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Influence of Large Deformation Repair of Small Partial Penetration Nozzle on ASME Sec.III Evaluation Results

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1. Introduction

Steam generator (SG) is a component that is installed in containment building of nuclear power plant and generates steam to make electrocity. It has number of nozzles to perform its function by connecting with other component, such as pressurizer, reactor, and etc. There are some nozzles with small diameter that are attached by partial penetration welding. The nozzles can deform during transportation or handling because those are weaker than full penetration nozzles.

In case that one of small partial penetration welded nozzle is bended by external forces, it should be replaced or repaired. Replacing the nozzle is the best way to ensure structural integrity, but it may be expensive and time consuming. If the second method is selected and the bended nozzle is straightened, not only residual stress is generated but also thickness reduction of nozzle wall occurs by plastic deformation. Residual stress and thickness reduction make structural integrity of the nozzle decrease, so it is necessary to evaluate influence of them on the nozzle.

In this study effects of residual stress and thickness reduction on ASME Section III evaluation are considered with a pressure test nozzle of SG.

2. Evaluation Method

Three cases were compared to evaluate the influence.

The first case (C1) considers only plant transients without residual stress as a control case. The second (C2) is modifying fatigue curve [1] without residual stress. Reference 1 describes a method modifying fatigue curve when mean stress is changed. Adding residual stress can be considered as changing mean stress. This case is used only for fatigue comparison. The third case (C3) is sum of stabilized residual stress and results of transient analysis. If residual stress is stabilized and does not change after the stabilization, the nozzle can be regarded as elastic, and thus stress superposition is possible.

3. Residual Stress Analysis

Three dimensional model of the pressure test nozzle is presented in Fig. 1. The figure shows locations considered as well. The model was established using ANSYS 10.0, and SOLID 185 element was adopted. TARGE170 and CONTA173 were applied to illustrate contact between shell of SG and the nozzle.

Stress-strain curves for materials of SG shell and the nozzle are necessary to analyze residual stress. Ramberg-Osgood equation [4] was used to make the stress-strain curves, and Gerber's method [5] was adopted to define constants for Ramberg-Osgood equation. Equation (1) is Rambér-Osgood equation, and Equation (2), (3) come from Gerber's method. Material properties that are essential to make stress-strain curve are referred from AMSE Section II [2].

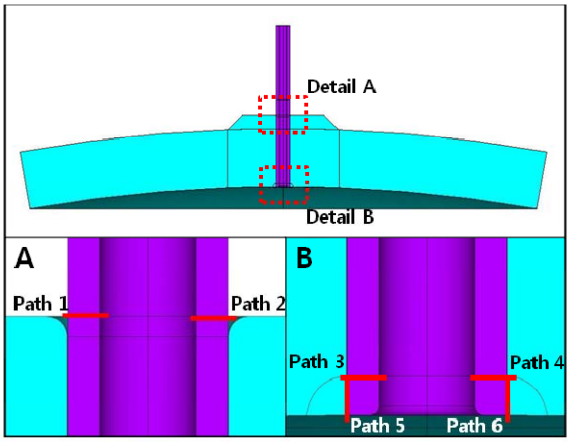

Fig. 1. Model for Analysis

$$\frac{\varepsilon}{\varepsilon_0}=\frac{\sigma}{\sigma_0}+\alpha\left(\frac{\sigma}{\sigma_0}\right)^n \tag{1}$$

$$n=\frac{1}{\ln(1+\varepsilon_u)} \tag{2}$$

$$\alpha=\left[\frac{\ln(1+\varepsilon_u)}{\ln\left(1+\frac{\sigma_y}{E}\right)}-\frac{\sigma_u(1+\varepsilon_u)}{\sigma_y\left(1+\frac{\sigma_y}{E}\right)}\right]\left[\frac{\sigma_u(1+\varepsilon_u)}{\sigma_y\left(1+\frac{\sigma_y}{E}\right)}\right]^{-n} \tag{3}$$

Residual stress analysis was done with the procedure below.

- Stage 1 : Bending the nozzle
- Stage 2 : Straightening the nozzle
- Stage 3 : Stabilizing distribution of residual stress

Figure 2 shows plastic strain intensities after bending and straightening stages.

Deformed shape of the finite element model was used to make a finite element model for transient analysis.

