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The full structural weld overlay procedure of PZR nozzles for KORI unit 1

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1. Introduction

The discovery of Primary Water Stress Corrosion Cracking (PWSCC) in Dissimilar Metal Weld (DMW) has led to the use of corrosion-resistant high-nickel welding alloys for repair and mitigation. PWSCC happens if susceptible material, tensile strength and corrosive environment are concurrently satisfied, so that weld overlay of pipe outside can prevent PWSCC due to put ID surface in compression. This paper will contribute to the understanding of field application and effect on Full Structural Weld Overlay (SWOL) of KORI-1 pressurizer nozzles.

2. Field Implementation

2.1 Structural Weld Overlay Methodology

The proposed SWOL procedure is a repair and mitigation method to satisfy structural design requirements and provide suitable accessibility for NDE. The deposited weld material for SWOL is highly resistant metal to prevent PWSCC. SWOL provides a new pressure boundary by adding a new structural reinforcement, which can change tensile stress into favorable residual stress over the pipe inside surface that helps to mitigate the propagation of existing cracks and prevent from initiating cracks.

2.2 Applied SWOL Area

The limit of SWOL application is dissimilar metal weld of pressurizer nozzles (Alloy 82/182) but it shall be extended to stainless steel pipe for ultrasonic examination. Figure 1 shows the applied SWOL area of KORI-1 pressurizer nozzles.

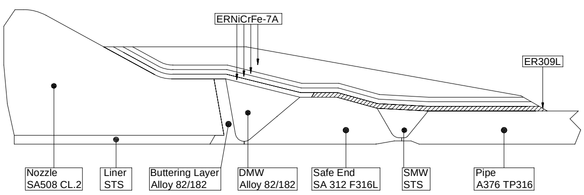

Fig. 1. Schematic view of SWOL

2.3 Applied Filler Material

Table 1 shows actual filler metal specifications used for KORI-1 SWOL application. Two (2) kinds of filler metals will be used: firstly, ER 309L filler metal will be used for the sacrificial layer over stainless steel safe-end to stainless steel pipe: secondly, Alloy 52M (ER NiCrFe-7A) filler metal will be used for Temper Bead Welding and applied SWOL area.

Table 1: Chemical composition of ER 309L and ER NiCrFe-7A (wt. %)

	Ni	Cr	Fe	Nb	Ta	Mn	Others	Ti	Co	Al	Si	Cu	C	Mo	Zr	B	P	S	V	N
ER 309L	13.5	23.2	Balance	0.009		1.91	-	0.003	0.05	-	0.53	0.06	0.023	0.08	-	-	0.02	0.001	0.08	0.068
ER NiCrFe -7A	59.28	29.97	8.65	0.84	<0.01	0.76	<0.50	0.22	0.016	0.11	0.11	0.03	0.019	0.09	0.0014	0.0005	0.003	<0.0005	-	-

2.4 SWOL Design Requirements

SWOL design thickness is based on ASME Sec. XI IWB-3640 and added some requirements such as a margin for fatigue, machining, and NDE.

· Crack Depth / ($t_{\text{orig pipe}}$ + t_{FSWOL}) = 0.75
· $t_{\text{orig pipe}}$ / ($t_{\text{orig pipe}}$ + t_{FSWOL}) = 0.75
· t_{FSWOL} = $t_{\text{orig pipe}}$ / 3

SWOL design thickness is based on ASME Code Case N-504-3, N-740-1 and added some requirements such as NDE accessibility.

· $L_{\text{FSWOL}} = 0.75\sqrt{RT}$

Table 2: Minimum SWOL Design Dimensions (mm)

	Alloy 82/182 Weld			Stainless Steel Weld		
	$t_{\text{orig pipe}}$	t_{FSWOL}	L_{FSWOL}	$t_{\text{orig pipe}}$	t_{FSWOL}	L_{FSWOL}
Surge N/Z	32.5	18.5	65.3	35.7	11.9	59.7
Spray N/Z	35.4	10.2	33.0	11.1	6.4	20.8
Safety /Relief N/Z	31.1	11.9	45.2	18.2	6.1	29.5

2.5 Potential Weld Defects and Preventive process

Experience of SWOL implementation has shown that many of austenitic overlay (stainless steel and nickel-alloy) have common defects. The following shows a variety of defects in weld overlay and provides preventive processes that will be applied for KORI-1 SWOL application.

2.5.1 Ductility Dip Cracking (DDC)

DDC is caused by tensile stress, inappropriate filler metal composition and high heat input, etc. Preventive processes from DDC are selection of optimized filler metal (Alloy 52M), use of low heat input/controlled heat input, control of maximum interpass temperature, etc.

