Confinement Analysis of Dual Purpose Metal Cask Subjected to Impulsive Loads due to Aircraft Engine Crash

Background

After the terrorist attacks of 11 September 2001, accident scenarios exceeding the design requirements, such as a forced aircraft crash, have been considered, and corresponding analysis has been executed with regard to the assessment of inherent safety in an interim nuclear spent fuel storage facility with combined transport and storage casks. In Japan, the first interim storage facility of spent nuclear fuel away from reactor site is being planned to start its commercial operation around 2010, in use of dual-purpose metal cask in the northern part of Honshu Island, Japan. The height, outer diameter and weight of the metal cask are 6.0m, 2.5m and 120ton, respectively (Fig.1).To succeed in the early realization of the storage facility, it is important to determine whether a forced aircraft crash event might lead to a considerable release of radioactive substances into the environment integrity.

Objectives

The purpose of this study is to investigate integrity of the lid structure of a metal cask during extreme impact load caused by aircraft crash through executing a vertical impact onto the head of a full-scale metal cask using a scale model aircraft engine and measuring leak rate from the metallic gasket (Fig.2) in the cask on impact.

Principal Results

1. Aircraft crash test

The test apparatus of aircraft crash test for vertical impact was constructed in the open air. The full-scale lid model cask was mounted on a supporting frame structure and the reaction forces were measured by the load cells installed between the model cask and the supporting frame. As the missile, a simplified deformable missile (weight 316kg, diameter 500mm) was used considering the rigidity of the actual aircraft engine and its geometry scale factor was set at 1/2.5, based on the limited condition of the testing facility. The missile was accelerated to the specified impact velocity (66m/sec) by driving force caused by the explosion of gunpowder inserted in the tail of the missile to hit the full-scale lid structure with the primary and secondary lids. Then, the leak rate, inner pressure between the lids and displacement of the lids were measured.

(1) There is no plastic deformation in the lid system and no considerable loss of the torque of the lid bolts.

(2) The leak rate of the secondary lid exceeded 1.0×10^{-3} Pa・m^3/sec at the instant of the impact. However, as no residual lid opening displacement occurerred after loading, the leak rate was recovered to less than 1.0×10^{-6} Pa・m^3/sec after three hours from the impact test. Moreover, the small loss (10kPa decrease from the initial value 305kPa) of the inner pressure between the lids occurred due to the instantaneous opening deformation of the secondary lid.

(3) The leakage rate from the primary lid might be considerably low (less than 1.0×10^{-7} Pa・m^3/s), and the loss of the inner pressure in the cask might be avoided during the extreme impact loading due to aircraft engine crash.

2. Verification of numerical evaluation method

To verify the accuracy of the numerical method to evaluate the sealing performance of the full-scale metal cask during the extreme impact loads, the impact analysis using LS-DYNA code has been executed. By comparing the impact test results, the reproducability of the impact behavior of the complicated gasket joints, such as the lid movements and the torque of the lid bolts, was confirmed (Fig.3).

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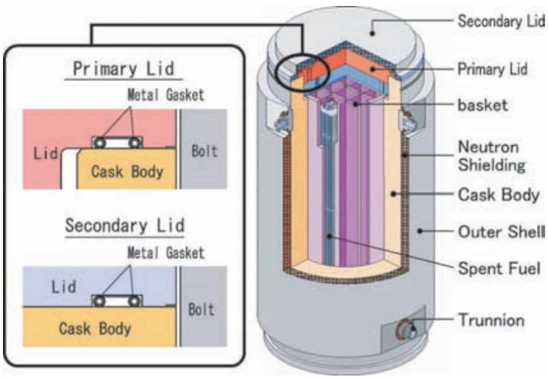
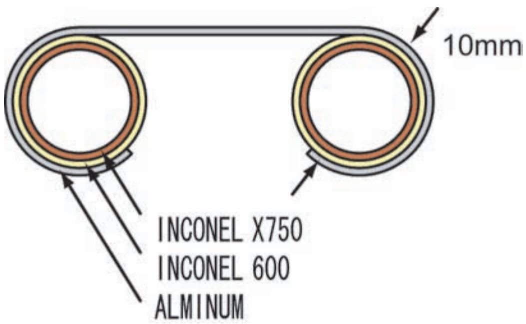
Reference

