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Effect of pulsed and spray multipass MAG welding on the corrosion resistance of 316L stainless steel.

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Abstract

In this study, the corrosion resistance of the ASTM A-240 TP 316L stainless steel submitted to a multipass metal active gas (MAG) welding was investigated. The stainless steel was MAG welded in two modes of metal transfer: pulsed and spray with protective gas (98% Argon and 2% Oxygen). The microstructure and corrosion resistance of base metal (BM) and fusion-zone (FZ) were characterized by scanning electron microscopy (SEM), ferritescope test, and anodic polarization tests. All zones were passive in the test solution (NaCl 1.0 mol L^{-1}) followed by passive film breakdown with a potential increase. The BM showed a higher tendency to film breakdown comparatively to the FZ. The FZ in the spray process presented a passive film with higher breakdown resistance than the pulsed FZ.

Keywords: 316L stainless steel, localized corrosion, metal active gas welding (MAG).

Introduction

316L stainless steels are widely used in severe corrosion environments where corrosion resistance is required. However, it is well known that high temperatures, commonly archived in welding processes, affects the microstructure of stainless steels and, consequently, reduces corrosion resistance of the joint [1,2]. Pulsed MAG is a controlled welding process that improves the quality of welding in comparison with spray MAG welding. It was developed to weld at medium currents, below the spray transition current [3,4]. In this study, the influence of both spray and pulsed mass transfer mode were analyzed in an ASTM A-240 TP 316L stainless steel MAG welded.

Methodology

ASTM A-240 TP 316L stainless steel with 15.80 mm (5/8") thickness was automated multipass welded in the flat position (1G). Compositions of base metal and filler metal are shown in Table 1. 316L was MAG welded in two modes of metal transfer: pulsed and spray with a protective gas (98% Argon and 2% Oxygen). The percentage of delta ferrite was determined using the ferritescope test.

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Table 1. Chemical composition of base metal 316L stainless steel and the filler metal ER 316L.

	C	Cr	Ni	Mo	Mn	Si	P	S	Cu
316L	0.02	18.33	8.40	2.10	1.25	0.45	0.030	0.001	0.09
ER 316L	0.02	18.88	11.3	2.6	1.70	0.70	0.023	0.015	0.06

The corrosion resistance of the welded samples was evaluated by anodic polarization tests in 1 mol L^{-1} NaCl solution at room temperature. The open circuit potential (OCP) and potentiodynamic polarization curves were performed applying the conventional three-electrode arrangement. Platinum wire was used as the counter electrode, a Ag/AgCl electrode as reference and the welded samples as the working electrodes. For the potentiodynamic polarization curves, the potential range was from E = −0.3 V_{SCE} below the open circuit potential up break potential at a scan rate of 1 mV s^{-1}.

Results and discussion

The micrographs in Figure 1 (a) show the difference between the BM and FZs and the XRD diffractograms (Figure 1(b)) confirm the presence of delta ferrite in all regions. Table 2 presents the % of ferrite for the BM and FZs.

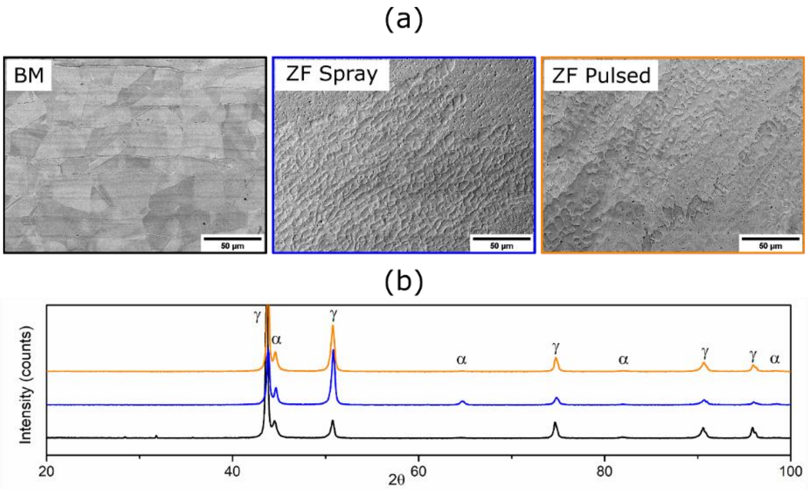

Figure 1. SEM images (a) and X-ray diffraction (b) of AISI 316L stainless steel base metal, spray fusion zone and pulsed fusion zone.

Table 2. Magnetic properties of BM and FZs of spray or pulsed methods.

Method	Spray		Pulsed	
Zone	BM	FZ	BM	FZ
% Ferrite	(2.9 ± 0.7)	(9.4 ± 1.6)	(1.7 ± 0.5)	(9.9 ± 0.9)

Results show significantly different properties between the BM and the FZ of the two modes of metal transfer. Despite the similarities in their chemical composition, FZ presents higher % of ferrite compared to BM.

Passive film resistances to breakdown potential when exposed to the test solution (1.0 mol L^{-1} NaCl) were compared (Figure 2) and the results showed that this resistance increased in the following order, BM, FZ by spray and FZ by pulsed methods.

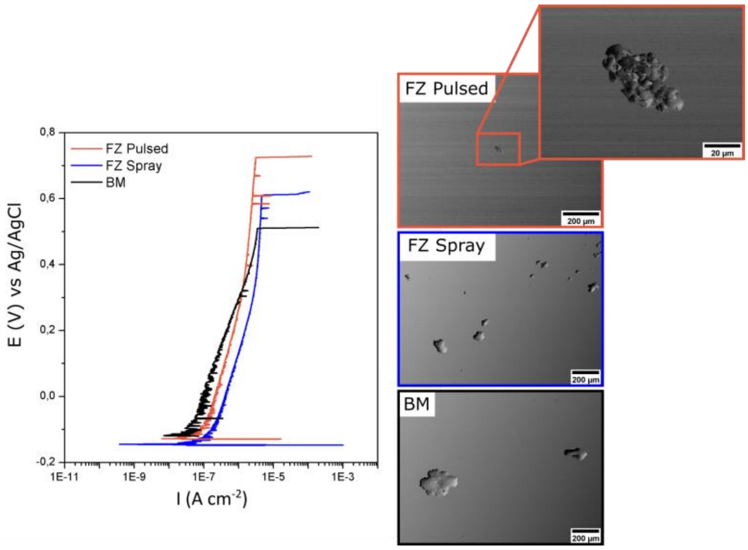

Figure 2: Anodic polarization curves of base metal (black), welding zone with metal transfer by pulsed (orange) and spray (blue) methods. SEM micrographs of polarized 316L samples corresponding to (a) BM, (b) spray and (c) pulsed methods after polarization tests.

It is interesting to note that the zones with larger ferrite content were more resistant to film breakdown. Surface observation after polarization tests showed that the FZs related to both methods of metal transfer present increased resistance to film breakdown than the BM. The corroded areas in the BM corresponded to the attack of the whole and larger grains that in the FZs, and whereas for the FZ by spray a large number of smaller grains were attacked, for the pulsed method the attack seemingly was inside very few grains that were likely exposed to different number of pulses, Figure 2.

Conclusions

Although all tested zones of the 316L stainless steel tested, either MAG welded using spray or pulsed methods, were passive in the chloride solution they showed susceptibility to passive film breakdown. The BM showed the lowest % of ferrite but also the highest tendency to film breakdown whereas the FZ by pulsed method was the most resistant to passive film breakdown despite its highest % of ferrite.

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