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Lid Mechanism Analysis of High Capacity Cask for the Transport of CANDU Spent Fuel Bundle

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1. Introduction

CANDU spent fuel bundle transport cask is designed to carry large quantities of spent nuclear fuel.

In the case of CANDU fuel, it is burned in a shorter time than LWR fuel, and used as a spent nuclear fuel to be sent to a storage pool.

Besides, compared to LWR, the number of spent nuclear fuel assembly generated in the CANDU is very high. And, in order to transport efficiently, the CANDU spent fuel transport cask have been produced for the purpose of transporting as much as possible in one cask.

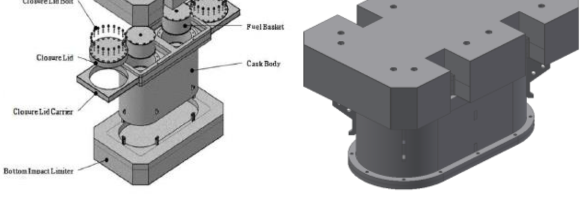
The purpose of this paper is to evaluate the integrity of the cask lid mechanism through the drop analysis of the casks carrying 360 assembles of CANDU spent nuclear fuel under the normal transport conditions.

2. Analysis of the transport cask

2.1 Model of CANDU Spent Fuel Transport Cask

The large-capacity CANDU spent nuclear fuel transport cask under development charges 60 assembly of spent nuclear fuel per basket and is capable of transporting six baskets.

Figure 1a shows original size transport cask, and b is a quarter model for conducting a preliminary safety test of the mechanism.



a. Original model   b. 1/4 scale model
Fig. 1. CANDU spent fuel Transport cask shape

The difference between the real size and the quarter model lies in the simplicity of the test purpose. The six basket and impact limiter underneath were removed and the weight and center of gravity were maintained.

The gross weight of the transport cask is 1,072 kg and the total size is 651 × 1,050.5 × H 729.5 mm.

2.2 Analysis of the Transport Cask

The impact limiter and carrier of the quarter-sized model of the large-capacity CANDU spent nuclear fuel transport cask are composed of very thin plates. As seen in fig.2, The inner gusset, INSIDE WALL SHELL, etc. are very thin plates with a thickness of 0.7 to 3 t.

Carriers are also very thin plates. Therefore, in this paper, a thin plate was modeled using an element called SolidShell.

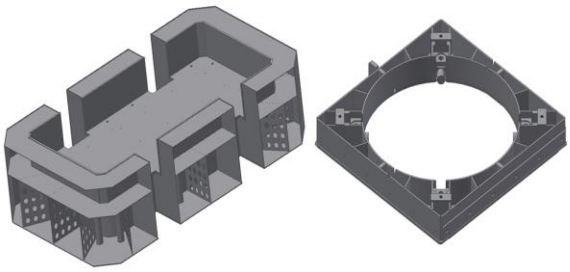


Fig. 2. original model and 1/4 scale model

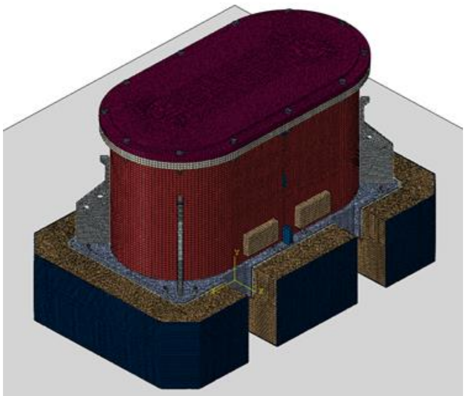


Fig. 3. FE Model of transport cask

The dropping posture was performed by the lid vertical drop. The fig. 3 shows the FE model for performing the drop analysis. The drop analysis was conducted using ABAQUS/explicit.

In load, the gravity acceleration is 9.81 m/s2 and the initial velocity is 0.3 m, free drop velocity of 2.4 m/s.[1]

As the boundary condition, the rigid surface of the floor is completely fixed. As the boundary condition, the rigid surface of the floor is completely fixed. The drop height was 0.3 m, which is the normal transport condition. The reason why the drop height is 0.3 m is because the weight of the prototype is 70 tons and the drop analysis condition under normal transport condition is 0.3 m.

A-240 TP304 material was applied to most of the materials, and A-36 material was applied to the dummy that replaced the existing component. The thin plate located to prevent contact between the carrier and the housing and the spacer located between the impact limiter and lid are composed of Peek material. The material properties of peek are use the density(1,350 kg/m^3), Hyperelastic(yeoh model) and consider the Mullins effect.

2.3 Result

Two results were confirmed by performing a 0.3 m lid vertical drop analysis. First, the stress which applied to the bolt of a carrier was confirmed. And the gap between the housing and the carrier to determine the normal operation of the carrier was confirmed.

For the stress of the carrier bolts, the bolt stress evaluation criteria given in ASME Section 3 Division 3 were applied.[2] Average Stress should not exceed 2/3 of Yield Strength value and Shear Stress should not exceed 40%. The allowable stress and results can be seen in Table 1. The actual stress is calculated using the section force of the bolt and the stress area of the bolt. The average stress is 483.3 MPa and the shear stress is 243.6 MPa.

Table I: result of bolt

	Limit(MPa)	Result(MPa)
Normal stress S_y x 2/3	483	383
Shear stress S_y x 0.4	290	243
SA 540 B23 Yield Strength : 725 MPa[3]		

In order to determine the normal operation of the carrier, the gap changes for three positions were analyzed. The three positions are at the sides and top of the carrier. The gap change for sides was only about ± 1 mm, and the movement up and down was a maximum of 1.7 mm, and a minimum of 0.8 mm. The gap change between the carrier top and the housing is shown in the figure 4.

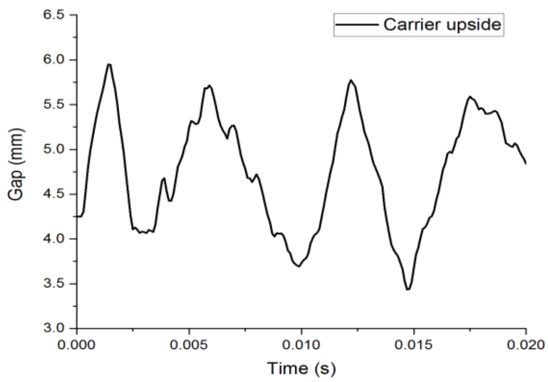


Fig. 4. Result of Carrier upper surface Gap

3. Conclusions

A 0.3 m high lid vertical drop test was performed on a large capacity CANDU transport cask. According to the analysis result of the carrier bolt and the carrier check whether the normal operation, The bolt was confirmed to be within the allowable stress, and normal operation of the carrier is expected.

REFERENCES

[1] Nuclear Safety and Security Commission, Regulation for radioactive material packing and transport, Notice 2019-07, NSSC(2019).

[2] The American Society of Mechanical Engineers, ASME Boiler & Pressure Vessel Code, section III, Division 3, ASME (2010).

[3] The American Society of Mechanical Engineers, ASME Boiler & Pressure Vessel Code, section II, Part D, ASME (2010).