Seismic Analysis for Decay Tank of Research Reactor

Jinsung Kwak [a*], Jinho Oh [a], Sangjin Lee [a], Jongmin Lee [a]
[a]*Korea Atomic Energy Research Institute*
[*]*Corresponding author:jskwak@kaeri.re.kr*

1. Introduction

The main Purpose of PCS (Primary Cooling System) is to remove heat generated from the reactor core through the heat exchangers. The coolant passing through the reactor core contains many types of radionuclides. N-16, one of them, governs the coolant radioactivity at the core exit, but it has a very short decay time. Specifically, to reduce the level of N-16 radioactivity, the reactor outlet PCS pipe is connected to decay tank immediately after it penetrates the pool. The decay tank is designed to provide enough transit time to ensure that the N-16 radioactivity decreases to a level similar to those of the other radionuclides before the coolant leaves the Decay tank shielding room by expanding the coolant path.

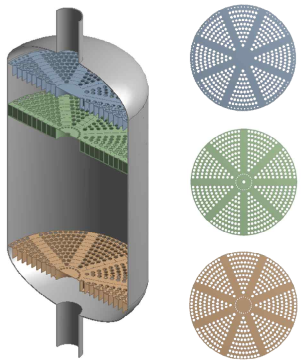

Fig. 1. Decay tank geometry

Fig. 1 shows geometry of Decay tank. The Decay tank has three internal perforated plates which spread the coolant into the whole section of the Decay tank to reduce dead zones and block the coolant flow to increase transit time.

Because the Decay tank performs safety related function, it is designed as Safety class 3, Quality class Q and Seismic category I. Decay tank is located on the lowest floor in the underground where the PCS pumps are installed and is shielded completely by heavy concrete due to the toxic radionuclides in the coolant as mentioned earlier. These make maintenance of the Decay tank impossible. Thus, structural integrity and functionality of the Decay tank must be evaluated and ensured before its construction.

The response of the Decay tank due to seismic is predicted by the frequency response spectrum analysis based on the FRS (Floor Response Spectra) by using ANSYS.

2. Analysis model

2.1 FE model

The finite element model of Decay tank is constructed by using linear shell element. The mass of coolant contained in the Decay tank is distributed to the Decay tank wall evenly except the perforated plates.

For the perforated plates, as they are submerged in the coolant, hydraulic added mass shall be applied to the each plate. Although there are some theses related to added mass for a submerged plate with regular holes[1], they are limited to very simple geometry. As shown in Fig. 1, the Perforated plates of the Decay tank have holes which have different sizes and irregular locations. To get the added masses in this paper, the modal analysis of the perforated plate itself are conducted ahead of the whole analysis.

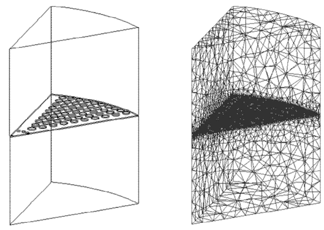

Fig. 2. FEM for the added mass of the perforated plate

Fig. 2 shows the FE model for the perforated plate analysis to get the added mass. The perforated model is enclosed by acoustic fluid element. The maximum size of the acoustic element is determined considering element order, acoustic wave speed and interesting frequency range. By comparing the modal analysis results between with and without fluid element, added mass can be estimated. After that, the added mass is applied to each perforated plate in the vertical direction.

2.2 Floor response spectra

Seismic analysis is conducted for the Safe Shutdown Earthquake (SSE). The FRS for the Decay tank is generated from DGRS (Design Ground Response Spectra) where the Decay tank is installed. The FRS are calculated followed by NUREG 1.122[2] and the critical damping ratio 4% for the welded and bolted steel structure is chosen according to NUREG 1.61[3].

3. Analysis results

3.1 Modal analysis

To describe the dynamic behavior of the Decay tank, 50 modes are extracted. For x-, y-, z-direction, more than 90% of mass participation factor is satisfied for each.

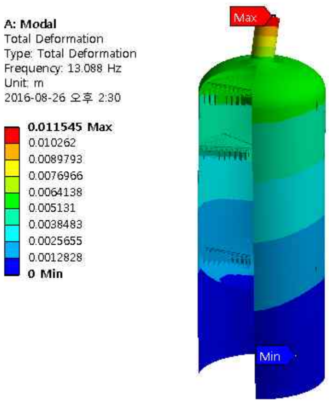

Fig. 3. 1st Bending mode (13.1 Hz)

As the lowest natural frequency of the global model shown Fig. 3 is lower than the frequency at ZPA, frequency response spectrum analysis is performed to capture dynamic characteristic.

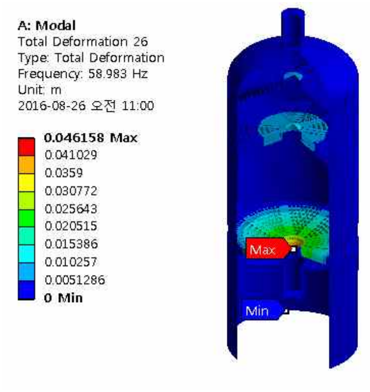

Fig. 4. Perforate plate mode (58.9Hz)

PCS pumps circulate the coolant with inducing harmonic pressure purse which can cause the perforated plate resonance failure. The lowest natural frequency of the 3rd perforated plate which is the closest to the PCS pumps is 59.98Hz. Since it is outside the ±20% range of pump blade passing frequency (above 75Hz), no perforated plate resonance will occurs.

3.2 Response spectrum analysis

Stress is categorized into membrane stress and membrane plus bending stress. Since ANSYS shell element uses linear stress distribution through the thickness of shell element, shell middle stress represents membrane stress and top/bottom stress represents membrane plus bending stress. Evaluation is conducted with service limit D. Seismic load, dead weight and hydrostatic load are considered.

Table I. Stress evaluation

		Stress [MPa]	**Service limit D** [MPa]	**Safety factor**
Shell[1]	P_m	23.28	230	0.10
	P_m+P_b	47.22	276	0.17
perforated plate[1]	P_m	14.67	230	0.06
	P_m+P_b	12.30	276	0.04
Skirt[2]	σ_1	11.98	177.6	0.07
	$\sigma_1+\sigma_2$	16.61	266.4	0.06

1) KEPIC MND / 2) KEPIC MNF

4. Conclusions

In this study, seismic analysis is conducted through response spectrum analysis with FRS. Structural integrity of the Decay tank when SSE occurs is ensured.

5. Acknowledgement

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[2] US, NRC, Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Component, Regulatory Guide 1.122

[3] US, NRC, Damping Values for Seismic Design of Nuclear Power Plants, Regulatory Guide 1.61