Deformation Evaluation for Weld Repair of Reactor Vessel Upper Head Penetration Nozzle and Weld

Kyoungsoo Lee[a*], Taeyoung Ryu[b]
[a]*Korea Hydro and Nuclear Power Co. Ltd., Central Research Institute, 1312-70, Yuseong-daero, Yuseon-gu, Daejeon, Republic of Korea, 305-343*
[b]*Sungkyunkwan Univ. 2066, Seobu-ro, Jangan-gu, Suwon, Gyeonggi-do, Republic of Korea*
[*]*Corresponding author: leekys@khnp.co.kr*

1. Introduction

As a repair for the nozzles and their welds in the reactor vessel upper head, embedded flaw repair (EFR) has been conducted. Since the embedded flaw repair adds another weld layers over the existing nozzle and weld, it may cause another weld residual stress and deformation to the component. To review the impact on structural integrity of the reactor vessel upper head after EFR, a finite element analysis (FEA) was performed. Through the FEA, the magnitude of weld residual stress and deformation due to EFR was evaluated. The results were reviewed to confirm that final value remain within the acceptance range. This paper describes only on the viewpoint of deformation.

2. Methods and Results

In this section some of the techniques used to analyze deformation accompanied by EFR are described. The analysis includes thermal analysis and structural analysis using finite element method.

2.1 FE Model

Reactor vessel upper head in a nuclear power plant has many penetration nozzles. The nozzles are welded to the vessel in the form of J-groove. Figure 1 shows the finite element (FE) model of the reactor vessel upper head and the penetration nozzle.

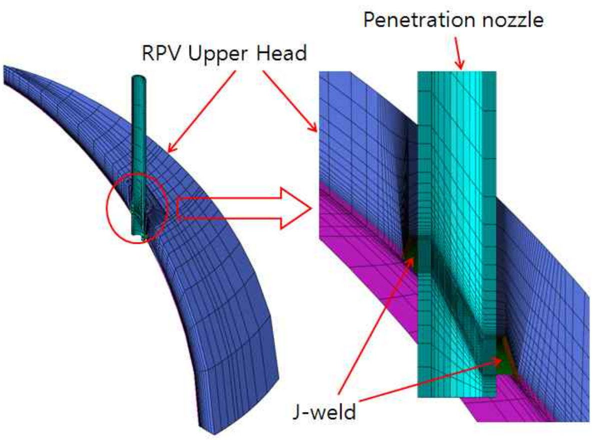

Fig.1 FE model for analysis

ABAQUS/CAE version 6.11 was used for modeling and analysis. A three-dimensional FE model was used to simulate the unsymmetrical condition.

Recently primary water stress corrosion cracking has been detected in the nozzle and J-weld. As a repair for PWSCC, EFR method has been widely used. Figure 2 shows the concept of EFR. EFR adds another weld layer with more resistant material on the surface of existing nozzle and weld. By doing that, the existing susceptible material does not contact primary and the PWSCC does not grow any more.

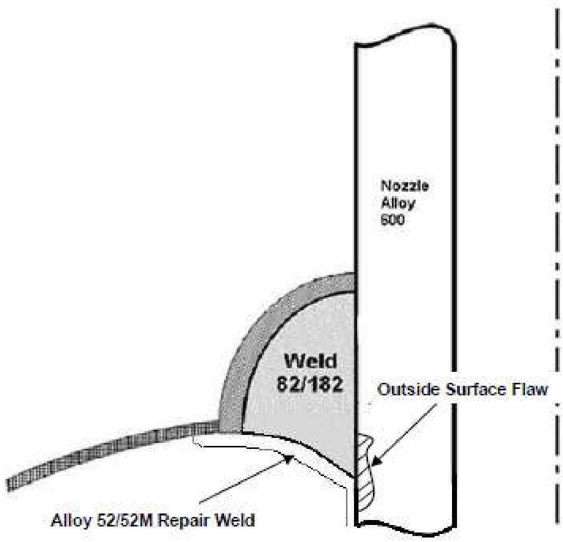

Fig. 2 A schematic diagram of EFR

2.2 Deformation Analysis

Most of the J-groove welds between upper head and penetration nozzles are unsymmetrical. Because of unsymmetrical welding, EFR may cause deformation of the nozzle and interfere with movement of control rod element. The possibility of contact between the control rod element and the nozzle was evaluated. According to the design drawing, the initial gap was 0.313 inches. For the evaluation, new three-dimensional finite element model including EFR was developed. Three weld layers of Alloy 52M were added on the Alloy 82/182 welds and two layers of Alloy 52M weld were added on Alloy 600 nozzle. The previous welding process applied to weld residual stress analysis for PWSCC integrity evaluation was applied in the same way and EFR process was added on them. Material properties for the welding analysis were obtained from technical codes, manufacturer documents, and other research papers. The nozzle was free constraint condition during welding. It was assumed that weld heat was transferred by conduction from metal to metal, and by convection from metal to air. Heat transfer analysis and structural analysis were performed. Figure 3 shows a FE model developed for deformation evaluation.

