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MEETING POINT OF THE SCIENCE AND PRACTICE IN THE FIELDS OF CORROSION, MATERIALS AND ENVIRONMENTAL PROTECTION

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Procedures for preventing corrosion of welded joints

Procedure za sprečavanje korozije zavarenih spojeva

Srđan Bulatović[1*],Vujadin Aleksić[1], Bojana Zečević[2], Ognjen Ristić[1], Ana Maksimović[2]

[1] *Institute for testing of materials, Bulevar vojvode Mišića 43, Belgrade, Serbia*

[2] *Innovation Centre, Faculty of Technology and Metallurgy, Karnegijeva 4, Belgrade, Serbia*

[*] *srdjan.bulatovic@institutims.rs*

Abstract

This paper describes the procedures for preventing corrosion of welded joints. Also, a theoretical overview of the forms of corrosion that are most prevalent in welded joints is presented.
The concept of corrosion in welded joints is very pronounced in real conditions. Welded joints are inseparable joints that form an integral part of steel welded constructions. The internal energy increases during the fusion welding especially in the heat affected places around the welded joint, which become initiating spot of corrosion degradation. That is why it is of vital importance to focus on ways to increase the resistance of welded structures to the impact of corrosion.
Keywords: *corrosion, welded joints, corrosion resistance*

Izvod

U ovom radu opisane su procedure za sprečavanje pojave korozije zavarenih spojeva. Takođe, prikazan je teoretski osvrt na oblike korozije koje su najzastupljenije kod zavarenih spojeva.
Koncept korozije u zavarenim spojevima je veoma izražen u realnim uslovima. Zavareni spojevi su nerastavljivi spojevi koji čine sastavni deo čeličnih zavarenih konstrukcija. Unutrašnja energija se povećava tokom zavarivanja topljenjem, posebno na mestima pogođenim toplotom oko zavarenog spoja, koja postaju inicijalna tačka degradacije korozije. Zato je od velikog značaja posvetiti se načinima za povećanje otpornosti zavarenih konstrukcija na uticaj od korozije.
Ključne reči: *korozija, zavareni spojevi, koroziona otpornost*

Introduction

Looking around, corrosion can be seen everywhere. Its formation is a consequence of natural chemical processes of decomposition of various materials. Protection of materials from corrosion is most important in its initial phase (production phase), because prevention of potential damage is significantly more profitable than possible reparation. Since it is not possible to completely protect materials from corrosion, it is also important to restore and protect them when corrosion occurs. Corrosion is basically a physical-chemical interaction between the material and the environment, and it can be defined in several ways. The impact of corrosion is most often reflected in the erosion and destruction of the surface, whereby the properties of the material change, which leads to a weakening of the load-bearing capacity and functionality of the structure, that is, permanent damage to the function of the metal and the associated construction.
The effect of corrosion in welded joints is very prevalent in exploitation, because in the welded joint itself there are several zones that are susceptible to corrosion, that is, the separation of phases along the grain boundaries. As a result of welding, the base metal is overheated in the immediate vicinity of the weld metal, which causes chemical and structural changes in the crystal lattice in the overheated zone. Structural heterogeneity is a frequent cause of the local occurrence of various types of corrosion in a welded joint [1,2].
Corrosion processes are classified differently for identification of corrosion mechanisms and for preventing corrosion with appropriate corrosion protection agents as well as for predicting the

corrosion behavior of metallic materials under operating conditions. Therefore, according to the above, corrosion processes are divided according to the mechanism of action, according to the geometry of corrosion damage and according to corrosive environments [3].

Types of corrosion

According to the mechanism of process, corrosion is divided into two basic forms/types: chemical and electrochemical corrosion. Chemical corrosion occurs in non-electrolytes, while for electrochemical corrosion an electrolyte is necessary and occurs on metals, welded joints of metals and alloys, where the processes of oxidation-releasing electrons and reduction-receiving electrons take place. Electrochemical corrosion is very widespread because a large number of metal welded structures and plants are exposed to water, moist soil or humid atmosphere, for example ship structures. Seawater is the electrolyte that attacks the welded joint and causes problems and ship damage [3].

In the types of corrosion according to the geometry of corrosion damage, the most common is general corrosion, which is the most widespread and least dangerous form of corrosion because it includes the entire metal surface together with its welded joints and it is possible to predict the service life of the welded structure. General corrosion is characterized by a uniform reduction in the thickness of the metal and represents the depth of penetration into the metal over a certain period of time [1].

