Structural Safety Evaluation Test for CANDU Spent Fuel Transport Cask (KTC-360)

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1. Introduction

The Wolseong Nuclear Power Plant is temporarily storing about 450,000 bundles of CANDU spent nuclear fuel in wet storage pools and dry storage facilities. Wolseong Nuclear Power Plant has been using the HI-STAR 63 transport cask since 2010 for on-site transport of CANDU spent nuclear fuel from wet storage to dry storage facilities. The capacity of the HI-STAR 63 cask is 120 bundles (2 baskets). In order to transport the CANDU spent nuclear fuel to an interim storage facility or a disposal facility in the future, the development of a large-capacity transport cask was required. The KTC-360 transport cask under development is capable of vertically transporting 360 bundles of nuclear fuel at a time by loading six baskets of spent fuel in two rows of three tiers each. This study describes the contents of drop, puncture, and water immersion tests using a 1/2 scale model to evaluate the structural integrity of KTC-360.

2. Preparing for Structural Evaluation Test

The test model for structural integrity evaluation is a 1/2 scale model shown in Fig. 1. The test model consists of a transport cask and upper and lower impact limiters.

Two dummy simulating the weight of baskets were loaded inside the left and right transport cylinders, respectively. One dummy has the weight of three baskets. According to the drop posture of the transport cask, the impact limiter that does not collide with the target surface was replaced with a dummy during the drop test.

Fig. 1. A half scaled test model of KTC-360

A total of 22 strain gauges and 3-5 accelerometers were attached to the inside and outside of the test model. All sensors were measured at 100,000 sample/s. To prevent aliasing of the measurement signal, a 10 kHz low pass filter was applied for acceleration and 1 kHz for strain. The low pass filter was applied using the built-in physical filter function of the DAQ device.

The 9 m drop tests and 1 m puncture tests of the KTC-360 test model consist of (1) Bottom vertical drop, (2) Lid vertical drop, (3-1) Long side horizontal drop, (3-2) Side puncture, (4) Long side oblique drop, (5-1) Long side Lid-COG drop, and (5-2) Lid puncture tests, which are 7 conditions shown in Fig. 2.

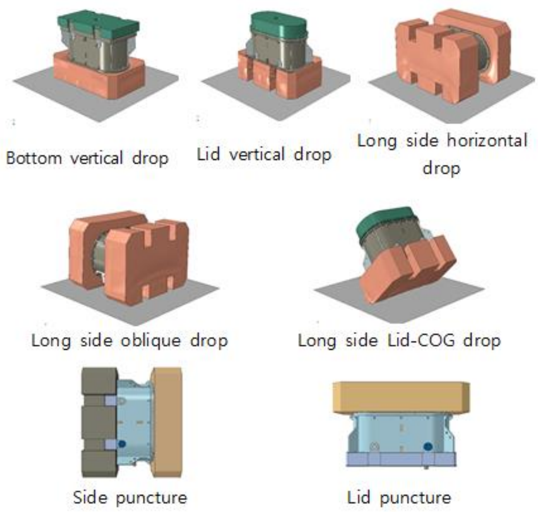

Fig. 2 Drop and puncture test conditions.

3. Test Results

Table 2 and Table 3 show the measurement results of acceleration and strain for each condition of the drop and puncture tests. Figures 3 and 4 show the deformed shape after the test. The magnitudes of acceleration and strain were not large enough to damage the shielding and containment performance of the transport cask. The leak rate measured from the leak test performed after each structural test was much lower than the allowable leak rate, confirming that the containment integrity was maintained.

After the drop and puncture tests, immersion tests were performed. The immersion test shown in Fig 5 is a test in which the transport cask is immersed for 8 hours in a method that receives maximum damage from a water head of 15 m or more. The test model was placed in a pressure container for the immersion test, and the internal pressure was increased to 150 kPa or more, and maintained for 8 hours. After that, the test model was pulled out, and the leakage into the test model was investigated to confirm the integrity of the cask.

