Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

Design Evaluation of the ABTR Internal Structure on Seismic Loads

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1. Introduction

The internal structure of the Advanced Burner Test Reactor(ABTR) is a single integrated unit that separates the hot pool from the cold pool, and provides for communication of the hot sodium from the discharge of the reactor core to the inlet of the intermediate heat exchanger. A reactor internal structure is supported vertically by the lower internal structures within the primary reactor vessel.

In this study, the seismic analysis including the fluid structure interaction modeling for the reactor internal structure submerged in the sodium pool is carried out and the vibration and seismic response characteristics are investigated. The Floor Response Spectra(FRS) at the core support structure which are generated using the floor time histories are applied for the seismic analysis. From the calculated results, the design integrity of the primary stress is evaluated by considering the combined loads including the seismic event.

2. Seismic Analysis

The seismic modelization is performed as using the 3D solid element of the ANSYS code[1]. Fig. 1 shows the seismic model of a reactor internal structure. The consideration of the fluid-structure interaction effect is important thing in the pool type SFR design concept. In this study, the natural frequency analysis and the response spectrum analysis are performed by considering the sodium and structure interaction effects.

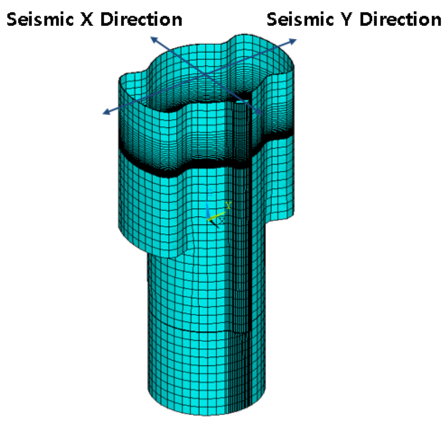

Fig. 1 Finite element model for seismic analysis

2.1. Added mass calculation

The fluid-structure interaction is considered as an added mass under the immersed condition of liquid sodium. In the seismic analysis, we use the modified mass distribution which considers an added mass. The added mass for the exciting force is calculated by using the FAMD code[2]. The used fluid properties for the fluid dynamic viscosity and the fluid density are $\mu=9.54\times10^{-4}$ N.s/m^2 and $\rho=850$ kg/m^3, respectively.

2.2. Response spectrum analysis

In the response spectrum analysis, we use the square root of the sum of the squares method. From the seismic analysis, the displacements and stresses which are required to check the design integrity are calculated. Three independent analyses are performed to obtain the results of the excitation for x-direction, y-direction and z-direction.

In the non-isolated condition, the seismic displacements and stresses of a reactor internal structure including the fluid-structure interaction effect are calculated. Fig. 2 shows the seismic stress intensity in the y-direction under OBE event in the non-isolated condition.

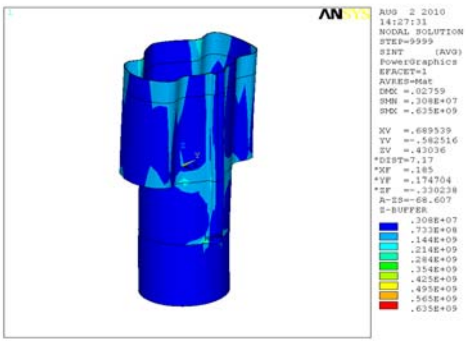

Fig. 2 Seismic stress intensity in the y-direction under OBE event in the non-isolated condition

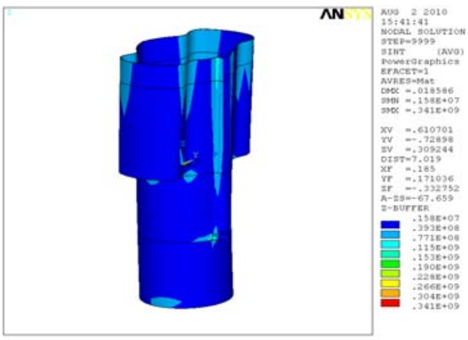

Fig. 3 Seismic stresses in the y-direction under OBE event in the isolated condition

In the isolated condition, in order to prevent excessive seismic loads on the reactor system, it is considered the reactor building is supported by the seismic isolator. Fig. 3 shows the seismic stresses in the y-direction under OBE event in the isolated condition. From this figure, one can see that the maximum stress is 341 MPa in the y-direction.

