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Characterization of heterogeneous welded joint of supermartensitic stainless steel with duplex stainless steel filler metal

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Introduction

Supermartensitic stainless steels (SMSSs) can be welded with similar or different filler metals [1]. In the second case, duplex (DSS) or superduplex stainless steels (SDSS) are the first options for filler metal [2]. Such a type of heterogeneous joint is used in pipelines and in mandrels for chemical products injection in the oil and gas reservoirs. The mandrels are made with forged parts welded to seamless pipes of SMSS, and are assembled in the production collumn. Harsh conditions of the fluids, such as high salinity, low pH and high H_2S partial presssure are expected in the Brazilian pre-salt wells. A proper post weld heat treatment must be performed in order to avoid failure in service [3]. In this work, an heterogeneous weld joint of SMSS with DSS filler metal, from a mandrel which operated for ten years, was analyzed.

Objectives

The main objective is to analyze the microstructure and mechanical properties of the welded joint of a mandrel for gas injection, which was took off from the oil production line after ten years of operation in a subsea wheel.

Methodology

The mandrel, composed of forged pieces and hot rolled pipes was took of from the production string after ~ 10 years of operation in a sub-salt reservoir in the Brazilian coast. The piece of mandrel received for analyis, including the weld, is shown in Fig.1.

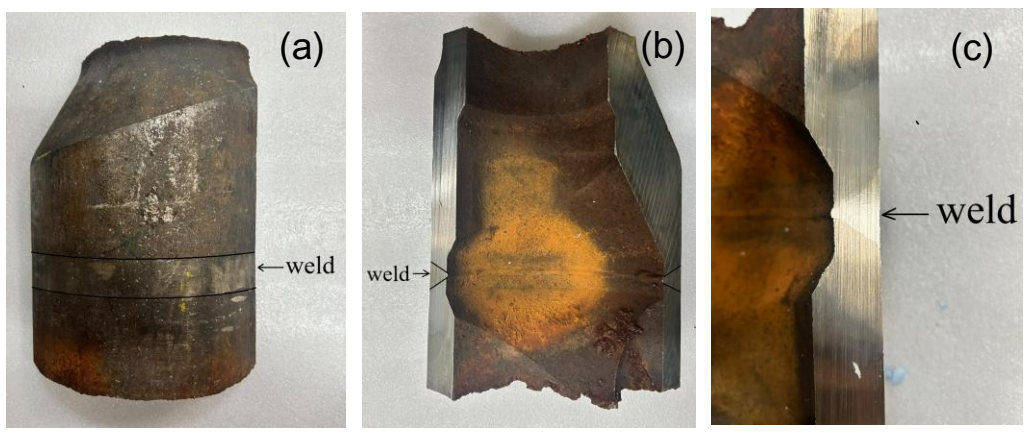


Fig. 1. Portion of the mandrel received for analysis.

The analysis conducted in the welded joint include:

- Chemical analysis (optical emission spectroscopy (OES), combustion (for C, N, and S) and EDS);
- Microhardness profile (HV0.50).
- Microstrucutural investigation
- Tensile test of welded joint;
- Stress corrosion test (4-point bend test in a solution containing 200g/L NaCl, pH=4.0 and p_{H2S} = 0.2 psi

Results and discussion

Table 1. Chemical analysis of base and weld metals (see Fig.2(a)). (%Fe=balance)

	C	Cr	Mo	Ni	Ti	V	Mn	N	S
BM	0.04	13.0	1.99	4.6	<0.001	0.021	0.700	0.072	0.006
WM	0.03	23.07	3.21	6.17	0.015	0.078	1.37	0.10	0.01

Table 2. Semi-quantitative analysis by EDS of regions of the weld metal. %Fe=balance (see Fig.2(b))

Region (Fig.2b)	Cr	Ni	Mo	Si	Mn
F1	23.84	8.09	3.00	0.43	1.55
F2	23.47	8.14	3.01	0.44	1.60
F3	23.87	8.12	2.99	0.47	1.59
M1	23.30	7.92	2.99	0.49	1.59
M2	23.43	8.05	2.98	0.44	1.52
R (root)	19.41	6.94	2.54	0.56	1.24

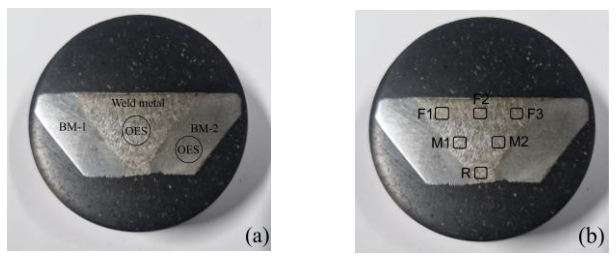


Fig. 2. Regions for (a) OES (Table 1) and (b) EDS (Table 2) analyses.

