Preliminary Analysis of Transport and Storage Cask under 9 m Side Drop Condition

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1. Introduction

Transport and storage cask is a container which carries spent nuclear fuel. When cask drop accident occurs during transportation, structural integrity of the cask should be maintained. So, the Nuclear Safety and Security Commission requires a 9 m free drop to demonstrate structural integrity of the cask [1].

KORAD conducted 9 m free drop analyses of transport and storage cask using commercial software ABAQUS. The free drop analyses were conducted under side, vertical, corner and oblique conditions. The most severe results were observed under side drop condition. Maximum primary membrane stress intensity (P_m) and primary bending stress intensity (P_b) were investigated to compare with allowable stress intensity values [2, 3]. In the previous study, fuel assembly was not evaluated. As it is important to guarantee the integrity of fuel assembly, detailed evaluation should be needed.

In this study, 9 m side drop analysis of the cask including fuel assembly was conducted using commercial software ANSYS [4]. The analysis results were verified through energy-time history. There by, maximum P_m and P_b as well as critical locations of each component were determined and compared with corresponding allowable values.

2. Analysis Model & Conditions

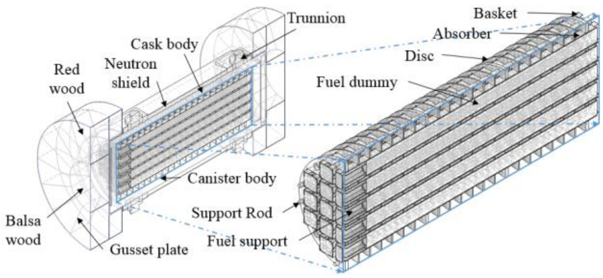

Fig. 1. Schematics of transport and storage cask

2.1 Transport and storage cask model

As shown in Fig. 1, cask model used in this study is a canister-based container for transporting spent fuel and can be roughly divided into cask, canister, and impact limiter. The cask is composed of a cask body, a cask lid, a neutron shield, an outer shell, and 4 trunnions. Components of the canister are 21 fuel assemblies, 22 discs, 4 support rods, and 21 fuel supporters. The impact limiter consists of impact limiter shell, red & balsa wood, and gusset plate. The Finite Element (FE) model was constructed with 504,036 nodes and 634,638 elements. Fuel assembly was modeled as dummy for simplicity. Fig. 2 shows a half FE model of the transport and storage cask.

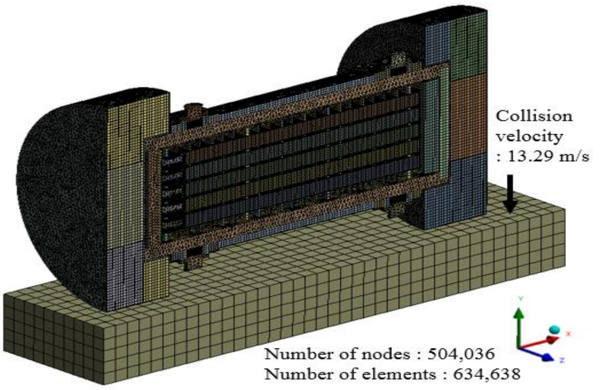

Fig. 2. FE model of transport and storage cask

2.2 Boundary conditions

Collision velocity (13.29 m/s) and gravity acceleration (9.81 m/s^2) were given as initial conditions assumed that the cask was dropped above 9 m from the rigid body. Z-axis symmetry condition was assigned and frictional coefficient was set as 0.2 for all bodies. 4 trunnions and 2 impact limiters were fixed to the cask body. 22 discs, 13 fuel supporters and 13 baskets were bonded to the canister body.

3. Analysis Results

3.1 Energy balance

Fig. 3 shows energy-time history curve obtained from side drop analysis. Internal and kinetic energies were exchanged each other so that total energy was maintained constantly. Maximum value of internal energy was 5.0239×10^6 J at 0.0214 s.

