Development of Welding Procedures for NPP Dissimilar Metal Weld

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1. Introduction

Nuclear primary system consists of various materials according to the function. Recently, concern about the integrity on Dissimilar Metal Weld (DMW) which was made of inconel material such as alloy 600/82/182 has arisen from industry. Leak from hot leg nozzle weld at V.C Summer and axial cracks in hot leg nozzle welds at Ringhals 3 and 4 were took placed at the DMW zone, which is major degradation mechanism known as Primary Water Stress Corrosion Cracking (PWSCC)[1]. In order to ensure operational ability of nuclear power plants, it is necessary to obtain measures against unexpected risks. KPS has developed the DMW technology, Narrow Groove Welding (NGW) system and field implementation procedures for alloy 600 since March 2005.

2. Experimental Details

There are two tests applying to the field implementation: firstly, Procedure Qualification Test (PQT) to evaluate quality of weld zone before the field implementation; and, secondly, Mock-up test for applying to the field implementation.

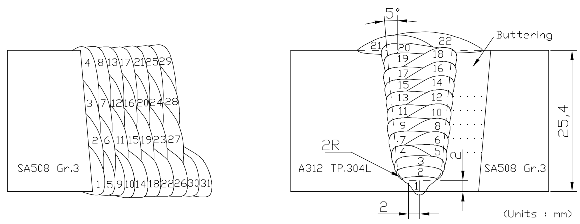
Basically, PQT contains fracture tests (tensile, bend, toughness test and chemical analysis, etc.), non-destructive tests (RT, UT, PT, etc.) and structure tests. Specially, some PQTs should contain additional tests and rules (IGC test, max. heat input is under 60 kJ/in (23.6 kJ/㎝), etc.). During Mock-up test, the problems of field implementation should be shown and the solutions for those problems must be given, also feasibility of welding process should be proven.

2.1. Experimental Procedures

Table 1 shows the welding coupons and welding process details for this study. As shown in Table 1, coupon #1 through #4 were beveled in 5˚ narrow groove by automatic beveling machine. After that, each coupon was welded by remotely operated Gas Tungsten Arc Welding (GTAW) machine. Fig. 1(a) shows coupon #5 buttering weld on the end of SA 508 Gr.3 pipe. Post Weld Heat Treatment (PWHT) was performed after buttering weld in accordance with the heat cycle in Fig. 2. Finally, the coupon #5 was beveled and welded by auto-GTAW machine with ERNiCrFe-7(alloy 52) type filler metal (Fig.1(b)).

Table 1. Description of Welding Process

	Base Metal		Filler Metal	Process
	Base #1	Base #2		
Coupon #1	A106 Gr.A	A106 Gr.A	ER70S-6	NGW
Coupon #2	A312 TP.304L	A312 TP.304L	ER316L	NGW
Coupon #3	A106 Gr.A	A312 TP.304L	ER309L	NGW
Coupon #4	A312 TP.304L	A312 TP.304L	ERNiCrFe-7	NGW
Coupon #5	SA508 Gr.3	A312 TP.304L	ERNiCrFe-7	Buttering⇒ PWHT⇒ NGW



(a) Buttering Weld (b) Narrow Groove Weld

Fig. 1. Configuration of Coupon #5

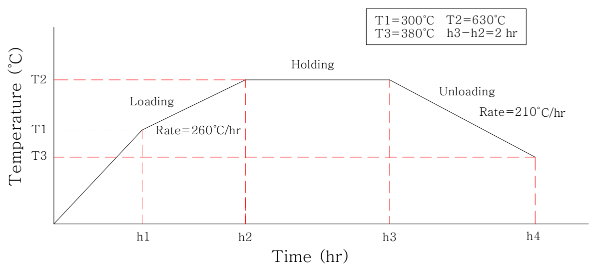


Fig. 2. Heat Cycle of PWHT

2.2. Experimental Material

2.2.1 Base Metal

Table 1 shows base metals used for this experiment. In this experiment, three kinds of base metals were prepared: firstly, austenitic stainless steel pipes for the nuclear primary pipe: secondly, the low alloy steel pipes for pressure vessel nozzle: lastly, the carbon steel pipes.

2.2.2 Filler Metal

Table 1 shows filler metals used for this experiment. In this experiment, four kinds of filler metals were prepared and all of the filler metal is the same size of Φ 0.9 ㎜ diameter.

3. Results

3.1. Set-up Welding Procedure

Optimized welding parameters acquired by experiment were applied to developing WPS/PQR for DMW. Detailed sequence of welding process is as follows: pre-purging→ arc start→ upslope→ welding→ down slope→ arc stop→ post-purging and all of the sequence is automatically proceeding.