Also, in the types mentioned above includes galvanic corrosion and corrosion in the crevice. Galvanic corrosion represents electrochemical corrosion between two or more different metals with the presence of an electrolyte and a potential difference between the metals in contact. For contact corrosion to occur, it is necessary that there is a sufficient potential difference between the metals in contact. If the potential difference is higher, contact corrosion is more intense. Galvanic corrosion is often present in welded joints when the composition of the additional metal is different from the composition of the base metal due to the difference in electrochemical potentials. It is most common due to the reparation of HSLA steel because fusible electrodes made of austenitic stainless steel are used. This process brings the stainless steel, which behaves cathodically, into electrical contact with the HSLA steel. In the presence of a corrosive environment, hydrogen is formed on stainless steel, which causes the cracks initiation of HAZ HSLA steel. The difference in temperature coefficients of expansion of ferrite and austenite causes internal stresses in the welded joint, which can cause cracks [4,5].

Crevice corrosion-this type of corrosion occurs in crevices that are large enough for the liquid to penetrate and at the same time the crevices are small enough for the liquid to remain in them. The very appearance of this corrosion is related to the production technology and the design of the structure itself. It is most common in stainless steels that are found in still and slow-flowing seawater [6].

Pitting corrosion, in Figure 1, is present in stainless steels that are in water or an aggressive environment by forming pits [3]. It is especially prevalent in ships because their large surface area is in the water. This corrosion occurs in a local area of the metal surface and the remaining areas are not corroded or are slightly corroded.

In the case of welded joints, pits are often formed in places with a certain microstructure, that is, in places of metallurgical heterogeneity of the metal [4]. Chromium-depleted areas that form when austenitic stainless steel is heated to the sensitization temperature are susceptible to pitting. Pits can also form at austenite-ferrite phase boundaries in stainless steel welds.

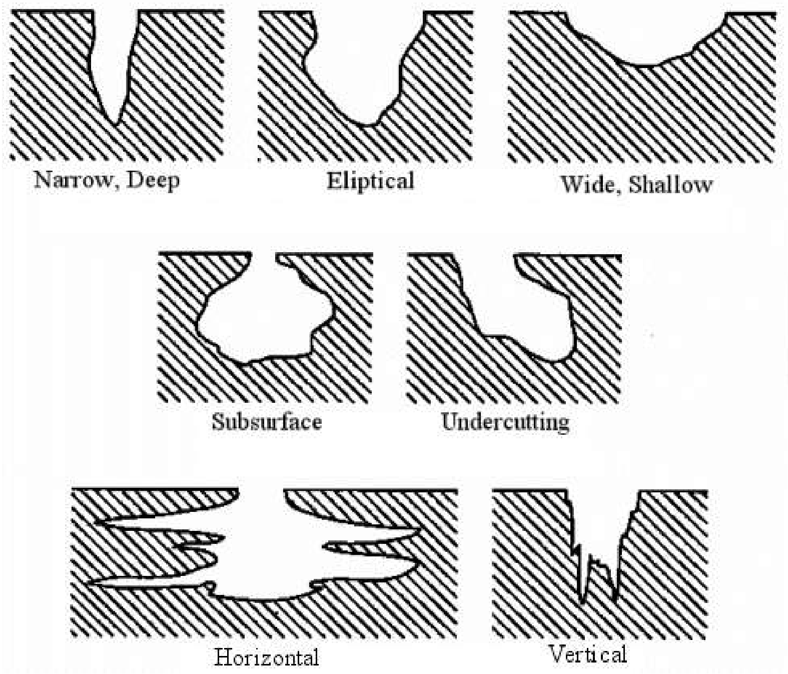

Figure 1. *Pitting corrosion according ASTM-G46 standard*

Stress corrosion and Hydrogen embrittlement

Along with the release of hydrogen at the top of the crack as a product of corrosion reactions, crack growth is accompanied by the process of local hydrogen embrittlement. At cracks, during welding, machining and places where inclusions disrupt the homogeneity of the surface, pitting corrosion occurs, Figure 2. It usually occurs in aqueous environments with the presence of ions that cause the fracture of alloys and stainless steels. Due to the influence of high voltages, welded metal joints can be exposed to stress corrosion. Residual stresses are proportional to the size of the weld metal, which directly depends on the heat input during welding. By means of heat treatment after welding and by making the weld metal smaller in size, stress corrosion cracking can be reduced [7]. Stress corrosion testing at a low tensile rate is performed by slowly increasing the load or strain. Samples that are in contact with a corrosive medium are tightened in a tear machine. The method is qualitative and is also used to determine the relative susceptibility of alloys and welded joints to stress corrosion. Its advantage is in the speed of obtaining results, the examination of one sample lasts from several hours to several days.

