CORROSION CHARACTERISTICS OF COATING TYPE 309L STAINLESS STEEL PREPARED BY WELD OVERLAY

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Abstract. *The electrochemical behavior of stainless steel AISI 309L coatings deposited by weld overlay was studied. Two different conditions from welding were selected and the properties of the resulting coatings were investigated in the highly aggressive solutions of H_2SO_4 (0,5 M) + KSCN (0,01 M) and H_2SO_4 (4,0M) at 25 ^0C. Different electrochemical methods such as open circuit potential measurements,* `double loop electrochemical potentiodynamic reactivation (DLEPR)` *and electrochemical impedance spectroscopy (EIS) were used. Morphology of the deposit was examined using a optical microscopy. The results showed that sensitization process was not verified for both samples, but the diagrams of impedance electrochemistry presented differences among them polarization resistance.*

Keywords: *Stainless steel, sensitization, corrosion, impedance.*

1. Introduction

The use of coatings of stainless steel, obtained by weld overlay, in equipment submitted to the high chemical aggressiveness is an option for the industry of the petroleum, as much of the economical point of view as for the good mechanical properties and high resistance to the corrosion, presented by the this deposit (Cardoso Filho et al., 2004 and Silva et al., 2003). This covering technique consists of the modification of the surface providing the deposition of an addition metal in a substratum. As example, the pressure vases or reactors are had that are covered internally by this technique, using stainless steels to improve the corrosion resistance.

It is known that during the welding process, due to the cycle thermal used, the material can have modifications in structural and mechanical characteristics, in other words, during and after the welding process the stainless steels can happen alterations in characteristics mechanical and chemical (Dias Lopes, 1993). Specified temperature intervals can be developed sensitization process, which consists of carbide precipitation at grain boundaries and chromium depletion in adjacent regions, making the material susceptible to intergranular corrosion (Sedricks, 1996 and Wolynec, 2003).

They are still few the studies as for the corrosion involving these coatings, however, researches were initiate in the sense of determining the effect of the composition of the deposit, `microstructure` and mechanical properties in the resistance to the corrosion. Some works study the effects of the structure on the resistance to the corrosion, where is told varied structural forms, in varied types of processes, such as conventional welding, methods of coverings (Park et al., 1998 and Seré et al., 1999) and superficial modification for laser (Damborenea, 1999 and Watkins, 1997). The differences among components of the microstructure phases, such as precipitate or located concentrations, can influence in the behavior of the resistance to the corrosion. (Song, 1999 and Osório, 2004)

The aim of the present study is to investigate the corrosion behavior of stainless steel 309L coatings deposited by weld overlay by means of electrochemical methods, including open circuit potential measurements, double loop electrochemical potentiodynamic reactivation (DLEPR) and electrochemical impedance spectroscopy (EIS). In the study presented here, the morphology of the coatings was examined using a optical microscopy.

2. Experimental method

2.1. Materials

The samples were made manual-arc-metal-welding by the deposition (weld overlay) of the stainless steel 309L in a sheet of stainless steel 304 with dimensions of 200 x 90 x 5 mm, and is shown schematically in Figure 1. The weld was then sectioned ($1cm^2$) to provide material for electrochemical test. Samples specifications of the stainless steel AISI 309L are shown in the Table 1.
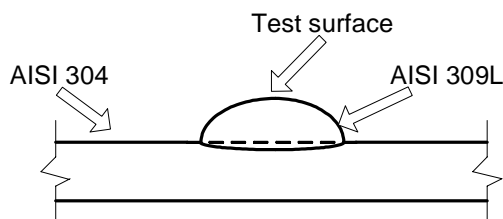

Figure 1. Schematic of the traverse section of deposit

Two conditions different from welding were selected being observed the variation obtained in the thermal contribution. The welding parameters and the chemical composition of the steel 309L are presented in the tables 1 and 2 respectively.

