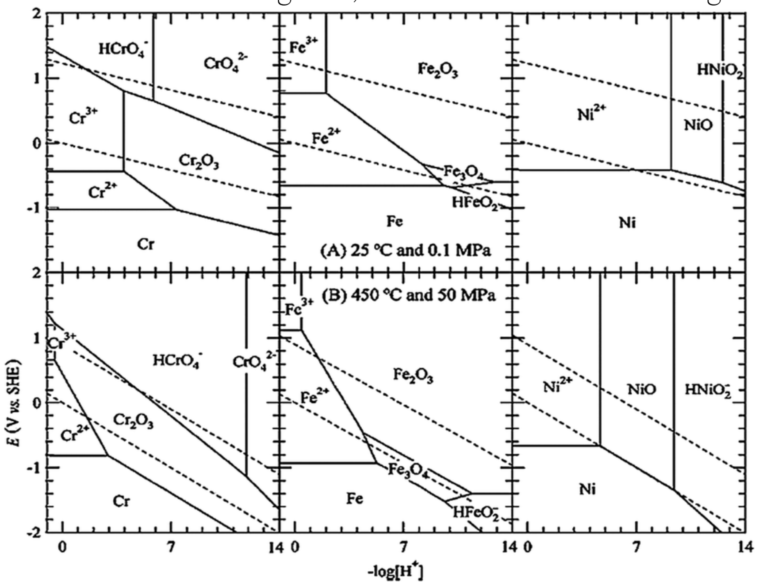



Figure 3. Porbaix diagrams for main alloying elements from stainless steel in water

The principal disadvantage of such diagrams is in its validation only for given material and for given conditions, it means just for one media. If any detail is changed that the new diagram must be examined and plotted.

## 3. FREQUENT TYPES OF CORROSION IN STAINLESS STEELS

Widely known types of stainless steels belong to: ferritic, austenitic, martensitic or a kind of their mixed structure, as like duplex steels or a precipitation hardening (PH) steels. The new generations of stainless steels, beside chromium or chromium&nickel, frequently contain a kind of (micro)alloying element(s). The presence of microalloying elements usually lead for improving the corrosion resistance and weldability. Frequently types of corrosion appeared in stainless steels are: general, pitting, intergranular, contact, galvanic or corrosion under stress. Another types of corrosion degradation at stainless steels (as like crevice, sulfide or chloride) are less present at our regia, so those ways of corrosion will not be discussed here. For all types of corrosion is characteristic influence of temperature: the higher temperature the corrosion rate is increasing, which is easily explainable by increasing the chemical activity.

Further, during welding at some kinds of stainless steel the corrosion may have appeared on a specific way – known as a sensitization, and this type here will be closely analized. Here is considered that mechanisms of general corrosion is pretty known, while other types as the empirical estimation of pitting corrosion needs detailed explanation.

— Pitting Resistance Equivalent number (PRE)

The effect of pitting corrosion frequently is visible by naked eye. It is established that resistance against to pitting corrosion may be explained by an equivalent number (PRE), which includes the sum of present main alloying elements into stainless steel; the greater PREN number means greater resistance to pitting corrosion, so this equivalent number needs short explanation The PREN numbers for stainless steels which contain high content of chromium or molybdenum and nitrogen are more resistant to pitting corrosion, and will be calculated as follows:

for ferritic steels: $$PREN = \%Cr + 3{,}3\,(\%Mo + 0{,}5\%W) \quad (1)$$

for austenitic and duplex steels: $$PREN = \%Cr + 3{,}3\,(\%Mo) + x(\%N) \quad (2)$$

where: x = 16 for duplex (austenitic–ferritic) stainless steels and
x = 30 for austenitic stainless steels.

On the base of these values obtained results for common steels are given in Table 1.

Table 1. Minimum PREN values for some stainless steels

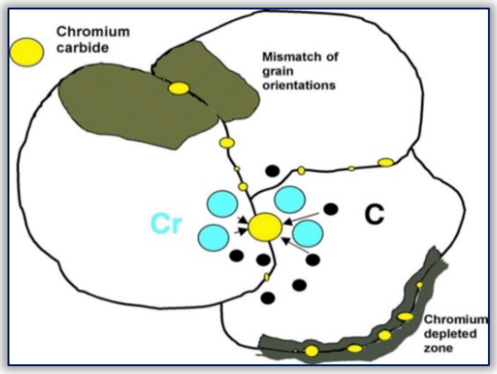
| steel | 304L | 316L | CAF 2304 | 317L | 2205 | 904L | CAF 2507 | 254 CMO | 654 CMO |
|---|---|---|---|---|---|---|---|---|---|
| $PREN_{16xN}$ | 19 | 26 | 26 | 30 | 35 | 36 | 43 | 43 | 56 |
| $PREN_{30xN}$ | 20 | 26 | – | 30 | – | 37 | – | 46 | 63 |

The influence of copper was not involved in equations 1 or 2, either it improves the corrosion resistance of such steel.

