Application of a Simplified Elastic-Plastic Analysis Procedure to Strain Determination of Nuclear Safety Class I Components under Seismic Loads

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1. Introduction

There were some Beyond Design Basis Earthquakes (BDBEs) in Japan. In response, the Earthquake Design Advisory Board was issued. The recent seismic event beyond Operating Basis Earthquake (OBE) occurred at Kyoung-Ju area in South Korea. As a result, Korea nuclear society has begun to increase interests in seismic safety margin. some studies have performed for strain-based seismic evaluation of nuclear safety class I components. The studies proposed guidelines of dynamic finite element elasto-plastic seismic analysis [1,2], and strain-based acceptance criteria [3].

However, existing time history EP seismic analysis considering plasticity has a problem that takes too much time. So, have been proposal a simplified EP seismic analysis procedure based on the previous elastic seismic analysis and the penalty factors presented in the ASME B&PV Code case N-77 [4].

In this paper, it was confirmed that existing simplified EP seismic analysis procedure [5] were applied to pressurizer nozzles(safe-end), the seismic weak point of nuclear safety 1 class component, and that a good agreement was reached in comparison with the reference model.

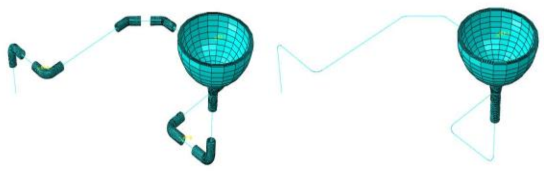
2. Target Model

For application of the simplified EP seismic analysis procedure, the surge piping system between pressurizer nozzle and hotleg tude of OPR-1000, a domestic operational nuclear power plants, was used as a model. The lower head of the pressurizer and the surge nozzle are made up of SA508 Gr.3 Cl.1, while the surge line and the safe-end are made up of ASS TP316. There are four supports in the piping system.

The target figure, properties and the time displacement histories for each supports are the same information used in the precious simplified EP seismic analysis procedure.

3. Finite Element Model

This fig 1. is a finite element model for the analytical target model. Each Model is a reference model, a hybrid model for the conventional elastoc-plastic analysis and a beam element model for elastic analysis. Element type used PIPE31 for beam element and C3D8I for solid element. Commercial program, ABAQUS, was used for dynamic time history finite element analysis, NLGEOM and Rayleigh damping(4%) were used.



(a) Hybrid Model (b) Beam model
Fig 1. Finite element model of target

4. Analysis Results

Fig 2. Shows the maximum point and contours of the equivalent plastic strain for the reference elasto-plastic analysis. Fig 3. Shows the time history of the equivalent plastic strain. The analysis shows that the maximum equivalent plastic strain is 0.1517% and the equivalent plastic strain amplitude (Ealt) is 0.07585%, which is half the maximum equivalent plastic strain.

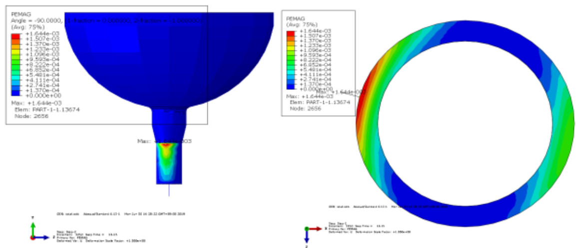


Fig 2. Maximum point and contour of the equivalent plastic strain

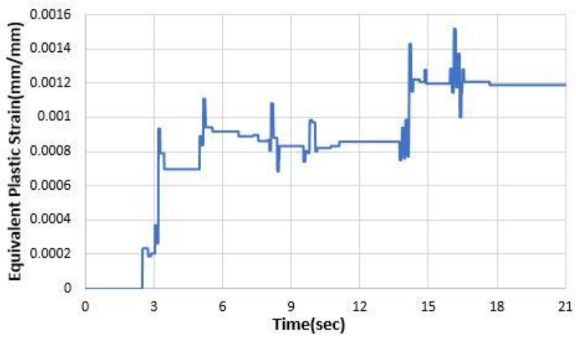


Fig 3. Time history of the equivalent plastic strain

Eq 1. Represents the equivalent plastic strain amplitude value calculated by considering the penalty factor in the value derived from the elastic analysis. And the equivalent plasticity strain amplitude values for the simplified EP seismic analysis procedure and the existing elasto-plastic analysis are compared in Table 1.

$$\varepsilon_{att} = \frac{1}{2E}[K_e(S_{P-SB-SL}) + K_n \cdot K_v \cdot S_{SB} + K_v \cdot S_{SL}] \quad (1)$$

Table 1. Comparison between proposed procedure and elasto-plastic FEA.

Proposed Procedure(A)	Elastic-Plastic FEA(B)	Relative Difference (C=100x(A-B)/B)
0.12406	0.07585	63.56

5. Conclusion

The simplified EP seismic analysis procedure, which was proposed for determining deformation of the nuclear safety class 1 piping under seismic load, was applied to the seismic weak point nozzle (safe-end), and conservative values were found to be derived compared with the results of the reference elasto-plastic analysis.

Acknowledgment

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