Corrosion resistance of welded joints of Lean Duplex 2304 stainless steel

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Introduction

With the increase in oil exploration in Brazil and worldwide, the need for materials corrosion resistant and weldable has increased. Seeking to address this question of corrosion resistance, combined with good mechanical properties after welding, capable of withstanding the loads existing in these new conditions, the duplex stainless steel appeared as an excellent option. The duplex stainless steels have a microstructure of ferrite and austenite mixed at a ratio of approximately 50% for both steps [1]. The two-phase microstructure combines the beneficial effects of the phases and allows the steel has high strength and toughness even at low temperatures. The high strength steel makes possible the use of thinner size in the equipment, achieving economy of material [2, 3].

The search for alloys with mixed microstructure, but lower cost led to the development of lean duplex stainless steels. In this material, the nickel is partly replaced with austenite forming elements such as manganese and nitrogen, and the molybdenum content is reduced. The Lean duplex steels used in this study has nominal composition comprising 23% chromium, 4% nickel and molybdenum additions (up to 0.6%), nitrogen and manganese (mass content). All fusion welding processes can be used in Lean duplex stainless steels, provided that adequate welding procedures are followed. High fractions of austenite in the weld metal, which promotes a way of solidifying mixture (ferrite and austenite), may result in an increase of segregation, while high fractions of ferrite can cause precipitation of chromium nitride [4,5,6] .

Stainless steels have a tendency of formation of sensitization when subjected to conditions of work at temperatures above 600°C. The precipitation of chromium carbides occurs in the grain boundaries that become depleted in chromium and more susceptible to intergranular and pitting corrosion [7, 8, 3, 9]. For these reasons, control of chemical composition and of the thermal cycle of welding is so important. The aim of this paper is to provide the necessary information to the market over the welding of Lean duplex stainless steels through the mechanical characterization and the corrosion resistance evaluation of welded joints. Welds were made for these in-groove plates using the SMAW, GMAW, FCAW welding processes. Then welded joints were subjected to mechanical and electrochemical tests.

Experimental

The material used in this study (S32304 steel) was provided by Aperam South America. The specimens were welded with SMAW, GTAW and FCAW processes. A base ceramic backing of the weld and gas protection (argon, and argon and nitrogen 2%) were used. The cross section of the weld was polished with sandpaper and sanded silicon carbide (SiC) with a particle size 220, 320, 400, 600, 800, 1000, 1200, and1500, using water as coolant solution and, subsequently, polished with diamond pastes, the particle size of 9, 6, 3, 1 and ¼ micrometers.

The equipment used in electrochemical experiments was the Versastat3 Princeton Applied Research potentiostat. The electrochemical experiments were performed in an aqueous solution of 3.5% w/v NaCl, using reference electrode of Ag/AgCl and platinum as the counter electrode. The open circuit potential was determined after 3 hours of immersion. The potential amplitude was of 10mV in relation to the corrosion potential; a frequency range of 100kHz to 10mHz was employed and were 10 readings per decade of frequency.

Results and Discussion

Figure 1 shows the polarization resistance values for welded samples by using the SMAW, GMAW and FCAW techniques and consumables with variable composition of the elements chromium and nickel. For the root of weld, the polarization resistance (Rp) was lower than for the top of weld. The root of weld has a highest dilution of the base metal where there is a greater contribution of metal chemical composition in the root bases compared to the top of the weld.

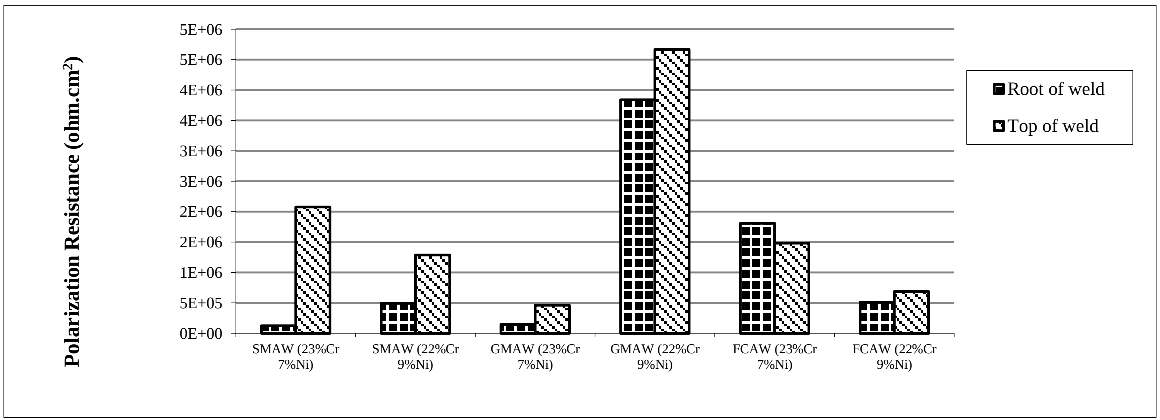

Figure 1: Polarization resistance of transversal section of welded samples.

