9 m Side Drop Test of Scale Model

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INTRODUCTION

A type B(U) shipping cask had been developed in KAERI for transporting PWR spent fuel. Since the cask is to transport spent PWR fuel, it must be designed to meet all of the structural requirements specified in domestic packaging regulations and IAEA safety series No.6. This paper describes the side drop testing of a one - third scale model cask.

In order to evaluate the structural integrity of this cask under the 9 m free drop conditions, a 1/3 linear scale model of the cask was fabricated and tested. The side drop test was planned to assess the effects of the dynamic impact of the cask as part of the safety evaluation. The model was dropped onto a massive steel-faced concrete target from a height of 9m.

The objective of the test was to obtain deceleration and displacement information for the cask and shock absorbing covers, verify the integrity of the cask, and examine the crush behavior of the shock absorbing covers.

Finite element analysis was performed by using a three-dimensional element model to understand the dynamic behaviors of the cask during the 9 m side drop. The three-dimensional analysis was to evaluate the structural integrity of the model cask. This paper describes the test and analysis results on the simulated model.

SCALE MODEL DESCRIPTION

A scale model was designed to a 1/3 linear scale size of the real cask for the drop test. The scale model was linearly scaled-down as possible, and all construction materials were the same as in the prototype.

All structural shells and plates were made of stainless steel. Pure lead was used for gamma shielding material, and solid resin was used for neutron shielding. The fabrication techniques such as the lead and resin pouring techniques were developed. The outer diameter of the scale model body was approximately 400 mm, and the overall length including shock absorbing covers was 1,900 mm. The total weight of the scale model was about 1.2 tons. The sketch drawing of the scale model was shown in Fig. 1.

Shock absorbing covers were made of balsa wood with steel cover. Shock absorbing covers attached to the cask ends were designed to absorb the energy from the fall by crushing and deforming. They were attached with four fixing bolts at each end of the cask. The shock absorbing covers were fabricated from blocks of balsa wood encased in 2.0 mm thick sheet metal. Ten radial metal gusset plates inside the shock absorbing cover provides confinement for the shock absorbing wood blocks. Wood blocks were cut in the appropriate shape and inserted in the steel case to form the wood blocks with grain directions shaped radially.

The design of the shock absorbing cover is an essential part of the cask design, because the shock absorbing covers directly control the deceleration experience of the cask during the 9 m drop accident. If the shock absorbing cover is too stiff, then the cask will decelerate rapidly, generating large inertia loads in cask. If the shock absorbing cover is too soft, then it can bottom out and generate high deceleration toward the end of the impact.

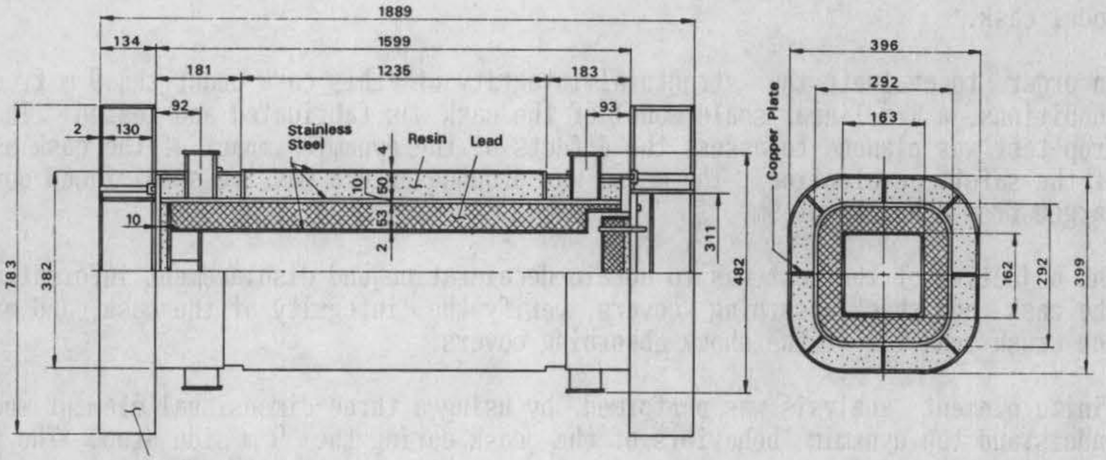

Fig. 1 1/3 Scale Model for Free Drop Test

TEST PROCEDURE

This test was conducted at a special drop test facility which met the IAEA criteria for an unyielding surface for scale model. A gantry type crane having a capacity of 10 tons and a height of 14 m was made available to perform the test. The rigid target a massive steel-faced concrete block. Prior to and after the side drop test, the leak test was conducted for 30 minutes to examine the containment performance of the cask with the gage pressure of 7 bar.

