Impact Analysis for the Lateral Impact Characteristics of a 16 by 16 type PWR Fuel Assembly using FE Method

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1. Introduction

This paper deals with the lateral impact analysis of a PWR fuel assembly (FA). The purpose of the fuel assembly lateral impact analysis is to obtain the impact characteristics of an axially preloaded fuel assembly with the top and bottom nozzles constrained within core boundary conditions in Fig.1. The analysis results will be used to verify the dynamic lateral characteristics of a fuel assembly finite element model for the safety analyses.

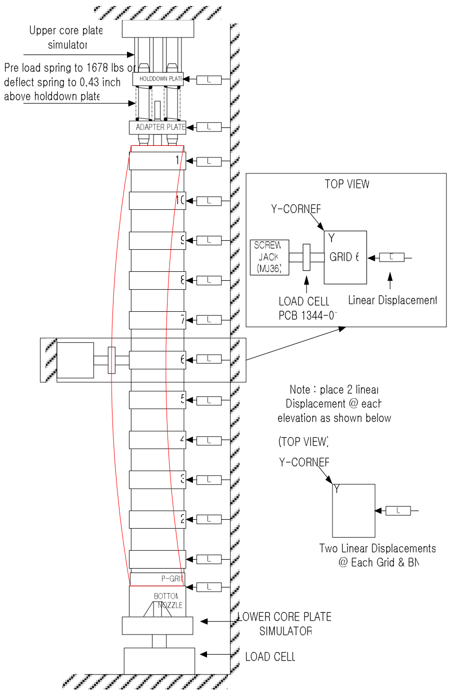

Fig. 1 Schematic diagram of the lateral impact test arrangement.

2. Analysis Model and Method

2.1 Analysis Model

The finite element model must be properly created as actual joint/connection configuration. Only centre guide tube was modeled as a contact surface definition between the two parts because it put on the bottom nozzle. However, the joints between the guide tubes and the top/bottom nozzles were made with a thread joint. And those joints between the spacer grids and the outer guide tubes have welding joint condition. Therefore, those joint parts were modeled with a one body for protecting the rigid body motion. However, the connections between the fuel rods and the grid supports revealed friction phenomena due to the insertion of the fuel rods. So it was necessary to perform the non-linear contact analysis between them. Because of these initial interferences they create a little higher stiffness of the global structure than that of the just contact case. The total number of node and elements were 340,126 and 274,811, respectively. And the global finite element model is shown in Fig. 2.

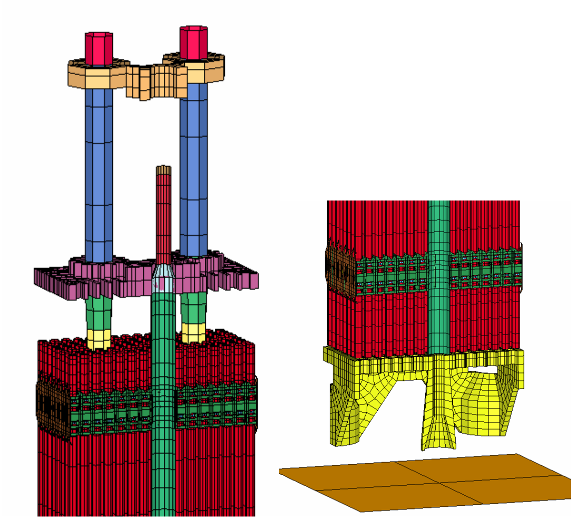

Fig. 2 Finite element model of a 16×16 type PWR fuel assembly for drop impact analysis.

2.2 Analysis Method

The finite element analyses are divided into two steps, one was the non-linear contact analysis, and the other is the lateral impact analysis. Of course, the beginning state of the second step is the actual state from the first step analysis result. The total computational time is defined as 0.35 sec. for the secondary impact simulation. The initial displacement in the lateral direction is 30mm. And the lateral output loads are extracted with the impact forces and duration times at the every grid positions.

3. Analysis Result

3.1 Forces vs. Deflections

The typical trace of the fuel assembly mid-grid impact forces and motion of sixth grid for an initial lateral deflection of 30mm is given in Fig. 3. The initial fuel assembly central grid deflections versus the impact forces obtained at the nine central structural grids when impacted to solid constraints are displayed in Fig. 1. The impact forces at each vertical location increased linearly with respect to the initial central grid displacement with fifth or seventh grid experiencing the large impact forces. The fifth grid from the bottom in Fig. 1 experienced an impact force of approximately 4238 N when released form an initial central grid displacement of 30mm.

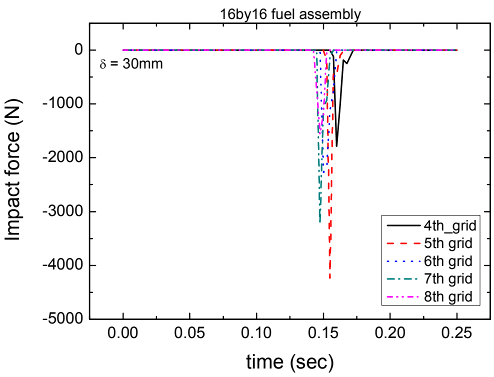

Fig. 3 Impact forces at the central structural grid positions from impact analysis.

3.2 Duration Times vs. Deflections

The duration time of the fifth grid position is approximately 0.175 second. The duration times at the central structural grid positions have ranged from 0.125 second to 0.175 second. These duration times are very similar with the previous test results. The impact forces and duration times are summarized in Table 1. The current values for the lateral impact analysis are a little differentiated form the test results.

Table 1. Impact forces at the central structural grid positions from the impact analysis.

These deviations are caused from the discrepancy applied boundary conditions between test and analysis conditions. The actual beginning-of-life hot conditions (BOL hot) differ from the fixed and simply supported conditions. The discrepancies at the fourth and eighth grid position are caused from the bottom grid (debris filter bottom grid).

4. Concluding Remarks

The lateral impact analysis for obtaining the FA dynamic characteristics was executed by using finite element method. The analysis results revealed a similar behavior when compared with the previously conducted test by a foreign vendor. Therefore, it was successfully verified that the present analysis method could provide reliable data of the fuel assembly behavior during a lateral impact load. It is regarded that the dynamic behavior in the present result is upside down due to the difference of the geometries. This 3D finite element model of a fuel assembly will be very useful tool for predicting the dynamic behavior of a PWR fuel assembly.

Acknowledgement

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