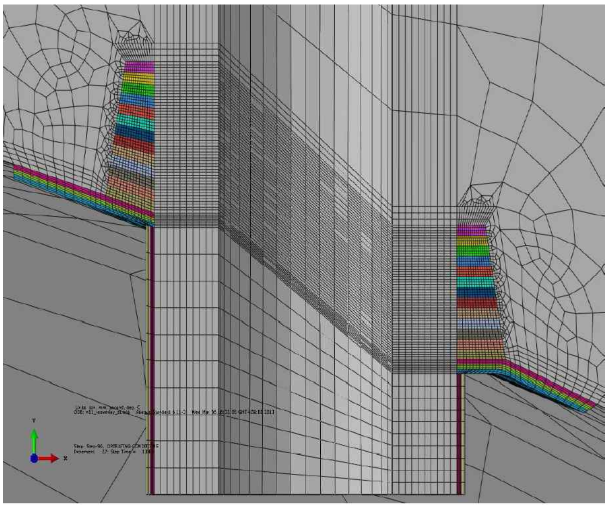

Fig. 3 A FE model for nozzle deformation evaluation

The analysis results showed that the nozzles were deformed to downhill direction after EFR. Figure 4 shows a result that there is enough clearance between control rod element and nozzle after EFR. Figure 5 shows the ovality of the nozzle becomes more even after EFR.

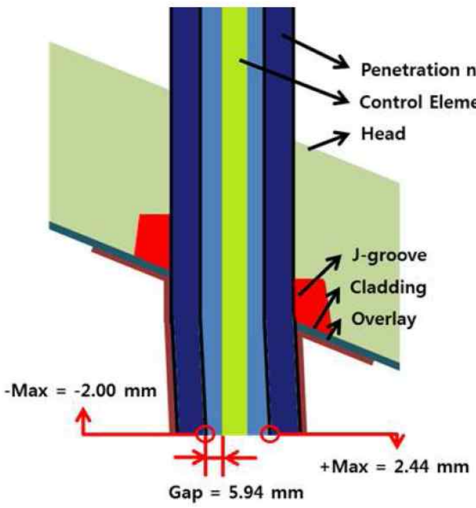

Fig. 4 Gap between a rod element and a nozzle after EFR

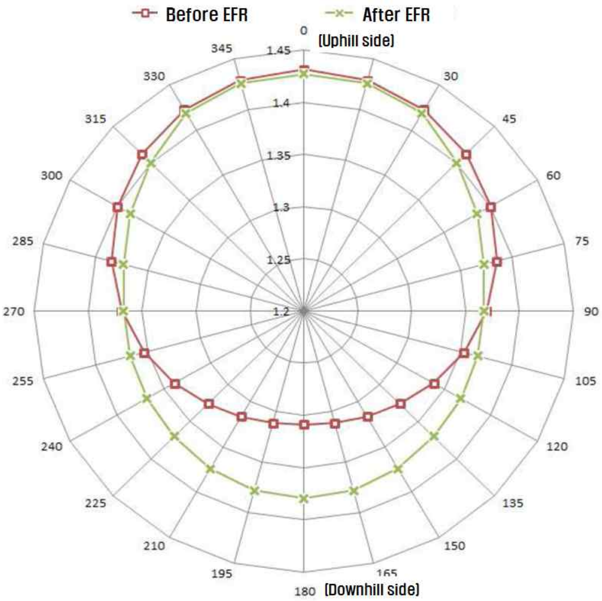

Fig. 5 Nozzle ovality before/after EFR

3. Conclusions

As a repair method, EFR was reviewed. Through the analysis for deformation, EFR was confirmed to be applicable for the repair.

REFERENCES

[1] K. S. Lee, W. J. Kim, J. K. Lee, C. Y. Park, J. S. Yang, T. R. Kim, J. H. Park, Finite element analysis and measurement for residual stress of dissimilar metal weld in presssurizer safety nozzle mockup, *Journal of JMST*, 23 (2009) 1-8

[2] K. S. Lee, T. R. Kim, J. H. Park, M. W. Kim, S. Y. Cho, 3-D Characteristics of the residual stress in the plate butt weld between SA 508 and F316L SS, *KSME A,* 33(4)(2009) 401-409.

[3] Y. J. Kim, T. K. Song, J. S. Kim, C. Y. Oh, K. S. Lee, C. Y. Park, Through-wall welding residual stress profiles for dissimilar metal nozzle butt welds in pressurized water reactors, *Journal of Fatigue and Fracture of Engineering Materials and Structures*, (2011), 1~18.

[4] C. King, "Reactor Vessel Closure Head Penetration Safety Assessment for U.S. Pressurized Water Reactor (PWR) Plants (MRP-110), EPRI 1009807, Nov. 2004

[5] C. K. Ng, A. Udyawar, "Technical Basis for Westinghouse Embedded Flaw Repair for Yonggwang Unit 3 Reactor Vessel Head Penetration Nozzles, WCAP-17702-P, Rev. 0, April 2013

[6] ASEA Brown Boveri (ABB) Design Report No. CENC-1938, Rev. 0, "Design Report for Yonggwang Nuclear Power Plant Units 3 and 4 Reactor Vessels"