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The use of potentiostatic pulse testing to study the corrosion behavior of welded stainless steels in sodium chloride solution

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ABSTRACT

In this paper, the corrosion behavior of welded stainless steels is studied by means of the potentiostatic pulse testing method. The evolution of the average pit density and the average pit surface area at the mouth in each zone of the welds is discussed considering its PREN value and its microstructure determined from electron back-scatter diffraction (EBSD) experiments. Critical parameters leading to pitting are proposed and weak zones of the welded joints are identified.

1. Introduction

The properties and performance of stainless steels are related to the welding process. Therefore, the microstructure, the mechanical properties and the corrosion behavior in aggressive media of the welded zone (WZ) and the heat-affected zones (HAZ) are expected to be different from those of the parent metals (PM). Numerous papers have been published about the corrosion behavior of welded joints made of stainless steels [1–24]. Experiments presented in these papers have generally been conducted using classical methods and/or standard practices such as ASTM A262, G48. All these methods and practices have limitations (average measurements on the whole surface, aggressive media not representative of the real situations…). In addition, some of these experiments have been performed on zones obtained via different heat treatment methods to simulate the real situations [6,9,17]. Although these methods provide general results that are considerably acceptable in terms of comparative studies, it still could not reflect the real behavior of the welded joints.

In recent years, local electrochemical techniques have been applied to correlate the microstructure of the different zones to their electrochemical response [25]. An alternative procedure has been the use of the lacquer coating to select a reduced uncovered area of the different zones [8,9]. This method seems not to give as good results as with local electrochemical techniques.

The potentiostatic pulse testing (PPT) is an efficient method for detecting the early stages of a coating degradation which standard electrochemical impedance spectroscopy (EIS) cannot detect [26,27], identifying precursor sites in stainless steels [28] and evaluating the influence of engineering techniques (such as machining) on the corrosion resistance of stainless steels [29]. PPT is used to initiate a high density of small pits in samples (to perform statistical analysis). Under these conditions, only pit initiation and the very first steps of propagation can be investigated (not the pit propagation). Pits are then semi-hemispherical. The active surface inside the pit (which is an important parameter) can then be deduced from the pit surface area at the mouth. Note that studying pit propagation requires the use of other methods (potentiostatic methods, for example). PPT is usually combined with a high-spatial surface observation system to determine the pit size distribution and to calculate an average pit density and size. In this method, the pit size is given by the pit surface area at the mouth.

By contrast to classical methods described above, PPT can be associated with working conditions (in terms of electrolyte, temperature and potentials) which are representative of real situations. To be representative of working conditions, potentials used in PPT are previously determined using the working conditions (electrolyte,

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Table 1
Global chemical composition of the parent materials (PM) and the filler material (FM).

	Cr	Ni	Mo	Mn	Si	Cu	C	S	P	N
PM#1A (304 L)	17.75	8.2	0.19	1.41	0.35	0.19	0.03	0.026	0.029	0.071
PM#1B (304 L)	18.33	10.13	0.09	1.16	0.38	0.05	0.009	0.006	0.021	0.055
FM#1 (308 L)	18.20	9.31		1.07	0.4		0.025	0.0034	0.028	
PM#2A (304 L)	18.33	10.13	0.09	1.16	0.38	0,05	0.009	0.006	0.021	0.055
PM#2B (X4CrNiMo16-5-1)	15.48	4.75	0.97	0.93	0.24	0.1	0.0605	<0.002	0.0168	0.0405

temperature…) and specific electrochemical techniques at the microscale [30]. In this purpose, the electrochemical microcell technique [31,32] can be used.

