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Consideration of Beyond Design Basis Earthquake on the Flaw Evaluation of Pipes

Ye Ji Kim [a*], Il Soon Hwang [a]
[a]Nuclear Materials Laboratory, Seoul National University, Republic of Korea
[*]*Corresponding author: kyeji00@snu.ac.kr*

1. Introduction

Integrity of plant piping has critical importance to the safety of nuclear power plants. So there are some non-destructive examination methods for to detect the flaws, but they have to wait for reactor shutdown, around 10 years. And there is an allowable size criterion of the crack to judge the continuation operation of the plant. But in practice, many cracks have been detected whose depth is larger than the code allowable size especially in weldment of the pipes. Considering the crack growth rate in PWR operation environment, the cracks in dissimilar welds could grows unusually fast especially during earthquake.

After Fukushima accident, the riskiness due to the unexpected seismic events has been well known. Design basis earthquake of the some Korean old plants is 0.2g, but in the latest stress tests for the old plants which are the follow-up measures, 0.3g seismic load is assumed to secure more high confidence of the plant. In this point of time, seismic consideration on the flaw evaluation is also needed. This study is basically consisted of steps of methodology to evaluate the flawed piping under beyond design basis earthquake.

2. Methodology

Figure 1 shows the schematic diagram of procedure for flaw evaluation. Detail of the each step is described below.

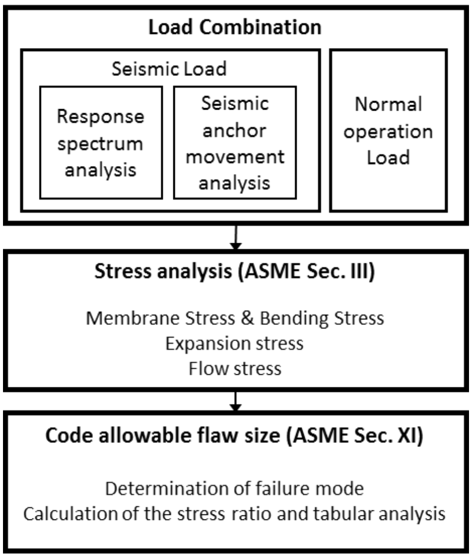

Fig. 1. Procedure for flaw evaluation

2-1. Seismic consideration and load combination

As appears by the Fukushima accident, the probability of the unexpected seismic events cannot be neglected anymore. In the stress test for old plant as a follow-up measures, the earthquake which has 10^{-5}/yr probability is assumed based on seismic hazard analysis to evaluate seismic margin of the plants.

To evaluate the flaw whose depth is larger than criteria in the IWB-3600 of ASME Sec XI, stress analysis using combined load is needed. The combined load includes the normal operation load as well as the load caused by seismic event. Normal operation loading can be referred the design report.

There are two types of load caused by earthquake; first one could be obtained by using response spectrum analysis. This method is basically based on the linear elastic fracture mechanics, so it could be assumed that the response of pipe under 0.3g seismic event case corresponds with 1.5 times the 0.2g case. In this way, larger earthquakes could be considered in analysis.

The other one is caused by difference of movements between the multiple anchors, and both of loading can be obtain by finite element methods.

2-2. Stress analysis

For the purpose of flaw evaluation, the stresses due to the loading in previous step shall be calculated according to ASME Sec. III and XI. The stresses to be used in flaw evaluation are the membrane, bending, and expansion stress.

In case of circumferential flaw, for example, the stresses can be calculated as described below.

$$\sigma_m = \frac{pD}{4t} \quad (1)$$

$$\sigma_b = \frac{DM_b}{2I} \quad (2)$$

$$\sigma_e = \frac{DM_e}{2I} \quad (3)$$

In the equations (1)-(3) t, D and I represent the pipe thickness, diameter, moment of inertia respectively. Membrane stress is mainly caused by pressure(p). M_b represents the primary bending stress due to the normal operation load and seismic load obtained by response spectrum analysis. Secondary moment, M_e includes the effect of thermal expansion and seismic anchor motion.

2-3. Flaw evaluation

Considering the results of previous steps, the allowable flaw depth can be obtained in association with the flaw length according to the Appendix C of ASME Sec. XI. The analysis method depends on the failure mode and needs the stress ratio as bellows.

$$\text{Stress ratio} = \begin{cases} \dfrac{\sigma_m+\sigma_b}{\sigma_f} & (4) \\ Z\left[\dfrac{\sigma_m+\sigma_b+\sigma_e}{SF_b}\right]/\sigma_f & (5) \end{cases}$$

Equation 4 is for limit load analysis and equation 5 is for elastic plastic fracture mechanics respectively. Z factor is ratio of the limit load on the basis of limit load analysis to the limit load estimated using an EPFM, and depends on the geometries of the pipe and toughness. Structural factor is also need for conservative analysis and the values for each case are presented in the code.

With this stress ratio, the limit of flaw depth to the pipe thickness ratio could be easily obtained in associated with the flaw length. Figure 2 shows the example result of code allowable size.

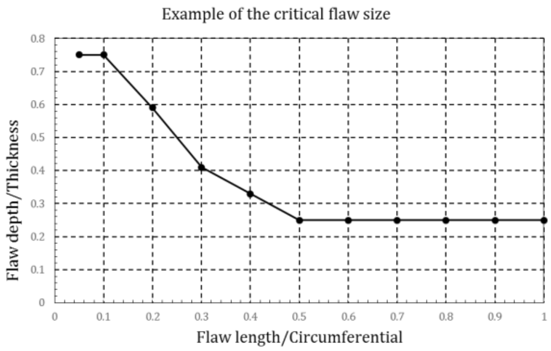

Fig. 2. The allowable flaw depth

3. Conclusions and Future Work

The objective of this study is to suggest the methodology to estimate the allowable flaw size with consideration over design basis earthquake using FEM with ASME code criteria. This could be applied in various flaw and pipe circumstances. The next step should be obviously actual analysis with real pipe model and date. In the overall steps, elaborate finite element analysis to estimate of the seismic load is needed. Further study pursues the flaw evaluation for the piping in OPR 1000.

REFERENCES

[1] J.W. Reed, et al., A Methodology for Assessment of Nuclear Power Plant Seismic Margin, Rev. 1, EPRI, 1991.
[2] ASME Boiler & Pressure Vessel Code Sec. III, 1994.
[3] ASME Boiler & Pressure Vessel Code Sec. XI, 1994.
[54 한국수력원자력, 월성 1 호기 원전 스트레스 테스트 수행보고서, 2013.