# Development of Fuel Assembly Finite Element Model for Spent Fuel Drop Analysis

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## 1. Introduction

Spent fuel (SF) integrity evaluation related to its handling and transportation for mid/long-term dry storage is a regulatory requirement in domestic and/or international such as US, IAEA, etc[1,2]. Especially drop event is the most fatal failure mode among many regulatory conditions[3]. However, in Korea, the SF integrity evaluation system related with drop event is not specified.

To establish the SF evaluation system, producing and analyzing sufficient experimental data must be performed preferentially. However, that is very inefficient in terms of both time and cost. Thus, finite element (FE) analysis is used as an alternative to the experimental test method to solve this problem.

In this study, 2D (two dimensional) FE model has been developed to simulate the SF drop which might occur during either transportation or handling. Static(stiffness) and dynamic(natural frequencies, mode shapes, impact spectrum, etc.) mechanical behaviors are simulated with this model, and compared to the fresh fuel assembly test results. Based on these results, the structurally weakest SF will be selected as the representative one among the target evaluation SFs, loaded in Korean nuclear power stations.

## 2. Finite Element Model

The FE model of the SF assembly consists of all major components including skeleton (top and bottom nozzles, guide tubes, spacer grids and top nozzle springs) and fuel rods as well as their joints, connections and interfaces. ANSYS 16.0 mechanical APDL has been used to create the parametric FE Model of the fuel assembly (FA)[4]. The typical 2D model and impact interface are shown in Fig. 1 and Fig. 2, respectively.

Each component in a FA is modeled as follows.

- Guide tubes are represented by beam elements (BEAM188) connecting the two nozzles. A pair of tubes is used to represent the total guide tubes and one instrumentation tube. The distance between these two guide tubes is calculated based on preservation of the lateral flexural rigidity of all tubes.
- The grids and nozzles are modeled using beam element (BEAM188).
- The fuel rods are represented by beam elements (BEAM188) and grouped into several groups as required. Gap conditions (COMBIN40) are defined between adjacent fuel rod groups to simulate the impact between them.
- The grid springs and dimples are modeled by preloaded gap elements (COMBIN40). in the horizontal directions, rotational springs and axial slider elements (COMBIN40).
- Elements for simulating axial impact are located at the top and bottom nozzles. In both cases, multilinear springs (COMBIN39) are defined to simulate the nozzle plasticity for high loads.
- Elements are introduced for simulating the lateral impact of the grids. The grid cell straps are simulated with slider elements (COMBIN40) that collapse at grid crush strength.
- In the case of the lateral drop, additional gap elements (COMBIN40) between the fuel rods and the impact surfaces are defined to obtain the loads on the fuel rods.

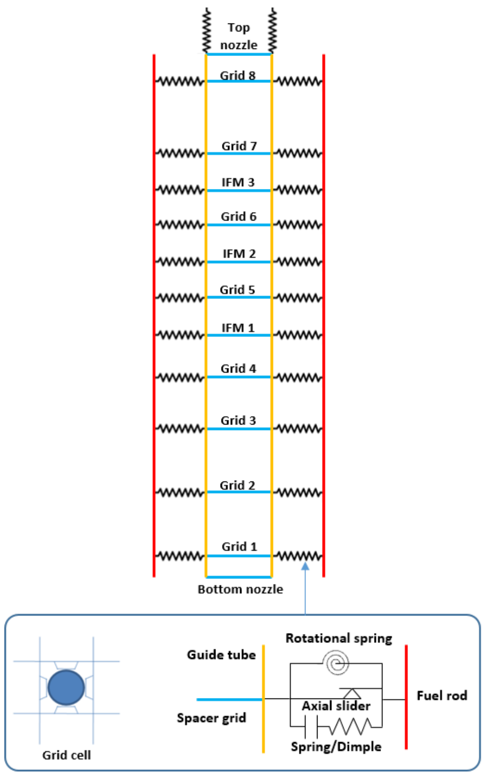
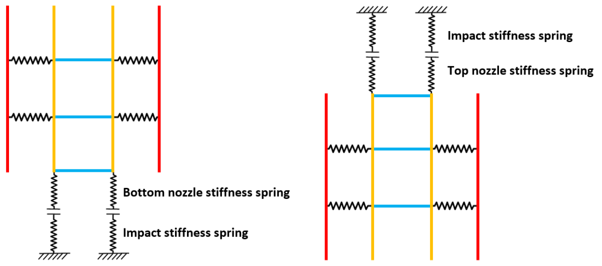
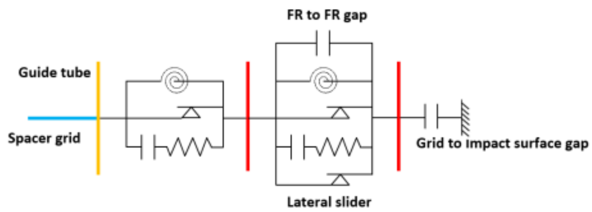



Fig. 1 Fuel assembly finite element model




(a) Axial impact




(b) Lateral impact
Fig. 2 Fuel assembly impact interfaces

## 3. Simulation results

The FE model predictions have been checked with test data as follows.

