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Effect Of Heat Input On Pitting Corrosion Resistance Of Super Duplex Stainless Steel Weld Claddings

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Abstract: One of the localized forms of attack that results in relatively rapid penetration at small discrete areas is called Pitting. The evaluation of pitting susceptibility of materials has been done by using the critical pitting potential, E_{pit}. Polarization is a very important corrosion parameter by which we can make statements about corrosion rates. In the present work the pitting corrosion behavior of FC 2507 Super duplex Stainless steel weld claddings in NaCl solution were investigated in terms of different heat input conditions by using potentiodynamic polarization measurement. The specimen has the best corrosion characteristics with low heat input, which is the result for the lack of deleterious phases such as sigma and Cr_2N and balanced ferrite-austenite proportion.

Keywords: Flux Cored Arc Welding, Super Duplex Stainless Steel, Pitting Corrosion, Heat input.

Introduction

Super duplex stainless steel has a ferritic-austenitic microstructure. Nowadays, it is used in various applications in refining and petrochemical industry, where high corrosion resistance and mechanical properties required.

However, the properties of the steel like low hardness, wear resistance to be improved, if it is used in highly stressed tribological systems (Bielawski et al., 2010). Duplex stainless steels (DSSs) with equal volume fractions of ferrite and austenite phases are increasingly used for various applications in fuel gas desulphurization (FGD) and desalination facilities due to excellent corrosion resistance and relatively low cost of raw material compared with the cost of high Ni and Mo containing super austenite stainless steels[1,3,4,5,6,]. Duplex stainless steel owes its considerable corrosion resistance to alloying elements such as Cr, Mo and N. However, the corrosion resistance of the stainless steel is highly dependent on its microstructure which is affected by heat treatment. During the process of welding, this alloy is exposed to high temperature which causes the metallurgical changes.

Perteneder et al., investigated the corrosion resistance of super duplex stainless steel in chloride in contrasting environments through a micro-electrochemical method[2]. The pitting resistance of the stainless steel is determined either by pitting potential (Epit) or critical pitting temperature (CPT) values[7-11]. In this manner, the better resistance to pitting corrosion of the stainless steel is obtained with higher values of the pitting potential or critical pitting temperature. The corresponding values can be determined by using any of the following electrochemical methods like potentiodynamic, potentiostatic and galvanostatic polarization tests which accelerate pitting corrosion[12-16]. Although, it is noted that the pitting potential is generally stochastic and it cannot be considered as a unique value[17-20]. The pitting potential is dependent on the environmental parameters, alloy composition, scan rate, heat treatment, etc [21-24].

The main objective of this work is to investigate the effect of heat input of flux cored welding process on corrosion resistance in the FC 2507 super duplex stainless steel.

Potentiodynamic Polarization Test

The detailed procedure of weld cladding experiment is discussed in Balan et al[25]. Four clad specimens were prepared by using the same procedure (based on high, medium, low and optimal heat inputs) based on welding process parameters and subjected to the following polarization test. The potentiodynamic polarization technique is a method of electrochemical corrosion test for finding pitting corrosion resistance as per the ASTM G5 standards. The heat input is calculated from the formula

$$Q = (60VI/1000S)X($$

The experimental setup (Fig. 1) consists of a Versa STAT MC Potentiostatic instrument with three-electrode configurations. The working electrode, houses the clad specimen (FC2507 super duplex stainless steel clad surface), second one houses the auxiliary electrode, AE, and reference electrode houses platinum gauze. The surface of the test specimens is wet polished with 600 grit SiC paper as per ASTM G5 and rinsed thoroughly with distilled water. The specimen is placed in the beaker in such a way that the polished surface of the clad portion is exposed to the test solution. The beaker is filled with 3.5% NaCl solution and all the tests are conducted at room temperature, 28±2°C. All the three electrodes are connected to corrosion measuring instrument through the leads provided in the flat cell. During the polarization study, the scan rate is 0.01V sec^{-1}.

From the polarization test the I_{corr}, E_{pit} and E_{corr} are measured continuously by using commercial data acquisition software provided with the instrument. The values of E_{pit} are determined from the polarization curves. Table 1 summarizes the electrochemical corrosion parameters such as corrosion potential (E_{corr}), corrosion current density (I_{corr}), and pitting potential (E_{pit}). Figure 2 shows the potentiodynamic polarization curve for different heat inputs like low, medium, high and optimum.