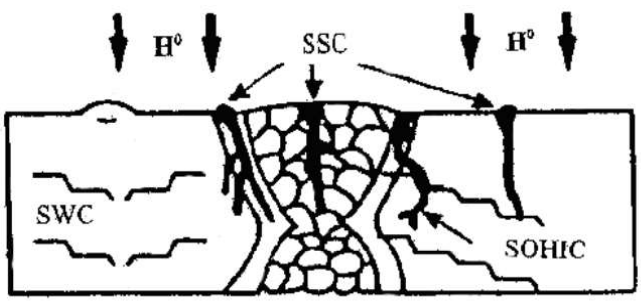

Figure 2. *Stress corrosion and Hydrogen embrittlement [7]*

Procedures for preventing corrosion of welded joints

Choosing the most fitting material and choosing the best construction solution of the machine part is one of the prior elements of anticorrosion protection of not only welded constructions. Further criterion of anticorrosion protection is the appropriate anticorrosion coating applied on the base material. There are distinguished two kinds of anticorrosion protections: organic and inorganic. The protective principle of organic coatings is to eliminate air humidity from the access to the base material. The quality of such a barrier is affected by many external factors. Inorganic coatings consist in nobleness of passivating metals comparing to the base material [8].

In general, there are several procedures to prevent corrosion of welded joints:

Correct choice of base metal and additional material-Careful selection of base metal and fusible electrode can reduce differences in the composition of the welded joint, that is, reduce the risk of galvanic corrosion.

Surface preparation-A properly selected surface cleaning procedure can reduce the occurrence of defects, which are often sites of corrosion attack in aggressive environments.

Weld Design-The weld metal should be low profile, with straight edges to prevent slag retention on the surface. An improperly designed welded joint can cause gaps in which electrolyte is retained, forming pits and corrosion in the crevice. Irregular shape of the weld metal can cause turbulent fluid flow in the pipes, i.e. the appearance of erosion corrosion.

Welding process-During welding, it is necessary to achieve a complete penetration, in order not to create a crevice under the weld metal. In multi-pass welding, slag should be removed after each pass. If welding under powder, the geometry of the welded joint must allow the removal of the powder because some of its constituents may be hydrophilic or corrosive.

Surface treatment of the welded joint-The best resistance to corrosion is achieved if the surface of the weld metal is smooth, evenly oxidized, without impurities. The roughness of the weld metal is usually reduced by subsequent grinding.

Protective surface coatings-When the difference in the composition of the welded joint can cause local corrosion, it is necessary to apply protective coatings. The protective coating should cover the weld metal and the base metal. Special surface preparation is necessary for applying protective coatings.

Heat Treatment-Post-weld heat treatment is often an effective way to increase the corrosion resistance of a welded joint. Thermal treatment achieves a reduction of internal stresses, which affect the growth of stress-corrosion cracks. Subsequent heat treatment (annealing) facilitates the removal of hydrogen from the welded joint and reduces the risk of hydrogen embrittlement. Subsequent heat treatment can also reduce differences in composition, which prevents the formation of microgalvanic couplings.

Preheating and intermediate heating-Application of preheating and intermediate heating can prevent hydrogen embrittlement of carbon and low alloy steels. Preventing gap formation. Proper selection of additional material, welding procedure and careful removal of slag after welding can avoid formation of gaps, i.e. local corrosion.

Removing the source of hydrogen-By carefully choosing a fusible electrode with a coating, drying it, as well as eliminating impurities and moisture from the surfaces to be welded, the risk of the appearance of hydrogen, i.e. hydrogen embrittlement (cold cracks), can be significantly reduced.

Increasing the resistance of welded joints from the aspect of corrosion

Figure 3 shows some of the characteristic forms of corrosion destruction of welded structures. For each form, there are procedures for assessing corrosion resistance as well as specific corrosion indicators [9].