Table 1. Deposits characteristics of the stainless steel AISI 309L

Sample	Welding speed (m/min)	Current average (A)	Time of pick (ms)	Current of pick (A)	Time of base (ms)	Current of base (A)	Effective Transport Thermal (KJ/mm)
CP – 05	8,5	266	2,00	429	3,6	177	1,3
CP – 07	6,0	217	1,5	486	6,5	155	0,8

Table 2. Chemical composition of the stainless steel (wt%)

Material	C	Mn	Si	Cr	Ni	P	S	Mo	Se
309L	0,2	2,0	1,0	22,0 – 24,0	12,0 – 15,0	0,045	0,03	0 – 0,6	0,15

2.2. Electrochemical measurements

All solutions were prepared with water distilled and reagent grade chemicals. The solutions of the inorganic acids (25^0C) used in electrochemical measurements of DLEPR and EIS were H_2SO_4 (0,5 M) + KSCN (0,01 M) and H_2SO_4 (4,0 M) respectively. A three electrode cell was used for electrochemical measurements. The counter electrode was platinum and the reference was a saturated calomel electrode (SCE). The exposed area of the working electrodes was $1cm^2$, and it was constructed using ASTM A 312 TP321 samples embedded in epoxy resin. An GAMRY potentiostat \ galvanostat model 750 was used to measure and record the electrochemical results of DC and AC. Electrochemical impedance measurements were carried out at open circuit potential with an amplitude of 10mV and a frequency range of 1KHz and 3mHz.

2.3. Metallographic tests

Weld microstructure was examined by analyzer of images (Leica). Before, specimen surface was polished to 1000 SiC abrasive paper, washed with distilled water and ethanol, dried and then exposed to Glicerégia reagent (HNO_3 10%; CH_3COOH 10%; HCl 15%; $C_3H_5(OH)_3$ 5%).

3.   Experimental results and discussion

3.1. Open circuit potential

Figure 2 shows the variation with time of the corrosion potential (E_c – V, SCE) for the steel AlSl 309L. The sample CP-05 showed initial potentials relatively more positive (E_C > -0,5V) and became steady-stable with the time and it can be seen that E_c is quickly established around –0,50 V to CP-07. No visible pit corrosion was observed in both samples.
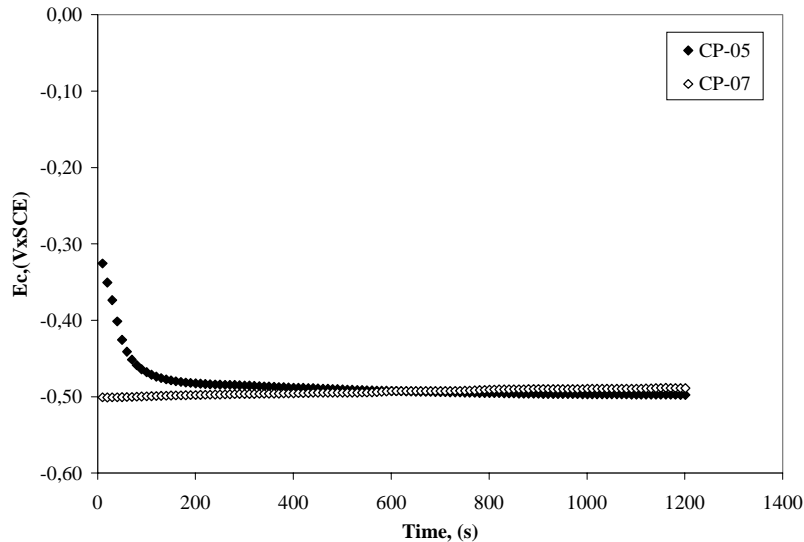

Figure 2. Variation of the corrosion potential (E_c) with time in H_2SO_4 (0,5 M) + KSCN (0,01 M).