Figure 1: Experimental setup potentiodynamic polarization techniques

Table 1: Results of electrochemical corrosion test

Test observations	**Low heat input specimen**	**Medium heat input specimen**	**High heat input specimen**	**Optimum heat input specimen**
Heat Input (kJ/mm)	0.6675	0.93429	1.19	1.02
E_{corr} (mV)	-559.275	-460.97	-438.501	-455.91
E_{pit} (V)	1.016	1.074	1.128	1.09
I_{corr} (μA)	-453.93	-93.54	-254.55	-.206.7

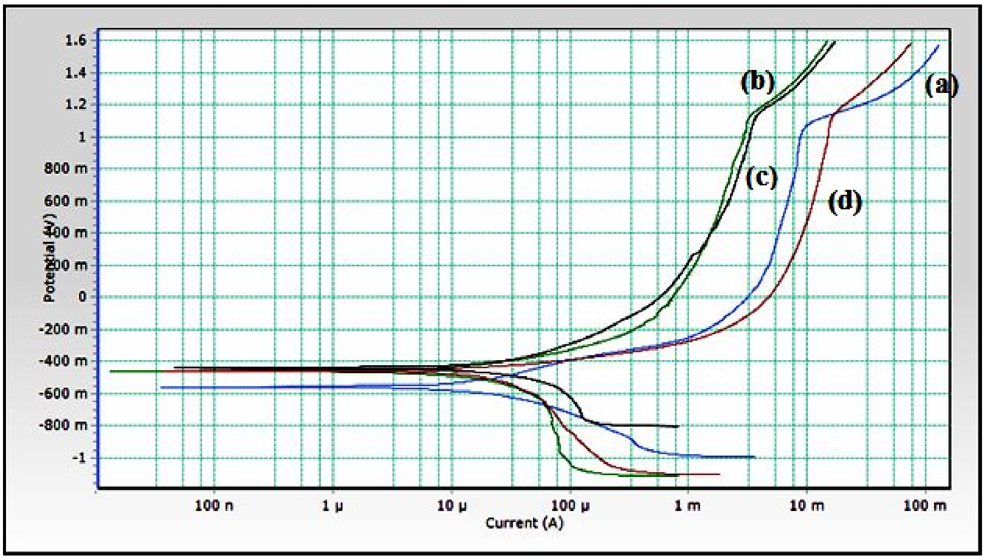

Figure 2: Potentiodynamic polarization curves of flux cored welded FC 2507 super duplex stainless steel in 3.5% NaCl solution (a) Low heat input (0.6675 kJ/mm), (b) Medium heat input (0.93429 kJ/mm) (c) High heat input (1.19 kJ/mm) and (d) Optimum heat input (1.02 kJ/mm).

Results and Discussion

A typical anodic polarization behavior of a stainless steel in a NaCl solution consists of active dissolution, passivity, and a rapid increase in the current density due to pitting. In Fig. 2 some current density spikes are observed at potentials below E_{pit}. Due to the occurrence of meta-stable pits and are explained by the consecutive formation and repassivation. Comparing the four curves together, the frequency and magnitudes of the spikes appear to increase with the potential. This transpassive dissolution of type FC 2507 super duplex stainless steel is due to the oxidative dissolution of Cr oxide, which is observed in solutions with no chloride ions.

From Table 1, it is found that cladding produced at low heat input and optimum heat input conditions have lower corrosion rates than that of other claddings in NaCl solution. The corrosion rate and heat input are inversely proportional to each other. The corrosion rate decreases when heat input increases. The increase in pitting corrosion resistance during the lower heat input values is attributed to its finer microstructure due to faster cooling rates. The effect of heat input on pitting corrosion resistance of flux cored welded FC 2507 super duplex stainless steel, it could be said that; as the heat input to cladding increases, the corrosion rate increases. It is observed that when the heat input increases the pitting potential decreases, thereby decreasing the pitting resistance.

Conclusions

On the effect of process parameters of flux cored welding process on pitting potential and corrosion rate of the FC 2507 super duplex stainless steel. The following are the salient conclusions.

- The effect that substrate polarization in FC 2507 super duplex stainless steel surfaces produces on the anodic dissolution of the metallic material has been explored. The controlled modification of acidity and chloride ion concentration in the aqueous solution facilitated the on the set of anodic local dissolution to be observed.
- All welds of FC 2507 super duplex stainless steel exhibited passivity in 3.5% NaCl solution, but their pitting resistance deteriorated as evidenced by lower pitting potentials and higher corrosion current densities compared with those of the various heat input parameters and optimized.
- The heat input to cladding increases, the corrosion resistance decreases. It is observed that when the heat input increases the pitting potential decreases, thereby decreasing the pitting resistance.

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