Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Modal Analysis of Pool Door in Water Tank

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1. Introduction

A pool door is installed at the chase of the pool gate by means of an overhead crane in the building of a research reactor. The principal function of the pool door, which is located between the reactor pool and service pool, is to separate the reactor pool from the service pool for the maintenance and/or the removal of the equipment either in the reactor pool or service pool. The pool door consists of stainless steel plates supported by structural steel frames and sealing components. The pool door is equipped with double inflatable gaskets. The configuration of the pool door is shown in Figure 1.

The FEM analysis and theoretical calculation by the formula were performed to evaluate the natural frequency for the pool door in the water. The results from the two methods were compared.

Figure 1 Configuration of the pool door

2. Methods and Results

2.1 Natural Frequency by FEM

The natural frequencies of the pool door were obtained from an analysis using the ANSYS code. The pool door was modeled using SHELL 63 element and the water in the pool was modeled using FLUID80 element. The finite element model by the ANSYS code is shown in Figure 2. All structural steel shall conform to ASTM Specification, A240-TP304L[1].

The size of each component is as follows;

Plate : 1.58x6.19x 0.0811(m), t=8.11(cm)
Service pool : 1.58x7.43x 4.9(m).
Reactor pool : 1.58x4.57x 4.9(m).

The boundary condition at the plate edge is assumed to be completely simply supported (S-S-S-S).

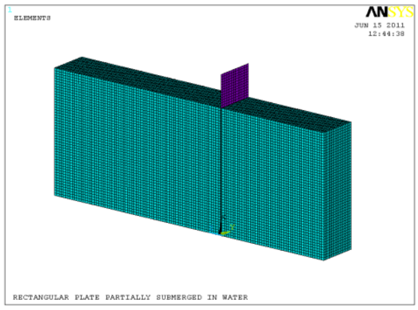

Figure 2 ANSYS model for the pool door

The results of the modal analysis are as follows.

Mode	Natural frequency (Hz)
1	33.96
2	55.78
3	82.07
4	114.14
5	151.14

The deformed shapes of the 1st , 2nd , 3rd and 4th mode are shown in Figure 3, Figure 4, Figure 5 and Figure 6.

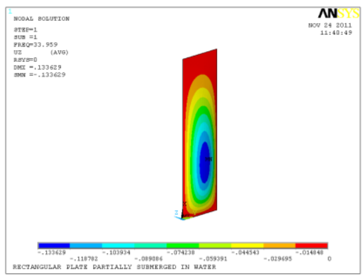

Figure 3 The 1st mode of the pool door

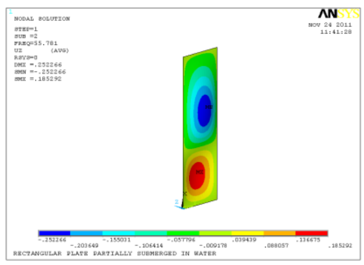

Figure 4 The 2nd mode of the pool door

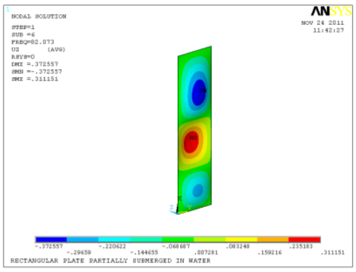

Figure 5 The 3rd mode of the pool door

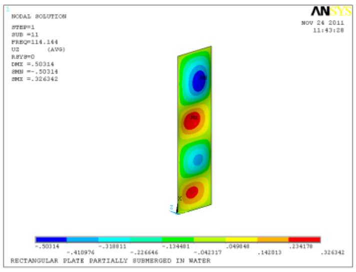

Figure 6 The 4th mode of the pool door

2.2 Theoretical calculation by formula

The total inertia moments for each component of the pool door :

$I = [(3x\ 24^3)/12] \times 2 + (152x\ 2.1^3)/12 \fallingdotseq 7029.3\ cm^4$

The equivalent thickness of the pool door was calculated as follows.

$t = {}^3\sqrt{}(12 \times I)/158 = {}^3\sqrt{}(12 \times 7029.3)/158 = 8.11$ (cm)

The added mass for rectangular plates with one side exposed to water [2].

$A_p = \alpha_{ij}\beta\rho ab^2$, $\alpha_{ij} = (\int z_{ij}\ dA)^2/(2ab\int z_{ij}^2\ dA)$,

where z_{ij} is the dimensionless mode shape.
A = ab =area of the pool door contacted in the water.
α_{ij} = function of the modal indices and the boundary conditions on the plate
β = aspect ratio dependent factor.

a/b	0.1	0.2	0.3	0.4	0.5	0.6
β=0	0.30	0.42	0.58	0.65	0.72	0.78

$a/b = 108/485 \fallingdotseq 0.22$

$\therefore\ \beta = 0.452$

α_{11} is obtained from the table below.

i	j	α_{ij}	
		C-C-C-C	S-S-S-S
1	1	0.3452	0.8106
1	2	0.0000	0.0000
1	3	0.1512	0.2702
1	5	0.0962	0.1620

where C-C-C-C indicates completely clamped edges and S-S-S-S indicates completely simply supported edges.

$\therefore\ \alpha_{11} = 0.8106$

The natural frequencies of the pool door were obtained from the following equation [2].

$f_{xij} = [\lambda_{ij}^2/(2\ \pi b^2)] \times [(Et^3)/\{12\ \gamma(1-\nu^2)\}]^{0.5}$,

where $\lambda_{ij}^2 = \pi^2[i^2 + j^2(b/a)^2] = \pi^2[1^2 + (619/152)^2] \fallingdotseq 173.5$

$\therefore\ f_{x11} = [173.5/(2\ \pi \times 619^2)] \times [(1.937 \times 10^6 \times 8.11^3)/\{12 \times 0.000392877(1-0.272^2)\}]^{0.5} \fallingdotseq 35.1$ Hz

Therefore, it was found that the results from the theoretical calculation can predict the finite element analysis results well, and the pool door can be assumed as a rigid body in the seismic analysis, since its fundamental natural frequency exceeds 33 Hz.

3. Conclusions

Comparing the results of ANSYS with those of the theoretical estimation, two results show good agreement. It was observed that the 1st mode of the pool door is 33.96 Hz. Since the fundamental natural frequency of the pool door exceeds 33 Hz, we can regard the pool door as a rigid body.

Acknowledgements

This work has been carried out under the nuclear R & D program supported by the Ministry of Education, Science and Technology, Korea.

REFERENCES

[1] Annual Book of ASTM, American Society for Testing Materials.

[2] Robert D. Blevins, Formulas for natural frequency and mode shape, 1979.