2.5.2 Hot Cracking

Hot cracking is caused by weld shrinkage stress from cooling, high impurity level such as sulfur, inappropriate filler metal composition and inappropriate welding parameters such as excessive heat input, excessive iron dilution, dilution from substrate, etc. Preventive processes from hot cracking are application of ER 309L sacrificial layer over stainless steel materials, reducing Alloy 52M power ratio over stainless steel safe-end to Alloy 82/182 DMW and lowering dilution from stainless steel base metal.

2.5.3 Lack of Bond/Lack of Fusion (LOB/LOF)

LOB/LOF is caused by surface contamination, a lack of penetration, wrong weld head movement, etc. Preventive processes from LOB/LOF are surface cleaning, use of optimized weld parameters, application of pre-qualified welding techniques such as stringer bead, slow Automatic Voltage Control (AVC) response, proper bead overlap, and proper torch angle, etc.

2.5.4 Floaters (oxides)

Oxide floaters are caused by inappropriate filler metals that contain excessive deoxidizer such as Alloy 52 (1.1% Aluminum, 1.0% Titanium), oxides intrusion into weld puddle, imperfect shielding and downhill progression. Preventive processes from oxide floaters are optimized filler metal selection such as Alloy 52M (0.11% Aluminum, 0.22% Titanium), optimized welding parameters, optimized gas shielding system providing optimized gas flow envelop and minimal gas turbulence.

2.6 Temper Bead Welding Process and Parameters

One of the alternative techniques for Post-Weld Heat Treatment (PWHT) is bead tempering during the welding process, where this technique is called Temper Bead Welding (TBW) and also specified into ASME Code Case N-638-1. In actual effect, the HAZ created by former of three successive beads is tempered by controlling the heat input ratio among three beads (which may also form three weld layers).
TBW technique shall be applied into overlay welds of pressurizer nozzles and heat input control is mandatory. For all layers, welding current, voltage, pulse width, and travel speed shall be controlled to assure that heat input rates do not exceed the minimum and maximum values pre-qualified in PQR as given in Table 3.

Table 3: Welding Conditions and Process Parameters

Process	Primary Current (A)	Background Current (A)	Arc Volts (V)	Pulse Width (%)	Travel Speed (㎝/min)	Wire Feed Speed (㎝/min)	Bead Overlap (%)	Heat Input Rate (J/㎝)
Pulse Current GTAW	230 ~240	130 ~140	9.5 ~10.5	60	10.2 ~12.7	91.4 ~114.3	50 ~60	9,444 ~11,722

2.7 Applied Welding Procedure Specification (WPS)

Welding Procedure Specifications for KORI-1 SWOL application has been developed in accordance with the requirements of ASME Code Section IX, Code Case N-638 and N-740. Six (6) kinds of WPS's will be applied: firstly, three (3) manual WPS's will be applied to repair welding: secondly, three (3) machine WPS's will be applied to sacrificial layer and overlay weld. Table 4 shows WPS applicability summary.

Table 3: WPS Applicability Summary

WPS No.	Filler Metal	Man/Mach	Applicable
WPS-001	Alloy 52M	Manual	F43 weld defect repair
WPS-002	ER309L	Manual	P8 base metal repairs
WPS-003	Alloy 52M	Manual	Contour bead welding at SS end of SWO
WPS-004	Alloy 52M	Machine	Sacrificial layer on low alloy steel; SWOL
WPS-005	ER309L	Machine	Sacrificial layer on SS Safe-End to SS Pipe
WPS-006	Alloy 52M	Machine	SWOL on SS Safe-End to SS Pipe

2.8 SWOL Installation Sequence

(1) Cleaning, Layout and Mark
(2) PT (Repair welding, if necessary)
(3) Initial Contour Profile and UT Thickness
(4) Welding Equipment Set-up
(5) Install ER 309L Portion of Sacrificial Layer
(6) Install Alloy 52M Portion of Sacrificial Layer
(7) NDE and Contour Profile
(8) Baseline UT Thickness
(9) Install SWO Layers 2, 3, and remaining Layers
(10) Prep SWO for final NDE
(11) VT, PT, PDI-UT (Repair welding, if necessary)
(12) Final Measurement

3. Conclusions

In PWR main components, the integrity of DMW has been a big issue. The SWOL project for KORI-1 pressurizer nozzles which will be applied at the domestic beginning it sprouts has important meaning by SWOL itself. Through this study, we have developed the field implementation methodology of SWOL to preserve DMW from occurring PWSCC and have established supporting procedures to prove structural integrity of weld overlay.

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