As preventive measures to avoid Lack of Fusion (LOF) and Lack of Bead (LOB), weld head should be proceeding with no oscillation and tungsten tilting toward each groove face for melting completely.

To maintain low heat input and high weldability, pulse current was applied and max. heat input of 20 kJ/㎝ was taken into the weld zone. Table 4 shows the optimized welding parameters to perform the 5G position pipe NGW.

Table 4. Parameters of NGW

	Current (A)	Voltage (V)	Pulse Freq.	Travel Speed (㎝/min)	Max. Heat Input (kJ/㎝)
Coupon #1	PRI : 180~280 BKG : 80~180	9.3~10.0	1.0	7.6~10.2	22.1
Coupon #2	PRI : 190~260 BKG : 90~160	9.1~9.8	1.0	7.6~10.2	20.1
Coupon #3	PRI : 180~260 BKG : 80~160	9.2~9.8	1.0	7.6~9.7	20.1
Coupon #4	PRI : 160~190 BKG : 60~90	9.2~9.5	1.0	7.6~9.1	14.3
Coupon #5	PRI : 160~190 BKG : 60~90	9.3~9.5	1.0	7.6~8.9	14.3

3.2. Welding Procedure Qualification Tests

Welding Procedure Qualification Tests were performed in accordance with ASME sec.Ⅸ and detailed tests are as follows

(1) Tension Tests
(2) Guided Bend Tests
(3) Notch-Toughness Tests
(4) Hardness Tests
(5) Inter-granular Corrosion (IGC) Tests
(6) Micro Structure Tests

All of the test results were passed the acceptance criteria of related ASME code. As a result of guided bend tests, several micro cracks under 1/8 in. were found in coupons #4 and #5. A few of micro cracks caused by Ti, Al oxides floaters, hot solidification cracking and ductility dip cracking were found in the weld zone welded with alloy 52 type filler metal.

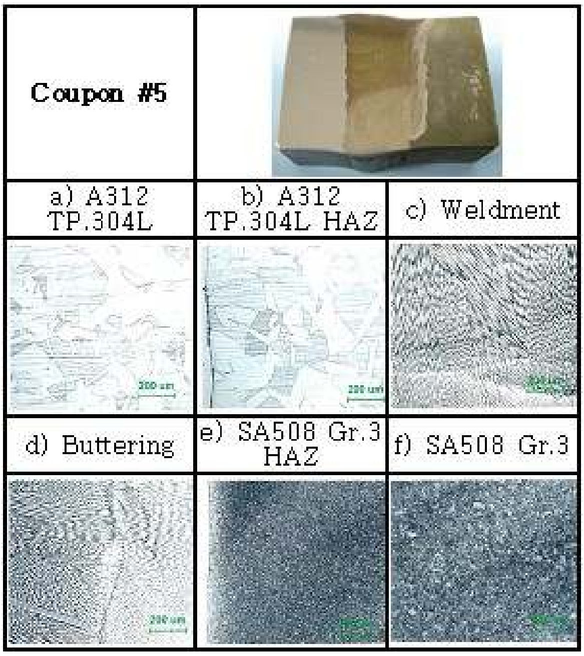


Fig. 3. Micro Structure of Coupon #5

4. Conclusion

Through this study, we have developed Welding Procedure Specification (WPS) and the NGW system for nuclear primary system.

The key to success field implementation welding with alloy 52 type filler metal is following: firstly, changing filler metal from alloy 52 type to alloy 52M type. Alloy 52M type filler metal which contains less Ti and Al has reduced tendency for oxides floaters: and, secondly, changing progression from orbital progression to double–up progression.

Finally, we can obtain the capability of mitigation for alloy 600 and lay groundwork of Weld Overlay (WOL) for the Pressurizer nozzles.

REFERENCES

[1] Primary System Piping Butt Weld Inspection and Evaluation Guidelines, MRP-139

[2] Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators. ASME Code Section Ⅸ(2007)

[3] Dissimilar Metal Weld Overlay for Repair of Class 1, 2, and 3 Items, ASME Code Case N-740

[4] B.I. Yang et al.: The Influence of Chemical Compositions of Weld Metal and Welding Conditions on Hot Cracking by Hot Cracking Test, The Korea Welding Society, Vol. 20 (2002), 330-339 (in Korean)

[5] K. Saida et al.: Microcracking in Dissimilar Multipass Welds of Alloy 690 and Type 316L Stainless Steel, The Korea Welding Society, Vol. 47(2006), 313-316.