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Effect of repeated weld-repairs on microstructure, texture, impact properties and corrosion properties of AISI 304L stainless steel

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ABSTRACT

An investigation is performed into the effects of repeated weld-repairs on the microstructural and mechanical properties of AISI 304L stainless steel. In preparing the specimens, the root weld is fabricated using gas tungsten arc welding (GTAW). The weld bead is then ground away, and the weld is repaired using shielded metal arc welding (SMAW). Two different weld-repair specimens are fabricated, namely one specimen repaired just one time (designated as WD-1) and one specimen repaired five times (designated as WD-5). The microstructures of the base metal (BM), WD-1 and WD-5 specimens are investigated using optical microscopy (OM), X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and electron back scattering diffraction (EBSD). The results show that the microstructures of all three specimens comprise a BCC solid solution austenite matrix with interspersed ferrite phrase. The EBSD results show that the number of weld-repairs has no significant effect on the $\sum 1$ boundaries of the fusion zone (FZ). In addition, no significant difference is observed in the texture orientations of the heat affected zone (HAZ) and the base metal (BM) regions of the WD-1 specimen. However, in the WD-5 specimen, the HAZ has a preferred orientation in the (1 1 1) plane, whereas the BM has a preferred orientation in the (2 1 2) plane. The grain boundaries (GBs) character results show that the low-energy coincident site lattice of the grain boundaries ($\sum$CSL GBs) are formed predominantly in the HAZs of the two weld-repair specimens. Moreover, the fraction of low angle grain boundaries decreases with an increasing number of weld repairs, the high-energy $\sum$CSL GBs remained similar to those of the HAZs in the WD-1 and WD-5 specimens. The impact test results show that the number of weld-repairs has no significant effect on the impact strength of the specimens, but affects the fracture characteristics. Finally, the corrosion test results show that the BM and HAZ of the WD-1 and WD-5 specimens exhibit significant corrosion following immersion in a 3.5% NaCl solution. The depth of the corrosion pitting increases with an increasing number of weld-repairs due to the corresponding increase in the amount of short ferrite phase in the austenite matrix.

1. Introduction

AISI 304L stainless steel has good mechanical properties at elevated temperatures, good corrosion resistance, and adequate weldability [1,2]. As a result, it is widely used throughout the chemical and nuclear industries. However, it is frequently necessary to carry out weld-repairs on the structural components used within such industries in order to prolong

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their service lives [3–5]. Thus, according to the GB50236-97 and -98 standards [6,7], no more than two repair welds should be performed in the same area. Although the literature contains a small number of studies on the effects of repeated-weld repairs [8,9], a systematic investigation into the effects of multiple weld-repairs on the microstructure and mechanical properties of AISI 304L stainless steel has not been performed. Accordingly, this study fabricates two weld-repair AISI 304L stainless steel specimens (one repaired just one time and another repaired five times), and then examines the effect of the number of weld-repairs on the microstructure, texture, impact properties and corrosion properties of the weldments.

2. Experimental

The chemical composition of the as-received AISI 304L stainless steel was as follows: 0.043C–18.12Cr–8.10Ni–1.16Mn–0.55Si–0.034P–0.002S–0.035 N (wt.%). V-shaped butt welds with the dimensions shown in Fig. 1(a) were prepared by a qualified welder using a single-pass gas tungsten arc welding (GTAW) method. The weld bead was then removed using a grinder, and the weld was repaired using the shielded metal arc welding (SMAW) method. A second specimen was prepared in which the weld was repaired five times. The two specimens were designated as WD-1 and WD-5, respectively. The GTAW and SMAW welding processes were performed using ER308L and E308L-16 filler metals, respectively, with the chemical compositions shown in Table 1. The corresponding welding parameters are shown in Table 2. In every case, the specimens were welded in a direction perpendicular to the rolling direction. Detailed microstructural observations were carried out in the fusion zone (FZ), heat-affected zone (HAZ) and base metal (BM) region of the two weld-repair specimens (see Fig. 1(b)). For comparison purposes, microstructural observations were also performed of the original (i.e., unwelded) AISI 304L stainless steel. The specimens for microstructural examination were polished mechanically and were then etched chemically in an acetic picric solution (10 ml HNO_3 + 30 ml HCl) for 10–45 s. The surface of each specimen was observed using optical microscopy (OM, Olympus BH-2) and scanning electron microscopy (SEM, JEOL JSM-6390 LA). The chemical composition and element distribution were determined using energy dispersive X-ray spectrometry (EDS). The crystalline phases were identified using X-ray diffraction (XRD, Rigaku D/Max-2500 diffractometer with Cu Kα radiation) with a scanning speed of 1°/min, and radiation conditions of 30 kV and 50 mA. Meanwhile, the precipitate phases were identified by transmission electron microscopy (TEM, JEOL 2000FXII, Lab6 Gun, Scanning Transmission Electron Microscope) using thin-foil specimens prepared using conventional thinning, electron polishing and ion milling processes. The morphological orientation and coincident site lattice of the grain boundaries ($\sum$CSL GBs) in the BM, FZ and HAZ regions of the two weld-repair specimens were examined using a field emission scanning electron microscope (FE-SEM, JEOL JSM-6390 LA) integrated with an electron back scattering diffraction (EBSD)

