Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Mechanical properties and residual stresses in temper bead welded specimens

Kyeong Ho Kim [a*], Hong Eun Kim [a], Ho Jin Lee [a], Bong Sang Lee [a]
a Nuclear Materials Research Center, KAERI, 1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
[*] *Corresponding author: :* khkim@kaeri.re.kr

1. Introduction

Welding is the principal joining technology used in the fabrication of metallic structures. One of the alternative techniques for post-welded heat treatment(PWHT) is bead tempering during the welding process, where this technique is usually called temper bead welding(TBW). Welding of mild steels and low alloy ferritic steels often requires stress relieving by using PWHT. These heat treatments can be carried out easily during initial fabrication processes. However, PWHT is almost impossible when there are mechanical loads on the structure since it can cause deformation of the structure. In actual effect, the HAZ created by former of three successive beads is tempered by controlling the heat input ratio between three beads(which may also form three weld layers). Also, in recent years considerable effort has been devoted to the development of procedures for incorporating residual stresses in to structural integrity assessments for power plant infrastructure[2-3]. However, systematic understandings of microstructural changes and mechanical properties as a result of varying in welding sequences and the resulting properties have not been established. The paper particularly investigates the role of the deposition sequence and the spatial deposition of the welding beads in microstructural variation in the critical zones of the resulting weldments such as HAZ, characterising the metallurgical properties, residual stresses, micro hardnesses of such zones.

2. Methods and Results

TBW of SA508 Gr.3 Cl. 1 low alloy steel base metal(chemical composition, as given in Table 1) was carried out by employing three kinds of energy ratio and by controlling the welding parameters as shown in Table 2. Filler material is Ni base Alloy 52(ERNiCrFe-7). The main objective of the experimental work is to carry out welds following well-defined parameters and variables as given in Table 2 using a pulsed current GTAW. Microstructural observations were made on the cross-sectional samples by using scanning electron microscope(SEM), an optical microscope(OM), and an energy dispersive X-ray spectrometer(EDS).

2.1 Micro Vickers Hardness

The micro hardness tests were performed using a Vickers indenter with a 200g load for each weld as shown in Figure 1.

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

Process	Base Current (A)	Traverse Speed (mm/min)	Wire Feeding Speed (mm/mi	Energy Ratio	Heat Input (W)	Input Energy per Unit Length
GTAW	117-419	80-251	816-4,404	1.0	1947	1168.2
Shielding gas	Ar					

Table 2 Welding Conditions and Process Parameters

The readings Vickers indenter with a 200g load for each weld as were taken at increments of 0.2mm traversing from the weld into the base metal. Also, the hardness measurements were taken on the 13 degree slop line as shown Fig. 1. and Fig. 2. For these tests, the primary concern was the heat affected zone (HAZ) hardness since a 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 to the HAZ hardness profile vs. the base metal. This is intended to show the resulting effects of different welding conditions on the peak hardnesses. The maximum hardness levels were achieved in the HAZ of all of the welds. It was noticed that the hardness was increased in areas that are nat tempered by a subsequent bead or layer.

2.2 Metallographic analysis

Metallographic analysis was carried out on the temper bead welded specimen in order to determine the extent of fusion zone and the different regions within the HAZ. Variations in the microstructure in TBW welded specimen are shown through the broad microstructural of the features of the weld metal, HAZ, and parent metal regions in Fig. 3.

2.3 Residual stress

Residual stress was determined by the hole drilling strain gauge method according to the ASTM standard E837 and X-ray diffraction method shown in Figure 4. This is a result of a nonhomogeneous residual stress field on a weldment back surface. Residual stresses are those that exist in a part independent of an external force or restraint. Neglect of these residual tensile stresses created during welding processes can lead to a

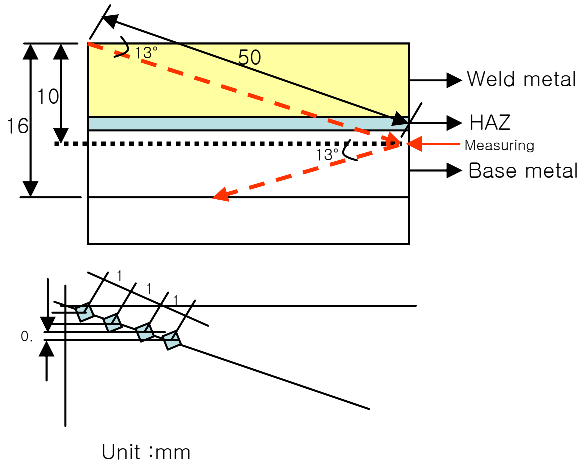

Figure 1. Schematic illustration of indent shape formed after micro Vickers hardness test at increments of 0.2mm traversing from the weld into the base metal.