Prior to the side drop test, the data acquisition system and the 9 m drop height between the model cask and the target was checked. The cask was suspended horizontally from the releasing device, so both the shock absorbing covers were impacted simultaneously onto the steel target.

The side drop test was performed with the 1/3 scale model to determine the structural behavior by obtaining induced strains, accelerations, and examining dimensional deformations. The primary parameters of interest in the structural evaluation of the dynamic impact test were strains, accelerations of the cask body, and deformation of the shock absorbing covers. With these parameters, it was decided that primary emphasis should be placed on the measurement of strains and acceleration during the side drop impact.

INSTRUMENTATION

The schematic diagram of the data acquisition system is shown in Fig. 2. Strain measurements were made on the surface of the outer shell surface with strain gauges. Four strain gauges were installed on the surface of the specified locations of the scale model with wiring and Wheatstone Bridges. Three strain gauges were to measure

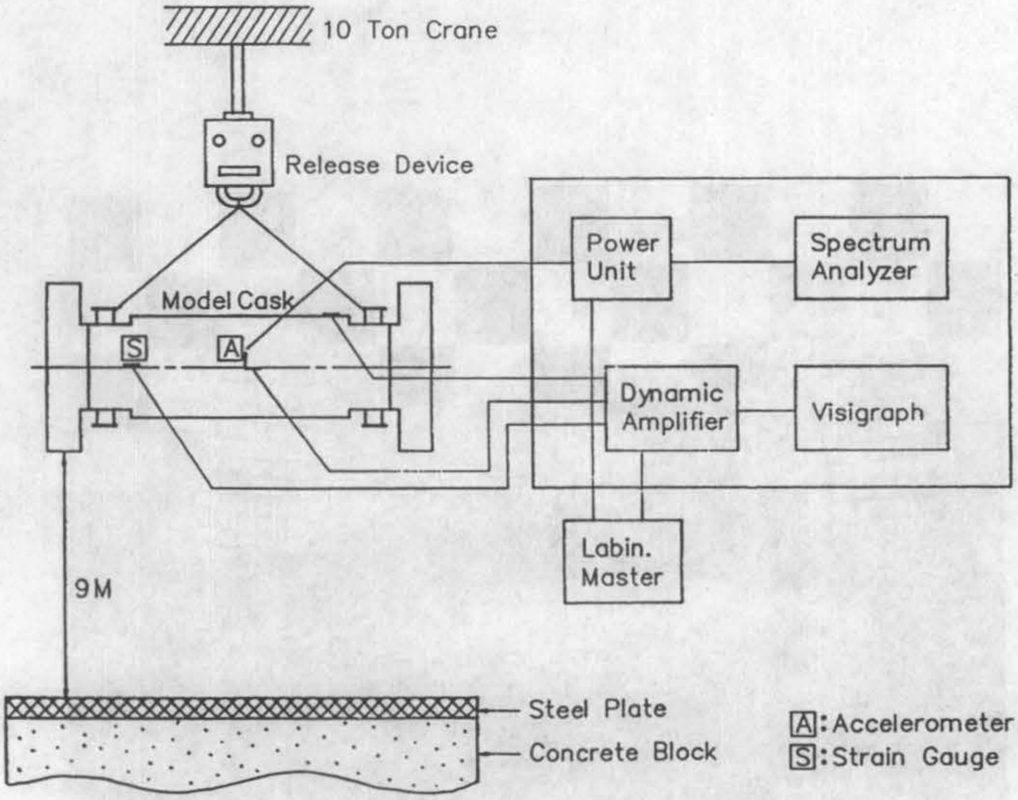

Fig. 2 Schematic Diagram of Data Acquisition System

axial strains and one was for hoop strain. The strain data acquisition system consisted of Wheatston bridges, a signal conditioning amplifier and a visigraph.

