

Evaluation of inter-granular corrosion susceptibility in 316LN austenitic stainless steel weldments

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ABSTRACT

The inter-granular corrosion resistance of 316LN austenitic stainless steel welding joints for an ITER Correction Coil case in the as-welded and post weld heat treatment (PWHT) condition were systematically investigated. Measurements were performed in accordance with the standard ASTM A262 and via double loop electrochemical potentiokinetic reactivation. The pitting corrosion resistance was determined for specimens immersed in sodium chloride solutions. In addition, the effect of microstructural characteristics on the corrosion resistance was analyzed. The results revealed that the dendrite size in the weldment slightly increased after PWHT. Moreover, the corrosion test results showed that the inter-granular corrosion resistance of the PWHT joint is significantly lower than that of the other specimens due to the element segregation in the weldments. However, all the specimens exhibit excellent pitting corrosion resistance, as indicated by the potentiodynamic polarization curves.

1. Introduction

Owing to their excellent mechanical properties and corrosion resistance, austenitic stainless steels have been extensively used in vessels, as well as in the petrochemical, aerospace, nuclear, and chemical industries [1–8]. The relatively high chromium (Cr) and molybdenum (Mo) contents of these steels, yield high corrosion resistance. This renders the austenite unstable at the temperature ranging from 873 to 1173 K with respect to the formation of Cr-rich carbides and inter-metallic phases, such as the sigma phase and chi phase at grain boundaries [9–17]. Inter-granular corrosion (IGC) of austenitic stainless steel is a conventional and serious problem as sensitization can occur with welding, heat treatment (e.g. post weld, stress relief) [18] or fast neutron irradiation [19]. Cr-rich carbides precipitate adjacent to grain boundaries, and the corresponding Cr-depleted zone is susceptible to attack in a corrosive medium, thereby resulting in IGC. The methods for preventing sensitization of austenitic stainless steel have included reduction of the carbon content of the material, stabilization of carbon atoms, local solution with a heat treatment by laser beam, and grain boundary engineering [20–22].

To determining the susceptibility to IGC of austenitic stainless steels include ASTM A262 [21–23], electrochemical potentiokinetic

reactivation [2,7,14,22–26], dynamic electrochemical impedance spectroscopy (DEIS) technique [27] and the electrochemical noise (EN) technique [28]. The standard tests for determining the susceptibility of ASTM A262 to IGC are qualitative, destructive, and restrained under certain terms. However, compared with the ASTM A262 tests, the electrochemical techniques for evaluating the sensitivity to IGC are rapid, quantitative, and non-destructive [23,29].

The 316LN austenitic stainless steel has been widely used in International Thermonuclear Experimental Reactor (ITER) components, such as the cases of superconducting magnets of the Toroidal coil and Correction coil. The ITER Correction coils are protected by a 20 mm thick 316LN case, which allows these coils to withstand the electromagnetic loads during the operation. Furthermore, the residual stress and deformation induced by welding and machining during fabrication of the cases, have been minimized by means of a post weld heat treatment (PWHT). The microstructure and mechanical properties of the 316LN and its weldments in the ITER components have been extensively investigated [5,6]. In contrast, the IGC of the 316LN weldment has rarely been investigated. Even if the corrosion issues would not be encountered in service, these general quality tests are useful (in conjunction with other specified tests) for a general cross check of the weldment quality. This ensures that quality and safety guidelines are

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Table 1
Chemical composition of the base material (316LN) and the filler material (ER 316LMn).

	C	Cr	Ni	Si	Mn	Mo	N	P	S	Co	Nb	B	Fe
316LN	0.02	16.33	12.53	0.50	1.67	2.10	0.11	0.015	0.001	0.01	0.01	0.001	Balance
ER316LMn	0.009	20.3	15.5	0.49	7.0	2.9	0.17	0.01	0.005	–	–	–	Balance

Table 2
Welding parameters used for TIG.

Passes	Voltage [V]	Current [A]	Flow rate [L/min]	Welding speed [mm/min]	Filler wire dia. [mm]
Root pass	12–14	90–120	10–14	70–90	2.0
Fill passes	12–16	140–160	10–14	80–100	2.0
Cover pass	12–16	140–160	10–14	80–100	2.0

satisfied during the fabrication and shipment of the components. Thus, in this study, the effect of PWHT on the IGC of a 316LN austenitic stainless steel weldment of ITER Correction coil cases was evaluated (i) in accordance with the ASTM A 262 standard and (ii) by means of an electrochemical method.