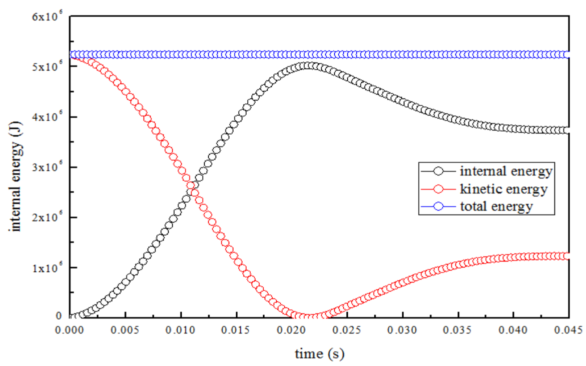

Fig. 3. Energy-time history under 9 m side drop condition

3.2 Stress analysis

Impact limiters and fuel supporters serve as a buffer protecting other components when the cask dropped. Table I shows maximum P_m and $P_m + P_b$ for each cask component.

Table I: Maximum stress intensity

Components	Stress classification	Maximum stress intensity (MPa)	Allowable stress intensity [2] (MPa)
Cask	P_m	78	338
	$P_m + P_b$	200	483
Canister body	P_m	88	247
	$P_m + P_b$	258	371
Support Rod	P_m	5	428
	$P_m + P_b$	28	551
Disc	P_m	110	428
	$P_m + P_b$	277	551
Basket	P_m	67	428
	$P_m + P_b$	133	551
Fuel assembly (Dummy)	P_m	61	289
	$P_m + P_b$	168	413

Fig. 4 depicts von-Mises stress distribution of the transport and storage cask. There was stress concentration between canister body and canister lid. Right side discs were more vulnerable than left side ones because cask is heavier on the right side. Left side of the basket was more susceptible than right side because they are bonded to canister body where stress can be transferred directly. Critical stress value occurred on left edges of the fuel assembly because they are in contact with the fuel supporters.

Fig. 5 shows von-Mises stress time history of fuel assembly. Maximum von-Mises stress value was 237 MPa at 0.0132 s. Fig. 6 shows von-Mises stress distribution of fuel assembly at the same time. A red mark on Fig. 6 represents at which the maximum value occurred.

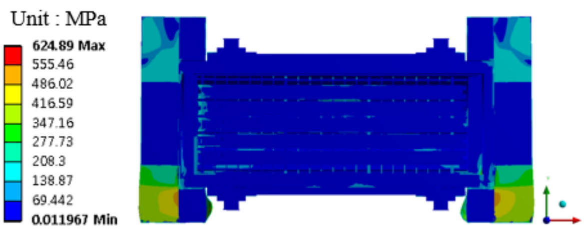

Fig. 4. von-Mises stress distribution of transport and storage cask (0.0132 s)

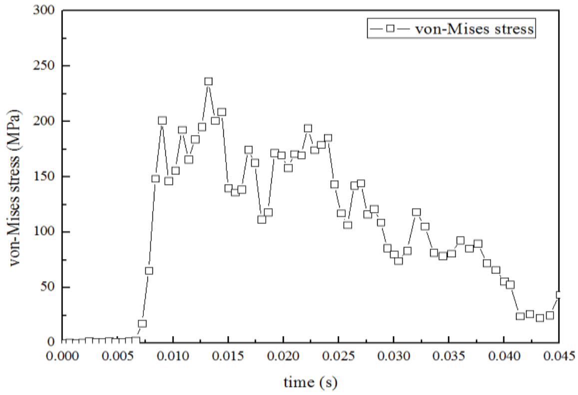

Fig. 5. von-Mises stress time history of fuel assembly

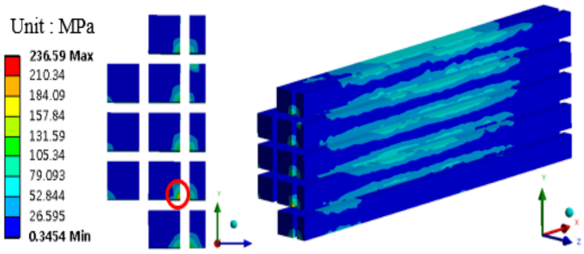

Fig. 6. von-Mises stress distribution of fuel assembly (0.0132 s)

4. Conclusion

In this study, a preliminary analysis was conducted under 9 m side drop condition and the followings were derived;

(1) 1/2 FE model of transport and storage cask was constructed as full scale.
(2) Maximum P_m and $P_m + P_b$ of each component were lower than corresponding allowable stress intensity values.
(3) Parametric FE analysis will be conducted considering detailed model of fuel assembly.

ACKNOWLEDGMENTS

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