Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

FEM Analysis and Measurement of Residual Stress by Neutron Diffraction on the Dissimilar Overlay Weld Pipe

Kang Soo Kim [a*], Ho Jin Lee [a], Wanchuck Woo [a], Baek Seok Seong [a], Jin Gwi Byeon [b], Kwang Soo Park [b], In Chul Jung [b]
[a] *Korea Atomic Energy Research Institute, 150, Dukjin-dong, Daejeon 305-353, Republic of Korea*
[b] *Doosan Heavy Industries and Construction Co., 555 Gwigok Dong, Changwon 641-792, Republic of Korea*
[*] *Corresponding author: kskim5@kaeri.re.kr*

1. Introduction

Much research has been done to estimate the residual stress on a dissimilar metal weld [1~6]. There are many methods to estimate the weld residual stress and FEM (Finite Element Method) is generally used due to the advantage of the parametric study. And the X-ray method and a Hole Drilling technique for an experimental method are also usually used.

The aim of this paper is to develop the appropriate FEM model to estimate the residual stresses of the dissimilar overlay weld pipe.

For this, firstly, the specimen of the dissimilar overlay weld pipe was manufactured. The SA 508 Gr3 nozzle, the SA 182 safe end and SA376 pipe were welded by the Alloy 182. And the overlay weld by the Alloy 52M was performed. The residual stress of this specimen was measured by using the Neutron Diffraction device in the HANARO (High-flux Advanced Neutron Application ReactOr) research reactor, KAERI (Korea Atomic Energy Research Institute). Secondly, FEM Model on the dissimilar overlay weld pipe was made and analyzed by the ABAQUS Code (ABAQUS, 2004). Thermal analysis and stress analysis were performed, and the residual stress was calculated. Thirdly, the results of the FEM analysis were compared with those of the experimental methods.

2. Methods and Results

2.1 Neutron diffraction measurements of residual stresses

The specimen was prepared to examine the residual stress distribution through the thickness of the dissimilar overlay weld pipe. This specimen is shown in Fig. 1. The material and the thermal properties for each dissimilar metal are shown in Table 1.

The edge of the SA508 nozzle became the buttering by Alloy 182. The SA508 nozzle and SA182 safe end were welded by the filler metal. The material of the filler and the buttering was Alloy 182 as shown in Fig. 3. The SA 182 safe end and SA 376 pipe were welded by the Alloy 182. Finally, the overlay weld on the nozzle, buttering, DMW part, safe end, SMW part and the pipe was performed by the Alloy 52 M.

The residual stress measurements were performed on the Residual Stress Instrument (RSI) at HANARO (High-flux Advanced Neutron Application ReactOr), KAERI (Korea Atomic Energy Research Institute), Fig. 1.

Table 1 Physical and thermal properties of each material at 21 °C

	E (GPa)	Poisson's Ratio	Thermal Expansion	Thermal Conductivity (W/mm °C)	Specific Heat (J/Kg °C)
SA508	192	0.29	1.15E-5	5.19E-2	460.24
SA182	195	0.27	1.53E-5	1.29E-2	451.45
SA376	195	0.27	1.53E-5	1.29E-2	451.45
Alloy182	214	0.27	1.22E-5	9.72E-3	397.48

Fig. 1 Specimen of the dissimilar overlay weld pipe and Neutron Diffraction device

2.2 Overlay FEM Model

The Overlay FEM Model is shown in Fig. 2 and consists of the SA 508 nozzle, Alloy 182 buttering, Alloy 182 DMW, SA182 safe end, Alloy 182 SMW, SA 376 pipe and Alloy 52M overlay part. The material properties of Alloy 182 instead of those of Alloy 52M were used. This model is made by the ABAQUS/CAE Code and the 2D axi-symmetric model. Thermal analysis and stress analysis were performed on this model and the residual stress was calculated.

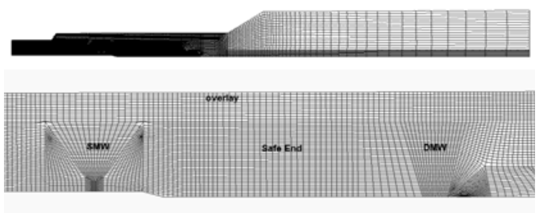

Fig. 2 Overlay FEM Model

2.3 Comparison of experimental and FEM values

The residual stresses measured by the Neutron Diffraction method were compared with the results of the Overlay FEM Model. These results are presented in Fig. 3. Fig. 3 is the comparison of the experimental value and FEM value for the axial stress and the hoop stress.

