Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

A Study on the Fuel Assembly Seismic Analysis without Holddown Springs

O Cheol Kwon [*], Dong Geun Ha, Kyou Seok Lee, Sang Yoon Jeon, Jung Min Suh
KEPCO Nuclear Fuel, 242, Deadeok-daero 989Beon-gil, Yuseong-gu, Daejeon, 305-353, Korea
[*] *Corresponding author: ockwon@knfc.co.kr*

1. Introduction

The fuel assembly contains a bottom nozzle, fuel rods, guide tubes, an instrumentation tube, grids (top, bottom, mid, IFM), and top nozzle with holddown springs and the mechanical integrity and the dimensional stability are maintained under the seismic event.

The holddown spring provides the holddown force to prevent the lift-off of fuel assembly in the reactor. The top and bottom nozzles are caught up upper and lower core pin, respectively. However, the top nozzle design removed holddown spring is recently needed in the small modular reactor design.

The large number of dynamic degree-of-freedom, storage capacity and extensive computation are required for fuel assembly seismic analysis, the simplified fuel assembly model, which simulates the dynamic characteristic of fuel assembly, is very important in terms of efficiency and confidence of analysis.

In this study, the effect for the fuel assembly removed holddown spring under seismic event has been evaluated through the comparison with the seismic analysis result of fuel assembly with holddown spring. In order to compare each design, the simplified fuel assembly seismic analysis models have been established according to reference [1]. The mid grid impact force, natural frequency, and top nozzle displacement for each fuel assembly model has been analyzed using ANSYS.

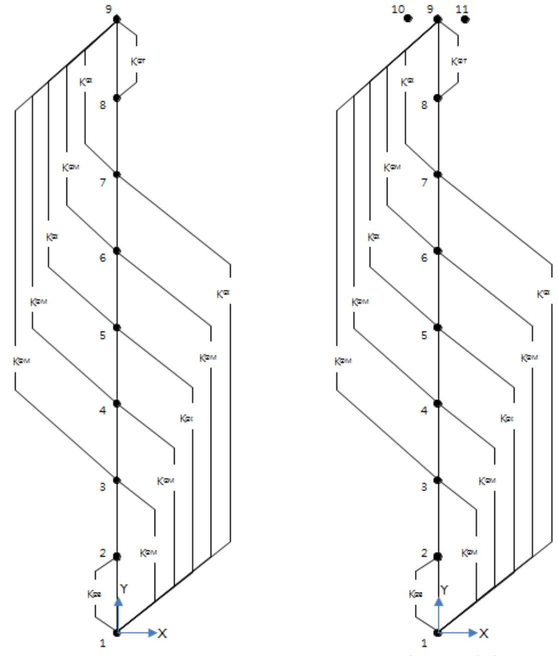
2. Fuel Assembly Seismic Analysis Models

A small size fuel assembly model for the small modular reactor (SMR) is considered for this study. The length of fuel assembly is approximately a half in comparison with the fuel assembly model of pressurized water reactor (PWR).

Fig. 1 presents the fuel assembly seismic analysis model with holddown springs (Model A) and the fuel assembly seismic analysis model without holddown springs (Model B). The fuel assembly models consist of beam elements and rotational spring elements. The effective beam inertia moment and spring constants in the simplified fuel assembly model are optimized using optimization method [1]. The locations of all nodes 1 to 9 are defined in the middle of each grid and top and bottom ends of fuel assembly. In the Model B, the contact elements between node 9 to 10 and node 9 to 11 are defined to simulate the interface between upper core pin and top nozzle core pin hole.

All degree-of-freedoms of the node 1 (bottom nozzle) for both models and the node 9 (top nozzle) of Model A considering holddown force are fixed but the node 9 of Model B is free condition. The time historic boundary condition at the node 9 of Model A and the node 10 & 11 of Model B will be imposed for core analysis.

A wide variety of factors affects such as the gaps between the fuel assemblies and fuel assembly to core shroud in reactor core, core plate motion (CPM), and fuel assembly stiffness affect the analysis results. All of the conditions affected analysis results are applied to be the same for comparing differences of the analysis models.



(a) Model A (b) Model B

Fig. 1 Fuel Assembly Seismic Analysis Models

3. Modal Analysis Results

In order to identify the fuel assembly dynamic characteristics, the modal analysis for each model is performed. Table 1 presents the natural frequencies as the fuel assembly models. The fundamental frequency of the Model A represents ω and the other modes are represent as normalized for ω. Fig. 2 presents the comparison of the mode shape for each model.