- FA lateral stiffness
- FA axial stiffness
- FA natural frequency and mode shape
- FA lateral impact force
- FA axial impact force on the bottom nozzle

The mechanical test and simulation results are presented in Fig. 3 through Fig. 8.

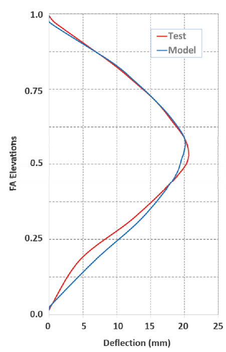



Fig. 3 Lateral stiffness

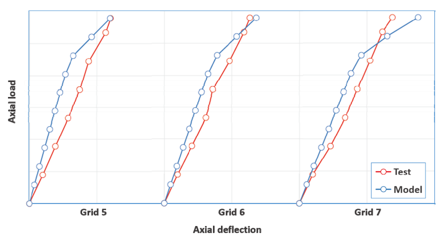



Fig. 4 Axial stiffness

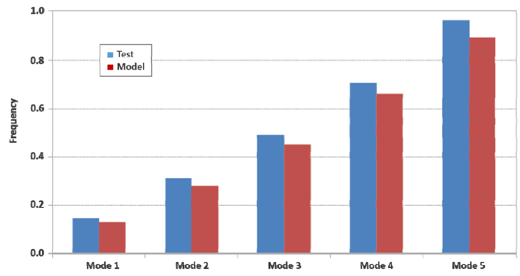



Fig. 5 Natural frequencies

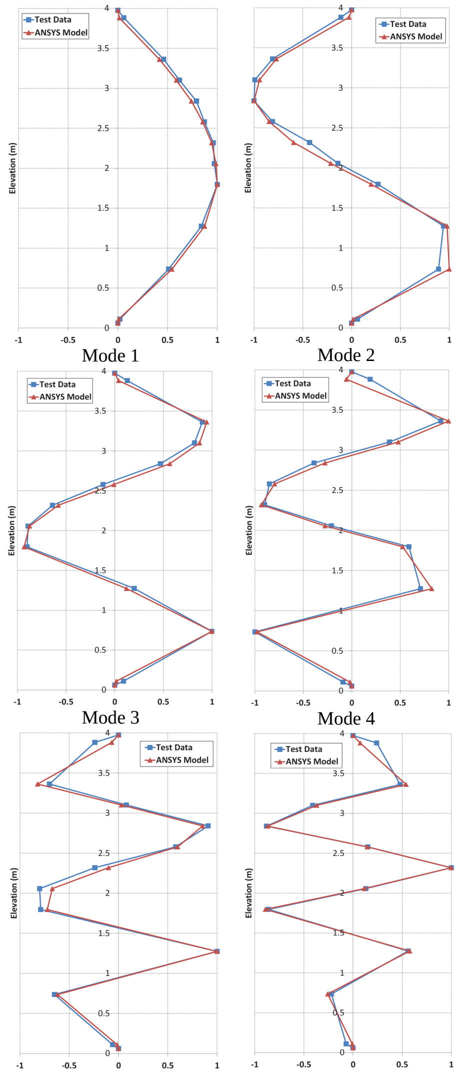



Fig. 6 Mode shape

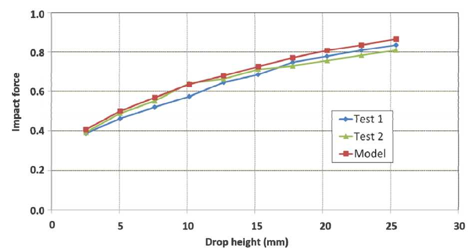



Fig. 7 Axial impact on bottom nozzle

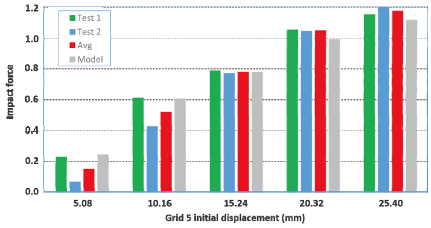



Fig. 8 Lateral impact

Finally, lateral free drop of 2 meters is simulated using developed model. The impact forces as a function of time are represented in Fig. 9.

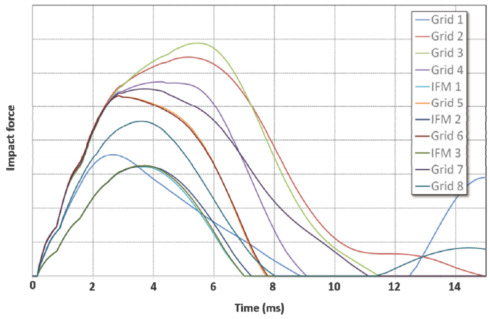



Fig. 9 Lateral free drop

## 4. Conclusions

Using the commercial software, the 2-D FA model is developed, and is verified with the test results. The proposed model shows almost similar mechanical test results, and can also simulate the FA drop accident. Based on the analysis results, the structural integrity evaluation will be performed in order to determine the relatively weakest SF among the target SFs loaded in Koran nuclear reactors. Further detailed evaluation will be planned on this selected SF.

## ACKNOWLEDGEMENT

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