Evaluation of Spent Fuel Damage in Actually Happenable 15 m Drop Accident Test

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1. Introduction

As we construct a safety case of transport cask and spent fuel, there are actually happenable accident conditions in the life-cycle, which are beyond the regulatory hypothetical accident conditions. To ensure the safety of spent fuel transportation, it is necessary to select the accident conditions for the safety evaluation based on the analysis of accident scenarios and to perform a safety assessment under these actual accident conditions.

2. Test plan for 15m drop accident conditions

2.1 Evaluation of actual accident conditions

Actual operation scenarios of spent fuel handling and transportation were derived by analyzing spent nuclear fuel storage facilities, transport systems and transport procedures in domestic nuclear power plants.

Among them, it was analyzed that there could be a possibility of a drop of nuclear fuel due to the shortage of the crane cables, the damage of the fuel handling device, or the operator's mistake during withdrawal, movement and loading of the fuel in the spent fuel wet storage tank.

In case of underwater fall, the maximum drop height was estimated to be about 5 m. The nuclear fuel would be damaged, but no radioactivity or radiation leakage would occur. In addition, when the cask is moved from the decontamination tank to the transportation vehicle, it is possible to cause a drop of 9.5 ~ 14 m due to the various reason described above.

One of the worst accident conditions in which the cladding of the spent nuclear fuel assemblies is damaged is dropping of cask from the high height without the impact limiter which is shock absorbing component. Therefore, it is necessary to evaluate the safety of the actual accident condition when the cask without impact limiter drops down from 15 m height.

In this study, structural integrity of cask, nuclear fuel assemblies, cladding tubes and support grids is evaluated when a transport cask without shock absorbers drops down to concrete pad at a maximum of 15 m.

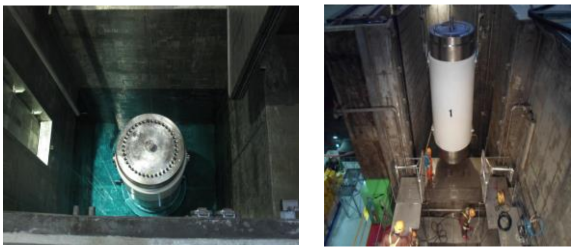

Fig. 1. Cask transportation w/o lid bolt fastening (Loading pit -> Decon. pit).

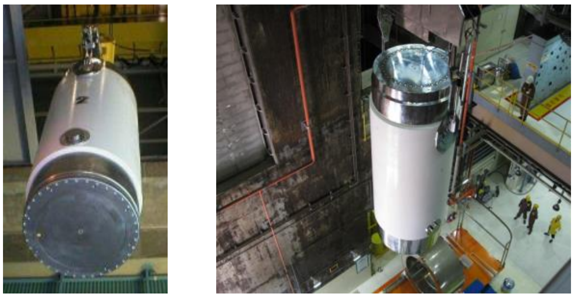

Fig. 2. Cask transportation w/o impact limiters (Decon. pit -> Truck bay).

2.2 Test plan simulating actual accident condition

To assess the actual accident conditions, KAERI conducted a non-absorbing drop test with a drop height of 15 m.

The scenario we want to simulate is to drop cask without impact limiter onto a concrete pad, which represent the second floor of a building. Therefore, we will construct the concrete pad laid over the ground through reinforcement work on the empty space of test facility. The protecting structure will be installed to prevent accidents caused by the rebound of the transport cask after the impact. We decided to use a portable heavy car crane to lift the cask to a height of 15 m and to drop it. A lot of budget was required for the series of works such as modifying of test facility, performing drop test, and restoration of facility after test. The preparation and layout for the test are shown in Fig. 3.

Fig. 3. Preparation for drop test.

2.3 Test results

A number of accelerometers and strain sensors were attached to the outer cask and internal fuel assemblies for impact test. The changes in acceleration and strain measured before and after the test are discussed in the following paper. In this paper, we focus on the deformation pattern of the simulated fuel assembly and the damage of the concrete pad as a result of the test.

Additional concentrated masses were attached with at the top end of the fuel rod to simulate the mass of the original length of fuel rod. After the test, the welding part of the concentrated mass was broken and hit the spacer grid at the below. We observed that the spacer grid was pushed down to the next spacer grid. However, buckling was not observed at the bottom span of the fuel rod, and it was found that the lateral deformation was small. The shape of the fuel assembly before and after the drop impact test is shown in Fig. 4.

On the other hand, concrete pads were observed to be considerably damaged. If it were not for the reinforcing bars in the concrete pads, it would probably have been penetrated. The deformed shape of the damaged concrete is shown in Fig. 5.

It was found that no leakage occurred in the leak test performed after the drop test. It is considered that most of the impact energy was absorbed by the concrete pad and the cask was not subjected to large impact energy.

Fig. 4. Damage and deformation of concrete pad.

(a) Before drop (b) After drop

Fig. 5. Displacement and velocity time history.

3. Conclusions

The actually happenable drop accident conditions beyond regulatory accident conditions were evaluated. Among them, preliminary structural integrity evaluation was carried out for the actual drop accident condition in which the transport cask without impact limiter drops at a maximum of 15 m. As a result, it was estimated that the deformation of claddings, supporting guide tube, bottom nozzle were small. But spacer grids had some deformation. The concrete pad had considerable damage. The cask was observed to be safe and no leakage occurred after the drop test.

The test condition of 15 m drop without impact limiter onto the concrete pad is less severe that the hypothetical accident condition, which is 9 m drop with impact limiter onto unyielding surface. However, the severe damage of concrete pad should be considered for the safety of cask manipulating area.