Table 1: Modal Analysis Results

Mode	Model A	Model B
1st	ω	0.42 ω
2nd	2.23 ω	1.47 ω
3rd	3.84 ω	2.66 ω
4th	7.05 ω	4.24 ω

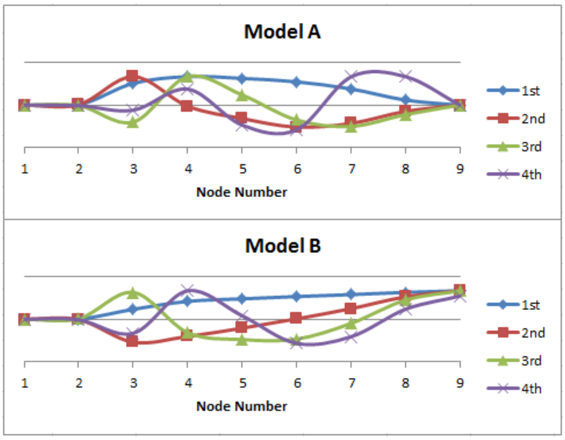


Fig. 2 Mode Shape

4. Seismic Analysis Results

The core models for seismic analyses have been established for 3, 5 and 7 fuel assembly rows using Model A and Model B. In the core model, the gaps between fuel assemblies are modeled using the contact elements with their dynamic stiffness and the linear spring element to simulate the flexibility of the fuel rods and the grid spring support system.

The 4 types of core plate motions for the reactor internal models are considered based on the postulated accident conditions. The each CPM of the horizontal direction is imposed at the nodes 1 and 9 of Model A and the nodes 1, 10 and 11 of Model B. The nodes 10 and 11 of model B are coupled for horizontal displacement. The seismic analyses for core models are performed using ANSYS.

The grid impact forces at each grid location for the 3, 5, and 7 fuel assembly rows are obtained. The maximum grid impact forces are compared in Table 2 and Fig. 3. The differences of impact forces for the both models are from 2.6% to 8.3%. However, the number of the elements for the Model B is increased comparing Model A and the analysis running time using ANSYS is also increased.

Table 2: Maximum Grid Impact Force Ratio

	Model B / Model A
CPM_1	0.974
CPM_2	0.917
CPM_3	0.952
CPM_4	1.061

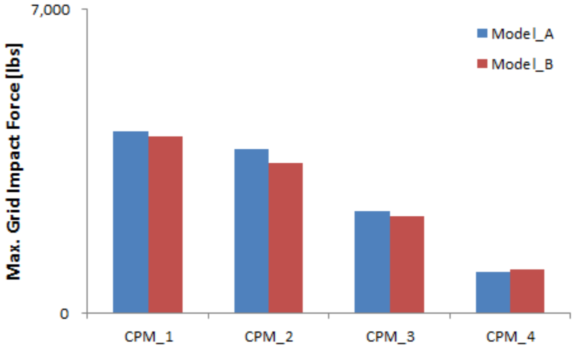


Fig. 3 Maximum Grid Impact Force

Fig. 4 shows the top nozzle relative displacement of Model B under the CPM_2 and all cases of the top nozzle relative displacements depending of CPM types are similar. The gaps of the upper core pin to the core pin hole in the top nozzle are approximately 0.018 inch and the relative displacement is within that value. Therefore, the Model B would be well analyzed.

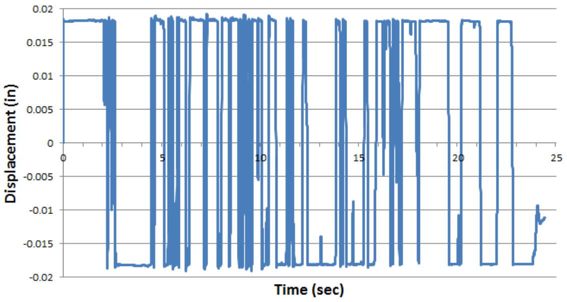


Fig. 4 Top Nozzle Relative Displacements (CPM_2)

5. Conclusions

The fuel assembly seismic analyses without holddown springs are performed and compared to the model with holddown springs. The grid impact forces of CPM_1 and CPM_2 are almost doubled in comparison with CPM_3 and almost tripled in comparison with CPM_4 so the grid impact forces depend on CPM types. The grid impact forces of the fuel assembly model without holddown springs have similar tendencies in comparison with fuel assembly with holddown springs. Moreover, the model without holddown springs analysis time is much longer than the model with holddown springs. Consequently, it is moderate that the fuel assembly analysis model with holddown springs would be used for effective analysis even though the actual model has no holddown springs.

REFERENCE

[1] K. S. Lee, S. Y. Jeon, and H. K. Kim, A Study on the Development of Simplified Fuel Assembly SSE/LOCA Analysis Model using Optimization Technique, Transactions of the Korean Nuclear Society Spring Meeting, May 22, pp. 317-318, 2009.