PROPERTIES OF CORROSIVE COATED COATINGS MULTI-GROOVE HARDFACING ON STAINLESS STEEL

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Abstract

Using the pad welding technique it is possible to regenerate machine parts or improve surface properties such as abrasion, corrosion and aging resistance. To ensure optimum processing conditions and economic efforts should be made, while providing a high deposition efficiency for the small amount of metal in the pad weld substrate. The pad welding process for the test subject should be carried out by preheating to evaporate the moisture and reduce the porosity of the weld. This treatment is required depending on the carbon equivalent. The article presents the results of corrosion tests of multi-groove pads made with the MIG method on a steel substrate. The samples were made of C45E steel. The additional material was a wire made of stainless steel with the factory name CASTOMAG 4554S. The results of previously performed tests allowed determining the optimal process parameters at which we obtain the smallest share of the base material in the padding. Steel samples were prepared and preheated to 300°C. The hardfacing process was carried out with constant parameters, i.e. current intensity, arc voltage, surfacing speed). Two protective gases were used to apply the additional material: CO_2 and argon. The samples were subjected to corrosion tests in two environments (3.5% sodium chloride solution and 0.001 sulfuric acid solution). The assessment of corrosive properties was made on the basis of constant current measurements (potentiodynamic method). The influence of shielding gas on corrosion properties was demonstrated based on the tests.

Keywords: corrosion, hardfacing, MIG, Taguchi method, seawater

1. Introduction

The wear of machine components takes place in all industries. Some parts stop functioning only because of lesser damage. Using the padding technique, it is possible to regenerate machine parts or improve the surface properties such as resistance to abrasion, corrosion, and aging [5]. The process of regeneration with the use of pad welding can be carried out using the same equipment that we use for welding. Additional metals and their alloys with the required properties in the form of wire, wire with powder, powder, or rod are selected for the additive, respectively. In order to ensure optimal technological and economic conditions, one should strive while ensuring high efficiency of the surfacing and a small share of the base metal in the padding. The surfacing process should be carried out using pre-heating in order to evaporate the moisture and reduce the porosity of the pad [6].

The action of aggressive, electrochemical interaction of sea/outboard water also affects the deterioration of working conditions and the destruction of machine components. Corrosion activity of seawater depends on its salinity, chemical composition, and temperature [3]. Corrosion protection of marine structures is achieved through the appropriate selection of materials with increased corrosion resistance and protective coatings. Corrosion of metals as a result of constant contact with seawater is of electrochemical nature.

The purpose of the work is to check the suitability of surfacing in the fight against corrosion in seawater. Pad welding was chosen due to the continuous development of welding techniques and their widespread use in marine constructions. Additionally, thanks to padding, we can apply

additional material other than native material, which is not possible in any application of additional coatings. The subject of the research is a sample of C45E steel, on which solid stainless steel wire was applied. Pad weld was made by semiautomatic welding method. The purpose of the surfacing was to increase the corrosion resistance, the strength of the material with the least amount of substrate material. After completion of the surfacing and preparation, the sample was subjected to corrosion tests. The purpose of the corrosion tests was to check the corrosion resistance of the pad. For this purpose, tests were carried out in two corrosive environments: sulfuric acid and seawater. The constant current method was used for the tests. The corrosion resistance of materials has been evaluated by testing using an impedance spectroscope.

The problem of corrosion in the marine environment is commonly described and whipping in literature, Polish and foreign language articles. Reports that the application of additional coatings reduces the value of the corrosion current density and increases the corrosion potential. The actual course of corrosion processes depends to a large extent on the additional material and the substrate material as well as the environment [2]. It showed a negative influence of the presence of iron on the padding surface. The formation of Fe_3O_4 oxide deteriorates the resistance of welders to corrosion and erosion [1]. In their research proved that welded, the smallest stainless steel sheet used in the tests undergoes the smallest corrosion damage and shows the highest resistance to corrosion in the spore 3.5% of sea salt [4].

