# Fatigue Analysis of Pressurizer Spray Nozzle by 3-Dimensional Finite Element Modeling

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## 1. Introduction

Because of the complicated geometry and the difficulty to select its boundary conditions, the fatigue integrity of the nuclear components has been evaluated by adopting partial and conservative two-dimensional stress and fatigue analysis. To alleviate the conservatism of this two-dimensional modeling and simplified analysis method and to perform more accurate fatigue analysis, it is needed to perform the analysis with the three-dimensional modeling[1].

A few of weak locations which are anticipated not to meet the code criteria when the environmental effect correction factor(1.33) is applied are selected[1]. The spray nozzle of a pressurizer is the one of them. Through this study, we've carried out a detail analysis of a PZR spray nozzle with the three-dimensional modeling.

## 2. Numerical Model

A PZR spray nozzle in Shin-Kori unit 3 and 4 is used as a target in this analysis. Geometries of the analysis model are shown in Fig. 1.

To save analysis time, 1/4 of the nozzle is modeled by its symmetry condition. Solid70 element was selected to model the target and SURF152 element was used to analyze heat transfer by internal fluids in a thermal analysis. In a stress analysis, Solid45 element was used. In modeling of the safe end attached to the nozzle, its length has to be long enough so that it doesn't make any influence to the analysis result of the spray nozzle. Minimum length is figured out by the following Eq. (1) and a safe end was modeled with 3 inch of length.

$$L_{\min}=\frac{3}{\beta}, \quad \beta=\sqrt[4]{\frac{3(1-\upsilon^2)}{R^2t^2}} \tag{1}$$

$$Blow\!-\!off\,Load=-\frac{(\pi r_i^2 P_D)}{\pi(r_o^2-r_i^2)} \tag{2}$$

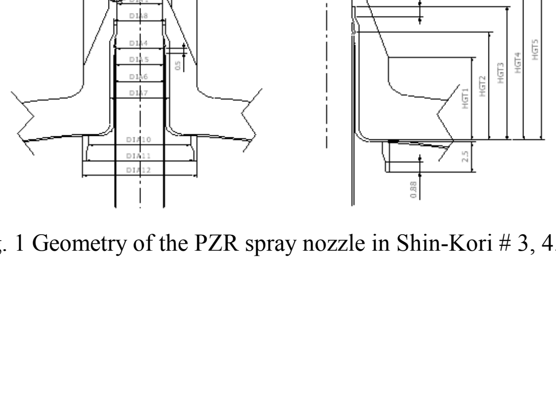

Fig. 1 Geometry of the PZR spray nozzle in Shin-Kori # 3, 4.

Blow-off load was obtained from Eq. (2) and applied to the end of a safe end in the stress analysis. Pressure, temperature, external loadings and operating transient conditions in the Shin-Kori # 3,4 design specification[3] are applied to this analysis.

## 3. Analysis Method and Results

Fatigue analysis is executed according to the ASME code section Ⅲ NB-3200[2]. Fig. 2 shows the procedure of a detailed fatigue analysis using three-dimensional finite element modeling.

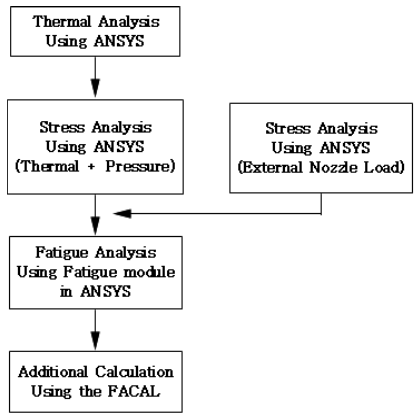


Fig. 2. Procedure of a detailed fatigue analysis.

First of all, a thermal analysis using ANSYS was performed for the overall transient conditions. With this result, cut sections whose temperature gradient is to be high are selected for the fatigue analysis. And then temperature distributions and the applied pressure values are used to calculate stress intensity for each transient. The analysis time used to obtain the above temperature distributions is determined by choosing the time when thermal stress between internal and external cut sections is maximum or minimum. If a temperature distribution in each cut section is a non-linear variation shown in Fig. 3, it is expressed and calculated as Eq. (3).

$$T=1/t\int_{-t/2}^{t/2}T(y)dy, \quad V=(12/t^2)\int_{-t/2}^{t/2}yT(y)dy \tag{3}$$

After those steps, with the alternating stress intensity for the overall transient conditions and the occurring frequencies during the life time, cumulative usage factors are calculated for the overall transient conditions by the post processing module in ANSYS. Since the elastic modulus ratio and Ke factor are not reflected in the ANSYS' module, FACAL programmed by Fortran

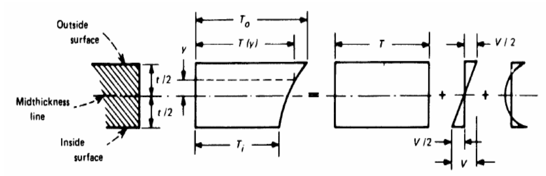


Fig. 3. Decomposition of temperature distribution range.

programming language was used to get more accurate results.