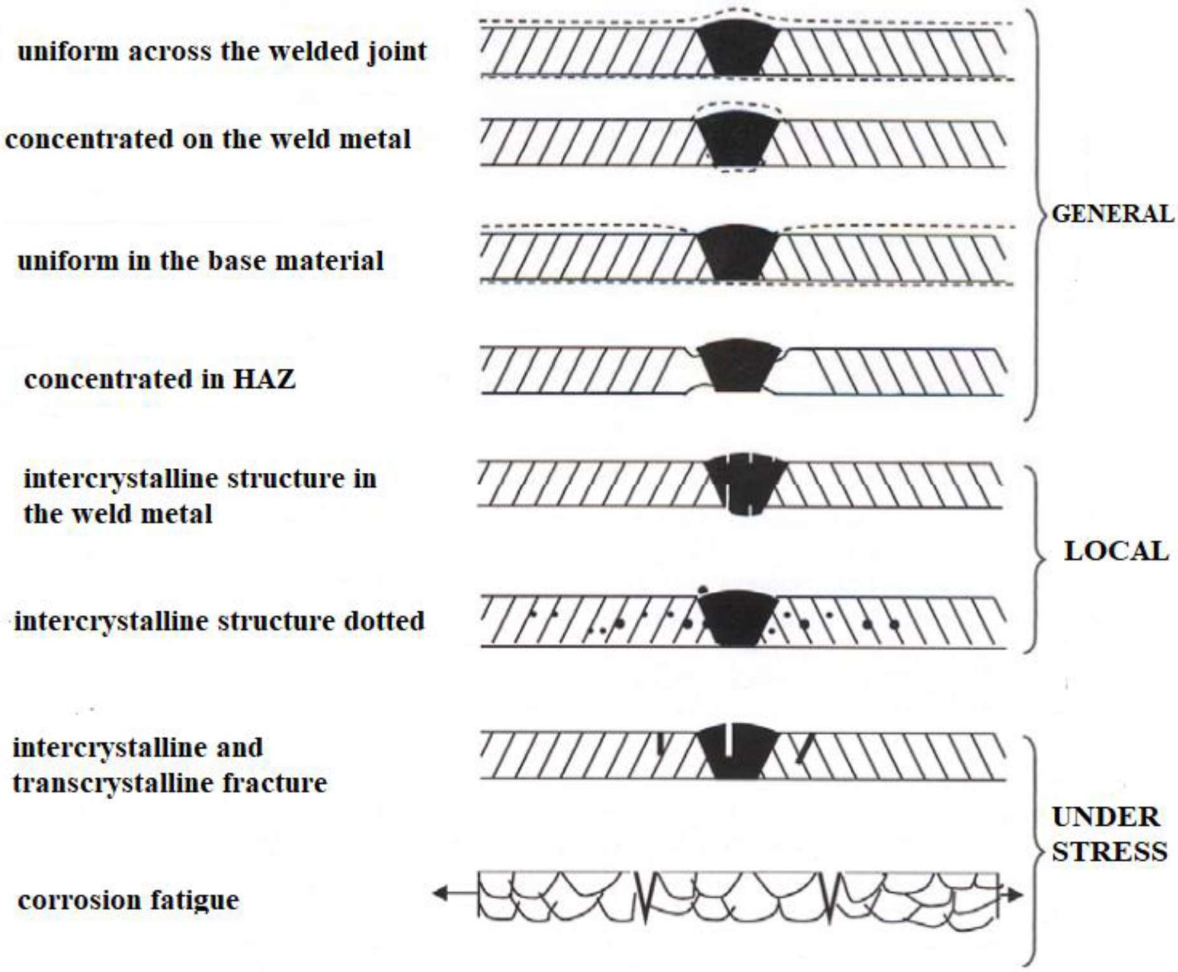

Figure 3. *Characteristic forms of corrosion destruction of welded structures [9,10]*

If the corrosion develops uniformly, the rate of destruction can be taken into account and the life of the structure can be determined in advance. This form of corrosion destruction is characteristic of most welded constructions made of structural steel in practice under ordinary conditions of exploitation, and refers to atmospheric corrosion, which mostly depends on meteorological conditions. it should be emphasized that it is very dangerous to concentrate general corrosion at the seam or in the heat-affected zone, which can lead to very quick destruction of the structure with relatively small mass losses.

Special forms of local corrosion are characteristic of welded joints of high-alloy steels and non-ferrous metal alloys. Spot corrosion is typical for electrochemically passive materials (chromium, aluminum, chrome-nickel steels).

Corrosion of welded joints due to the effect of stress is among the most dangerous in practice. During the hardening of the welded joint, high level residual stresses appear, which are often the cause of stress corrosion and corrosion fatigue. Due to stress, the speed of general metal corrosion increases in acidic environments, and very little in neutral ones. Stresses have little effect on general but increase local corrosion.

The resistance of welded structures against corrosion can be increased by various methods/procedures, divided into two methods [11]:

- reduction of chemical and structural inhomogeneity (choice of optimal composition and heat treatment of the base material before welding, selection of additional materials and construction of the welded joint with the aim of regulating the chemical composition of the material, regulation of the thermal cycle of welding and crystallization conditions, heat treatment after welding).

- improvement of the stress state (reduction of the stress value, regulation of the thermal cycle, no defects in the weld metal, removal of residual stresses).

Conclusion

Along with a brief review of the main divisions of corrosion in welded joints, the paper defines procedures for preventing corrosion of welded joints, by applying which we can ensure the integrity and life of welded structures. By reducing the inhomogeneity of the welded joint itself and less heat input in the welding zone, the service life of the welded structure is also extended and their reliability is increased. As a proposal for further research, it is necessary to emphasize the improvement of procedures for preventing corrosion and improving the resistance of welded joints to corrosion through the education of professional staff.

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