Structure Integrity Evaluation of Fresh Nuclear Fuel

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1. Introduction

For safe transport and storage of fuel, the integrity evaluation should be performed. But, considering the current research infra such as test facility, it is considerably difficult to implement test evaluation about many kinds of fuel. Therefore, finite element analysis evaluation can be more efficient alternative solution.

IAEA Safety Standard Series No.SSR-6[1], According to the notification 2014-050 from Nuclear Safety and Security Commission, the radioactive transport cask for the accident transport condition evaluation should be performed with such as 9 m free drop test, 1 m puncture test, thermal test and water immersion test. Through this process, the structure integrity of the transport cask can be evaluated.

In this study, the 9m free drop analysis was performed and the structure integrity evaluation was implemented about fresh nuclear fuel FEM model which is located in the transport cask.

2. Analysis

2.1 FEM model of fresh nuclear fuel

Fig 1. Shows the finite element model of the fresh nuclear fuel. Because the fuel meat and fuel cladding consisted of very thin plate, the shell element is used, and the side plate and end fitting are modeled as the solid element. The finite element model of the fresh nuclear fuel consists of 219,356 of elements and 184,172 of nodes.

Fuel cladding is constrained to side plate with tie conditions. PF foam is designed to absorb the impact force at the top, bottom, and side of the fresh nuclear fuel. End fitting and side plate consists of Al6061-T6 and fuel cladding is made of Al6061.

The transport cask usually carries 12 of fresh nuclear fuels assemblies. But this study modeled the 1 fresh nuclear fuel FEM model in the cask in order reduce the analysis time.

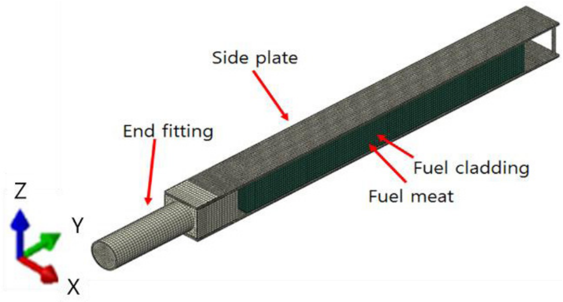


Fig. 1. FEM model of fresh nuclear fuel.

2.2 Drop analysis of the fresh fuel model

The free drop analysis of the transport cask including fresh nuclear fuel was performed using ABAQUS 6.14 [2]. Free drop was analyzed for four times in total, two times of horizontal drops, bottom vertical and Lid vertical drops. Horizontal drop was analyzed in two times, when the fuel cladding is arranged in vertical, and when it is arranged in horizontal. Fig. 2. Shows the finite element model of transport cask.

The floor target is rigid wall which is conservative condition. The drop velocity is 13.288 m/s corresponding to a height of 9 m.

Table 1 shows the results of fuel cladding and side plate stress for each drop posture. Fig. 3 shows the drop analysis results and focuses on fuel cladding. The left is the strain, and the right is the result of von Mises stress.

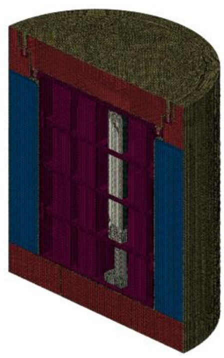
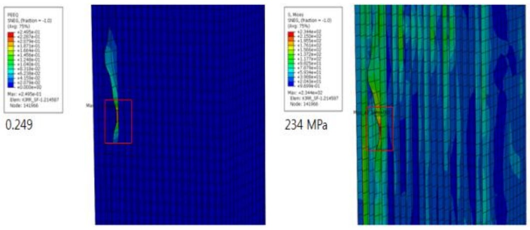


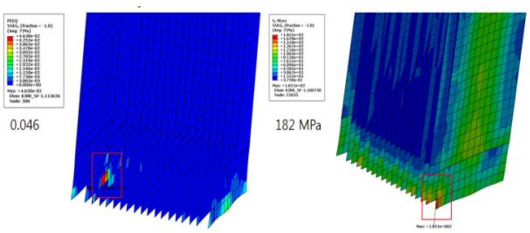
Fig. 2. Finite element model of transport cask.

Table 1. Max. von-Mises stress (unit:MPa)

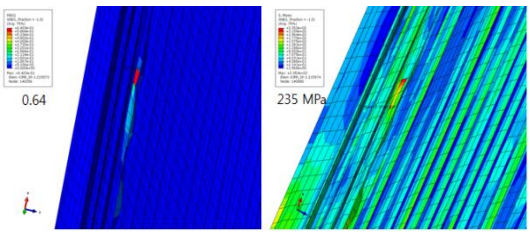
Direction	Cladding	Side plate
Bottom Vertical End Drop(Y)	234	259
Lid Vertical End Drop(Y)	182	324
Cask-Horizontal(Z) Fuel- Horizontal(X)	235	293
Cask-Horizontal(Z) Fuel- Vertical(Y)	228	240



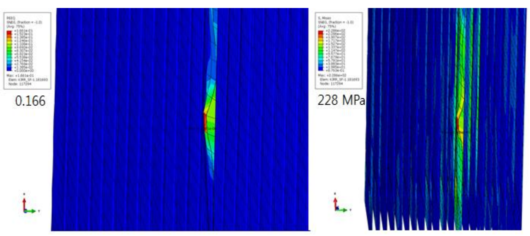
(a) Bottom Vertical End Drop(Y)



(b) Lid Vertical End Drop(Y)



(c) Cask-Horizontal(Z) Fuel- Horizontal(X)



(d) Cask-Horizontal(Z) Fuel- Vertical(Y)

Fig. 3. Distributions of the effective plastic strain and von-Mises Stress for each drop conditions.

In the case of bottom drop and lid drop, the direction of fresh nuclear fuel only changed, but not significantly different, and the upper side of the side plate showed some buckling.

In the case of a horizontal drop, the shape in which the stress appears depends on the direction of the fresh nuclear fuel. When the fresh nuclear fuel dropped horizontally, cladding caused a lot of stress due to bending, and when the fresh nuclear fuel dropped vertically, it appeared to come out higher at the part contacting the side plate.

3. Conclusion

The structural integrity of fresh nuclear fuel was evaluated by carrying out several 9 m drop analysis of the transport cask including fresh fuel. The local permanent deformation of the fuel cladding occurred in all 9-m drop conditions. In addition, it was observed that there was a considerable difference depending on the direction of the fresh nuclear fuel even though the drop directions of the cask are same. However, we did not conclude yet if the structural integrity of the fresh nuclear fuel is able to be maintained since there are so many stress localization in the analysis results.

In the future, we will conduct again model verification of the fresh nuclear fuel model and evaluate the structural integrity of it more precisely.

REFERENCES

[1] IAEA safety standard series No.SSR-6, “Regulation for the safe transport of Radioactive Material”, 2009.

[2] ABAQUS(6.14) analysis user manual.