3.2. Double loop electrochemical potentiodynamic reactivation (DLEPR)

The experiments were initiated after nearly steady-state *(*E_c) had developed (about 10 min.). The sensitization intensity was evaluated from the ratio *Ir* /*I*a, where *Ia* is the peak current of the anodic scan and *Ir* is the peak current in the reversed scan. The curves in figures 3 and 4, repeated in twice, shown a good reproduction and absence of *Ir* indicated that a low degree of sensitization existed.
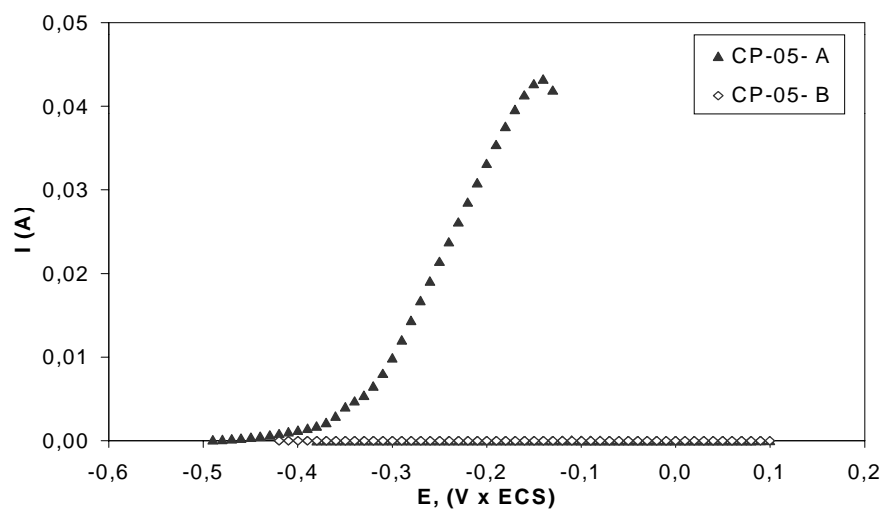

Figure 3. DLEPR recorded at sample CP-05 in H_2SO_4 (0,5 M) + KSCN (0,01 M).
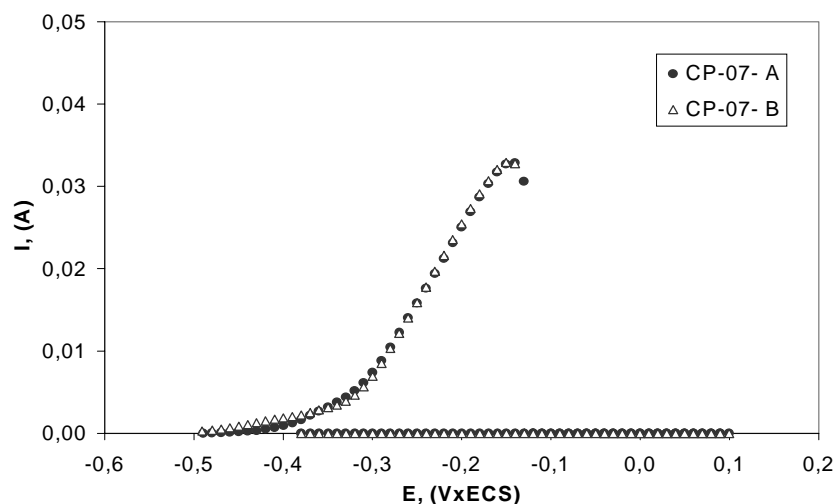
Figure 4. DLEPR recorded at sample CP-07 in H_2SO_4 (0,5 M) + KSCN (0,01 M).