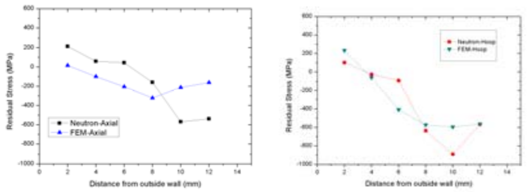

Fig. 3 Comparison of experimental values and FEM values.

As shown in Fig. 3, the experimental values and the results of the overlay FEM Model have a little deviation over 10 mm distance from outside wall, but as a whole, these experimental values show a trend which is in agreement with the analysis values of the overlay FEM Model.

2.4 Stress analysis of the overlay FEM model

In total, the 3 layers were overlaid. Whenever each layer was overlaid, a thermal analysis and a stress analysis were done respectively. Fig. 4 is the stress results of the axial stress (σ_y) and the hoop stress (σ_z) at the inner surface of the pipe according to the distance from the welded line of pipe after each overlay weld respectively. The results of the stress analysis at the DMW/SMW part after each overlay weld are summarized in Table 2.

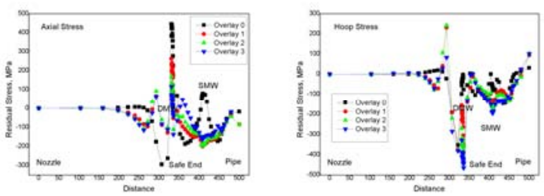

Fig. 4 Comparison of the axial stress at inner surface of pipe after each overlay weld

Table 2 Stress results at DMW and SMW part

	DMW (MPa)		SMW (MPa)	
	Axial	Hoop	Axial	Hoop
Overlay 0	394	-38	67	-63
Overlay 1	198	-213	-200	-140
Overlay 2	85	-349	-197	-166
Overlay 3	21	-416	-163	-194

As shown in Table 2, the overlay weld lowers the stress values of the DMW/SMW part not only in the thickness direction but also at the inner surface of the pipe. This means that the overlay weld has good benefits with a view to a stress relaxation and a PWSCC.

3. Conclusions

The specimen of the dissimilar overlay weld pipe was manufactured, and the residual stresses of this specimen were measured by using the Neutron Diffraction device in the HANARO research reactor. The overlay FEM Model on this specimen was made and analyzed by the ABAQUS Code. The results of the FEM analysis were compared with those of the experimental methods. As a whole, the values of the FEM Model showed a trend which was in agreement with the experimental values and the values of FE analysis were found to be reasonable. Therefore, when a new model of the dissimilar metal welds is developed, the residual stress can be estimated by an analysis with an appropriate FEM model without the experimental methods.

Also, the overlay weld lowers significantly the stress of the DMW/SMW part not only in the thickness direction but also at the inner surface of the pipe. Especially, the compression stress at the inner surface of the pipe in the DMW/SMW part was formed by the overlay weld. Therefore, the overlay weld has good benefits with a view to a stress relaxation and a PWSCC.

Acknowledgements

This work has been carried out under the nuclear R & D program supported by the Doosan Heavy Industries and Construction Co., Korea.

REFERENCES

[1] EPRI, 2007. Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaw in Pressurizer Dissimilar Metal Weld(MRP-216).

[2] Fricke, S., Keim, E., Schmidt, J., 2006. Numerical weld modeling – a method for calculating weld – induced residual stress. Nuclear Engineering and design, 139-150.

[3] Hutchings, M.T, Withers, P.J, Holden, T.M, Lorentzen, T., 2005. "Introduction to the Characterization of Residual Stress by Neutron Diffraction', 1st edn, London, Taylor and Francis.

[4] Hutchings, M.T, Withers, P.J, Holden, T.M, Lorentzen, T., 2005. "Introduction to the Characterization of Residual Stress by Neutron Diffraction', 1st edn, London, Taylor and Francis.

[5] Kim, K.S., Lee, H.J., Lee, B.S., Jung, I.C., Byeon, J.G., Park, K.S., 2008. Residual stress analysis of an overlay weld on a repair weld. In: Transactions of the Korean Nuclear Society Autumn Meeting.

[6] Kim, K.S., Lee, H.J., Lee, B.S., Jung, I.C., Park, K.S., 2009. Residual stress analysis of an Overlay weld and a repair weld on the dissimilar Butt weld. Nuclear Engineering and Design, 2771–2777.