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Analysis of Impact Load Distribution in the Reactor Core due to Seismic Loading Condition

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1. Introduction

During the seismic event, the fuel assemblies will collide with the core shroud or the other fuel assemblies. The distribution of impact load in the reactor core was calculated to account for the collision of the fuel assemblies according to the following procedures:

Firstly, the core seismic motion was obtained from coupled reactor internals and core. Secondly, the impact loads in the spacer grids of the fuel assemblies were analyzed by the core model. Thirdly, the distribution of the impact loads was calculated with post-processing. Finally, the distribution of the impact loads determined the range of impact load as well as the impact number of time in the spacer grids.

This paper presents the calculation of the impact load distribution of the fuel assemblies in the reactor core under seismic loading condition.

2. Analysis Methods

2.1 Core Model

Five row core models are adopted for analysis, which was corresponding to the shortest row in the core as shown in Figure 1.

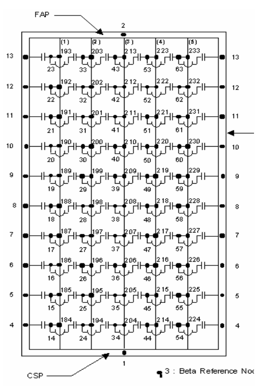

Figure 1. Core Model (5 Row)

The model was created by the lumped masses and springs. The gaps between the fuel assemblies and the core shroud were modeled by the gap elements [1].

2.2 Analysis Procedure

Firstly, the time history analysis was performed using the FEM analysis which computes dynamic responses of the lumped mass spring systems following a step-by-step integration procedure. In this analysis, time history analysis considering the entire analysis time requires a large amount of time to carry out a dynamic response analysis of core models. Therefore we assumed that the total analysis time was the 1.0 sec of analysis time and 100 times of excitation force to reduce the total analysis time. Accordingly, the analysis procedures are as follows:

- After the core seismic analysis was performed using the core model, the impact load was calculated in the spacer grid.
- By using impact load time history, this analysis grouped all the impact loads together by the time zone which occurred on the impact loads.
- With each group, the maximum impact load was calculated.
- With each group, the range and the number of times of maximum impact load was determined.

2.3 Impact Load Calculation in the Spacer Grid

The impact load was defined as one-sided impact load and through-grid impact load as shown in Figure 2.

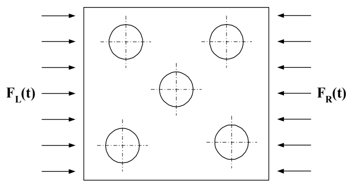

Figure 2. Impact Load of $F_L(t)$ & $F_R(t)$

Impact load which occurs simultaneously with both side directions shows a different impact characteristic with the only one side direction of the spacer grid. Considering one spacer grid in the Figure 2, impact loads which operate with the right side directions $F_R(t)$ and the left side direction $F_L(t)$ can be divided. From $F_L(t)$ and $F_R(t)$ in the spacer grid, the impact load time history is defined. The numerical formulae are as follows:

$TG(t)$ = The Maximum of either $F_R(t)$ or $F_L(t)$
$F_L(t)'$ = The Residual Force on the Left Side
$F_R(t)'$ = The Residual Force on the Right Side

If $F_L(t) < F_R(t)$
Then $TG(t) = F_R(t)$
$F_L(t)' = F_L(t) - F_R(t)$
$F_R(t)' = 0$

If $F_L(t) > F_R(t)$

Then $TG(t) = F_L(t)$

$$F_R(t)' = F_R(t) - F_L(t)$$

$$F_L(t)' = 0$$

Impact loads in the spacer grid depend upon two major non-linear characteristics of gap and stiffness. The spacer grid in the core model is different from non-linear characteristics in each row. Table 1 summarizes two major non-linear characteristics of gap and stiffness in each row.

