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A Study on Puncture Simulation of Transportation Cask

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1. Introduction

In most of drop conditions, the comparisons show that global deformation of test and simulation are quite similar. The acceleration and strain histories are well coincident to each other.

However, there are some difficulties in performing numerical simulations to analyze puncture phenomena. Therefore, the considerations would be focused on the side puncture, and the lid vertical puncture conditions in this study.

2. Puncture Simulation Issues

In general, safety evaluation test was conducted with 1/3 scaled model and so was analysis for the developed cask. Numerical simulation results can be different based on the analysis models. The reliable FE model makes it possible to be proceeded stably by analysis and generated more realistic results compared to those of test. By the comparison between analysis and test results, the validity and appropriateness of the modeling technique and analysis methodology should be verified.

2.1 Specification of Developed Cask

Korea is currently developing two transportation and storage casks for spent fuel. They are the dual-purpose metal cask, KORAD21, and the concrete storage cask, KORAD21C. Their specifications are given in Table 1, and Fig. 1 contains an illustration of the casks.

Table I: Design specification of KORAD21 and KORAD21C

Items	Description
Capacity	. 21 PWR F/A(WH & CE)
Design Basis Spent fuel	. BU: 45,000 MWD/MTU .Enrichment: 4.5 wt.% U235 .Cooling time: 10 yrs .Decay heat: 16.8 kw/canister
Dimensions	.Canister: 1,686 mm O.D.×4,880 mm L .Metal cask: 2,216 mm O.D.×5,285 mm L .Concrete cask: 3,266 mm O.D.×6,030 mm L
Weight	.Canister: 33.0 t (with loaded fuel) .Metal cask: 104.7 t (with loaded canister) .Concrete cask: 143.8 t (with loaded canister)

(a) DPC for transportation (b) DPC for storage (c) Concrete storage cask

Fig. 1. New transportation and storage casks developed in Korea.

2.2 Test and Simulation for puncture condition

For the side puncture condition, overall deformation of cask and the perforated hole of cask side are presented in Fig. 2 for the comparison between the numerical simulation and the test. The sheath containing neutron absorber of cask side was penetrated by puncture spike after the puncture test. However, it was not fully penetrated in the simulation. The reason for this is the option of material property of stainless sheath. The option of eroding mesh would be good for penetrating phenomenon.

The acceleration histories of accelerometer #09 during analysis and test were compared in Fig. 3. The acceleration ranges of analysis and test are quite similar. However, the trend is different. In the test, the acceleration decreased rapidly at 0.021 sec when the stainless steel sheath became penetrated. In the simulation, the sheath did not become penetrated. Therefore, the acceleration maintained its magnitude for a certain time period.

The strain histories of strain gauge #19 during analysis and test were not coincided in their trend in Fig. 4. The reason for the difference of trend came from the similar phenomenon in acceleration.

The maximum strain and strain energy of the analysis are bigger than those of test, respectively, which means that conservatism was maintained in analysis compared to test results.

For the lid vertical puncture condition, overall deformation of cask and the perforated hole of top impact limiter are presented in Fig. 5 for the comparison between the numerical simulation and the test. The impact limiter sheath containing shock absorber material wood was penetrated by puncture spike after the puncture test. This penetrating phenomenon in the test seemed to be well simulated in the numerical simulation in Fig. 5.

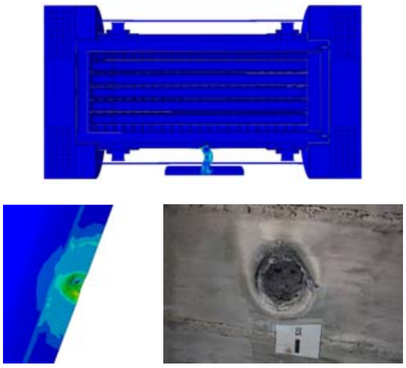

Fig. 2. Comparison between test and analysis – Deformation of side cask in side puncture.

