Seismic Sloshing Analysis for Research Reactor Pool

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1. Introduction

Pools in research reactor are designed to remove heat from reactor core as well as provide storage for spent fuel and equipment which is to handle radioisotopes. For this matter, water level of the pool have to be monitored for safety purpose under any conditions.

When the external loads such as seismic excitation occur in the research reactor pool, it could lead to sloshing behavior. And the sloshing phenomena has been continuously reported with regard to the earthquake event. It was reported that, due to the 2007 Niigata-ken Chuetsu-oki earthquake, the spent fuel pool water was overflowed onto the operation floor. [1] Recently, overflow of spent fuel pool water was also reported at the Fukushima Daini NPPs in 2021.[2] For this reason, lots of studies have been conducted to evaluate the effects of seismic sloshing for spent fuel storage pool and rectangular tanks. [3, 4]

In this paper, sloshing analysis for research reactor pool under seismic excitation was performed to confirm the flow characteristics such as overflowed amount and pressure distributions due to the flow inertia on the wall. To analyze the seismic sloshing, VOF (Volume of Fluid) technique is adopted. Simulation was carried out by using commercial software, ANSYS.

2. Analysis Model and Conditions

2.1 Research Reactor Pool Model

Fig. 1 depicts the schematic of the research reactor pool model. To reduce the numerical cost, inner components such as spent fuel storage rack, cell pipes and several devices were not considered. All the surface which contains the water is regarded as wall. For analyzing the pressure distributions, 3 representative points were selected. Each point represents pool bottom, half of the pool water and pool surface respectively. Pool water level is 85.5 % of total pool height. Standard earth gravity is also adopted in this model.

The prediction of sloshing behavior via the linear theory that the sloshing liquid may be compose of impulsive and convective motion are generally proposed and researched. The impulsive response is associated with the lower portion of the liquid which moves transmitting the structure motion. Subsequently, the convective response represents that the propagation of sloshing wave near the surface of the pool and the subsurface water affected by the sloshing motion. These waves are generated from the relative interaction between the wall and water to affect the wall pressure.

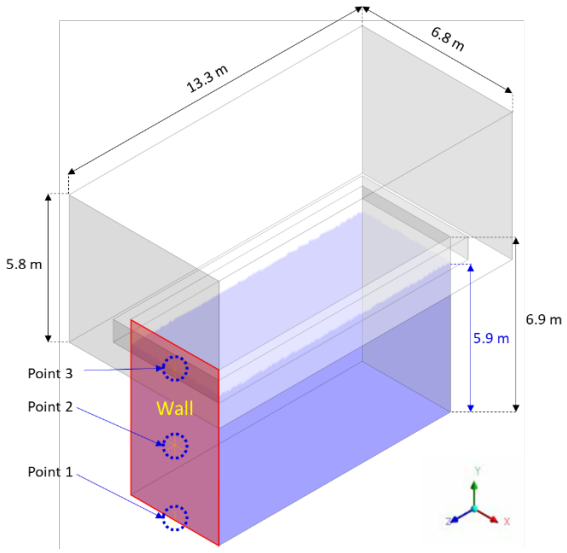

Fig. 1. Schematic of the research reactor pool

2.2 Analysis conditions

Postulated earthquake loading was adopted as shown in Fig. 2. The loading is 1-way directional excitation, which are to be examined 2-directional and 3-directional loadings in future study. For researching the longitudinal effects on the sloshing amounts and pressure, z-directional was assigned to be loaded.

Since the sloshing phenomena represents the multi-phase behavior, VOF (Volume of Fluid) model was used with air and water properties. Atmospheric pressure and temperature were applied in the whole model. SST Turbulence model which has an advantage in combination of $k-\varepsilon$ and $k-\omega$ model was selected.

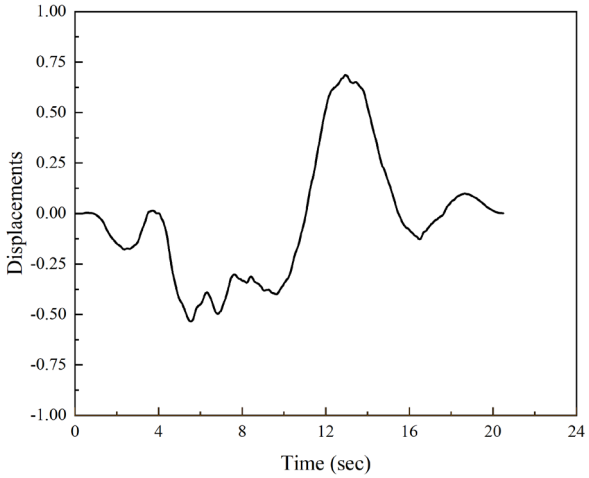

Fig. 2. Displacements for input data

3. Analysis Results

3.1 Overflowed Amount

Normalized water volume is value of cumulative amount of overflowed water volume divided by initial volume of the pool water. Fig. 3 shows the values which began to overflow onto the outside in the latter half of a first principal shock of the seismic motion. The total value of overflowed amount were calculated as 0.92 %.