Table 1. Non-linear Characteristics

Dir.	Characteristic	1 Row	2 ~ 4 Row	5 Row
Left	Gap (m)	0.00376	0.00191	0.00191
	Stiff. (N/m)	1.05E7	5.25E6	5.25E6
Right	Gap (m)	0.00191	0.00191	0.00376
	Stiff. (N/m)	5.25E6	5.25E6	1.05E7

2.4 Impact Load Distribution Calculation

After calculating impact loads in the spacer grids at the total analysis time, all impact loads became grouped by the time zone. The load range is given in detail in Table 2.

Table 2. Impact Load Range

No.	Title	Load Range	Title	Energy Range
1	Force (N)	4445~6668	Energy (J)	10.6~23.7
2		6668~8891		23.7~42.2
3		8891~11113		42.2~66.0
4		11113~13336		66.0~95.0
5		13336~15558		95.0~129.3
6		15558~17781		129.3~168.9
7		17781~20003		168.9~213.7
8		20003~22226		213.7~263.9

3. Results and Conclusions

In this analysis, the calculation of impact load distribution was proposed using core analysis. The impact load distribution calculation was performed for the specific seismic loading condition. Table 3 and 4 are the results of the spacer grid. From these tables, the analysis results of core model show a dynamic impact tendency at each spacer grid. Figure 3 shows the plots of Impact Load Distribution result calculated at the No.58 spacer grid. In this paper, the distribution of impact loads at the No.20 and No.58 as shown in Figure 1 was calculated. The distribution of impact loads at the other spacer grids can be obtained according to this procedure. Moreover, these procedures can be expanded to the fifteen row core model which was corresponding to the longest row in the core.

Table 3. Impact Load Distribution of Grid No.20

FEM Analysis		One-sided		Thru-Grid
No.	Load (N)	Left	Right	
Grid No.20	4445~6668	3	2	0
	6668~8891	1	0	0
	8891~11113	0	0	2
	11113~13336	0	0	1
	13336~15558	0	0	0
	15558~17781	0	0	0
	17781~20003	0	0	0
	20003~22226	0	0	0

Table 4. Impact Load Distribution of Grid No.58

FEM Analysis		One-sided		Thru-Grid
No.	Load (N)	Left	Right	
Grid No.58	4445~6668	4	4	2
	6668~8891	0	2	2
	8891~11113	0	0	0
	11113~13336	0	0	0
	13336~15558	0	0	0
	15558~17781	0	0	0
	17781~20003	0	0	0
	20003~22226	0	0	0

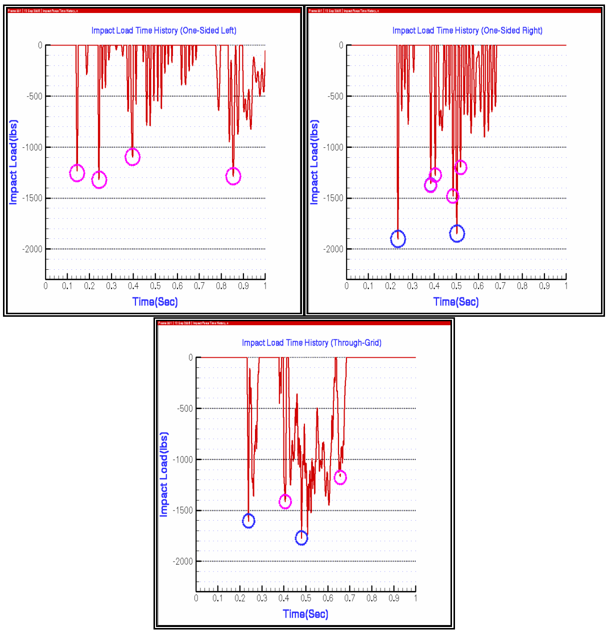

Figure 3. Plots of Impact Load Distribution

REFERENCES

[1] ANSYS 7.1 User's manual, ANSYS Inc.