Comparison of ASME Code NB-3200 and NB-3600 Results for Fatigue Analysis of Primary Piping Spray Nozzle

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1. Introduction

A study was performed to get more actual Cumulative Fatigue Usage Factors(CUFs) which excluded over-conservatism. A usual procedure of fatigue analysis of primary piping spray nozzle has been to follow ASME B&PV Code NB-3600 method because the nozzle is attached on the primary piping. The NB-3600 method is known to be very conservative in comparison with NB-3200 method. We performed stress and fatigue analysis according to NB-3200 method in order to reduce the conservatism. This sort of change of analysis method is acceptable according to NB-3611.2, which says that when the stresses determined by the methods given in NB-3630 exceed the limits thereof, the design can be accepted provided it meets the requirements of NB-3200[1].

2. Component Description

The primary piping has a nominal pipe size of 30" and is constructed of SA-508 Gr.1a. The primary piping spray nozzle is configured to match 3" Sch.160(nominal pipe size) piping. The nozzle is constructed of SA-508 Gr.1a. The safe end is constructed of SA-182 F316[2,3].

The length of safe end pipe and primary piping must make enough length so as not to exert influence to analysis results. These are calculated using equation (1)[6].

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

where, R: mid-radius of nozzle or piping, respectively
t: thickness of nozzle or piping, respectively
ν : Poisson's ratio

The length of safe end pipe modeled is 3", and of primary piping 17".

3. Model Development

A quarter section of the primary piping and spray nozzle was modeled 3-dimensionally considering the symmetry. Element type of SOLID70(3-D Thermal Solid) and SURF152(3-D Thermal Surface Effect) are used in thermal analysis. The 3-dimensional model is shown in Fig.1 consists of 15,920 elements and 16,944 nodes.

In structural analysis the cladding is excluded according to NB-3122. This is allowed when clad thickness is less than one tenth of shell thickness, in which case cladding does not have meaningful effect on stress intensity.

4. Analysis Methodology

4.1 Thermal Analysis

Outside surface of primary piping and spray nozzle are assumed to be perfectly insulated. Symmetry boundary conditions are applied to the planes of symmetry. Inside performed thermal transient analysis. Transient group 3 of Shin-Kori units 3 and 4 design specification[3] is applied. The results of thermal analysis are post-processed to reduce the number of time points to be used in thermal stress analysis. The time points at which maximum or minimum temperature gradients through the wall occur are included in the selected group of time points.

4.2 Structural Analysis

4.2.1 Analysis Cases

Two cases are studied in order to evaluate the relieving of conservatism. Case 1 is to apply minimum or maximum pressure. Case 2 is to apply actual pressure. Pressure is obtained from group 3 of Shin-Kori units 3 and 4 design specification[3].

4.2.2 Boundary Condition

Symmetry boundary condition is applied to the planes of symmetry. Blow-off load, which is a stress distribution at the model boundaries due to pressure, is calculated using equation (2) derived from the relation of equilibrium of force.

$$\text{Blow-off load} = -\frac{(\pi r_i^2 P)}{\pi (r_0^2 - r_i^2)} \qquad (2)$$

Where, $r_0 =$ outside diameter of nozzle or piping
$r_i =$ inside diameter of nozzle or piping
P = applied pressure

4.2.3 Boundary Condition for external load analysis

A full model is constructed to analyze the nozzle for external loads applied at the nozzle/branch line interface and at the location of the nozzle in the run piping. One side of primary piping is fixed in hoop and axial directions. External loads are applied at the other side of the piping and at the end of the nozzle.

4.3 Fatigue Analysis

① Evaluation Section

Evaluation sections of fatigue analysis are shown in Fig.2. The evaluation sections are chosen based on stress distribution and past experience.

② Results of Fatigue Analysis

The CUF values are shown in Table 1. Case 2 shows smaller CUF values than Case 1.

5. Comparison of Results between NB-3200 and NB-3600 CUF Calculations

Table 1 shows comparison of results from UCN 5&6 report and those from this analysis. The UCN 5&6 evaluation of the spray nozzle was done according to ASME Code NB-3600. We performed according to ASME Code NB-3200. The NB-3600 calculation showed that the maximum CUF was 0.5900 at the nozzle-to-safe end. However, the NB-3200 calculation shows that the individual CUFs are negligible for most of the part. The reasons for this difference are inferred as follows.

① Thermal transient conditions were treated very conservatively in UCN 5&6 to envelope the transient conditions[4]. For some transients step change of temperature were assumed. However, we applied the thermal transients as given in the design specification.

② High CUFs of UCN 5&6 report can be attributed to the K_3C_3 stress indices of $1.7 \times 1.8 = 3.06$ applied to the $\alpha_a T_a - \alpha_b T_b$ term in the NB-3600 analysis. It was evident that large CUF occurred by excessive stress indices at Cut-A. However, we didn't apply these stress indices by incorporating a very fine finite element model.

6. Conclusions

We performed stress and fatigue analysis using 3-Dimensional model. The CUFs calculated using actual pressure showed smaller than those using maximum and minimum pressure. The maximum CUF was shown 0.0101, much less than the allowable of 1. And the CUFs calculated with NB-3200 method were significantly less than those with NB-3600 method. Fatigue analysis result tells that the stress indices of NB-3600 are exceedingly conservative. A study of M. E. Nitzel shows similar results[8].

REFERENCES

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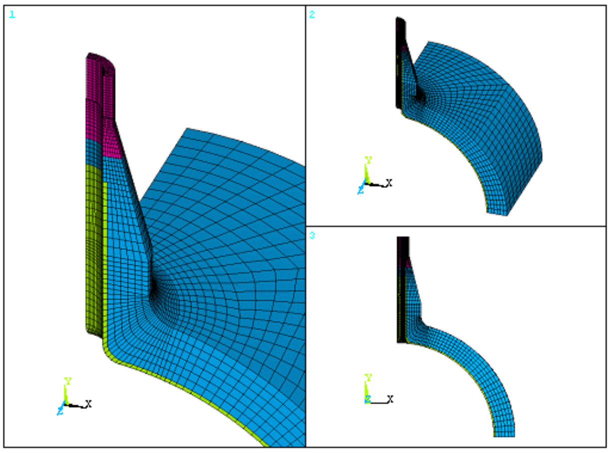

Fig.1 3-D finite element model of the Spray Nozzle

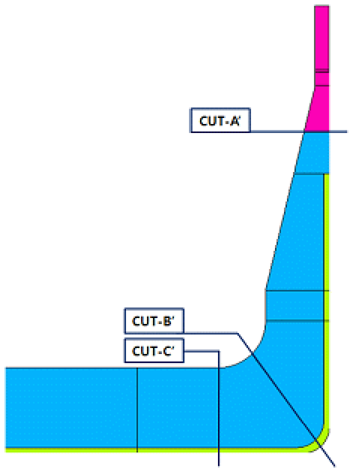

Fig.2 Location of evaluation sections

Table 1 Cumulative usage factor

Cut ID	(1) UCN5/6 (NB-3600)	(2) This Paper (NB-3200) CASE 1 (Inside) (Note1)	(2) This Paper (NB-3200) CASE 2 (Inside) (Note2)	(2)C1/(1) (%)	(2)C2/(1) (%)
CUT-A	0.5900	0.0000	0.0000	0.0	0.0
CUT-B	No evaluation	0.0101	0.0088	-	-
CUT-C	0.0658	0.0018	0.0012	2.7	1.8

Note 1: Minimum and maximum pressure
Note 2: Actual pressure