Fig. 4 shows one of the temperature distributions for the heat-up transient condition obtained from the thermal analysis.

Stress intensity distributions that maximum and minimum pressure was applied at a certain time of thermal analysis for the heat-up transient condition are shown in Fig. 5.

Based on the thermal analysis, cut sections where the temperature gradient is high or the stress concentration is to be severe were selected for the fatigue analysis. Locations of these cut sections are represented in Fig. 6.

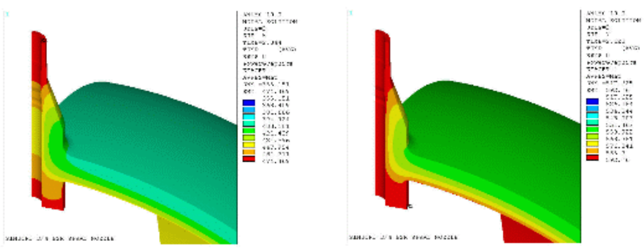

Fig. 4. Temperature distributions(heat-up transient).

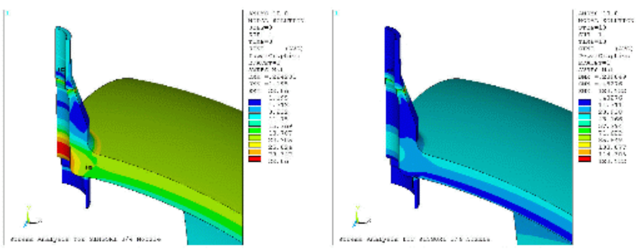

Fig. 5. Stress intensity distributions(heat-up transient).

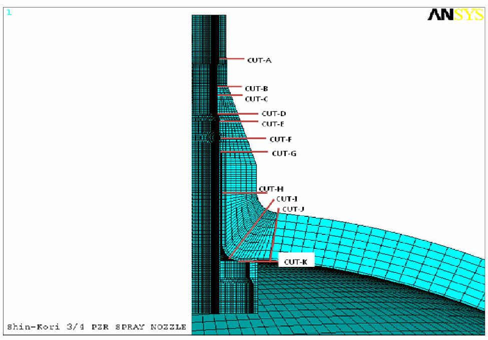


Fig. 6. Locations of cut sections for fatigue analsys.

Table 1. Fatigue analysis results

| Cut ID | Cumulative Usage Factor | |
|---|---|---|
| | Inside | Outside |
| A | 0.02808 | 0.01192 |
| B | 0.03472 | 0.00789 |
| C | 0.00154 | 0.00079 |
| D | 0.00154 | 0.00153 |
| E | 0.00154 | 0.00152 |
| F | 0.00152 | 0.00152 |
| G | 0.00153 | 0.00153 |
| H | 0.00208 | 0.00152 |
| I | 0.00169 | 0.00153 |
| J | 0.00152 | 0.00153 |
| K | 0.43413 | 0.17264 |

With the results of stress intensity using ANSYS, alternating stress intensity reflecting the elastic modulus ratio and Ke factor was obtained from the FACAL program. Usage factors were figured out for the each event-substep combination and then finally summed up. In consequence of the fatigue analysis, cumulative usage factors are listed in Table 1. The maximum cumulative usage factor was at the inside of a head part in the PZR spray nozzle and its value is 0.43413.

## 4. Conclusions

Using three-dimensional finite element modeling, a detailed fatigue analysis has been carried out for the PZR spray nozzle. Besides the modeling, the process reflecting the elastic modulus ratio and Ke factor was added to this fatigue analysis. Later, the above results will be compared with the results from a two-dimensional fatigue analysis which has been being performed.

## REFERENCES

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[3] KOPEC, Design Specification for Pressurizer Assembly for Shin-Kori 3 and 4, No.3L186-ME-DS275-00, Rev.1.

[4] T. Kim, B. Kim, K. Lee, 3D Fatigue Analysis for the Steam Generator Economizer Feedwater Nozzle of the Advanced Reactor, Trans. KNS Spring Meeting, Jeju, Korea, May 10-11, 2007.