One accelerometer was installed on the center of the outer shell. The amplitude linearity of the accelerometer must remain essentially constant over the measurement range. The accelerometer was subjected to an acceleration level over a broad range of frequencies for calibration. For this type of calibration the transducer sensitivity was determined from the output of the accelerometer at the specified frequency divided by acceleration level. The acceleration data acquisition system consisted of power unit and spectrum analyzer.

TEST RESULTS

The deformed shape of the model after the side drop was shown in Fig. 3. Relatively large deflections occurred near the impacted part of the shock absorbing covers. The maximum deformation of the shock absorbing covers was 124 mm. However, the cask body maintained its structural integrity. As shown in Fig. 3, the damage to the shock absorbing covers consisted of wood crush and buckling of gusset plates. In the finite element analysis, the maximum displacement of the shock absorbing cover was calculated as 176 mm. This was slightly larger than test results, because in this analysis, we neglected the stiffness of the steel cover and gusset plates.

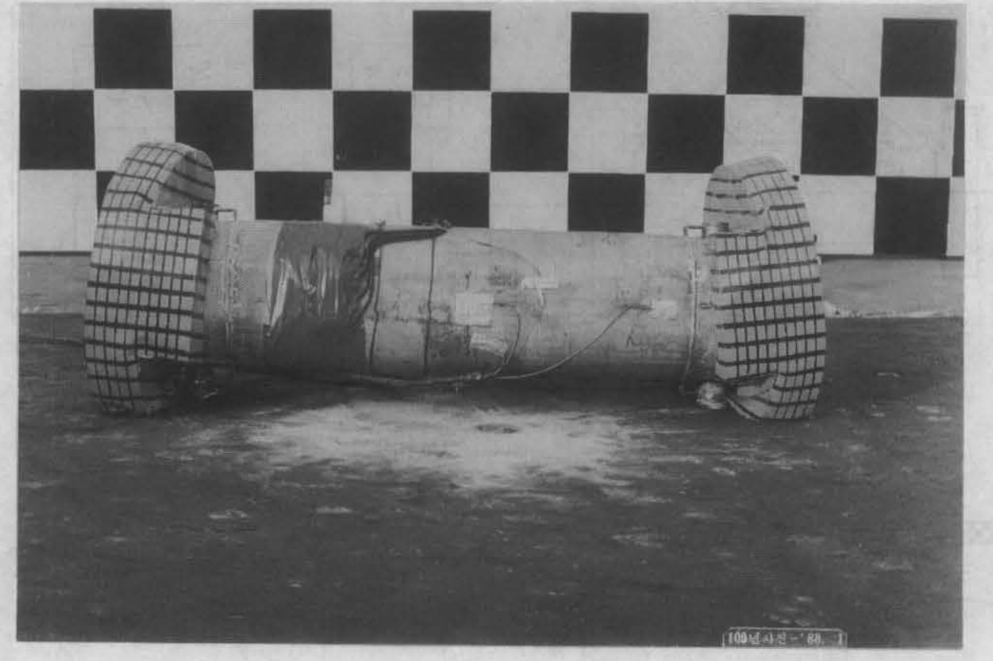

Fig. 3 Deformed Shape of Model Cask after 9 M Side Drop Impact

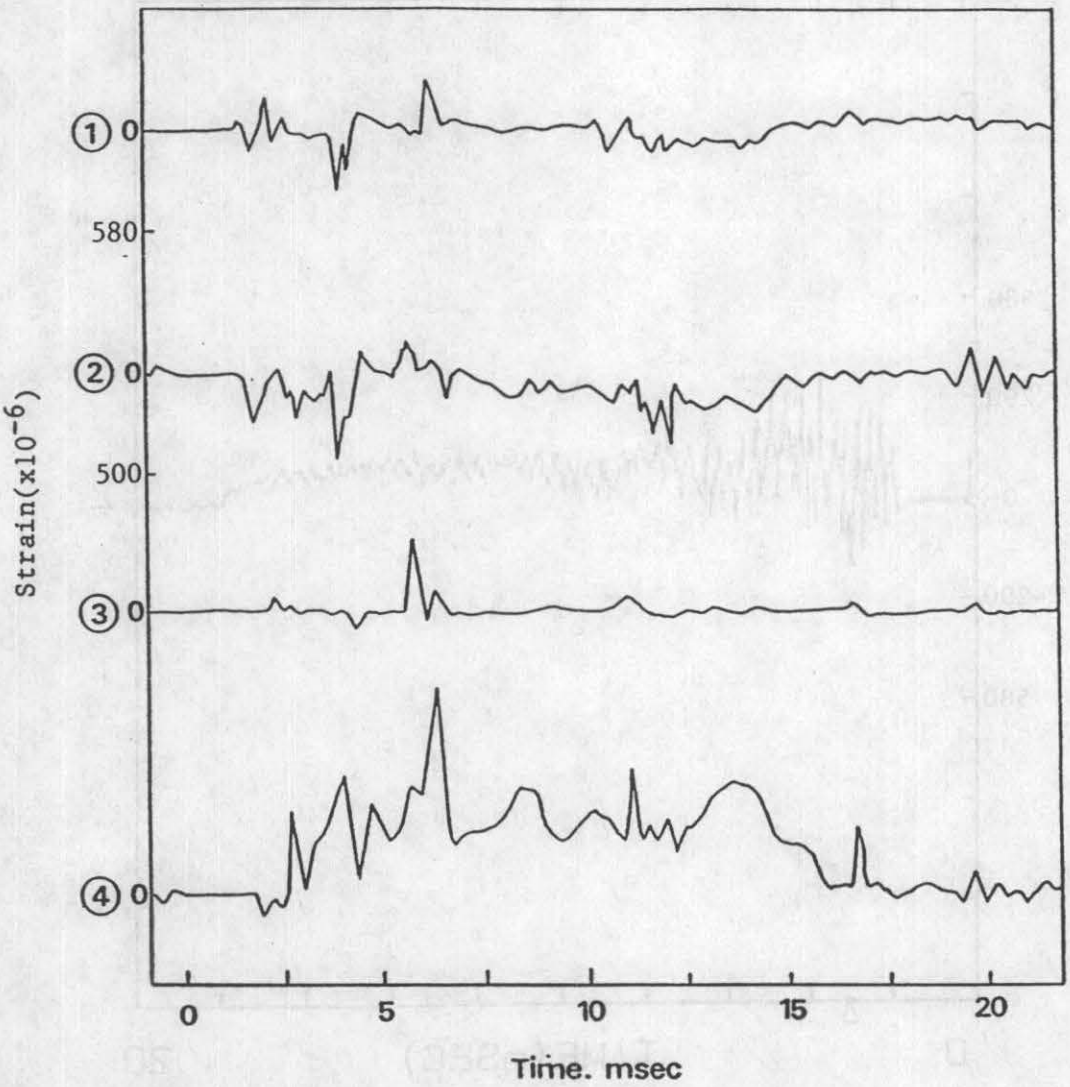

Fig. 4 Strains Time Histories under 9 M Side Drop Impact

The strain time histories are shown in Fig. 4. Axial strains from strain gauges No.1 and No.2 mounted on the side center line of the cask body show slightly negative values. Hoop strains from strain gauges No.3 mounted on the side center of the cask body show nearly zero values. Axial strain from strain gauge No.4 mounted on the upper center line of the cask body shows relative large positive value.

Fig. 5 shows the acceleration time histories obtained from the midpoint of the cask body. From this time history we could find the impact duration of 15 msec. The

