Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2018

Structure Integrity Assessment of Spent Nuclear Fuel of WH type for Transportation Cask Side Drop on the Normal Transport Condition

Young-Oh Lee [a*], Sung-Hoon Jung [a], In-Su Jung [a], Seong-Ki Lee [b], Young-Ik Yoo [b], Jae-Jun Lee [b]
[a]*Korea Nuclear Engineering & Service Co #5, Hyundai Plaza., 341-4 Jangdae-dong, Yuseong-gu, Daejeon, Korea*
[b]*KEPCO Nuclear Fuel: 242, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Korea, 34057*
[*]*Corresponding author: leeyo@kones21.com*

1. Introduction

In the case of studies on spent nuclear fuels, evaluations of mechanical integrity of spent nuclear fuel assembly and studies on fuel rod of the spent nuclear fuel have been mostly carried out domestically and overseas. Analyses of spent nuclear fuels loaded in transport casks have been performed at EPRI, being evaluated by the center spacer grid slice model [1]. The spent nuclear fuels are transported by loaded in a transport cask upon transport, and the impact characteristics received by the spent nuclear fuels vary with transport casks. Therefore, in the present study, structural integrity of the spent nuclear fuels as a result of drop under normal conditions of transport casks in domestic operation will be evaluated.

2. Analysis Methods

For the spent nuclear fuels used in the structural integrity evaluation of the spent nuclear fuels resulting from drop of transport cask, WH 14x14 has been used among the fuels used domestically, while transport casks have been evaluated by using KN-12 in operation at a nuclear plant among the transport casks transporting spent nuclear fuels of WH type.

2.1 Material Properties

In the drop analysis under normal conditions, ASME BPVC Section II, Part A, D has been referred to for material properties of the transport cask, and material properties for fresh fuel have been used for the spent nuclear fuels.

2.2 Analysis Model

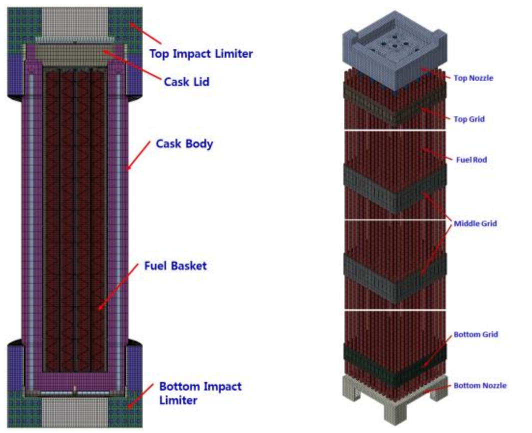
As the transport casks of spent nuclear fuels for evaluation of the effects resulting from drop, the impact limiter is mounted which is composed of a wood absorber material in the upper & lower parts as a cylindrical container with a large wall thickness as shown in Fig.1(a). Interior of the transport cask consists of fuel basket of a square tube form for loading of the spent nuclear fuel assembly. By considering symmetry, 1/2 of the entire model has been modelled for the transport cask.

For the spent nuclear fuel assembly, there are one component of top nozzle and bottom nozzle at the end of upper & lower parts as shown in Fig.1(b), being connected to the guide tube and the instrument tube. Between the top & bottom nozzles, support grid is positioned, being configured in the form where fuel rods are inserted in the grid. Cladding tube and grid of the spent nuclear fuel assembly are modelled as a shell, while the top and bottom nozzles are modelled as a solid.

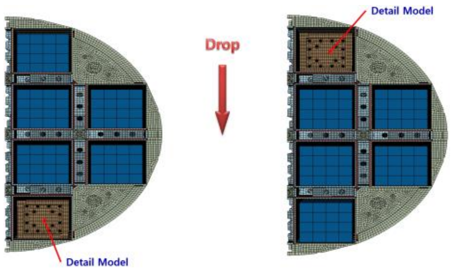
To evaluate behavior for drop conditions, a finite element analysis model for transport casks and spent nuclear fuel assembly has been modeled by using ABAQUS V6.10 as a general code [4]. For the fastening part of the transport cask, Beam element was used, while solid element was used as the constituent for the overall transport cask excluding the fastening part. The numbers of nodes and elements for the finite element analysis model of transport cask were 1,039,397 ea. and 637,634 ea. for modeling.

The spent nuclear fuel assembly are comprised of top and bottom nozzle, top, middle and bottom grids, guide tube and fuel rods, with pellet and instrument tube being excluded from the model. For the top and bottom nozzles, solid elements were used while shell elements were used for the remaining constituents. For the finite element analysis model of spent nuclear fuel assembly, the nodes and the elements were modeled as 783,837 ea. and 680,304 ea. respectively.