2. Material and method

In the previous studies, the influence of particular welding parameters on the value of relative errors scattering was analysed using multiple variance analysis. The purpose of the quantitative assessment of the influence of arc welding parameters, i.e. the current I intensity and the v_l wire feed rate on the content of the substrate in the padding (CSM). A randomized, orthogonal plan of the experiment was taken into account, taking into account the trivalence of independent variables, predicting the performance of 9 experiments with five repetitions. The selection of the current during welding of the C45E steel with the additional material CastoMag 4554S was related to the short-circuit mode of transferring the liquid metal. Taking into account the current values changed in the range of 60-90 A and the wire feeding speed of 1.5-2.5 m/min, a plan of experiments was generated using the STATISTICA statistical program. On the basis of statistical analysis, it was found that the smallest CSM was obtained with the parameters: the padding process is carried out using the following parameters of the technological process $I = 60$ A, $v_l = 2.5$ m/min [8]. The samples for testing were made of a C45E flat bar with a thickness of 6 mm. Solid CastoMag solid wire, factory marked CastoMag4554S, was used for pad welding. The chemical composition according to the manufacturer contains chromium. nickel and manganese. The diameter of the wire is 1.2 mm. The samples were subjected to blasting or preheated to 100ºC. Then multi-groove pad were made. The welding process was carried out using the MIG method. The welding was carried out with the following parameters: arc voltage within 20 V, electrode wire outlet length 15 mm, pivot angle of the wire pushing, left-to-right pad welding direction, polarity on the positive wire, shielding gas flow rate 16 l/min. The first sample shielding gas was a mixture of 82% argon and 18% carbon dioxide – CORGON18. To perform a second sample used in the shielding gas – carbon dioxide. Both samples were made with the following pad welding parameters: current $I = 60$ A, wire feed speed $v_l = 2.5$ m/min and pad welding speed 2 mm/s. The MIG Mig c340 PRO MIG welder from ESAB was used to make the pads.

In order to assess the corrosion properties, a direct-current electrochemical method – polarization – was used. This is a classic method, well known and widely used. The measurement speed is significant compared to other test methods. Thanks to electrochemical polarization tests, we are able to estimate the instantaneous rate of corrosion as well as determine the nature of partial processes [7]:

$$j = j_{corr}\left[\left(1 - \frac{j_a}{j_{da}}\right)exp\left(\frac{2.3(E - E_{corr})}{b_a}\right) - \left(1 - \left|\frac{j_k}{j_{dk}}\right|\right)exp\left(\frac{-2.3(E - E_{corr})}{b_k}\right)\right]j =$$

$$j_{corr}\left[\left(1 - \frac{j_a}{j_{da}}\right)exp\left(\frac{2.3(E - E_{corr})}{b_a}\right) - \left(1 - \left|\frac{j_k}{j_{dk}}\right|\right)exp\left(\frac{-2.3(E - E_{corr})}{b_k}\right)\right], \tag{1}$$

where:

j – polarization current density (mA/cm^2),
j_{corr} – corrosion current density (mA/cm^2),
E – polarization potential (mV),
E_{corr} – corrosion potential (mV),
b_a – anode ratio Tafel (mV),
b_k – cathode Tafel (mV),
j_a – density of the partial current of the anodic reaction (mA/cm^2),
j_k – density of the partial current of the cathode reaction (A/cm^2),
j_{da} – density of the anodic limit current (diffusive) (A/cm^2),
j_{dk} – density of the anodic boundary current (diffusive) (mA/cm^2).