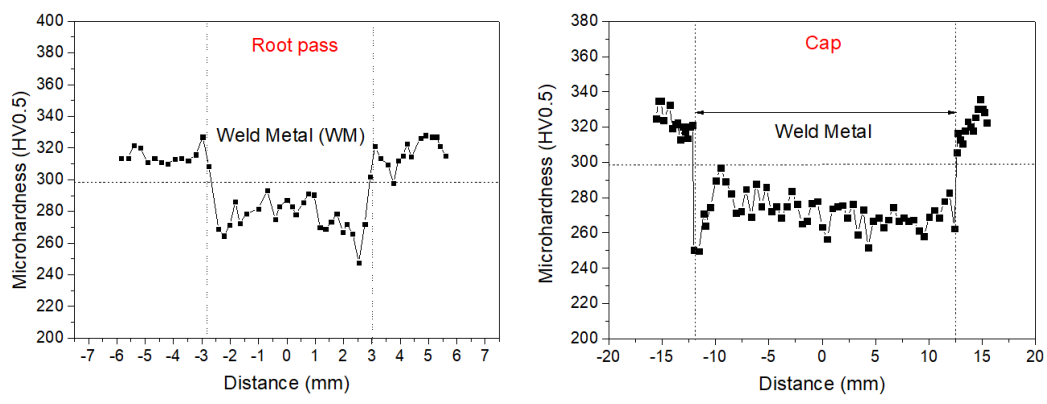


Fig. 3. Microhardness profiles: (a) root pass; (b) cap.

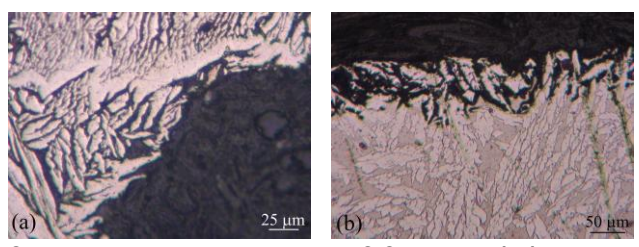


Fig.4: Preferential corrosion of ferrite (a) root; (b) face.

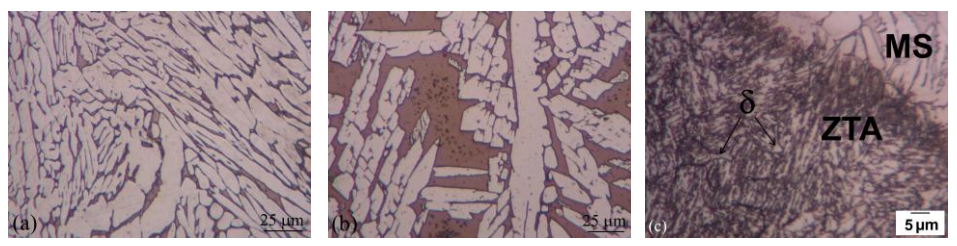


Fig.5: Microstructure: (a) Root pass (27%δ); (b) Cap pass (42%δ); (c) Heat attected zone/Weld metal.

Table 3. Tensile mechanical properties.

Specimen	σ_{YS} (MPa)	σ_{UTS} (MPa)	Elongation(%)	Reduction of area (%)
Base Metal	655	849	15.20	55.4
Welded joint	646	754	4.66	13.2
Class 95ksi [3]	655	758	8,0	-

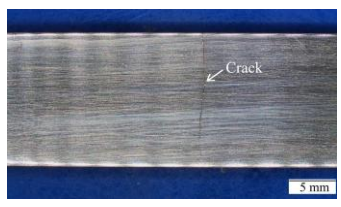


Fig.5: Result of 4-point bend test of welded joint: Reproved.

Referências e Agradecimentos

[1] Lippold, J.C., and Kotecki,D.J., Welding Metallurgy and Weldability of Stainless Steels, Wiley Interscience, 2005.
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[3] Tavares, S.S.M. et al., Failure of super 13Cr stainless steel due to excessive hardness in the welded joint, Eng. Fail. Anal. **91**, 92–98 (2018).