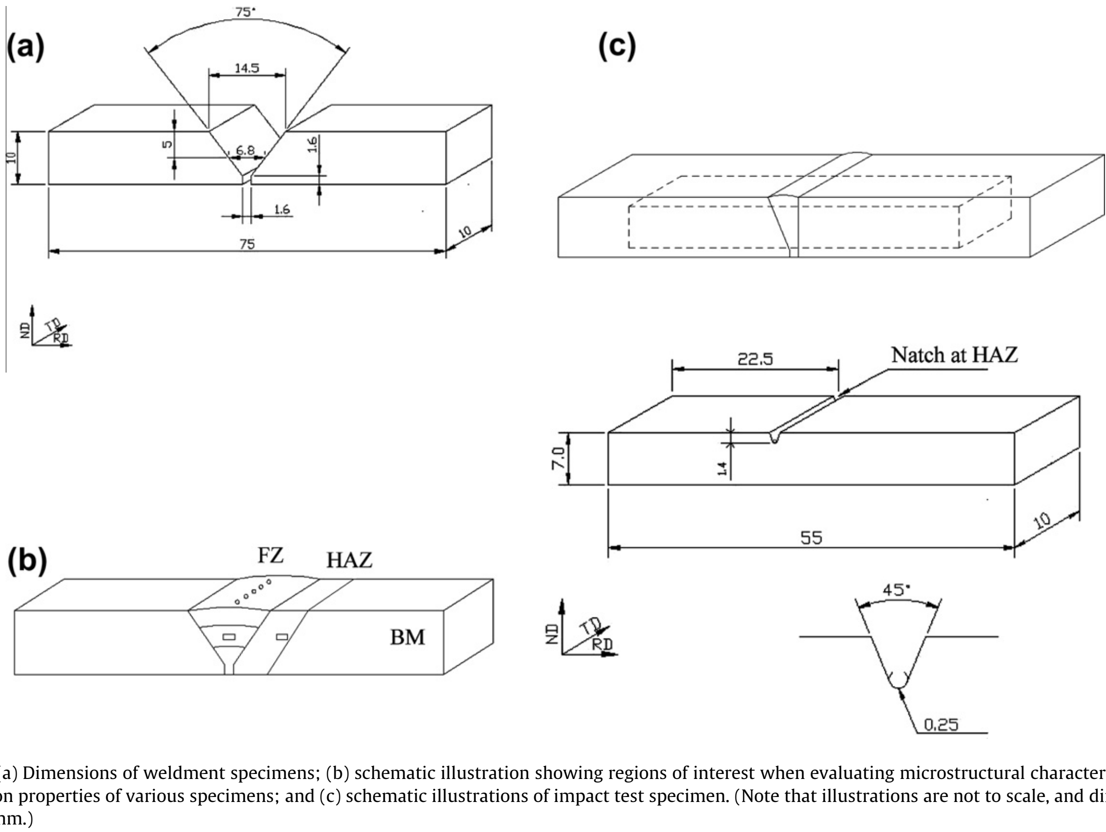

Fig. 1. (a) Dimensions of weldment specimens; (b) schematic illustration showing regions of interest when evaluating microstructural characteristics and corrosion properties of various specimens; and (c) schematic illustrations of impact test specimen. (Note that illustrations are not to scale, and dimensions are in mm.)