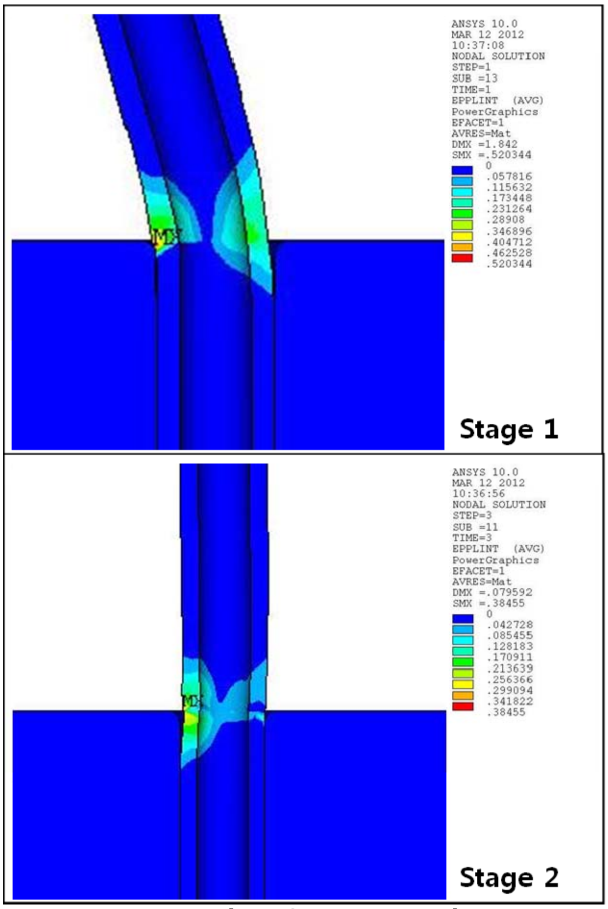

Fig. 2. Plastic Strain Intensity Plot

4. Transient Analysis

Thermal hydraulic data, pressure and temperature transients for OPR1000 were adopted for transient analysis. Analysis tool is ANSYS 10.0; SOLID5 element and elastic material properties [2] were used.

Stage 1 & 2 of repair procedure were involved as one transient with one occurrence for C3.

5. Results

Primary plus secondary stress intensity and cumulative usage factor for the cases are presented in Table 1.

Increase of primary plus secondary stress intensity due to the repair procedure is significant at Path 1 & 2 where plastic strain is high. Affection of the repair transient is not considerable at the other paths

Cumulative usage factors of C3 at Path 1 & 2 result from one occurrence of repair transient. C3 can consider stress range between the greatest stress during all transients and zero stress when repair procedure starts. The stress range makes greater alternative stress that results in cumulative usage factor. However C2 method is not able to account for the zero stress, so the fatigue results of C2 at Path 1 & 2 are not different with those of C1. Nevertheless there is no distinctive difference among the three cases.

Table 1. Results of Three Cases

Location		P+Q(1) (ksi)		CUF(2)		
		C1	C3	C1	C2	C3
Path 1	In	6.44	53.40	0.0000	0.0000	0.0186
	Out	6.81	53.64	0.0000	0.0000	0.0241
Path 2	In	5.86	54.49	0.0000	0.0000	0.0224
	Out	6.20	57.55	0.0000	0.0000	0.0283
Path 3	In	48.31	26.33	0.0140	0.0150	0.0140
	Out	28.96	34.11	0.0217	0.0235	0.0218
Path 4	In	50.20	59.17	0.0153	0.0156	0.0154
	Out	39.71	55.85	0.0466	0.0481	0.0472
Path 5	In	17.55	22.50	0.0032	0.0033	0.0032
	Out	26.25	34.11	0.0217	0.0235	0.0232
Path 6	In	38.62	43.16	0.0036	0.0039	0.0036
	Out	36.71	79.95	0.0466	0.0481	0.0479

Note)
(1) Primary stress plus secondary stress intensity
(2) Cumulative usage factor

6. Conclusions

Influence of residual stress on ASME SECTIONIII evaluation was studied for straightened small nozzle that is connected vessel with partial penetration weld.

The residual stress made the primary plus secondary stress intensities increase. Those are greater than code criteria, 3Sm, so simplified elastic-plastic analysis should be conducted [3]. Therefore the effect of residual stress generated due to repair procedure cannot be neglected for ASME SECTION III evaluation.

Fatigue result of partial penetration welded small nozzle is not significantly affected by residual stress generated due to straightening repair. Additionally, the residual stress effect on fatigue cannot be evaluated with shifting mean stress.

REFERENCES

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