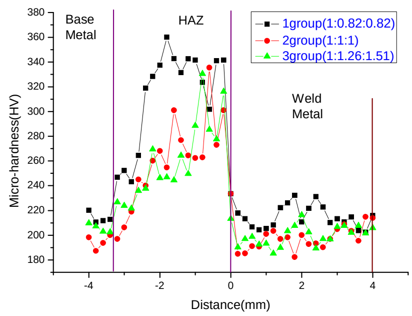

Figure 2. Micro vickers hardness distribution to the direction of depth in temper bead overlay cross-section.

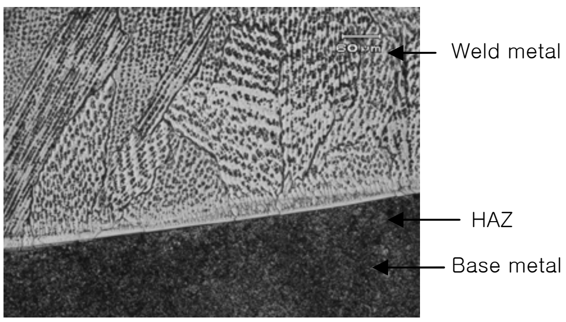

Figure 3. Microstructure of the weld metal, the HAZ and the base metal; coarse grain martensite and bainite phase.

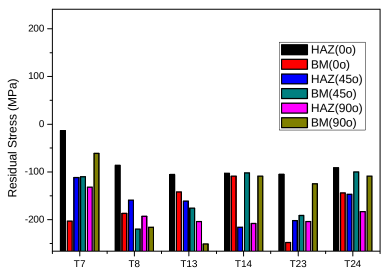

Fig. Residual stress distribution of SA508 weldments at HAZ and base metal region

Figure 4. Residual stresses in TBW specimen as a function of specimen regions.

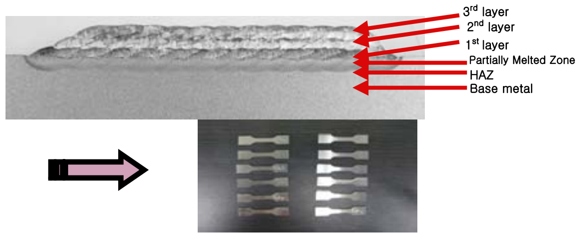

Figure 5. Tensile specimens were prepared from TBW specimens

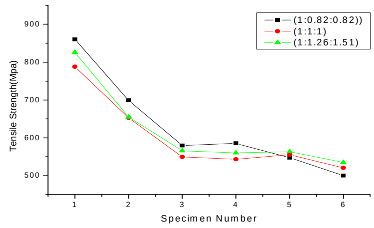

Figure 6. Tensile strengths of TBW specimens with energy ratio

stress corrosion cracking, distortion, fatigue cracking, and premature failures in components. The heat affected zone is usually the most affected by a residual stress and hence where a failure will usually occur.

2.4 Tensile properties

Tensile test was carried out in 500kgf, Instron 4505 static universal testing machine. The specimens were prepared to evaluate the tensile properties as shown Fig. 5. The magnitude of the tensile stresses were measured as shown Fig. 6.

3. Conclusion

In this study, systematic understandings of microstructural changes and mechanical properties as a result of varying in welding sequences and the resulting properties have been established. All the temperbead weldments exhibited a good weldabilities between the filler alloy and both base materials.

REFERENCES

[1] Gandy DW, Findlan SJ, Viswanathan R., Weld Repair of Steam Turbine Casings and Piping-an Industry Survey. ASME J Pressure Vessel Technol Vol. 123, p.157-160, 2001
[2] R.A. AINSWORTH, J.K. SHARPLES and S.D. SMITH, Effects of Residual Stresses on Fracture Behavior-Experimental Results and Assessment Methods, Journal of Strain Analysis for Engineering Design, Vol. 35(4), P.307-316, 2000
[3] Y. LEI, N.P. O'DOWD and G.A. WEBSTER, Fracture Mechanics Analysis of a Crack in a Residual Stress Field, Inter. J. of Fracture, Vol. 106(3), p. 195-216, 2000