2. Experimental method

2.1. Welding and PWHT

The chemical compositions of the 316LN austenitic stainless steel and its filler material, ER 316LMn, are shown in Table 1. The 316LN plates with a thickness of 35 mm were solution-annealed at 1050 °C for 140 min, then water quenched and welded via TIG with argon as the shield gas. The welding position was vertical up welding in single side and the welding parameters is shown in Table 2. The maximum inter-pass temperature was strictly controlled and kept below 150 °C. During the PWHT, the joint was held for 1 h at 760 °C in a fiber box-type resistance furnace [6], and then cooled to the ambient temperature in the furnace.

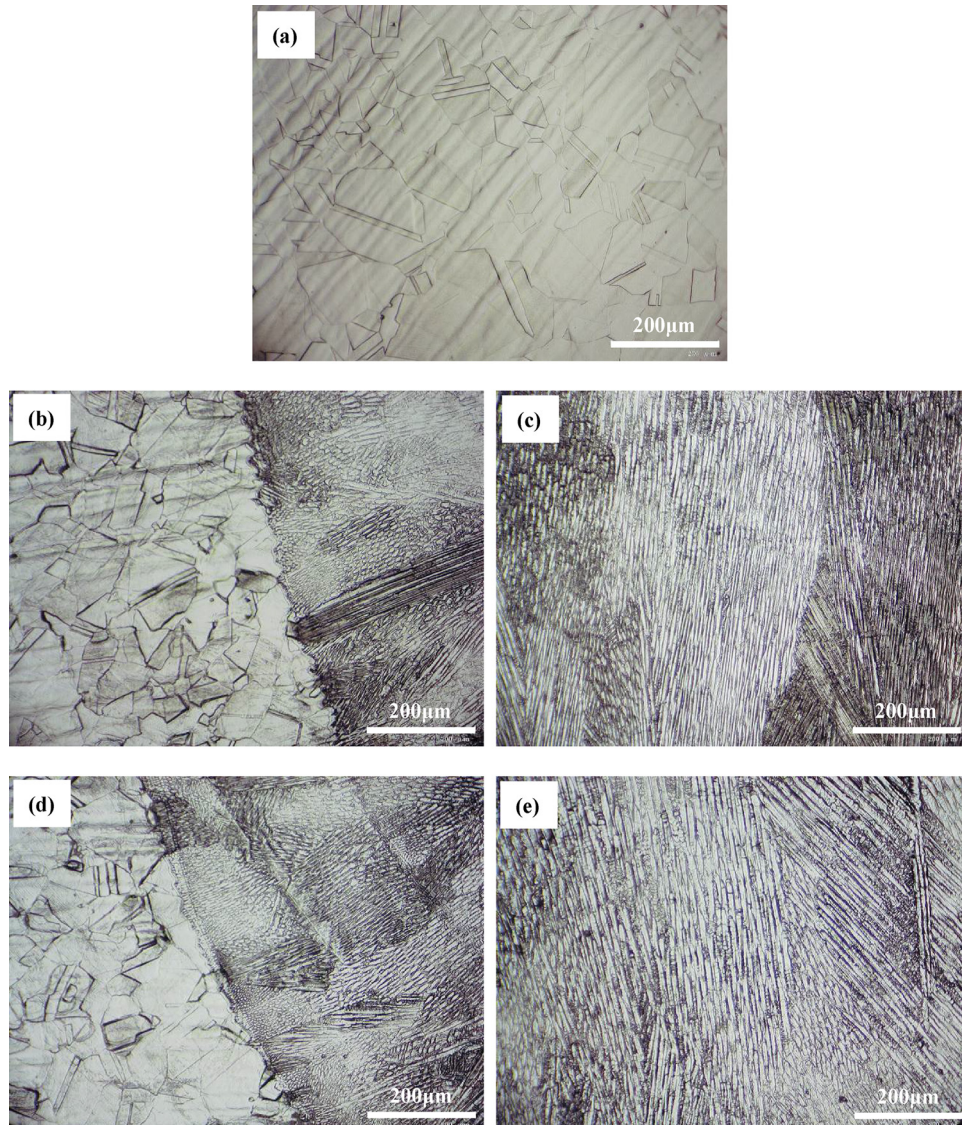


Fig. 1. Microstructure of the joints by OM: (a) BM, (b) and (c) as-welded specimen, (d) and (e) PWHT specimen.

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