K. Shirai, et al., 2008, “Safety Analysis of Dual Purpose Metal Cask Subjected to Impulsive Loads due to Aircraft Engine Crash”, Journal of Power and Energy Systems, Vol. 3, No. 1, 2009

K. Namba, et al., 2009, “Structural Evaluation of Spent Nuclear Fuel Storage Facilities under Aircraft Crash Impact (II) – Horizontal Impact Test onto Reduced Scale Metal Cask due to Aircraft Engine Missile –”, CRIEPI Report, N08079 (in Japanese)



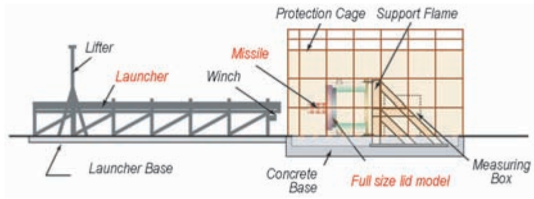
(Confinement system of the metal cask)



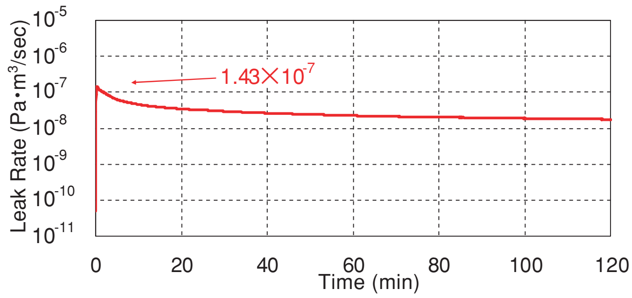
(Overview of the Metal Gasket)

The containment function is secured by inserting gaskets between the cask body and the lid, and then bolting them together.

Fig.1 Overview of the Metal Cask



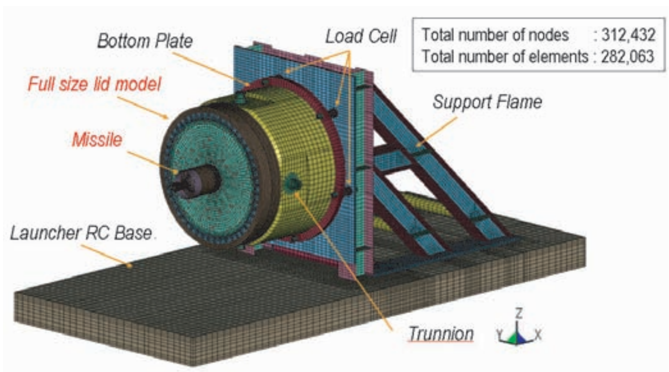
(Vertical impact test)



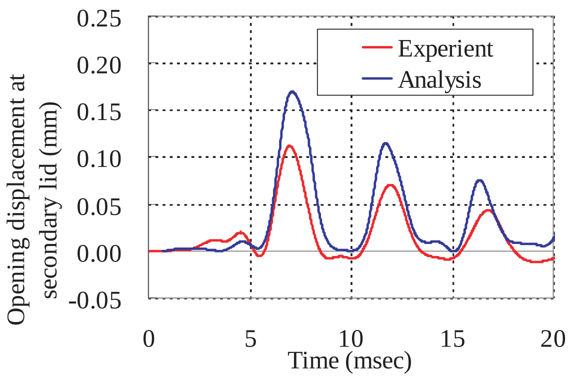
(Leak rate measured at the primary lid)

The missile was accelerated to 66m/sec to hit the full-scale lid structure. Then, the leak rate, inner pressure between the lids and displacement of the lids were measured.

Fig.2 Impact Test Apparatus



(Overview of the Analytical Model)



(Verification of the impact analysis)

For the good numerical estimation of the sealing performance of the full-scale metal cask during the extreme impact loads using LS-DYNA code, the following points should be considered.

* Well-benchmarked material model for concrete and neutron absorber material (such as, resin) should be applied.
* Shape of the lid structure and the contact condition (such as the gap between the lid and cask body) should be modeled faithfully.
* The lid bolts should be well considered to simulate the dynamic response of the tightening force during impact loading.

Fig.3 Verification of numerical evaluation method