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Prevention of delayed cracking of iron based hardfacing welds

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ABSTRACT

Longitudinal and transverse cracks were observed to occur on the surface of Norem hardfacing welds for a period of time after welding. The welds were mainly cracked by hot cracking. To prevent the weld from cracking, a hammer peening process was employed to mitigate its tensile stress. A scanning electron microscope (SEM), equipped with the electron backscatter diffraction (EBSD) capability, was used to study the phase and carbide distribution in the weld. The results showed that the hammer peening process could help prevent crack propagation by reducing the welding residual stress and inducing a great number of low angle grain boundaries. The microstructures and micro-hardness of the peening-treated welds are also compared to the as-welded specimens in this paper to demonstrate the efficacy of the peening process to prevent weld from cracking.

1. Introduction

Norem, a cobalt-free alloy, is used as the hardfacing cladding on the valves for nuclear applications in place of Stellite to lower the activation level [1,2]. It has good galling wear resistance, which is equivalent to that of Stellite [2–6].

As a result of welding contraction, the ductility of hardfacing welds decreases and cracking occurs. Appropriate preheat treatments or buttering layers are the mitigation measures often applied to prevent the cracking occurrence of hardfacing. However, the cracking incidences have been reported on the Norem welds with both buttering layers and preheat treatment in the literature [6–8]. Further studies on the cracking mechanism and the mitigation approaches are needed to prevent Norem welds from cracking.

This work was intended to identify and better understand the cracking mechanism by metallographic examinations of the cracks of Norem welds on mockup specimens. Efforts were also made to study a mitigation measure to prevent welds cracking by reducing the tensile surface stress while maintaining a sufficient surface hardness level.

2. Experimental

The weldments were prepared on the base metal of ASTM A36 steel. The dimensions of the base metal are $150(l) \times 100(w) \times 38(t)$ mm. All welding processes were carried out by manual gas tungsten arc welding and the base metals buttered with two layers of ER309L. The welding current and speed were set at about 140 A and 10 cm/min. To induce a compressive stress layer on the weld surface, a single-pass hammer peening (SP) or multi-pass hammer peening (MP) process was employed to peen the welds either subsequent to the welding of the final layer or each layer, respectively. The

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peening was applied normal to the weld face at a force level around 7 kN with a hemispherical hammer of 18 mm in diameter. The average distance between the peening points is less than 1 cm.

The weld specimens were polished, following the standard metallographic procedures, and etched with the Picral etching solution of 5 g Picric acid and 100 cc Ethyl alcohol and then examined with an optical microscope to characterize the weld microstructures. A scanning electron microscope (SEM) was employed to study the surface morphology, which was also equipped with energy dispersive X-ray spectroscopic (EDS) analysis and electron beam backscattering diffraction (EBSD) capabilities for further analysis of Norem weld properties such as chemical composition, grain mis-orientation, and grain size. Vickers hardness and Rockwell hardness tests were conducted to investigate the mechanical properties of the welds.

3. Results and discussion

3.1. Chemical composition and visual examination

The measured chemical compositions of Norem weld, along with the supplier's reports on the compositions of ER309L and A36 base metal, are listed in Table 1. It has been reported that the higher Mn and Mo contents could reduce the hot

Table 1
Chemical compositions of A36 base metal, Norem weld, and ER309L.

wt%	C	Cr	Si	Mn	Ni	P	S	Mo	Fe
ASTM A36 steel	0.17	–	0.2	0.92	–	0.03	0.03	–	Bal
NOREM 02	1.26	26	3.1	4	4.1	0.006	0.012	–	Bal
ER309L	0.03max	23–25	0.3–0.65	1.0–2.5	12–14	0.03max	0.03max	0.75max	Bal

Note: The chemical data of ER309L and the A36 base metal are from supplier's test reports, while Norem 02 was measured at this laboratory.

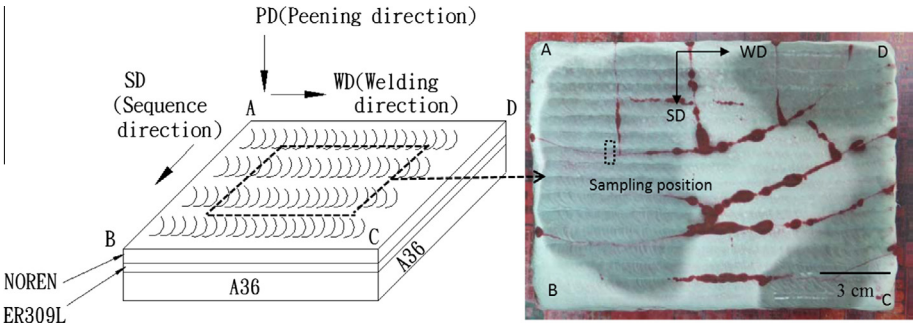

Fig. 1. The cracks in the hardfacing Norem weld on the A36 base metal with a thickness of 38 mm prepared in a welding sequence of two ER309L buttering layers and three Norem layers.

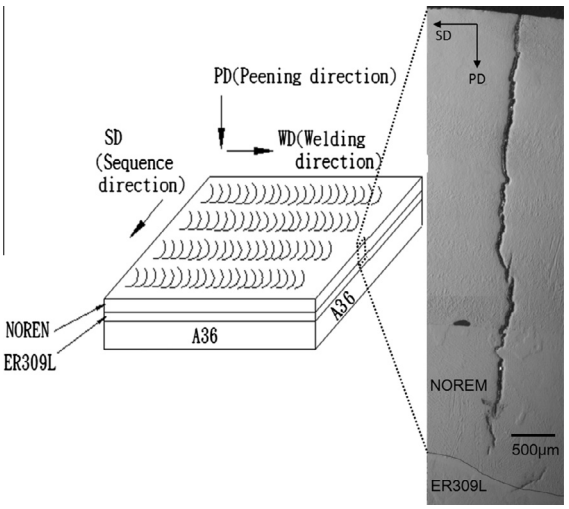

Fig. 2. Optical micrograph of the longitudinal section of the Norem weld specimen boxed in Fig. 1.