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Analysis of Drop Accidents for Dry Storage System

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1. Introduction

As the storage facilities for Spent Nuclear Fuel(SNF) within nuclear power plants become increasingly saturated, the demand for independent storage facilities outside the power plants is rising. These facilities serve as an intermediate disposal solution for long term storage until final disposal. Consequently, dry storage systems are being extensively developed worldwide. The transportation of Spent Nuclear Fuel(SNF) employs dry storage systems and requires demonstrating safety in the face of accident scenarios during transit[1], [2]. In particular, ensuring the safety of canisters, which are metallic containers designed to enclose and seal spent nuclear fuel, is crucial to minimizing damage in case of accidental falls.

2. FE Analysis and Results

In this paper, a finite element model of a dry storage system was constructed as show in Fig. 1, and the response of the structure to impact during a falling situation in transportation accident scenarios was analyzed.

2.1 Dry Storage System Model

Dry storage system is composed of internal components including fuel, a canister, a cask, and a impact limiter. Detailed modeling was performed for structures that are expected to have a significant impact on the dynamic characteristics and response to impact loads for each component.

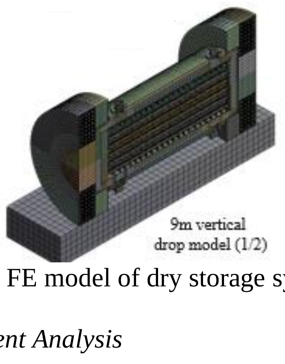

Fig. 1 FE model of dry storage system

2.2 Finite Element Analysis

Utilizing the developed analytical framework, finite element simulations were executed to investigate various accident scenarios involving a dry storage system. These scenarios encompass a 9 m vertical free fall, a 9 m horizontal free fall, a 9 m oblique free fall, and a 1 m vertical and horizontal penetrating fall. Following the thorough analysis of each individual scenario, a stress-based assessment was performed to gauge the dry storage system's safety under the circumstances of a fall accident.

According to the analysis results, it was confirmed that the accident scenarios of a 1 m horizontal penetrating fall and a 9 m oblique fall would cause the most significant damage to the dry storage system.

2.2 Material Properties

The material properties were based on the material characteristics of the dry storage system, and an analytical model was created by inputting these material properties for each component of the cask, canister and impact limiter. For the wood material used in the impact limiter, the Stress-Strain curve was input based on actual test results and applied to the analysis.

Table 1 Material properties of Dry Storage System

Component	Material	Density [kg/m^3]
Cask	SA-350 GR. LF3	8030
	SA-182 GR. F6NM	7850
	SA-240 TP.304	8030
	NS-4-FR	1760
Canister	SA-240 TP. 316L	8030
	SA-240 TP. 304	7850
Impact Limiter	Balsa Wood	120
	Red Wood	380

2.3 Finite Element Analysis

Using the established analytical model, finite element analysis was performed for accident scenarios involving a dry storage system. These scenarios encompass a 9 m vertical free fall, a 9 m horizontal free fall, a 9 m oblique free fall, and a 1 m vertical and horizontal penetrating fall. Following the analysis of each scenario, a stress-based evaluation was carried out to assess the safety of the dry storage system in the event of a fall accident. The analysis outcomes for each accident scenario, categorized by the components of the dry storage system, are depicted in Figure 2 below.

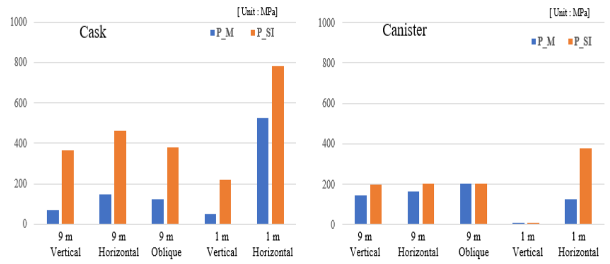

Fig. 2 Stress-based evaluation for each part

3. Conclusions

The dry storage system's performance was investigated using nonlinear impact analysis, with an emphasis on stress-based assessments across a range of accident scenarios. In both free-fall and penetrating impact scenarios, the greatest responses were observed during horizontal falls. The outcomes of these analyses are meant to provide guidance for structural enhancements and assess potential cumulative damage that may occur within the dry storage system as time progresses.

4. Acknowledgements

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