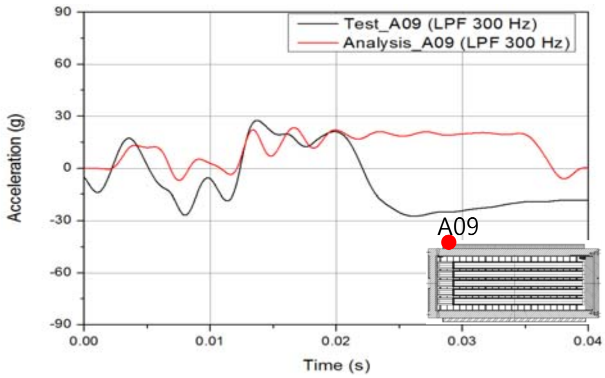

Fig. 3. Comparison between test and analysis – Acceleration (A09) in side puncture.

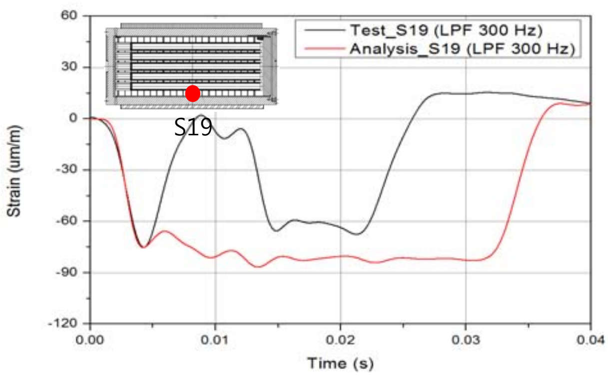

Fig. 4. Comparison between test and analysis – Strain (S19) in side puncure.

The acceleration histories of accelerometer #10 during analysis and test were compared in Fig. 6. The acceleration in the test decreased around 0.02 sec, which might present the penetration of the impact limiter sheath. However, this phenomenon was not found in the acceleration of the simulation. We can find the definitely perforated hole of the impact limiter sheath in the test figure. On the contrary, the area around the hole in the simulation figure was rounded inwardly curved. There was no deceleration around 0.02 second. Therefore, there was a difference in the fine trend of the simulation acceleration history.

In the simulation, the eroding option was adopted for wood material property. This option helps the material can disappear when the strain level of the material reaches to certain value. In case that this option was not adopted, the simulation was terminated abnormally with the large distorted mesh error.

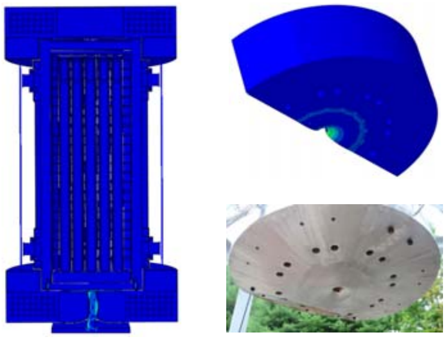

Fig. 5. Comparison between test and analysis – Deformation of top impact limiter in lid vertical puncture.

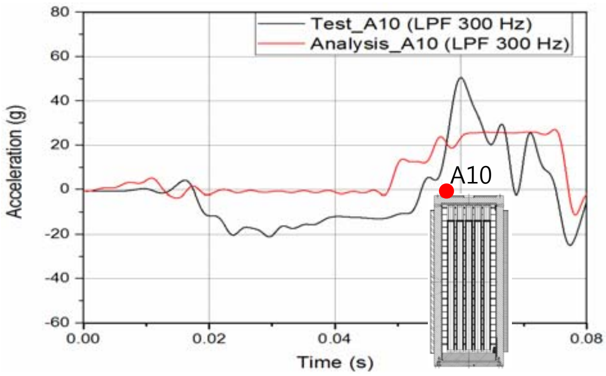

Fig. 6. Comparison between test and analysis – Acceleration (A10) in lid vertical puncture.

3. Conclusions

When we assign the material property of the sheath part, which contains the neutron absorber material of shock absorber material, great care should be needed for good simulation. It would influence on the detailed behavior of penetration.

When we assign the material property of the shock absorber material such as wood, the shock absorbing ability can be changed if we adopt the crushable foam option for the drop condition. Eroding material option can be adopted for the puncture condition.

By the comparison between test and simulation, the validity and appropriateness of the modeling technique and analysis methodology can be verified.