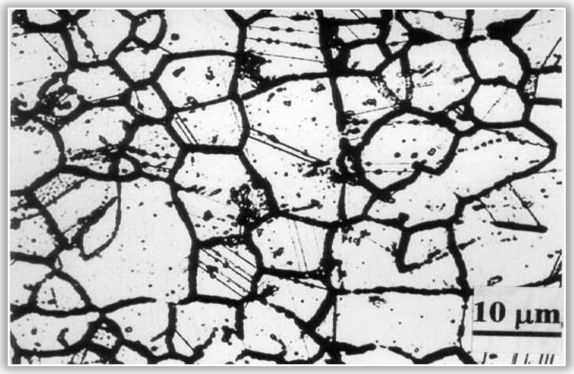

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

— Sensitization as a intergranular corrosion

Sensitization is a kind of intergranular corrosion associated with carbide or nitride precipitation along crystal grains, when chromium and carbon in the steel forming the chromium carbide particles, Figure 4a), making the dark net throughout the steel. Figure 4b).




a)




b)

Figure 4. Scetch of precipitation of chromium carbides along grain borders a) and metallographic view of sensitization at stainless steel 304 b)

At austenitic stainless steels the critical temperatures are around 700–750°C, see Figure 5.

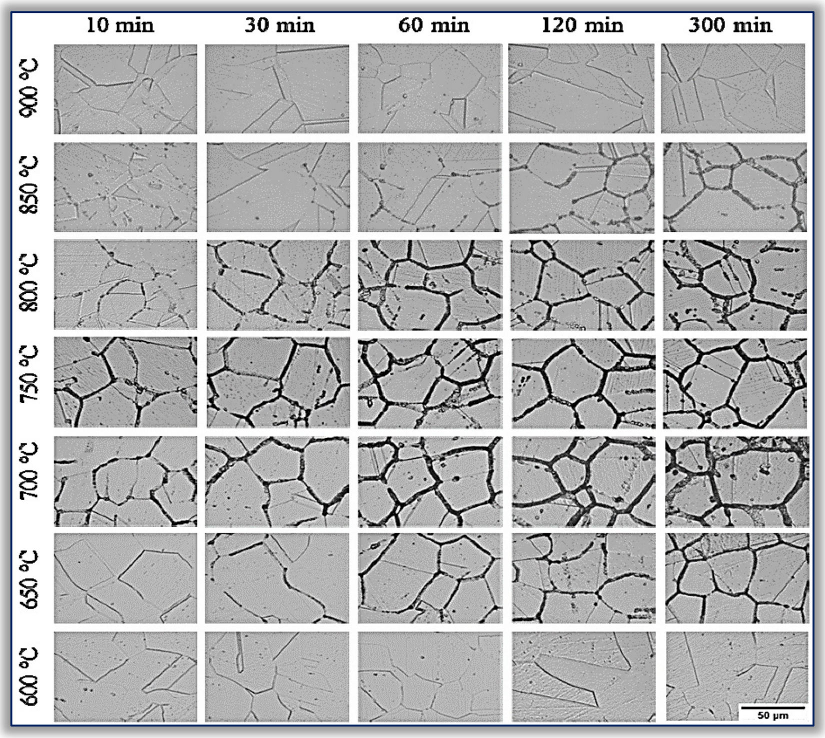


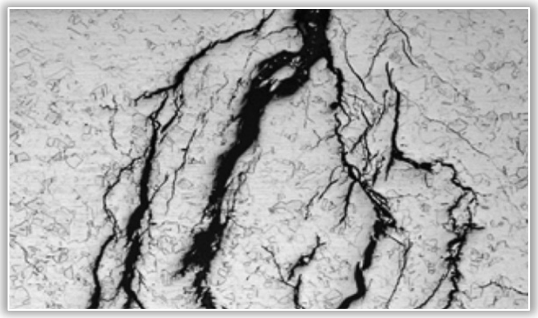

Figure 5. Annealing temperatures responsible for sensitization of an austenitic stainless steel [8]

