Equivalent Drop Analysis Model of Transportation Cask Including Spent Nuclear Fuel Assembly

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1. Introduction

The purpose of this study is to develop an equivalent analysis model for evaluating the integrity of a spent fuel cladding tube from drop impacts under normal transport conditions and accident conditions of a transportation cask. This study proposes the equivalent drop analysis FE model of the transportation cask including the spent nuclear fuel assembly under normal transport and accident conditions, and a verification test was performed for showing the reliability of the equivalent analysis model.

2. Equivalent Drop Analysis FE Model

2.1 Spent Nuclear Fuel Assembly FE Model

The fuel assembly consists of a 16x16 fuel cladding, a bottom nozzle, a top nozzle, an intermediate support grid, an upper support grid, a bottom support grid, an outer guide tube, and a center guide tube. The fuel claddings, grids and guide tubes are modeled using beam elements, and the bottom nozzle is modeled as solid elements. The springs and dimples in grids are modeled using the spring connectors. Fig. 1 is a finite element model of spent nuclear fuel assembly developed in previous study[1, 2].

2.2 Equivalent Drop Analysis FE Model

Fig. 2 shows the bottom vertical impact analysis model in which the basket and the impact limiter are connected to the finite element model of spent fuel assembly in section 2.1. As shown in Fig. 2, the basket is modeled on the outside of the nuclear fuel assembly, and the horizontal displacement of the nuclear fuel assembly are restricted by adding contact conditions between the cladding and the basket, the support grid and the basket. The impact limiter is modeled as the beam element with a circular cross section, and whose diameter and height are used with the actual dimension of the impact limiter. The impact energy can be absorbed by applying the elasto-plastic properties of the impact limiter into the beam element. The element between the fuel assembly and the impact limiter is connected by a spring element to model the stiffness between the bottom nozzle-canister-cask. The magnitude of the stiffness between these components was determined by comparing with the drop analysis results using the detailed FE model[1].

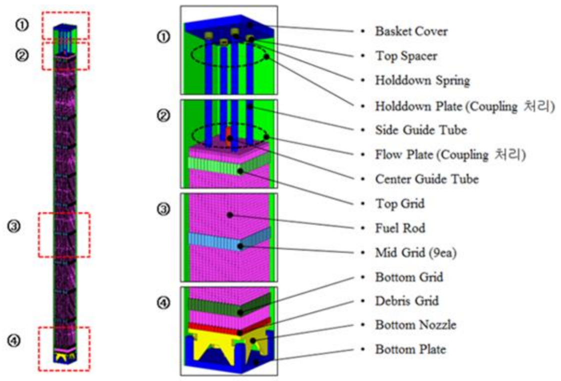
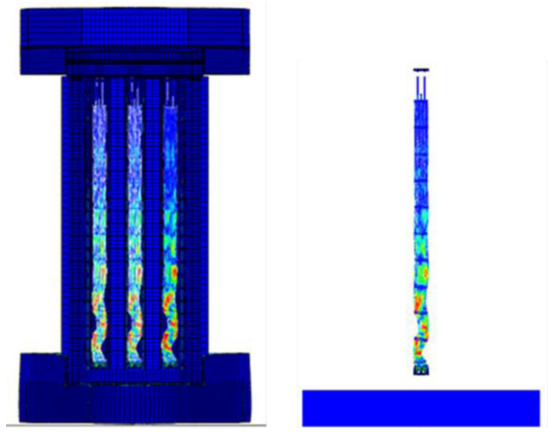


Fig. 1. Detailed FE Model of Spent Nuclear Fuel Assembly.



(a) Detailed FE model (b) Equivalent FE model

Fig. 3. Comparisons of deformed shape and stress distribution between Detailed FE model and Equivalent FE model in case of 9m Vertical Drop.

3. Analysis Results

Fig. 3(a) shows the deformed shape and the stress distribution of the detailed transportation cask FE model containing the spent fuel assembly model in case of 9 m vertical drop analysis. Permanent deformation occurred in the impact limiter at the bottom of the cask and large plastic strain occurred in the cladding of the fuel assemblies in the canister. Fig. 3(b) shows the result of the vertical drop analysis of the 9 m height using the equivalent drop analysis model including the spent fuel assembly. The analysis showed very similar results to those of the detailed FE model.

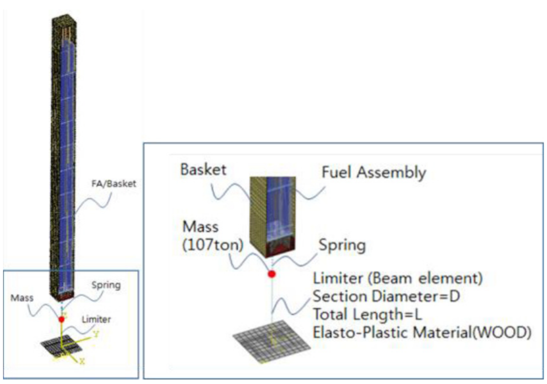


Fig. 2. Equivalent Drop Analysis FE Model of Transportation Cask including Detailed Spent Nuclear Fuel FE Model.

4. Conclusions

This study presents the equivalent finite element model for the vertical drop analysis of the transportation cask including the spent nuclear fuel assembly under normal transport and accident conditions. The analysis results showed that the present equivalent FE model had the reliability by comparing with the drop analysis results using the detailed FE model.

REFERENCES

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