Polarization measurement was performed in a three-electrode system. A 1.2 cm^2 de-acetone sample, a platinum polarizing electrode and a reference electrode (calomel saturated) were placed in a vessel containing 500 ml of 3.5% NaCl solution (substitute seawater) at ambient temperature. Before taking measurements, the samples were subjected to one hour of exposure in the electrolyte. During the measurement, the electrolyte was mixed all the time. The polarization tests were performed with the ATLAS 0531 instrument. By registering the polarization curves j = f(E) in the range of ±500 mV from the corrosive potential. The potential speed in all cases was 10 mV/min. In order to determine the values of values characterizing the corrosion properties of the tested material, the computer program "Elfit − corrosion polarization data fitting program" was used, which counts parameters from equation (1). To assess the effect of padding on corrosion resistance of steel, the calculated values of corrosion current density and corrosive potential were used.
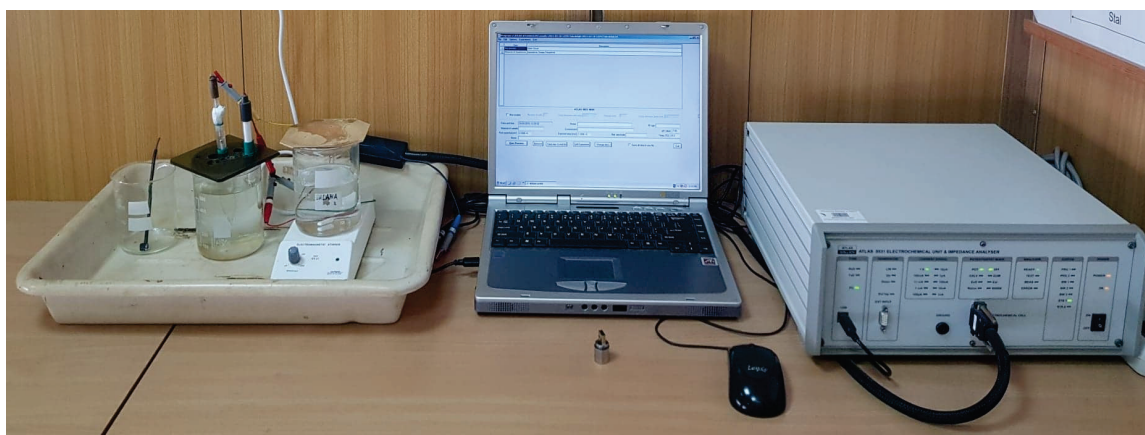

Fig. 1. A stand for corrosive tests

3. Results

Presented are the basics and specificity of electrochemical corrosion measurements and examples of their applications in corrosion practice. The measurement of metal potential in a corrosive environment enables, among others, control of electrochemical protection. Analysis of the current dependence on the potential of the metal allows estimation of the corrosion rate. The results of the tests carried out allowed obtaining the values of corrosion potential and corrosion current in a given environment. Both samples were made of stainless wire on a stainless substrate

with the same pad welding parameters. The first attempt was made in the carbon dioxide shield, the second sample made in the gas mixture shield – argon with carbon dioxide. The first sample shows worse corrosion properties. Tab. 1 presents the density values of the corrosive current j_{corr} and the corrosion potential E_{corr} calculated from individual measurements by the Elfit program on the basis of formula (1) for both corrosive environments.

Tab. 1. Characteristic of examined materials corrosion resistance by using polarization curves method

No	Environment	Shielding gas	E_{corr} [mV]	j_{corr} [μA/cm^2]	Shielding gas	E_{corr} [mV]	j_{corr} [μA/cm^2]
1	H$_2$SO$_4$	CO$_2$	-136.69	8.91	CORGON	-583.61	9.43
2			-122.70	8.85		-642.56	9.22
3			-269.18	8.83		-432.58	8.92
4	NaCl		-176.74	8.24		-763.15	2.17
5			-179.07	12.05		-698.15	2.13
6			-234.82	9.85		-704.36	2.77

Figures 2-5 show examples of polarization diagrams of pad welded stainless steel coatings obtained on C45E steel in an environment of 0.01 M H$_2$SO$_4$ and 3.5% NaCl.
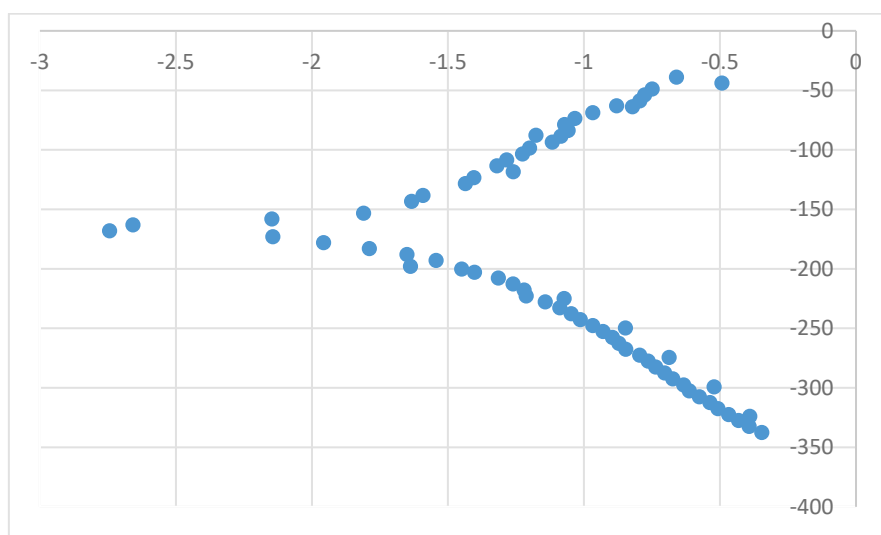