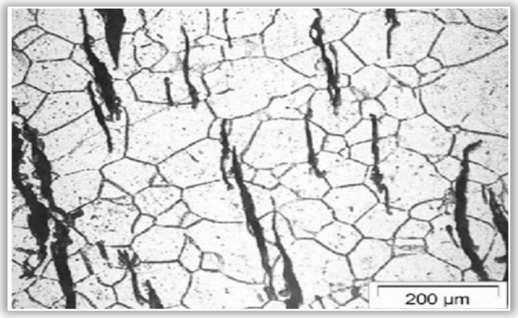
Such distributed carbides, along to grain boundaries, reduces the corrosion resistance. Sensitization will be appeared in austenitic steels if they exposed at temperatures 425–850°C and then cooled at a relatively slow rate, commonly after welding or air cooling after annealing. Also, the carbide precipitation depends from carbon content. The most critical temperature range is around 700°C, at which 0.06% carbon steels will precipitate carbides in about 2 minutes, whereas 0.02% carbon steels rather are immune for precipitation. The precipitated carbides may be dissolute if the steel is heated over 950°C, in duration 10–40min, followed by water quenching, but this kind of heat treatment will not be applicable on large (welded) components/structures. Stabilized grades of stainless steels, with titanium, niobium even tantalum, are less exposed to this kind of corrosion.

— Stress Corrosion Cracking (SCC)

Such corrosion is appeared during the combined action of stress and certain corrosive environment. This kind of corrosion might be intergranular, Figure 6a) or transgranular, Figure 6b), but always at normal direction to tensile stress, as could be seen from Figure 6c).


ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665


a)



b)

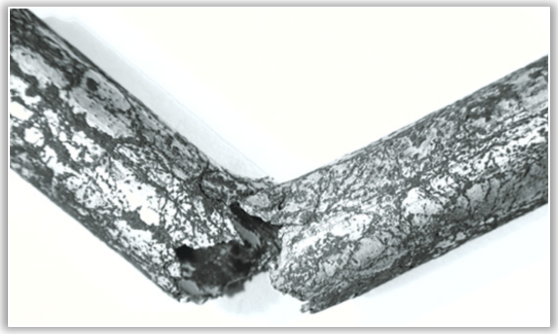

c)

Figure 6. Microscopic view of stress corrosion at stainless steels: a) cracks as irregular net, b) cracks at direction normal to tensile stress and c) macroscopic view of one damaged bar under stress corrosion

In some cases the resistivity of stress corrosion may be reduced by shot pinning at the surface of the object, when compressive stress is introduced. Another approach for avoiding the stress corrosion effects is applying a final annealing, but both methods are not a warranty for successful elimination of stress corrosion.

— Chloride Corrosion Cracking

In chemical plants in contact with chloride solutions this type is emphasis. The cold worked stainless steels are more active for corroding at chloride containing atmosphere. The presence of nickel in steel reduces this form of corrosion.

— Sulfide Stress Corrosion Cracking (SSC)

This type of corrosion is important for users in the oil/gas industry when hydrogen sulfide ($H_2S$) is present. The tensile stresses always favorize this kind of corrosion.

— Galvanic Corrosion

Corrosion is, however, an electrochemical process with flow of electrons especially in the contact of dissimilar metals. The two metals must be widely separated according to their position on the galvanic series, as could be found in wide literature [4,10]. Practically, it is necessary to avoid the mixing of metals, even during fabrication of a given metal structure.

— Contact corrosion

Contact corrosion should be avoided even at stainless steels, when two metals possess large differences in electronegativity of coupled materials, even when an usual structural steel is in contact with stainless steel, see Figure 7.

Figure 7. Two examples of contact corrosion at atmospheric conditions between stainless steel and galvanized plain steel


ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

For avoiding this kind of corrosion, at warehouse the stainless steels and plain carbon steels must be separated. The clean surface and atmosphere is well protection, however.

## 4. CONCLUSION

Either stainless steels were developed for preventing corrosion at plain steels, in some circumstances (explained by electrochemical potential and pH of surrounding media) those steel may corrode. On a simplified manner, the corrosion processes may be regarded as outer (in contact with different media or material) or inner type (when internal structural changes took place) at used stainless steel. For most outer corrosion types, the changes at the surface frequently are visible just by naked eye, while for monitoring the inner types are neccessary to provide the metallographic analysis. Some important types of corrosion here were shown.

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**Note**: This paper was presented at IIZS 2022 – The XII International Conference on Industrial Engineering and Environmental Protection, organized by Department of Mechanical Engineering and Department of Environmental Protection of the Technical Faculty "Mihajlo Pupin" Zrenjanin, from the University of Novi Sad, in cooperation with partners – University Politehnica Timisoara, Faculty of Engineering, Hunedoara (ROMANIA), University "St. Kliment Ohridski", Technical Faculty, Bitola (MACEDONIA), "Aurel Vlaicu" University of Arad, Faculty Of Engineering, Arad (ROMANIA), University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo, Sarajevo (BOSNIA & HERZEGOVINA) and University of Giresun, Faculty of Engineering, Giresun (TURKEY) – in Zrenjanin, SERBIA, in 06–07 October, 2022.



ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN–L 1584 – 2665