Table 1 Measured acceleration (LPF 300Hz)

Test	Max. Accel.(g)		Min. Accel.(g)	
	Magnitude	Sensor ID	Magnitude	Sensor ID
Bottom Vertical	92	A05	-70	A04
Lid vertical	108	A15	-43	A15
Horizontal drop	676	A07	-516	A07
Horizontal puncture	201	A10	-148	A10
Oblique	227	A07	-198	A07
COG	62	A14	-29	A16
Lid puncture	193	A13	-213	A13

Table 2 Measured strain (except internal sensor, No filtering)

Test	Max. strain (μm/m)		Min. strain (μm/m)	
	Magnitude	Sensor ID	Magnitude	Sensor ID
Bottom Vertical	202	S16	-110	S20
Lid vertical	201	S1	-330	S22
Horizontal drop	1215	S21	-235	S19
Horizontal puncture	509	S21	-305	S21
Oblique	1068	S21	-1579	S21
COG	190	S21	-115	S21
Lid puncture	75	S3	-45	S19

As a result of the dimensional inspection after the immersion test, there was no deformation of the cask. From a result of the leak test, it was measured within the allowable leakage rate, and the tightening torque was maintained because the cap bolt did not loosen. Removing the lid and checking the inside of the cylinder, water did not flow into the test model, and no damage or buckling occurred, so that the cask containment integrity was maintained under the immersion test conditions.

For the leak test, a quantitative method was selected from the leak test methods stipulated in ANSI N-14.5 and ISO 12807. Evacuated envelope gas test method, which is applicable to containers requiring high sensitivity (10^{-9} ㎤/s) was applied.

To perform the leak test, after filling the inner space of the test model with 0.9 kg/cm^2 pressure of helium of 99.999% purity and maintaining the pressure in the inner space for at least 15 minutes, Alcatel's Model ASM-142 Helium Mass Spectrometer was used.

The leak rate measured before and after all tests was within the allowable leak rate of normal condition and accident condition, respectively. Therefore, the containment integrity was maintained under normal and accident conditions.

Fig. 3. Deformed shape after drop test

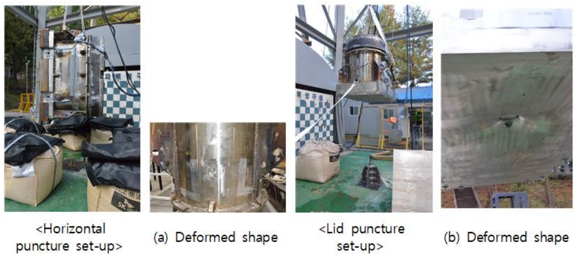

Fig. 4 Deformed shape after puncture test

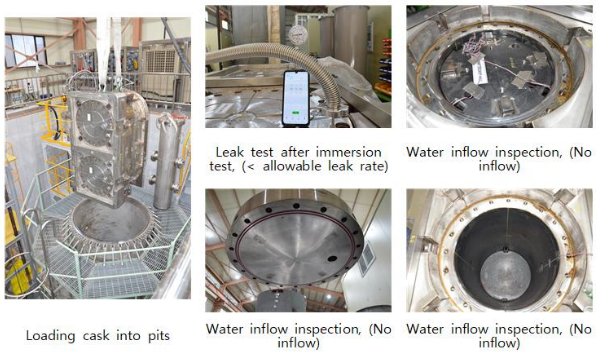

Fig. 5 Water immersion test, leak test and water inflow inspection

4. Summary

Drop, puncture, and water immersion tests were performed to evaluate the structural integrity of the KTC-360. Before and after the test, a leak test was performed to check whether the containment integrity was maintained. Acceleration and strain were measured before and after the drop and puncture tests, and deformation was investigated. As a result of the structural test, it was verified that the structural integrity of KTC-360 was maintained.

ACKNOWLEDGMENTS

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