Fig. 2. Polarization curves of the tested samples in the seawater replacement environment sample 1
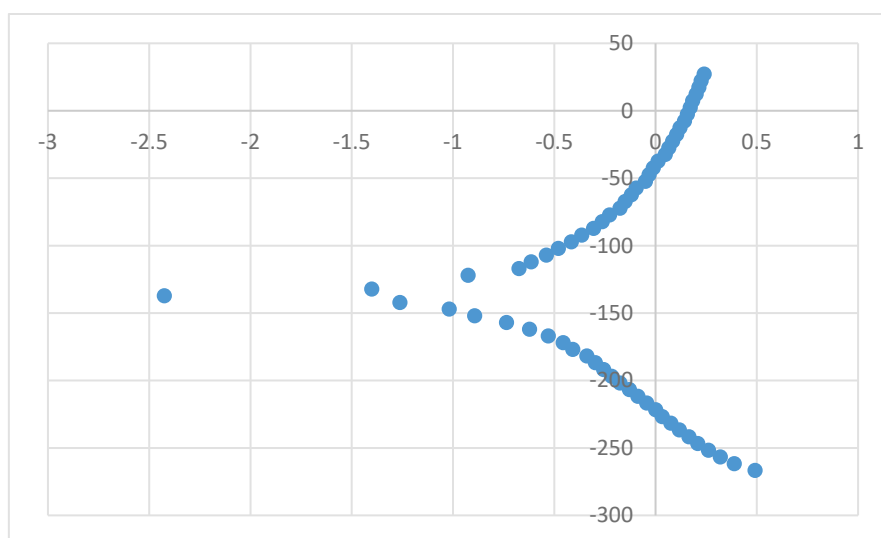