3.3. Electrochemical impedance spectroscopy (EIS)

All measurements of EIS were performed starting from the corrosion potential (E_c). Figure 5 shows capacitive loop at high frequencies, followed by inductive loop at low frequencies and to both samples (CP-5 and CP-7) the same behavior is verified.
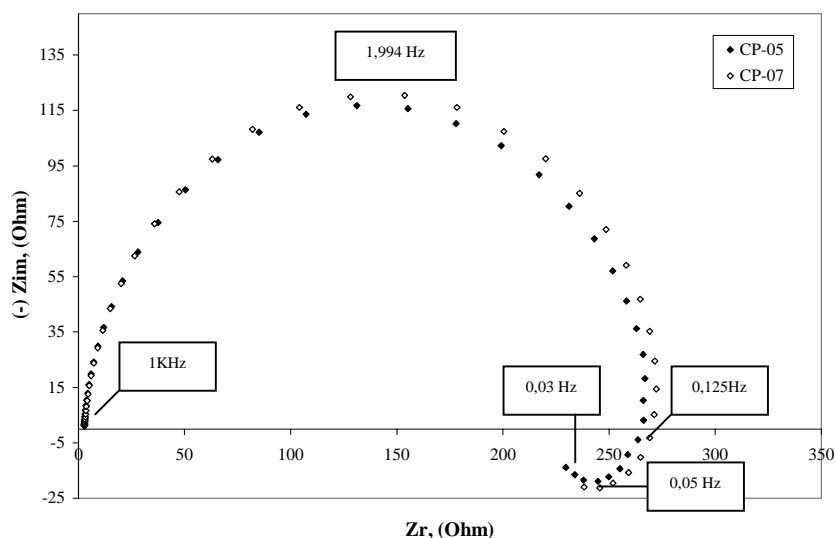

Figure 5. Nyquist diagrams obtained in H_2SO_4 (0,5 M) + KSCN (0,01 M) to samples CP-05 and CP – 07.

In the whole frequency spectrum studied (1KHz - 0,03Hz) a significant similarity is observed in form and in size for both diagrams. The results of impedance electrochemistry showed in Figure 5 are in agreement with those obtained in the DLEPR.

A further aim of this work was to verify the electrochemical behavior of samples investigated in a environment still more aggressive (H_2SO_4 4,0 M – 25^{0}C). The Figure 6 showed a similar results verified in Figure 5 and a capacitive loop at high frequencies, followed by inductive loop at low frequencies are observed again. On the other hand, the size of both diagrams is about twenty times smaller then observed in Figure 5 and this can be understood as a increase in the corrosion rate of samples in H_2SO_4 (4,0 M). However, the small difference among the diagrams of the Figure 6, corresponding the samples CP-05 and CP-07, suggests that it is not possible to verify difference of the corrosion process among the same ones.
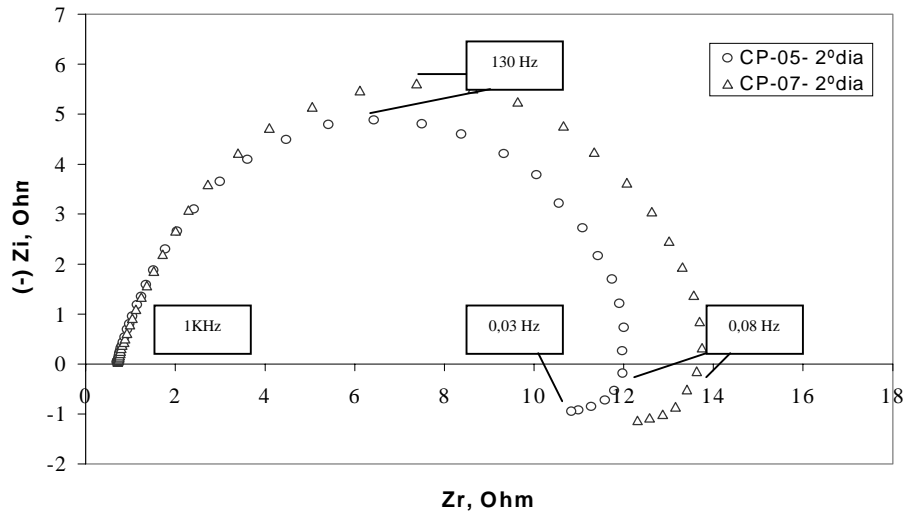
Figure 6. Nyquist diagrams obtained in H_2SO_4 (4,0 M) to samples CP-05 and CP – 07.

3.4. Metallurgical characterization

Figures 7 and 8 shows the microstructures of the samples CP-05 and CP-07 respectively. Metallurgical examination revealed that both deposits did not present sign of sensitization and white areas are primary regions of austenite and darker areas are ferrite. The samples obtained with different effective transport thermal (see Table 1), provided a more refined microstructure for the sample CP-07 (0,8 KJ / mm).

