Lesson Learned from Drop and Tip-Over Test of a Dry Storage Cask System

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1. Introduction

To study an appropriate storage system with the consideration of a nuclear power plant situation, a status evaluation of the technology and a feasibility study has been performed in Korea. As a part of doing these, a dry spent fuel storage cask has been developed. The dry storage cask under development consists of a cask body, a canister, and an in-canister structure. 24 fuel assemblies are stored in canister structure. The spacer disks in this in-canister structure are designed to dissipate the heat from the baskets and to provide a lateral support to the baskets. The support rods keep the spacer disks at an even interval. To assess a structural integrity after a hypothetical accident condition of this dry storage system, a 1/4 scale model is fabricated for the drop test. Drop tests of this test model were performed and the test results were also discussed.

2. Test for Hypothetical Accident Condition

To evaluate the behavior characteristics and the structural integrity of a storage cask, an end drop test and a side drop test of the canister were performed. And a top-over test of the cask was also performed.

2.1 End Drop Test

The drop height is 0.1 m and 2.1 m shown in Fig. 1. 6 strain gauges and 1 accelerometer are attached to the outer surface of canister. Strain histories in the axial direction at each position of the canister and a center basket are represented in Figs. 2 and 3, respectively. The filtered acceleration data manipulated with a cutoff frequency is shown in Fig. 4. A proper cutoff frequency is selected based on an examination of the strain history profile. Acceleration history represents the first impact and the following second impact caused by a rebound and a re-impact. A sampling rate is chosen as 20 k. The maximum values of strain and acceleration are shown in Table I.

Fig. 1. End drop test with 2.1 drop height

Table I: Max. value of strain and accelerationdrop test

0.1 m drop							
strain [με]						accel. [g]	
#3	#5,6	center basket	out basket	center disk	out disk	raw data	filtered
65	40	500	50	20	13	120	78
2.1 m drop							
strain [με]						accel. [g]	
#3	#5	center basket	out basket	center disk	out disk	raw data	filtered
400	230*	1350	N/A	1000	N/A	1800	750

* strain data acquisition @ #6 failed.

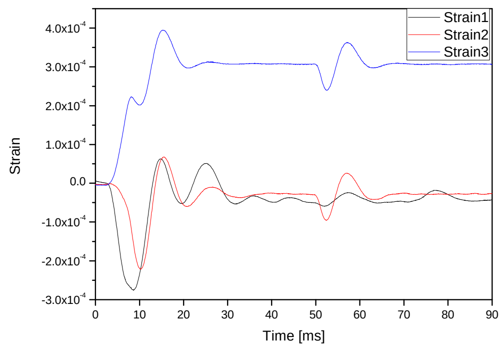

Fig. 2. Strain histories @ #1, 2, 3 in the end drop test

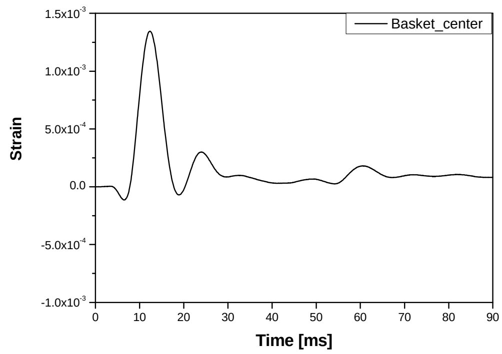

Fig. 3. Strain history @ center basket in the end drop test

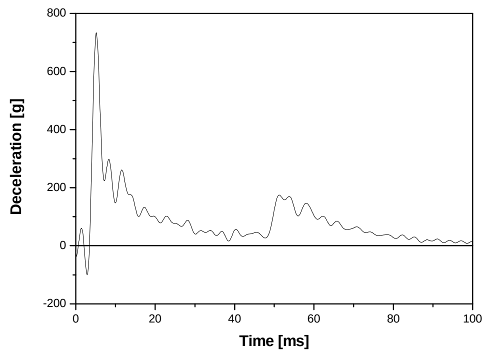

Fig. 4. Acceleration history filtered with cut-off frequency

2.2 Side Drop Test

The drop height is 0.1 m and 3.1 m. 6 strain gauges and 6 accelerometers are attached to the outer surface of canister. Strain histories in the hoop direction at each position of the canister are represented in Fig. 5. The filtered acceleration data manipulated with a cutoff frequency is shown in Fig. 6. A sampling rate is chosen as 20 k. The weight of a canister including an in-canister structure is 636 kg. The maximum values of strain and acceleration are shown in Table II.

