Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Evaluation of Microhardness and Residual Stress in SA508 Weldments Using GTAW Temperbead Technique

Kyeong Ho Kim, a Ho Jin Lee, a Ki Baik Kim, b Kwang Soo Park, b In Chul Jung
a Nuclear Materials Research Center, KAERI, 1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea, khkim@kaeri.re.kr
b Materials Evaluation & Development Team, Corporate R&D Institute, Doosan Heavy Industries & Construction Co., Ltd.,555 Gwigok-Dong, Changwon, Gyeongnam, 641-792, Korea

1. Introduction

In the 1980's & 1990's BWR plants around the world pioneered the use of Structural Weld Overlays(SWOL) to combat Inter-Granular Stress Corrosion Cracking(IG SCC) issues related to stainless steel piping systems. In recent years PWR plants abroad have experienced PWSCC in Alloy 600 materials located at various locations. This increased concern over the susceptibility of these locations to Primary Water Stress Corrosion Cracking (PWSCC), have caused plant owners with Westinghouse/CE and B&W designed pressurized water reactors to look for practical repair contingencies. In response to this industry demand, PCI/Westinghouse has developed a new approach for SWOL repair applications. PCI/Westinghouse has developed repair methodologies and specialized equipment that can be readily deployed to install SWOL at nozzle locations. Temperbead welding is the conventional alternative to PWHT. It is an effective alternative because it involves sequenced deposition of weld beads in such a manner that welding effectively accomplishes an 'in-process' stress relief of the weld heat affected zone (HAZ). Conventional gas tungsten arc welding (GTAW) temperbead, however, involves several requirements that are not feasible when welding on water-filled piping (reference ASME Code Case N-432). For example, preheating the weld area and adjacent base material to a minimum temperature of 176^{o}C is required. A minimum of six tempering layers is required. In addition, conventional temperbead welding requires an elevated temperature heat soak (232 ^{o}C to 287 ^{o}C) for a minimum of four hours following weld completion. An alternative to conventional temperbead welding was needed in order to achieve acceptable tempering for reactor components [1-3]. The intent of this paper is to evaluate residual stress, micro hardness and microstructure as a result of welding and subsequent manufacturing processes.

2. Methods and Results

To complete the technical study, Base metal is SA508 low alloy steel. Filler material is Ni base Alloy 52(ERNiCrFe-7). The nominal compositions of the base metal and the filler metal are given in Table 1. The main objective of the experimental work is to carry out welds following well-defined parameters and variables as given in Table 2 using pulsed current GTAW.

Table 1 Chemical compositions of SA 508 and Alloy 52(wt.%)

Element	C	Si	Mn	P	S	Ni	Cr	Mo	V	Ai	Cu	Ti	Nb+Ta	Fe
SA508 Base metal	0.19	0.09	1.33	0.004	0.001	0.82	0.16	0.51	0.01	-	-			Rem.
Alloy 52 Filler metal	0.026	0.17	0.25	0.004	0.004	60.12	29.09	0.05	-	0.71	0.011	0.50	0.02	8.88

Table 2 Welding Conditions and Process Parameters

Specimen ID Voltage (V) 11V constant	Peak Current (A)	Base Current (A)	Traverse Speed (mm/min)	Wire Feeding Speed (mm/min)	Energy Ratio	Heat Input (W)	Input Energy per Unit Length
T11	236	118	100	1200	1.0	1947	1168.2
T12	171	120	100	1020	0.82	1600.5	960.3
T13	171	120	100	1020	0.82	1600.5	960.3
T101	229	114	183	2377	1.0	1886.5	618.5
T102	254	178	183	3091	1.26	2376	779.0
T103	304	213	183	3709	1.51	2843.5	932.3

Microstructural observations were made on the cross-sectional samples by using an optical microscope(OM), scanning electron microscope(SEM), and an energy dispersive X-ray spectrometer(EDS). The micro hardness tests were performed using a Vickers indenter with a 200g load were taken on each weld as shown in Figure 1. and Figure 2.

2.1 Micro Vickers Hardness

The readings were taken at increments of 0.2mm traversing from the weld into the base metal. For these tests, the primary concern was the heat affected zone (HAZ) hardness since the weld hardness is an effect of the temperbead welding parameters. While the weld metal hardness readings were taken for most of the materials, the following information relates the HAZ hardness profile vs. the base metal. This is intended to show the resulting effects of the different welding conditions on the peak hardnesses. The maximum hardness levels achieved in the HAZ of all of the welds.