Fig. 3. Polarization curves of the tested samples in an environment of 0.01 M sulfuric acid sample 1
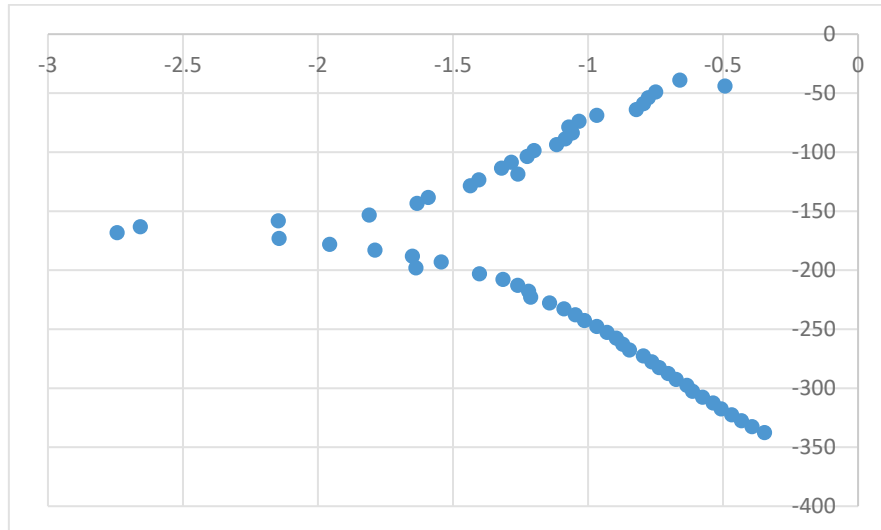
Fig. 4. Polarization curves of the tested samples in the seawater replacement environment sample 2
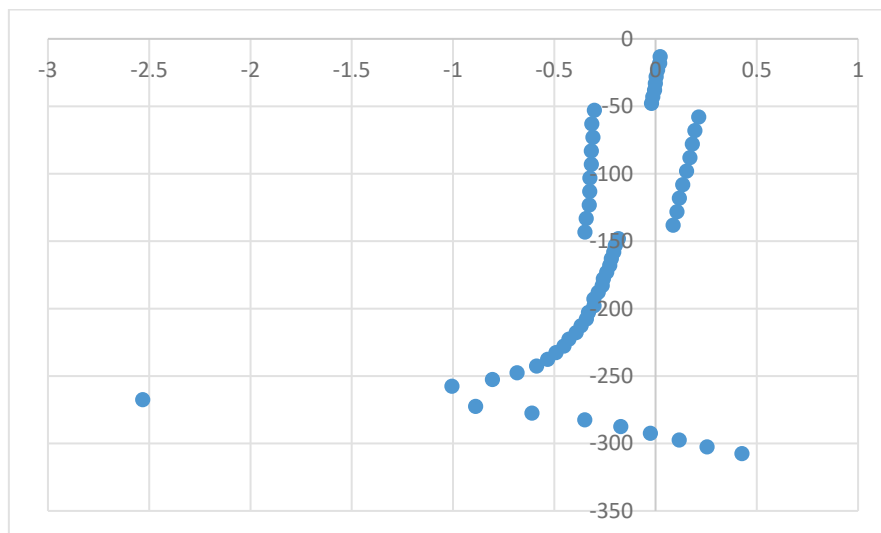

Fig. 5. Polarization curves of the tested samples in an environment of 0.01 M sulfuric acid sample 2

The analysis of the polarization graphs showed that in the environment of the sulfuric acid solution, corrosion proceeds under the control of activation, and in the environment of 3.5% NaCl solution, the diffusion constraints accompanying the reduction reactions are observed. Corrosion potential value for sample 1 – carbon dioxide shield in the marine environment is on average 176.191 mV, in an environment of sulfuric acid an average of 196.87 mV. The average value of the corrosive current for the marine environment is $8.87\,\mu A/cm^2$ for sulfuric acid $10.05\,\mu A/cm^2$. In the sample 2, the values of average corrosion potentials and currents are higher and are respectively: for the marine environment, corrosion potential 552.92 mV and corrosion current $9.19\,\mu A/cm^2$, while for sulfuric acid the potential is 721.89 mV and corrosion current $2.36\,\mu A/cm^2$. The higher values of the corrosion potential of paddings, made in the argon-carbon dioxide blend coating, show higher corrosion resistance. The lowering of the corrosive current indicates a slower corrosion process in the second sample in the seawater environment.

4. Conclusions

The article is an introduction to a series of corrosion tests for the seawater environment and its impact on changes on the surface of machine parts and equipment. The composition of the

shielding gas affects the physical properties of the welding arc, metal transfer in the arc, spattering depth, penetration depth, and pad weld formation, as well as joint properties. During measurements of MAG welded semiautomatic welds on a steel substrate, it has been shown that pure carbon dioxide as shielding gas worsens the corrosive properties of padding. The coatings obtained have a satisfactory corrosion resistance. Density of corrosive current in the seawater replacement environment occurs in the case of sample 1 – 8.87 $\mu A/cm^2$, in the sample 2 – 9.19 $\mu A/cm^2$. However, for 0.01 M sulfuric acid in the sample 1 – 10.05 $\mu A/cm^2$, sample 2 – 2.36 $\mu A/cm^2$, respectively. Corrosion potential for the seawater environment in the first sample is 196.87 mV, in the second 721.89 mV. However, for 0.01 M sulfuric acid in the first sample – 176.19 mV, in the second – 721.89 mV. Analysis of the results showed that in the sea water environment the corrosion process is slower in the case of 2 samples.

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