Figures 2 and 3 showed Nyquist diagrams for the root and top of weld. The welded sample GMAW 23%Cr 7%Ni showed an anomalous result due to a greater dilution on surface and a major contribution of the base metal.

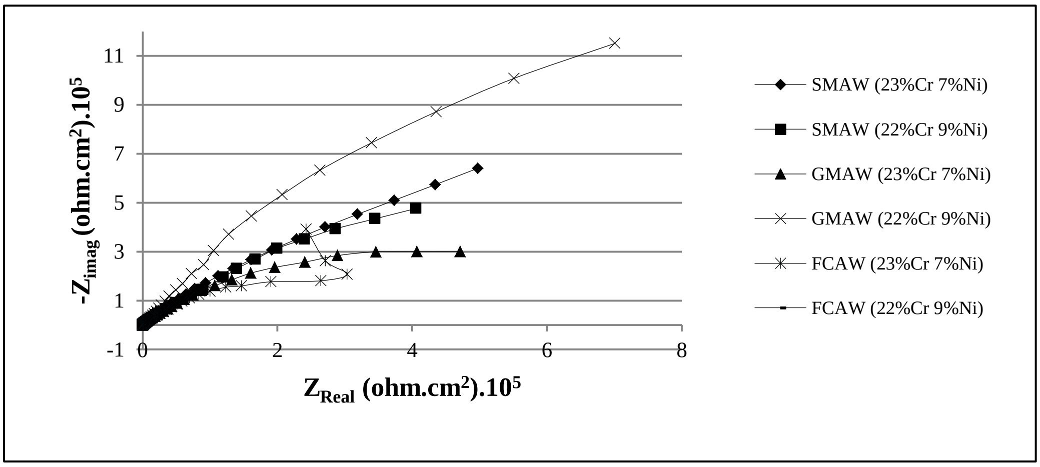

Figure 2: Nyquist diagrams of transversal section of welded samples (top of weld).

Nyquist diagrams showed one capacitive arc. The use of ceramic backing can generate the lower values of polarization resistance in the root of weld. The melted material can react with oxygen producing reactions with chromium and nickel, weaken the root structure. The top of weld was protected by protection gas of argon, and argon with nitrogen 2%.

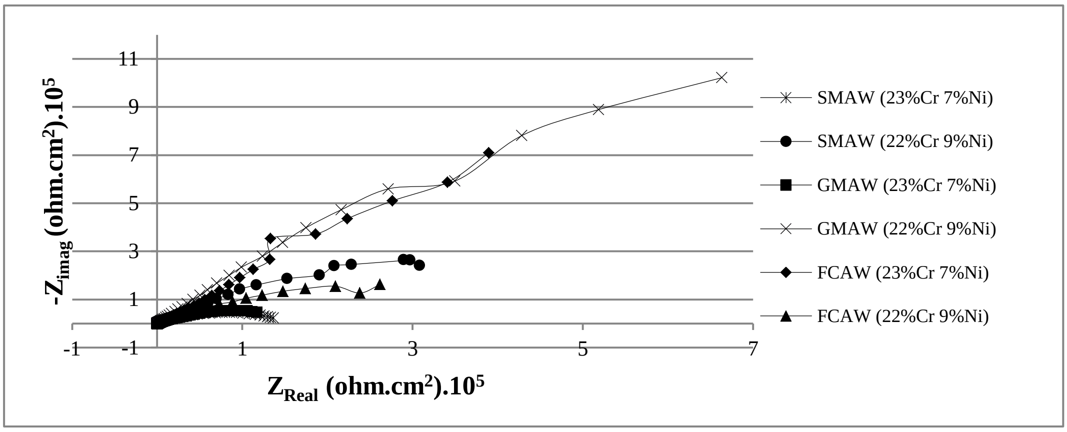

Figure 3: Nyquist diagram of transversal section of welded samples (root of weld).

The sample welded using the GMAW process and the 22%Cr and 9%Ni electrode showed the highest polarization resistance. This sample had a highest toughness and a lower content of inclusions in the molten zone [10].

Conclusions

The root of weld showed a lower polarization resistance than the top of weld in Lean duplex welded samples. The samples welded by using the GMAW process showed a higher polarization resistance than the samples welded by using SMAW and FCAW.

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