Development of the Stress Evaluation Method of Nuclear Power Plant Piping System Considering Characteristic of Relative Displacement

Jin Sung Park[a*], Tae Young Ryu[a], Han Bum Surh[a], Min Kyu Kim[a], Jin Won Hong[a], Seok Jun Kang[a], Moon Ki Kim[a], Jae Boong Choi[a], Eun Woo Ahn [b]
[a]*Department of Mechanical Engineering, Sungkyunkwan Univ.*
[b]*KEPCO Engineering & Construction Company, inc.*
[*]*Corresponding Author: rtn8822@skku.edu*

1. Introduction

To prevent potential accidents, it is important to secure the safety of the structure. And as you can see in the case of Japan and Haiti, there are so many severe earthquakes all over the world. So there are many research being proceeded to prepare against the earthquake.

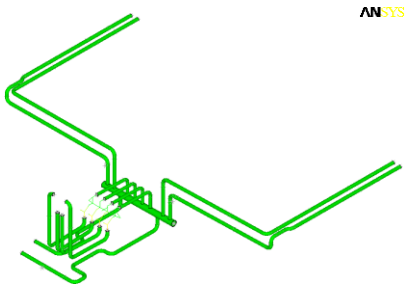
Generally, seismic design and base isolated design are used to prevent damage by the earthquake. Seismic design concept is increasing stiffness of the structure to resist earthquake. And base isolated design concept is reducing the vibration energy transferred to the structure from ground. The base isolated design can be conducted by buffers between the structure and ground. The buffers may deformed instead of the structure and absolve the earthquake vibration energy. Lately base isolated design is being researched in nuclear power plant system in Korea.

In this research, Frequency Response Spectrum(FRS) analysis, Seismic Anchor Motion(SAM) analysis and Time History(TH) analysis are performed to evaluate the stress occurred during the earthquake. And also a new method for evaluated the stress in the case of large relative displacement.

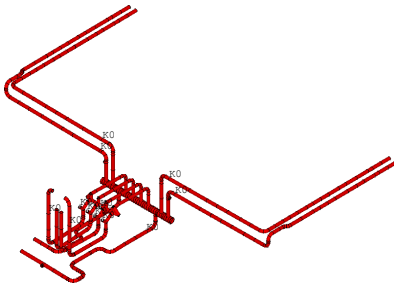
2. Methods and Results

2.1 Analysis Model

In this research, the main steam piping system of the APR1400 is used as analysis model. The model is prepared as two types; 1D and 3D. Pipe16 and Pipe18 are used as element types of 1D FE model in ANSYS. And Solid 185 is used as element types of 3D FE model. Fig. 1 shows FE models that is used in this research.



(a) 3D FE Model



(b) 1D FE Model

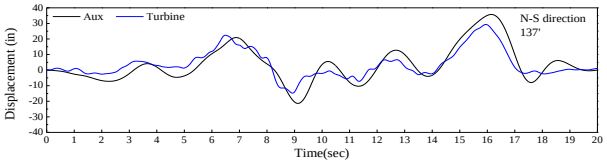
Fig. 1. FE models of main steam piping system

2.2 Loading Conditions

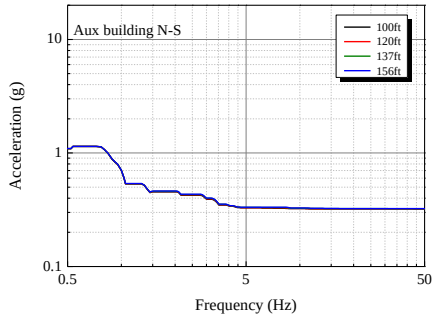
The analysis model consists of two sectors. The one is auxiliary building sector, another one is turbine building sector. The base isolated system is applied to auxiliary building sector only and turbine building area is considered as traditional seismic design. Therefore, auxiliary and turbine building piping have different seismic input data at the analysis. As I mentioned before, the base isolated design reduces vibration transfer. As a result, structure motion changes to long period motion. Therefore, the turbine building sector and the auxiliary building sector may have different motion. For this reason, large relative displacements can occurred between the structures.

2.3 Analysis conditions

In this research, FRS, SAM and TH analyses are performed. At each analysis, different input data are used. And input data is also different by the support location, height and directions. Fig. 2 shows typical input data of FRS and TH analyses.



(a) Time history input data



(b) Frequency response spectrum input data

Fig. 2. Analysis Input data

Generally, FRS analysis results is calculated by Square Root of the Sum of the Squares(SRSS) and SAM analysis results is calculated with SRSS and Absolute sum.

2.4 Results

In general, 3D analysis results are considered as less conservative than 1D analysis results. However it is believed that 1D analysis results and 3D analysis results show similar tendency. But, in Fig. 3, 3D analysis results are more conservative than 1D analysis results, and 1D analysis results and 3D analysis results shows different tendency in Fig. 4 and Fig.5.

