Transactions of the Korean Nuclear Society Spring Meeting
Pyeongchang, Korea, May 27-28, 2010

Investigation on Circumferential Variation of Residual Stresses in Dissimilar Welds of Small Bore Penetration Nozzle

Jong Sung Kim [a*], Joong Hyun Seo [a]
[a] *Sunchon National Univ., Dept. of Mechanical Engineering, 413. Jungang-ro, Suncheon, 540-742*
[*] *Corresponding author: kimjsbat@sunchon.ac.kr*

1. Introduction

Axial and circumferential PWSCCs(primary water stress corrosion crackings) have occurred on the dissimilar welds of small bore nozzles such as steam generator drain nozzle and vent nozzle in South Korea [1]. Performing root cause analysis of the PWSCCs, PWSCC initiation potential and growth rate of the dissimilar welds have to be evaluated via residual stress assessment. The PWSCC initiation locations, predicted by using the stresses calculated by axis-symmetric and three-dimensional finite element analysis and the PWSCC initiation threshold stress value of Alloy 600, are compared with the examination results. The three-dimensional effect on the total stresses including residual and operating stresses is investigated via comparing three-dimensional analysis results with axis-symmetric analysis results.

2. Finite Element Modeling

Fig. 1 shows configuration of the dissimilar weld in steam generator drain nozzle. The dissimilar weld is constructed from SA508 Gr.3 Cl.1, Alloy 600 and Alloy 82/182 for lower head, drain nozzle, buttering/ weld metal respectively. Welding is performed by GTAW (gas tungsten arc welding) and SMAW (shielded metal arc welding).

The material property variations vs. temperature such specific heat, thermal conductivity, thermal expansion coefficient, elastic modulus, yielding strength determined from ASME B&PV Code, Sec.II [2], the previous study results [3,4], CMTR(certificated material test records) [5].

Fig. 2 illustrates a finite element model of the dissimilar weld developed by using PATRAN [6] and ABAQUS [7]. In order to investigate the circumferential variation effect of residual stresses, two finite element models are used. One is an axis-symmetric finite element model and the other is a three-dimensional finite element model.

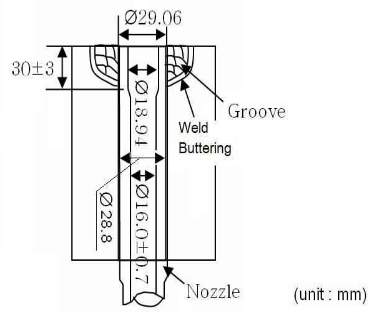


Fig. 1 Dissimilar weld of steam generator drain nozzle

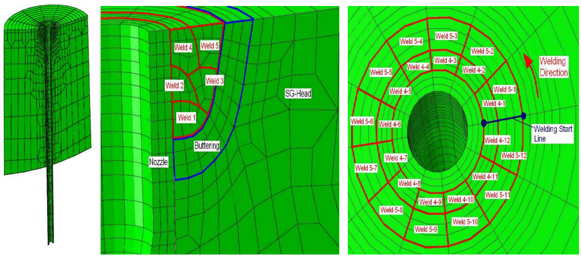


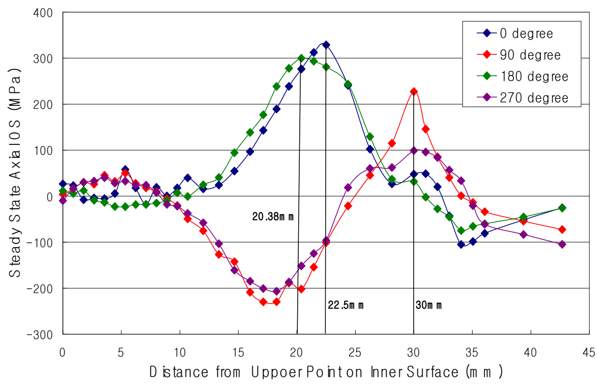
Fig. 2 Finite element model (3D)

3. Stress Analysis

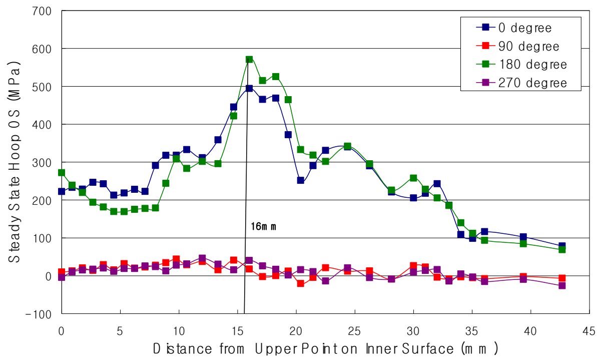
Elastic-plastic stress analysis is performed by using ABAQUS. Total stresses at the steady state during normal operation are derived considering welding residual stress, hydrostatic pressure test and cyclic normal operation.