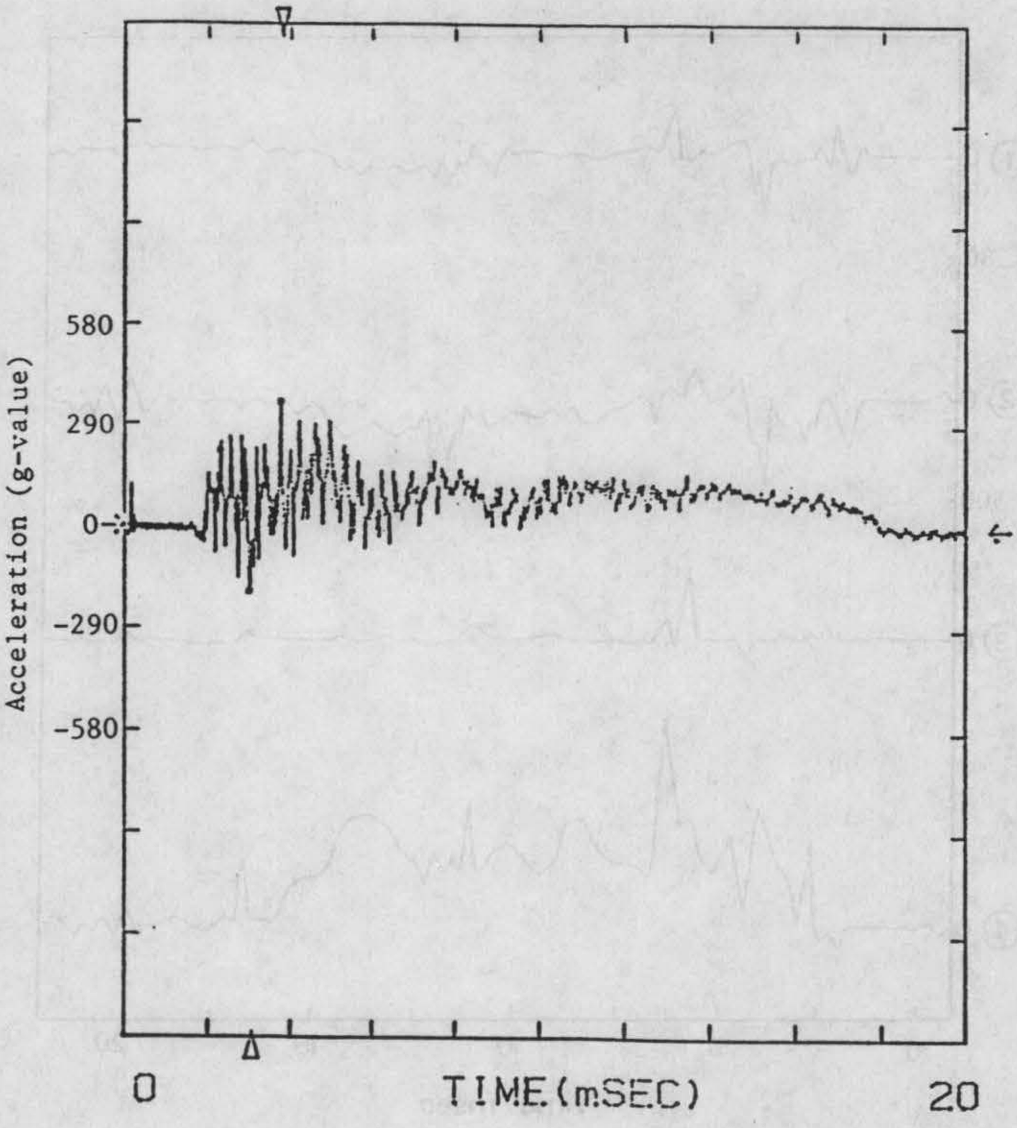

Fig. 5 Acceleration Time Histories under 9 M Side Drop Impact

maximum g-value was recorded as 380g. In the finite element analysis, the maximum deceleration g-value of the cask body was calculated as 582g. This value of analysis was much larger than that of the test. This is the reason that the shock absorbing cover was fixed at the end of the cask body, so the impact loads from shock absorbing cover were directly transferred to the cask body. But, in model test, the impact loads from the shock absorbing cover were transferred to the cask body through the shock absorbing cover fixing bolts and shear pins. During this load transfer process, some fraction of the impact loads are dissipated. The analysis results gave more conservative results.

The maximum stress intensities in the model body were presented and compared with the allowable stresses in Table 1. As shown in Table 1, the stress intensities of the structural shells were in the elastic range and below its limiting values specified in ASME code sec. Ⅲ. From these results, we could see that this model cask maintains its structural integrity under the 9 m side drop impact.

Table 1. Maximum Stresses during Side Drop Impact for Scale Model

(unit : Mpa)

Components	Maximum stress		Allowable stress	
	Pm	Pm + Pb	2.4 Sm	3.6 Sm
Inner shell	52.0	68.7	331	517
Inter. shell	25.4	26.2	331	517
Outer. shell	49.6	67.5	331	517

CONCLUSIONS

The crush and deformations of the shock absorbing covers directly control the deceleration experiences of the cask during the 9 m side drop impact. The shock absorbing covers greatly mitigated the inertia forces of the cask body due to the side drop impact. Compared with the side drop test and finite element analysis, it was verified that the 1/3 scale model cask maintain its structural integrity of the model cask under the side drop impact The test and analysis results could be used as the basic data to evaluate the structural integrity of the real cask.

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