Fig. 4 depicts the flow distributions of pool water. The first principal shock sloshing phenomena is founded near 5.0 sec. After 9 sec, the overflowed amount were increased. From 16 sec, the value was stabilized.

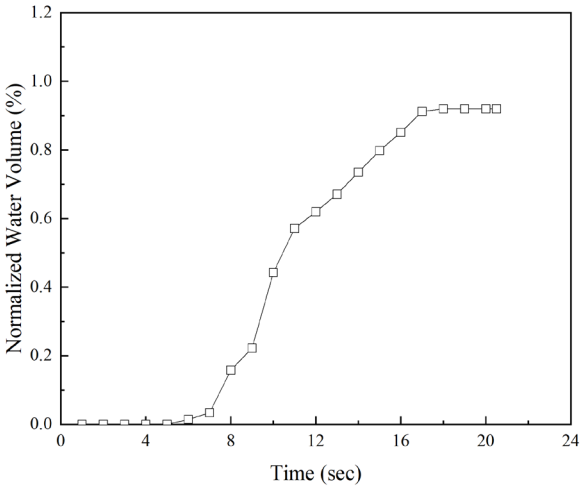

Fig. 3. Normalized overflow water volume history

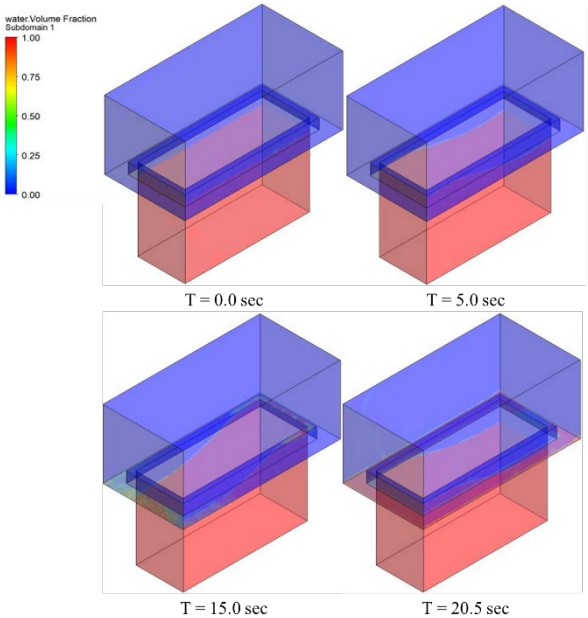

Fig. 4. Flow distributions of research reactor pool

3.2 Pressure Distributions

Fig. 5 represents the pressure distributions at the point 1, 2 and 3. The maximum absolute pressure was 168.4 kPa at point 1 which located at the bottom of the research reactor pool wall. And the minimum absolute value was 110.9 kPa at point 3 which located at the surface of the pool wall. General appearance depends on the water which is subjected to sloshing water impacted wall.

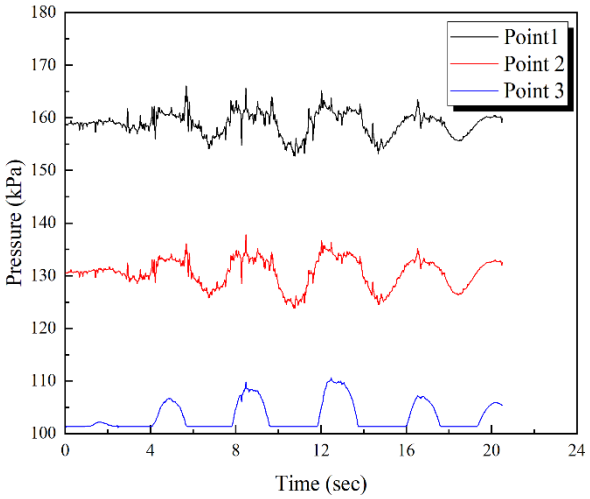

Fig. 5. Pressure distributions of research reactor pool wall

4. Conclusions

In this study, seismic sloshing analysis were carried out to investigate the flow characteristics, overflowed amount and pressure distributions of the research reactor pool and following key findings were observed.

(1) Normalized water volume were calculated under the postulated seismic loading conditions.
(2) Pressure distributions on the pool wall were obtained at 3 representative points.
(3) Further research accompanying additional loading conditions will be conducted.

ACKNOWLEDGEMENTS

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