A Study on Drop Analysis of the Spent Nuclear Fuel Metal Cask (OASIS-32D)

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1. Introduction

The purpose of this study is to evaluate the structural integrity of spent nuclear fuel cask, which OASIS-32D is transport and storage metal cask developed by KEPDO-E&C [1]. OASIS-32D should be designed to meet the requirements of 10CFR 71 [2]. The 9m free drop accident presented in 10CFR 71 is considered as the most critical scenario of hypothetical accident conditions during transport.

In this paper, the 9m free drop for OASIS-32D using the LS-DYNA program was evaluated. The results of the analyses confirm that the structural integrity of OASIS-32D is maintained.

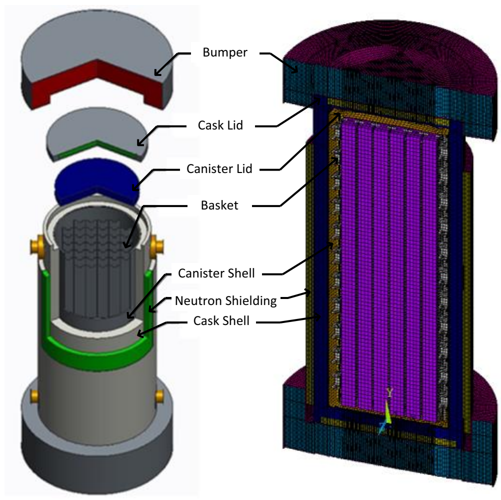


Fig. 1. Geometry and FE model of OASIS-32D.

2. Development of modeling

2.1 Geometry

OASIS-32D consists of the canister and cask as shown in Fig. 1. The canister is comprised of a canister shell, canister lid, fuel bundles, basket, and so on. The cask is composed of a cask lid, cask shell and bumpers used as energy-absorbing components to protect the cask.

2.2 Modeling

To improve the efficiency of analysis, the components such as trunnions, heat transfer fins, etc. cause little influence on the drop analysis were not considered for modeling. The fuel assembly is modeled as a simplified hexahedron with solid elements. However, the total weight of OASIS-32D is maintained using the equivalent density. The canister and its contents are modeled using the shell element because these components are very thin relative to its height, while cask is modeled as the solid element. Fig. 1 shows the finite element model.

3. Drop analysis

3.1 Method

The 9m free drop analyses are performed for two typical conditions, horizontal and vertical drop.

The target surface is conservatively considered as the rigid, and all DOF of the surface are restrained for boundary condition. The initial velocity of 13.3 m/s corresponding to the 9m free drop condition is applied on the cask and canister. The contact condition between bumpers and target surface is the node to surface contact used in impact analysis.

3.2 Results

Table 1 shows the ratio of the maximum stress intensities to allowable stress based on the Regulatory Guide 7.6 [3]. The stress intensities of the horizontal drop case are less than those of the vertical drop case because the bumpers in the horizontal drop case absorb more impact energy.

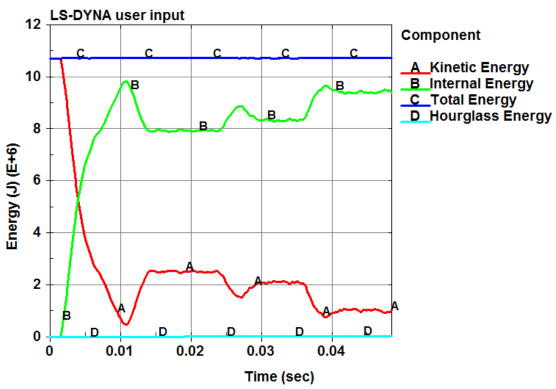
Fig. 2 and 3 show the energy histories and stress results of drop analyses. The appropriateness of the 9m drop analysis is confirmed from the constant total energy and small hourglass energy as shown in Fig. 2.

Although Table 1 shows that the maximum stress intensity of cask shell is close to the allowable, it is occurred only at the very small area in the inner surface of the cask bottom as shown in Fig. 3(a). Therefore, it is ensured that the structural integrity of OASIS-32D is maintained for the 9m free drop analyses at two conditions.

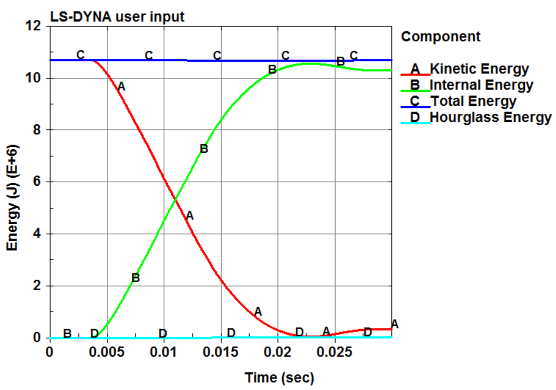
Table 1. Maximum stress intensities

Components		Maximum S.I.	
		Vertical	Horizontal
Cask	Lid	0.80	0.51
	Shell & Bottom	1.00	0.63
Canister	Lid	0.53	0.26
	Shell	0.79	0.60
	Bottom	0.75	0.59

Note: Normalized values to allowable stress [3].

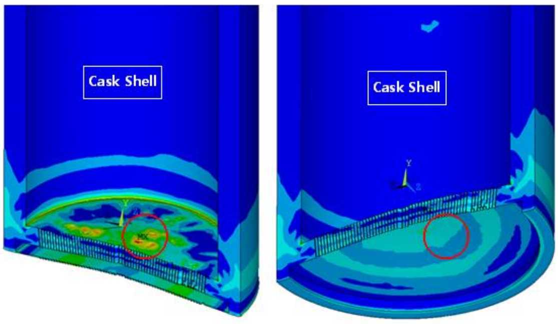


(a) Vertical drop



(b) Horizontal drop

Fig. 2. Energy histories for 9m free drop analyses.



(a) Vertical drop

(b) Horizontal drop

Fig. 3. Stress distribution.

4. Conclusion

The 9m free drop analyses of OASIS-32D were carried out for typical conditions. The results of the analyses show that the structural integrity of OASIS-32D is maintained for the 9 m free drop analyses of horizontal and vertical drop conditions.

In the near future, the additional drop analyses considering various drop conditions will be performed to evaluate the structural adequacy of OASIS-32D.

REFERENCES

[1] K.J. Ko, S.H. Kim, M.G. Kim, Y.H. Cho, H.M. Kim, J.G. Ahn, “Design Features of an OASIS-32D Metal Cask for both Transport and Storage of SNF” Proc. of the KRS 2016 Autumn Conference, 14(2), Oct. 12-14, 2016, Jeju.

[2] US NRC 10CFR 71, “Packaging and Transportation of Radioactive Material”, Jan. 2017.

[3] US NRC Regulatory Guide 7.6, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels”, March 1978.