3. Design limit check for the load controlled stress

Fig. 4 shows the finite element model of a reactor internal structure with the evaluation sections presented in Table 1. In this study, the design limit checks for the seismic loads are performed for the load controlled design limits of the ASME-NH rules[3]. In a sodium cooled fast reactor, the thickness of the main shell structures such as a main vessel and a reactor internal structure is thin. Thus, the dynamic forces that are developed by a seismic event cause a great concern to the structural integrity of the thin shell structures. The studies in this paper are to evaluate the structural integrity by the load combinations and to quantify the seismic response under the two design cases. One is in case the reactor building is the non-isolated structure constructed without the base isolation bearing and the other is in case the reactor building is an isolated structure. Table 2 shows the primary stress evaluation results for the load controlled design limits in the non-isolated condition. In this table, one can see that the check results of the primary stress intensity at the evaluation section A3 exceed the allowable limits of ASME-NH rules excessively.

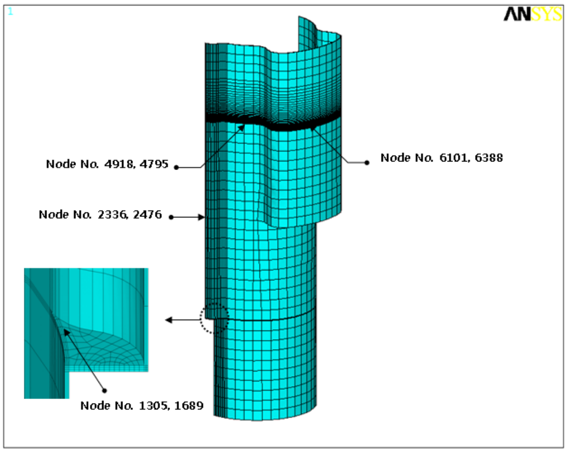

Fig. 4 Finite element model of a reactor internal structure with the evaluation sections

Table 1 Evaluation sections

Sections	Node No.(Inside)	Node No.(Outside)
A1	4918	4795
A2	6101	6388
A3	2336	2476
A4	1305	1689

This is caused by the design FRS at core support structure have very large value in the horizontal direction. Thus, the seismic isolation capable of reducing the seismic input transmitted to the foundations is needed to satisfy the allowable limits of ASME rules. Table 3 shows the primary stress evaluation results for the load controlled design limits in the isolated condition. It is noted that there is an overall decrease of stress intensities at the evaluation sections due to the isolated condition. From this result, one can see that the load controlled design limits in the ASME-NH rules are satisfied in the isolated condition.

Table 2 Primary stress evaluation results for the load controlled design limits in the non-isolated condition

	Section	P_m (MPa)	P_L+P_b (MPa)	P_L+P_b/K_t (MPa)	S_{mt} (MPa)	KS_m (MPa)	S_t (MPa)	$T_{max\ m}$ (℃)	Design Check
ASME-NH	A1	75.8	79.6	78.7	109.4	164	141	432.8	Ok
	A2	59.6	66.2	64.8	109.4	164	141	432.5	Ok
	A3	540	545	543.7	109.4	164	141	432.8	Not Ok
	Section	P_m (MPa)	P_L+P_b (MPa)	$P_L+P_b+P_e+Q$ (MPa)	S_m (MPa)		$1.1X3S_m$ (MPa)	T_{mean} (℃)	
ASME-NG	A4			361			367.6	390	Ok

Table 3 Primary stress evaluation results for the load controlled design limits in the isolated condition

	Section	P_m (MPa)	P_L+P_b (MPa)	P_L+P_b/K_t (MPa)	S_{mt} (MPa)	KS_m (MPa)	S_t (MPa)	$T_{max\ m}$ (℃)	Design Check
ASME-NH	A1	33.8	38.4	39.5	109.4	164	141	432.8	Ok
	A2	30.2	31	30.8	109.4	164	141	432.5	Ok
	A3	54.1	54.5	54.4	109.4	164	141	432.8	Ok
	Section	P_m (MPa)	P_L+P_b (MPa)	$P_L+P_b+P_e+Q$ (MPa)	S_m (MPa)		$1.1X3S_m$ (MPa)	T_{mean} (℃)	
ASME-NG	A4			286			367.6	390	Ok

4. Conclusions

For the two design cases for the isolation and non-isolation condition of the ABTR reactor building, the structural integrity of a reactor internal structure is studied by considering the seismic loads. In the non-isolated condition, the check results of the primary stress intensity exceed the allowable limits of ASME rules excessively, but it is confirmed the load controlled design limits are satisfied in the isolated condition

Acknowledgements

This study was supported by the Korean Ministry of Education, Science and Technology through its National Nuclear Technology Program.

REFERENCES

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[2]G. H. Koo and J. H. Lee, ''Development of FAMD code for analysis of fluid added mass and damping,'' KAERI/TR-2309/2002, KAERI(2002).
[3] ASME Boiler and Pressure Vessel Code Section III, Subsection NH, ASME, 2004