A Study on the Impact Analysis for the Spacer Grid by Peripheral Temperature

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1. Introduction

As the amount of Spent Nuclear Fuel (SNF) in KOREA domestic spent fuel pool increases dramatically, the storage capability of the PWR SNF is expected to saturate in 2024 [1]. The SNFs in the pool must be transferred to the designated wet or dry spent fuel storage facility. In the issues of the SNF treatment, handling and transport of the SNF have been considered as an important factors. The integrity of SNF during dry storage should be assessed.

The spacer grid (SG) is the main structure for securing the fuel rods from an external impact. A typical test method for evaluating the soundness of SG is a pendulum type impact test. In this study, we analyzed the uncertainty factors that may occur in the impact test and try to simulate by reflecting the factors. We investigated the impact behavior of the SG according to various temperature.

2. Property of Zry according to Temperature

In order to carry out the impact analysis of the spacer grid under dry storage condition, the temperature-dependent property of the zircaloy(Zry) which is the spacer grid material is required. The zircaloy properties were determined by the MATPRO.[2] As the temperature increases, the stress of the Zry decreases, and as the strain rate increases, the stress of the Zry increases as with ordinary metal materials.

3. Uncertainty Analysis in Impact Analysis

As shown in Fig. 1, the pendulum impact tester is divided into two parts. One is equipment to impact the SG by the kinematic energy of the pendulum and the other is a furnace to heat the SG itself. The furnace is designed to have temperature deviation per position within ±10 K. Under the assumption that all kinematic energy of the pendulum is transferred to the SG itself, the uncertainty that could occur in the impact test is defined as three factors: misalignment angle (θ, φ) and coefficient of friction (COF)). In order to analyze the impact analysis with the uncertainly factors, each factor is represented by three levels as shown in Table 1.

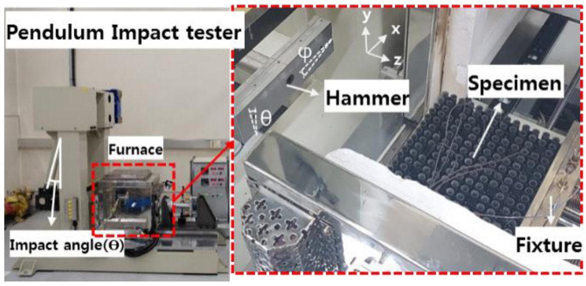

Fig. 1. Pendulum impact tester.

Table 1. DOE of impact simulation

Case	θ (A)	φ (B)	COF (C)
1	0°	0°	0.1
2	0°	1°	0.2
3	0°	2°	0.3
4	1°	0°	0.2
5	1°	1°	0.3
6	1°	2°	0.1
7	2°	0°	0.3
8	2°	1°	0.1
9	2°	2°	0.2

4. Impact Analysis for Spacer Grid

In evaluating the mechanical integrity, the strength of SG is determined by the impact load after buckling under successive impacts of increasing kinetic energy. In order to simulate the impact of SG, the commercial FE code, ABAQUS 6.14/explicit is used. The analysis was carried out under the same conditions as the impact test, which was performed by increasing the pendulum angle from 27° to 32°.

The temperature of dry storage system of a SNF decrease at a very slow rate over its lifetime. [3] There are various atmospheric temperature (673 K ~ 298 K) during dry storage. The impact tests and analysis are carried out at room temperature up to 673 K. Figure 2 compares the results of the impact test specimens and analysis result by temperature. It could be seen that the deformed shaped are similar except for 573 K.

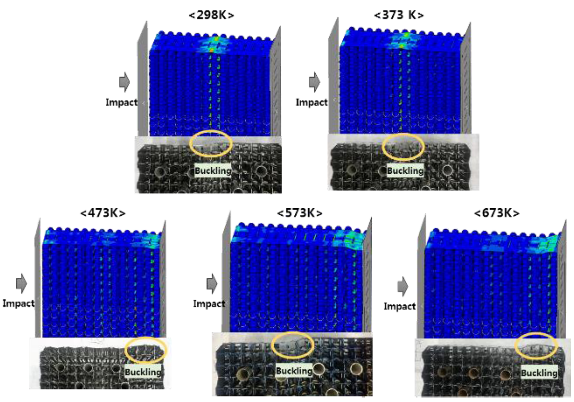

Fig. 2. Comparison of numerical and experimental deformation shape of spacer grid at various temperature conditions.

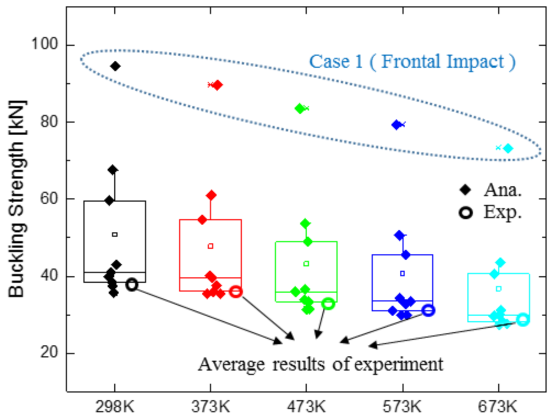

Fig. 3. Comparison of numerical and experimental buckling strength of spacer grid at various temperature conditions.

Figure 3 shows the buckling strength of the SG at various temperature conditions. As expected, the buckling strength decreases as the temperature increases, due to softening of the SG material (Zry). When impact is applied ideally, it shows the highest buckling strength. It could be seen that the results of the impact test are included in the range of the results for analysis in considering the uncertainty.

5. Conclusions

Impact analysis was performed to evaluate the mechanical integrity of the SG under dry storage condition. In order to reflect the change of the properties for the SG material according to the ambient temperature, the property of Zry from MATPRO was applied to the analysis. In addition, the main uncertainty factor was defined, and the experiment of design for impact analysis was established to consider the uncertainty of the test. The impact test results are located within the range of the impact analysis results taking into account the uncertainty of the test. However, the range of impact analysis results was wide and the test results were in the lower range of the analysis results. In order to better analyze the test results, we plan to analyze the influence of welds on the SG itself and the dissipated energy in the test.

ACKNOWLEDGEMENT

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