To our knowledge, this method has never been applied to welded joints. The present work aims at studying the corrosion behavior of two welded joints between stainless steels in a classical sodium chloride

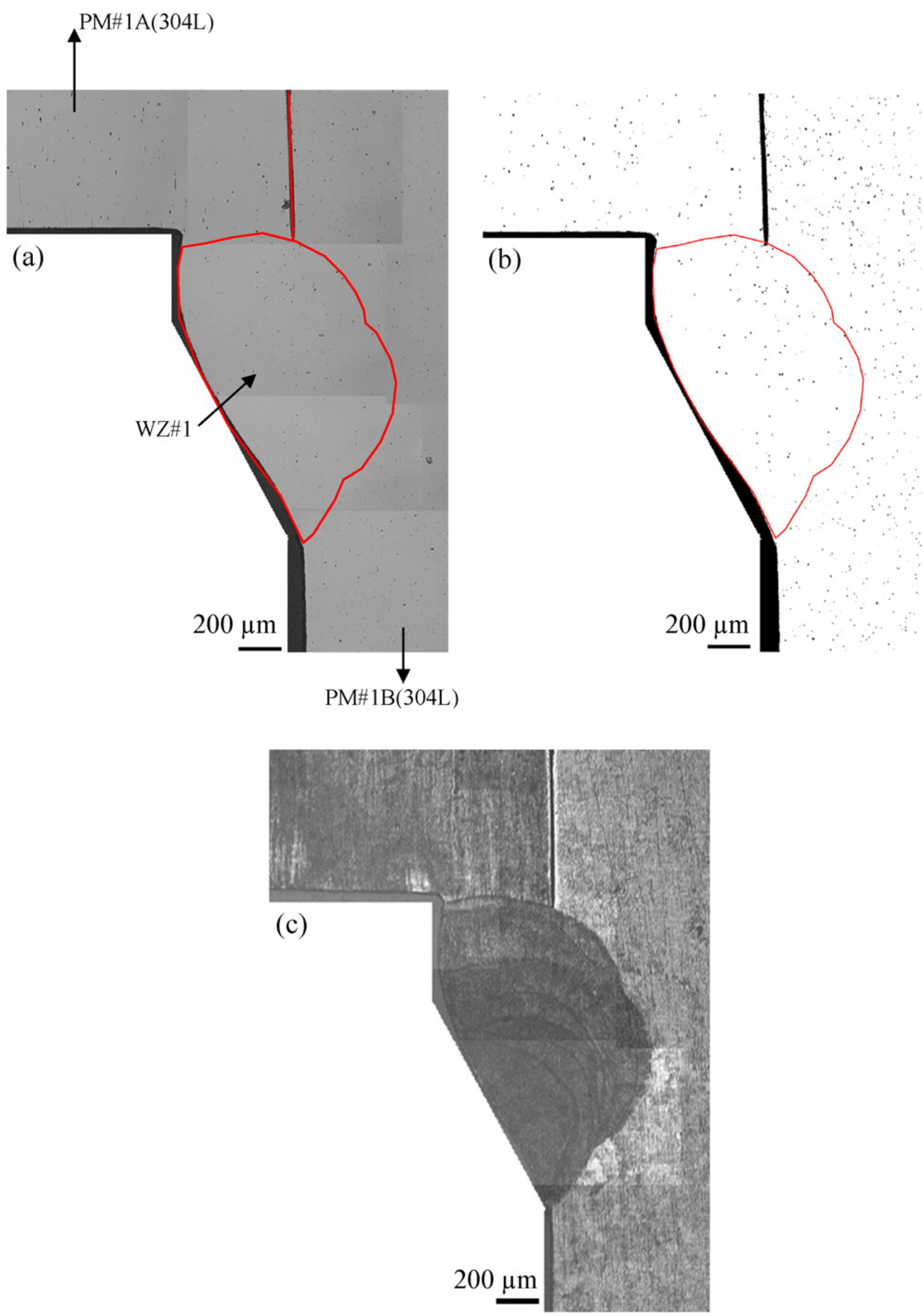

Fig. 1. Optical images (a) after mechanical polishing and PPT test in 0.1 M NaCl and (b) after image analysis to reveal pits. (c) Optical image of sample #1 after etching to reveal the different zones.