The results of metallurgical analysis in CP-05 and CP-07, are in agreement with the electrochemical results (DC and AC) presented in this work.
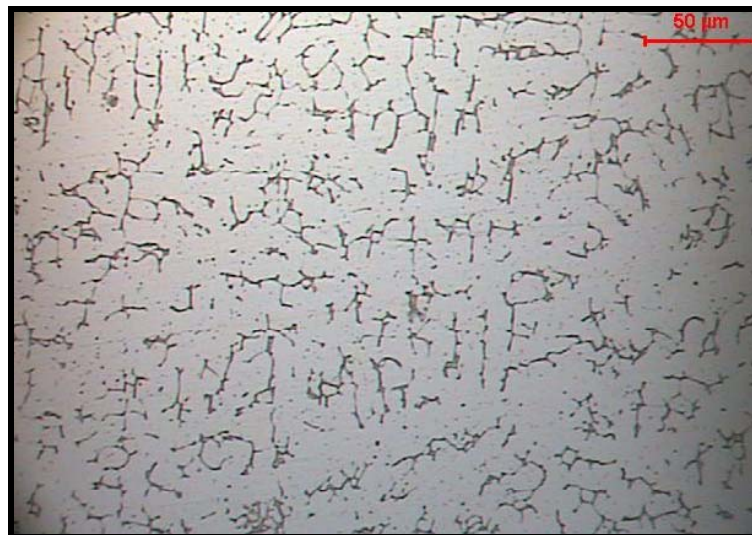

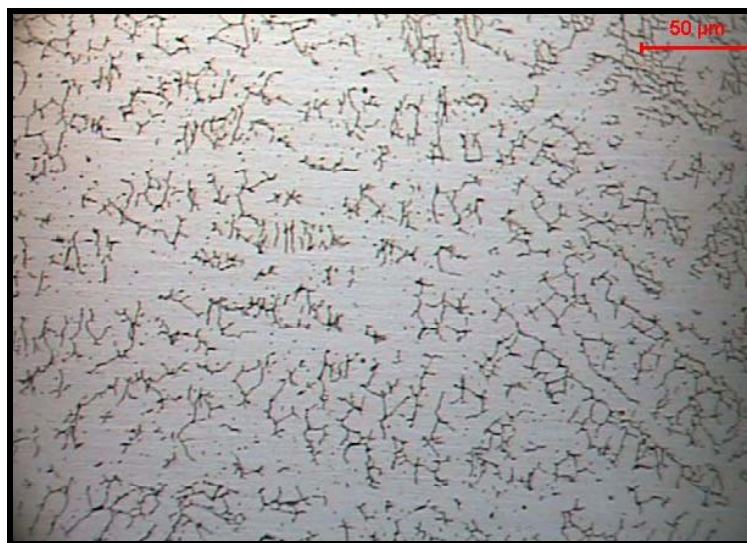Figure 7. Optical micrograph of sample CP-05 (X 500).

Figure 8. Optical micrograph of sample CP- 07 (X 500).

4. Conclusions

The results of double loop electrochemical potentiodynamic (DLEPR) reactivation showed an absence of sensitization in two of stainless steel AISI 309L coatings deposited by weld overlay and obtained with different values of different effective transport thermal (CP-05, 1.3 KJ / mm and CP-07, 0.8 KJ / mm).

The results of electrochemical impedance spectroscopy (EIS) showed the same diagrams for samples CP-05 and CP-07 in H_2SO_4 (0.5 M) + KSCN (0.01 M), what confirms the DLEPR results. In solution of H_2SO_4 (4.0 M) the EIS technique showed that the corrosion process is very accelerated for both sample.

Optical micrograph showed an absence of sensitization in two of stainless steel AISI 309L coatings deposited by weld overlay and more refined microstructure for the sample CP-07 (0.8 KJ / mm).

5. Acknowledgments

6. References

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