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

Repair and Inspection Technology for RPV Nozzle

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1. Introduction

Nuclear primary system consists of various materials according to the function. Recently, the integrity of dissimilar metal weld which was made of Inconel materials such as alloy 82/182 has been became a matter of interest. Leak from hot leg nozzle weld at V.C Summer, axial cracks in hot leg nozzle welds at Ringhals 3 and 4 were took placed at the dissimilar metal zone, which major degradation mechanism have been known as primary water stress corrosion(PWSCC)[1]. In order to ensure operational ability of nuclear power plants, it is necessary to obtain measures against unexpected risk.

2. Analytical Assessment for Welding Procedure

2.1 Assessment for Welding Procedure

The purpose of assessment for welding procedure is analysis for weld variables in order that compression residual stress may act on the inside surface of pipe after weld repair. The procedure used in this analysis for overlay weld applied the normal direction(pipe-to-nozzle) of welding and reverse direction(nozzle-to-pipe) of welding respectively.

Figure 1&2 show hoop and axial stress distribution as their welding conditions. Through the stress analysis results, we can see that the normal direction welding is more favorable method than the reverse direction welding in that residual stress.

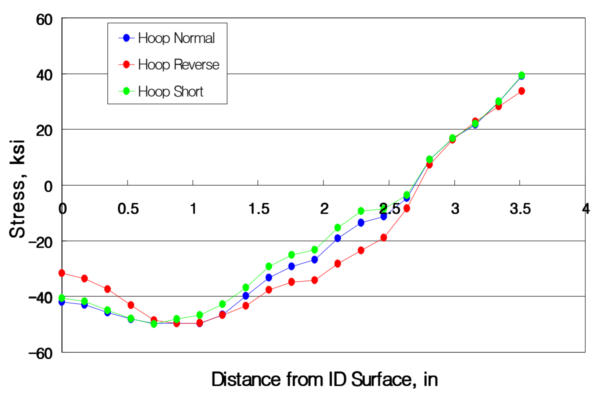

Figure 1. Distributions of Hoop Stress

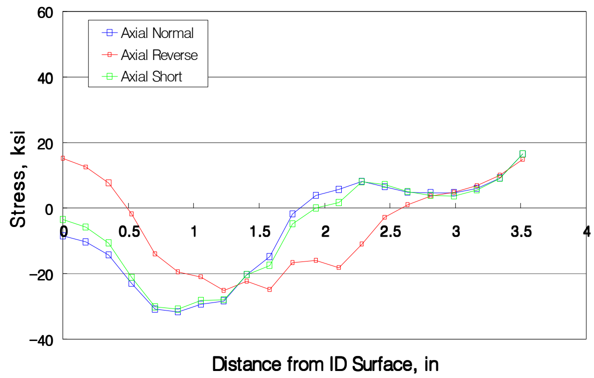

Figure 2. Distributions of Axial Stress

2.2 Flaw Analysis for Weld Zone

Weld defects that exist inside weld zone will be reached to critical crack size by PWSCC or fatigue during operation. Because Alloy 82/182 have high toughness, non liner elastic-plasticity fracture mechanics should be applied, but generally liner plasticity fracture mechanics is applied in order to get conservative value.

It is necessary to calculate stress intensity factor in order to assess crack propagation because of PWSCC and fatigue. In this present study, Raju & Newman method was applied[2].

$$\sigma_j = \left(\frac{z}{a}\right)^j \quad \text{for } j = 0, 1, 2 \text{ or } 3$$

$$K_I = \sqrt{\Pi \frac{a}{Q} G_j \left(\frac{a}{c}, \frac{a}{t}, \frac{t}{R}, \psi\right)}$$

$Q = 1+(1.464(a/c)_{1.65}$ G_j = Influence Coefficients
$a/c = 0.2$ ~ 1.0 (a : flaw depth, c : flaw length/2)
$a/t = 0.2$ ~ 0.8 (t : nozzle thickness)
$t/Ri = 0.1$ ~ 0.25 (Ri : nozzle inside diameter)

In case free stress is applied, above equation becomes as following.

$$\sigma_{\theta\theta} = \sum_{j=0}^{3} A_j z^j$$

Also, above equation can appear as following.

$$\sigma_{\theta\theta} = \sum_{j=0}^{3} A_j a^j \left(\frac{z}{a}\right) \frac{da}{dt}$$

Modified Scott's Model was used to evaluate crack growth by PWSCC. In case of Kori Unit 1, the crack growth rate based on 312℃ is as follows;

$$\frac{da}{dt} = 1.51 \times 10^{-12} (K-9)^{1.16}\ m/\sec$$

Where, K= Stress Intensity Factor,(MPa√m)

3. Development of Repair System and Procedure

For development of WPS/PQR, optimum pre-WPSs were made after review welding repair method.