Under horizontal drop conditions for the transport cask, position of the spent nuclear fuel assembly of the detailed model positioned inside the fuel basket is as shown in Fig. 2, and the fuel model other than the detailed model was modeled as dummy with the outside dimension and the weight matched. For horizontal drop



(a) Transport Cask (b) Spent nuclear fuel
Fig. 1. Analysis model



(a) Case 1 (b) Case 2

Fig. 2. Loading position of spent nuclear fuel detail model

condition in normal transport, analysis was performed under Case 1 and Case 2 conditions, respectively.

2.3 Load & Boundary Conditions

For the drop height, the free drop condition of 0.3m set in the ordinance by Nuclear Safety & Security Commission. Evaluation for the drop direction was performed for the horizontal drop condition with the largest impact among the drop conditions according to Sandia Report(SAND 90-2406).[2] For the transport casks, axially symmetric boundary condition was applied to the symmetry face, while full constraint condition was applied so that the bottom plate of rigid body has no change in displacement and degree of freedom upon impact. For the contact condition, general contact option provided by ABAQUS has been applied.

3. Analysis Result

Stress distribution for free drop under normal transport conditions of spent nuclear fuel assembly is as shown in Fig. 3, while the analysis results for each part of the spent nuclear fuel assembly are indicated in Table 1. Analysis results were made dimensionless based on the yield strength of each components.

According to the results of analysis, analysis results for each component were compared with yield strength. Under the horizontal drop condition, side impact occurred in the top and bottom nozzles, and the top nozzle was shown to be exceeded the yield strength in the case 1. With the grid, yield strength was exceeded

Table 1. Analysis result

Item		Max Stress(MPa) Case 1	Max Stress(MPa) Case 2	Sy (MPa)	Remark
Top Nozzle		1.62	0.54	1	NG
Fuel Tube		0.63	0.63	1	OK
Grid	Top	1.34	1.34	1	NG
Grid	Mid.	1.59	1.36	1	NG
Grid	Bot.	1.28	1.30	1	NG
Bot Nozzle		0.33	0.97	1	OK

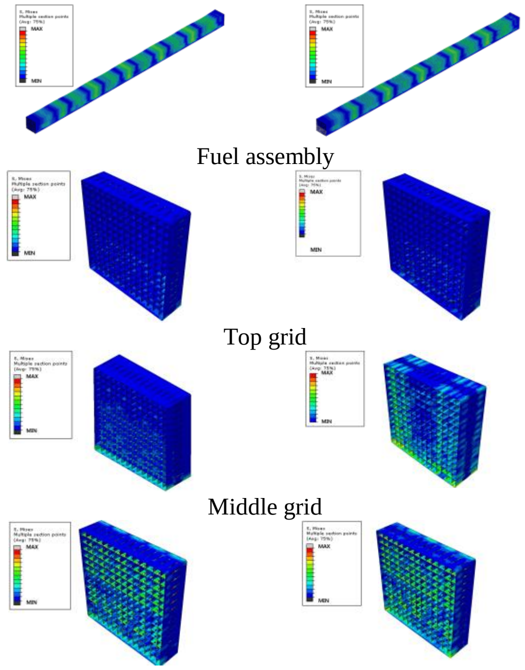


Fig. 3. Stress contour of Spent nuclear fuel

under all conditions irrespective of positions. In the cladding tube, stress occurred due to bending moment and pinch force upon horizontal drop. The maximum stress in the cladding tube was shown to be smaller than the allowable stress at 0.63 in Case 1 and Case 2, respectively, and structural integrity has been evaluated to be secured.

4. Conclusions

According to the drop analysis results for transport cask of spent nuclear fuels under normal conditions, although the top nozzle and the support grid comprising the spent nuclear fuel assembly had yield strength exceeded in localized parts due to horizontal impact, the cladding tube positioned inside has been evaluated to secure safety. In addition, integrity for fuel recovery after drop is considered to be secured.

ACKNOWLEDGMENTS

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning(KETEP) and the Ministry of Trade, Industry & Energy(MOTIE) of the Republic of Korea (NO. 20141710201660C)

REFERENCES

[1] EPRI report, Spent-Fuel Transportation Applications Normal Conditions of Transport, Electric Power Research Institute, June 2007.
[2] Sandia report, A Method for Determining the Spent-Fuel Contribution to Transport Cask Containment Requirements, SAND90-2406, 1992.