Table II: Maximum value of strain and acceleration

0.1 m drop				3.1 m drop			
strain [με]		accel. [g]		strain [με]		accel. [g]	
#1	#5	#2	#6	#3	#5	#2	#6
140	22	168	152	460	80	1600	1780

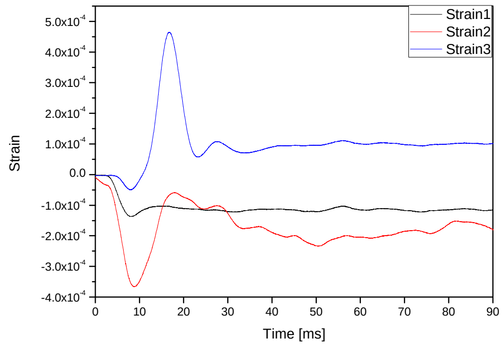

Fig. 5. Strain histories @ #1, 2, 3 in the side drop test

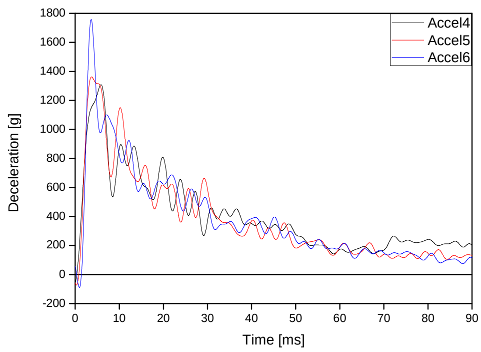

Fig. 6. Acceleration history filtered with cut-off frequency

2.3 Tip-over Test

The initial tip-over angle is 61°. 7 strain gauges and 7 accelerometers are attached to the outer surface of cask. Strain histories in the hoop direction at each position are represented in Fig. 7. The filtered acceleration data manipulated with a cutoff frequency is shown in Fig. 8. A sampling rate is chosen as 20 k. The weight of a cask including a canister and in-canister structure is 2,134 kg. The maximum values of strain and acceleration are shown in Table III.

Table III: Maximum value of strain and acceleration

Location	#1	#2	#3	#4	#5	#6	#7
Strain	-89	217	78*	89	75	23	-17
Accel.	142	102	71	138	N/A*	51	163

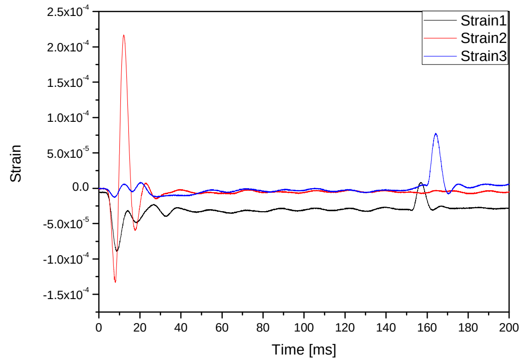

Fig. 7. Strain histories @ #1, 2, 3 in the side drop test

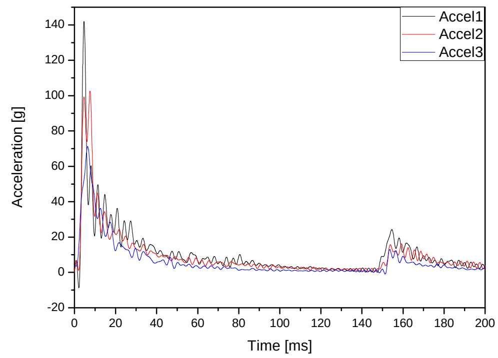

Fig. 8. Acceleration history filtered with cut-off frequency

3. Conclusions

A new type of dry storage system has been developed in Korea. The dry storage cask under development consists of a cask body, a canister, and an in-canister structure. The in-canister structure is a complicated structure with 24 baskets and 25 spacer disks. A 1/3 scale model was analyzed and tested for a drop and a tip-over accidents. In the end drop test, the strain at the outer baskets is relatively high since they are along the critical loading path. In the side drop test, the magnitude of the hoop strain close to the target is larger than that at the opposite side from the target. In the tip-over test, a metal o-ring named Heliflex was used for leak tightness. A metal o-ring has an advantage of durability and a disadvantage of having precise tolerance especially on seating surface. Leak tests before and after the drop tests and a tip-over test showed that the canister and the cask maintain a leak tightness and structural integrity after tests.

REFERENCES

[1] IAEA Safety Standard Series No. TS-R-1, Regulations for the Safe Transport of Radioactive Material. 2005.
[2] IAEA Safety Standard Series No. TS-G-1.1(ST2), Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material. 2002.
[3] Korea Most Act. 2001-23, Regulations for Packaging and Transport of Radioactive Material. 2001.
[4] U.S. Code of Federal Regulations, Packaging and Transportation of Radioactive Material, Title 10, Part 71, 1997.