3.1 Spool Piece Replacement Method

Spool piece replacement method was applied to V.C Summer NPP. This method can minimize residual stress through application of NGW(narrow groove welding) technique. Advantage of NGW method is that defects can be fully removed. Figure 3 shows the shape of spool piece replacement to develop WPS/PQR.

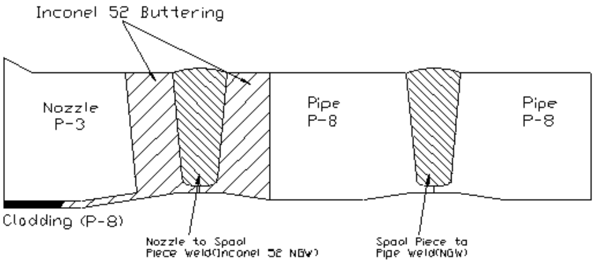

Figure 3. Schematic view of Spool Piece Replacement

3.2 Structural Weld Overlay Method

Structural weld overlay(WOL) is designed using ASME Code Case N-504-2. WOL is applied to get structural margin since weld fully encompasses entire pipe circumference. Figure 4 shows the shape of weld overlay to develop WPS/PQR.

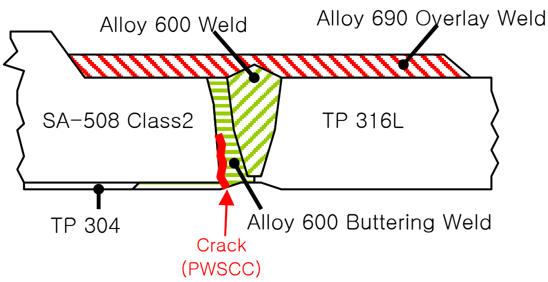

Figure 4. Schematic view of Weld Overlay Repair

3.3 Construction of Remote Control NGW System

Welding system is remote controlled automatic NGW machine that can be applied butt welding and structural overlay welding. Applying NGW technique, it is possible to achieve uniform weld quality, less filler material, shorter welding time and less shrinkage. Welding system is consisted of power supply, video control console and weld head. Figure 5 and 6 show welding scene and weld bead formation state respectively.

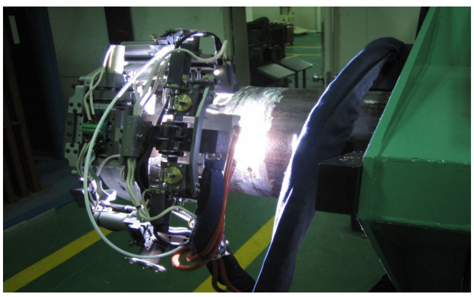

Figure 5. Welding Scene

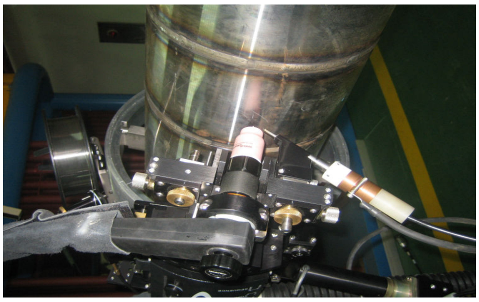

Figure 6. Weld Bead Formation State

4. Construction of NDE System

NDE system to confirm integrity for weld zone is consisted of phased array transducer, Omni Scan, Ultravision and end effector. Using Ultravision software for signal estimation, it is possible to print out examination results automatically as well as to confirm defect size after examination. Figure 7 shows composition of the NDE system.

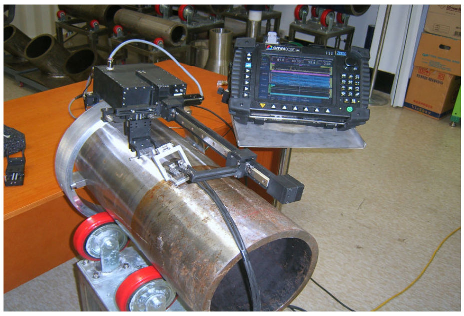

Figure 7. NDE System

5. Conclusion

Through this present study, we have established analytical assessment to develop optimum welding procedures as well as weld repair system and NDE system have constructed to apply various pipe size including RPV nozzle.

REFERENCES

[1] EPRI, "PWR Materials Reliability Project Interim Alloy 600 Safety Assessments for US PWR Plants(MRP-44NP)," April , 2001.

[2] Raju, I.S. and Newman, J.C., "Stress Intensity Factor Influence Coefficients for Internal and External Surface Cracks in Cylindrical Vessels," in Aspects of Fracture Mechanics in Pressure Vessels and Piping, ASME Publication PVP Vol.58, 1982.