Fig. 3 shows variation of the total stress distributions on nozzle inner surface according to circumferential location. As shown in the figure, the total stress distribution at welding start location 0^{o} is similar to the one at 180^{o} from welding start location in clockwise. Also the total stress distribution at 90^{o} is similar to the one at 270^{o}. Each maximum location on inner surface of the axial total stress at 0^{o} and 180^{o} is 22.5 and 20.38mm from nozzle upper point, respectively. Maximum location on inner surface of the axial total stress at 90^{o} and 270^{o} is 30mm from nozzle upper point.

Fig. 4 depicts the total stress distributions vs. circumferential angle on nozzle inner surface at the maximum stress generation locations presented in fig. 3. As depicted in the figure, the axial and hoop total stress distributions have periodic characteristic for circumferential angle. Amplitude and mean value of the hoop stresses are relatively higher than the axial stresses



(a) Axial stresses



(b) Hoop stresses

Fig. 3 Stress distribution variation on the inner surface vs. distance from nozzle upper point according to circumferential location

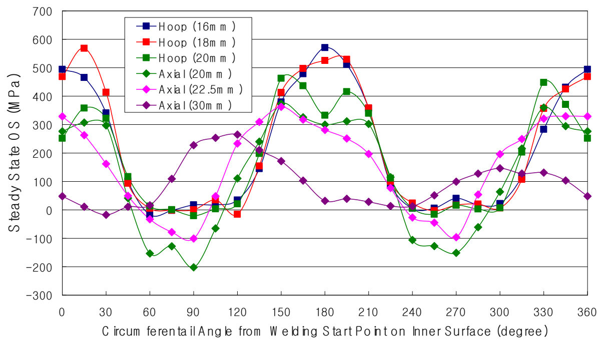


Fig. 4 Stress distribution on the inner surface vs. circumferential angle

Table 1 presents maximum total stress values and generation locations according to various finite element analyses. In this study, PWSCC initiation threshold value of Alloy 600 is assumed to range on 210~240MPa at 325°C based on the previous study result [8]. As comparing between Table 1 and PWSCC initiation threshold value, the following conclusions can be inferred:

- Circumferential PWSCC may occur on deeper inner surface than axial PWSCC,
- Initiation potential of axial PWSCC is greater than circumferential PWSCC if Alloy 600 material is isotropic,
- PWSCCs may occur at specific periodic circumferential locations.

The examination results via penetration, eddy current and destructive tests are as follows:

- There is no finding related to crack on weld metal,
- Eleven axial PWSCCs are initiated within 16~30mm region from nozzle top point and maximum axial PWSCC length is about 10mm,
- Three circumferential PWSCCs are initiated about 20mm region from nozzle top point and maximum circumferential PWSCC length is about 70°.

Table 1 Maximum total stress values and generation locations

FE Characteristic	Maximum Total Stress Value (MPa)				Maximum Total Stress Generation Location[1]	
		Axial		Hoop	Axial	Hoop
Axis-symmetric		242.9		229.6	20.5mm	16.3mm
		285.3		274.3	21.8mm	16.3mm
3D	20.4 mm[2]	307.2	16mm	494.0	15°	0°
		373.1		570.6	150°	180°
		359.9		-	330°	-
	22.5 mm	328.7	18mm	568.4	0°	15°
		362.5		529.6	150°	195°
	30 mm	265.0	20mm	357.8	120°	15°
		146.4		462.7	300°	150°
		-		448.3	-	330°

Note 1) Distance from nozzle upper point for 2D, and circumferential angle from welding start point for 3D
2) Distance from nozzle upper poi

Comparing the review results from Table 1 with the examination results, it is identified that the stress analysis results using finite element models have reasonable agreement with the examination results.

4. Conclusions

Based on the welding residual stress analysis results of the dissimilar weld on small bore penetration nozzle, the following findings are derived:

- Circumferential PWSCC may occur on deeper inner surface than axial PWSCC,
- Initiation potential of axial PWSCC is greater than circumferential PWSCC if Alloy 600 material is isotropic,
- In the viewpoint of crack initiation potential and location, the predicted results have good agreement with the examination results.

Acknowledgments

This work has been supported by KESRI (2009T100100561), which is funded by MKE(Ministry of Knowledge Economy).

REFERENCES

[1] KHNP, Structural Integrity Report for Dissimilar Welds on SG Drain Nozzle of Y#3 & #4, 2007, 2009.
[2] ASME B&PV Code, Sec.II, 2001
[3] J. Lee, C.H. Jang, J.S. Kim and T.E. Jin, 2007, "Mechanical Properties Evaluation in Inconel 82/182 Dissimilar Metal Welds," Proceedings of SMiRT 19.
[4] C.H. Jang, J.S. Kim and T.E. Jin, 2006, "Spatial Variation of Mechanical Properties in Alloy 82/182 Dissimilar Metal Welds," The 6th ASINCO.
[5] Daido Steel, Co., Ltd., 1990, CMTR, KJN-89-2074.
[6] MSC, PATRAN User's Manuals, Ver.2005 r2, 2005.
[7] Simulia, ABAQUS User's Manuals, Ver.6.8, 2009.
[8] EPRI, EPRI TR-103696, 1994.