Generally, 1D TH analysis results are calculated with B indices presented in ASME Sec.III NB-3680. The B indices are mainly used to calculate primary stress. However, in this condition of large relative displacement, secondary stress increases significantly. Therefore, to reflect the effect of the secondary stress, it is necessary to calculate the stress using C indices that is also presented in ASME Sec.III NB-3680. The C indices are used to calculate the secondary stress.

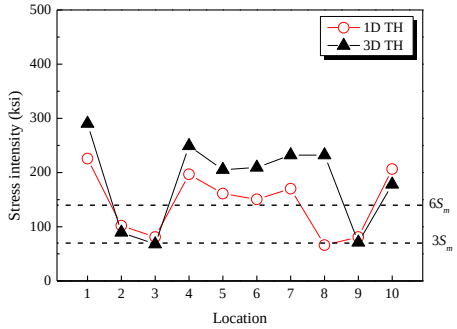


Fig. 3. Time history results

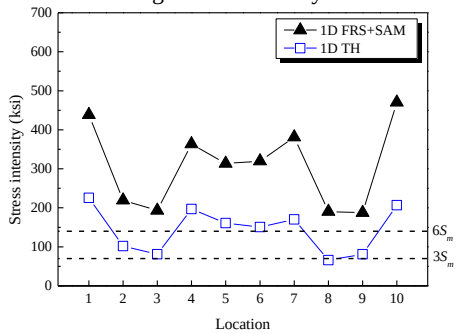


Fig. 4. 1D TH results vs FRS+SAM results

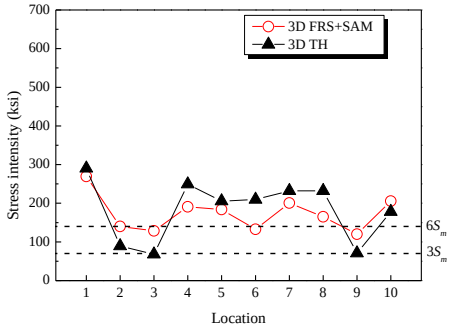


Fig. 5. 3D TH results vs FRS+SAM results

Consequently, equation (1) is proposed to combine with the results using B indices and C indices.

$$\sigma_{B+C} = \gamma \times \sigma_B + (1-\gamma) \times \sigma_C \quad (\gamma = \frac{\sigma_{FRS}}{\sigma_{SAM}+\sigma_{FRS}}) \ (1)$$

The γ is the ratio of the stress of FRS and FRS+SAM results. Then, the resultant stress is calculated by multiplying with B indices results and C indices results.

In Fig. 6, the 1D FRS+SAM analysis results and the 1D TH analysis results by B+C are seemed to similar. And In Fig. 7, 3D TH analysis results and 1D TH analysis results by B+C also have similar tendency. And 1D time history analysis results are bigger than 3D time history results. Note that the two main questions that I have mentioned are cleared by using the equation (1).

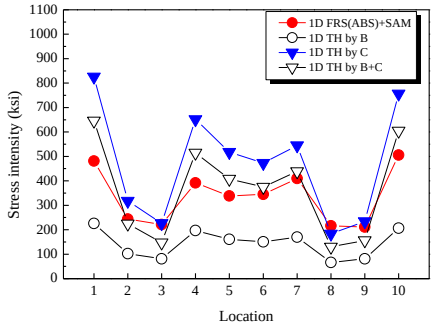


Fig. 6. 1D TH results by B, C and B+C vs FRS+SAM results

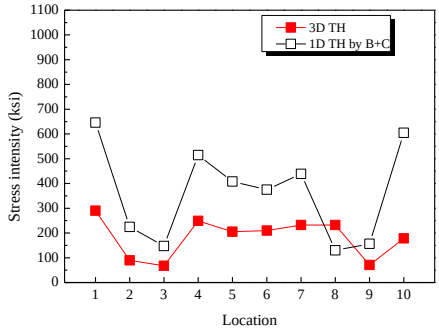


Fig. 7. 3D TH results vs 1D TH results by B+C

3. Conclusions

In this research, the stress was evaluated on the APR 1400 main steam piping system with the base isolated

design. The results show weird tendencies; the 3D results seems less conservative than the 1D results, and show different tendency between 1D and 3D results. A new method was conducted to reflect the effect of the secondary stress by the large relative displacement and it shows reasonable results.

REFERENCES

[1] H. J. Heo, H. B. Surh, E.H. Ban, J. B. Choi, J. C. Koo, E. W. Ahn and M. K. Kim, 2012, " Assessment of Relative Displacement Effect on Base Isolated Nuclear Power Plant Piping Using 3D Finite Element Analysis," Proceeding of KSME Spring Conference, pp. 198~199.

[2] ASME Boiler and Pressure Vessel Code Section III, 2007, “Rules for Construction of Nuclear Power Plant Components.” The American Society of Mechanical Engineers.