2.2 Residual stress

Residual stress was determined by the hole drilling strain gauge method according to the ASTM standard E837 and X-ray diffraction method in shown Figure 3. This is a result of a nonhomogeneous residual stress field on the weldment back surface. Residual stresses

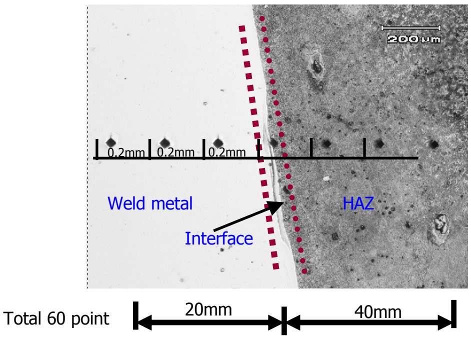

Figure 1. Photograph of indent shape formed after micro Vickers hardness test at increments of 0.2mm traversing from the weld into the base metal.

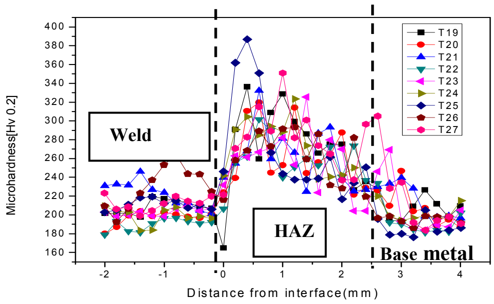

Figure 2. Micro vickers hardness distribution to the direction of depth in temper bead overlay cross-section.

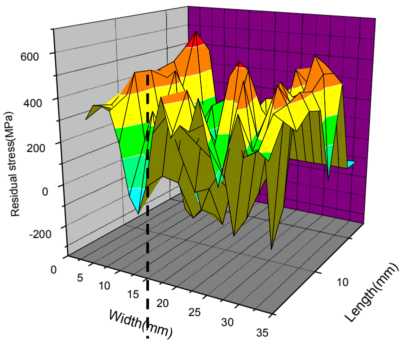

Figure 3. Residual stress distribution of T9 specimen induced by temper bead overlay welding process.

are those that exist in a part independent of external force or restraint. Neglect of these residual tensile stresses created during welding processes can lead to stress corrosion cracking, distortion, fatigue cracking, premature failures in components. The heat affected zone is usually most affected by the residual stress and hence where failure will usually occur.

2.3 Weld cross-section examinations

These microstructural photos reveal that all the temperbead weldments exhibit a good weldabilities between the filler alloy and both base materials. The elemental distribution in the weldment was analysed on

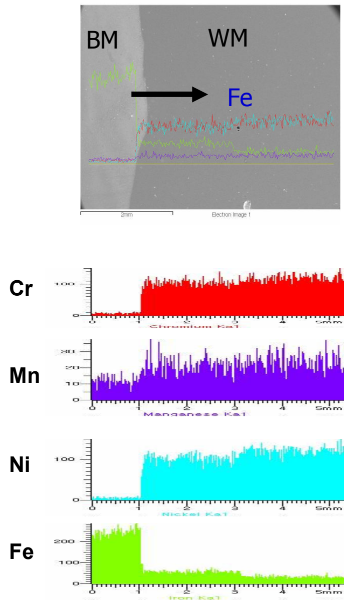

Figure 4. Element distribution line scan across the weldment .

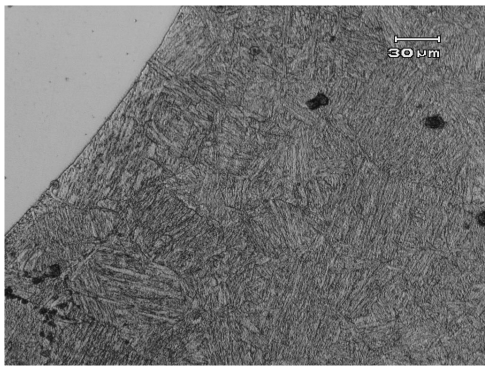

Figure 5. Optical microstructure of the HAZ in a temperbead weldment, coarse grain martensite and bainite phase.

the weld cross-section by EDS as seen in the X-ray maps of Figure 4. Major elements detected included Ni, Cr, Fe, and Mn. Results from EDS reveal that small amount of Fe in weld metal moved into base metal.

3. Conclusion

Temperbead welding of low alloy steel SA508 base metal and Ni-based Alloy 52 filler metal have been studied by applying pulsed current GTAW. All the temperbead weldments exhibit a good weldabilities between the filler alloy and both base materials.

REFERENCES

[1] Brian P. Baranowski, Steven Janes and Kenneth Muller, The New Age of Structural Weld Overlays in the PWR World, Welding and Repair Technology for Power Plants, Seventh International EPRI Conference Proceedings, June 21-26, 2006.
[2] Steve McCracken, PE, Fracture Mechanics Analysis of Socket Welds Repaired by Weld Overlay, Welding and Repair Technology for Power Plants, Seventh International EPRI Conference Proceedings, June 21-26, 2006.