Structural Evaluation Under Accident Condition for Concrete Storage Cask of Spent Fuels

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1. Introduction

The concrete storage cask has been developed with containing canister loaded with spent fuel. The storage consists of reinforced concrete is filled between inner and outer shell of cask body and the carbon steel made cask lid filled with concrete is bolted into cask body to maintain structural integrity. The evaluation results were reviewed with respect to every design criterion, in terms of whether the results satisfy the criteria, provided by US 10CFR Part 72 and NUREG-1536 [1.2]. Description of the concrete storage cask and the maintainability and assumptions include in the analysis were confirmed through detailed explanations of the acceptable standards, analysis model and analysis method. ABAQUS 6.10, a widely used finite element analysis program, was used in the structural evaluation [3]. The evaluation results of this work show that the maximum stress was below the allowable stress under accident condition, and the concrete storage cask satisfied the design criteria.

2. Model description

2.1 General information of concrete storage cask

A concrete cask body is a cylindrical shell structure for the storage of canisters loaded with spent fuels. Concrete for shielding is filled between the internal and external carbon steel shells of the cask body, and air intake and exhaust vents are installed at the top and bottom of the cask body to eliminate the decay heat from the spent fuel through air circulation due to natural convection. The concrete cask body of the concrete cask protects the canister from the external environment to maintain the integrity of the spent fuels, and the canister maintains the confinement boundary while it is loaded with the spent fuels as like Fig. 1 [4].

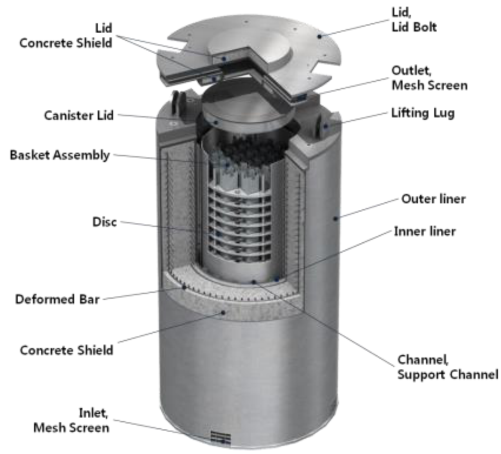


Fig. 1. The cross-section of concrete storage cask.

2.2 Load combinations of accident condition

The structural analysis based on the accident condition of the concrete storage cask was considered with pressure load, thermal load, earthquake load, cask drop and tip-over. ASME B&PV Code Section III, Division 1, Subsection NB (Level D) was applied to the stress evaluation of the canister, and ASME B&PV Code Section III, Division 1, Subsection NF (Level D) was applied to the cask body. The design criteria under accident condition are listed in Table 1.

Table 1. Design criteria under accident condition

Type	Criteria	Basis
Drop height	60 cm	-
Tip-over	Assumed	-
Fire (Duration/Temp)	8min/800℃	10CFR72.122(c)
Blockage of air inlets	100%	10CFR72.128(a)
Flood	15m (4.6m/sec)	10CFR72.73
Seismic (Horizon, Vertical)	0.3g, 0.2g	10CFR72.102(f)
Extreme temp	40℃	ANSI/ANS-57.9

2.3 Material properties

The concrete storage cask body was produced from carbon steel, and the elements other than the body were produced from stainless steel. The canister utilized SA-240 316L material to increase the salt resistance due to the external environment under storage conditions [4].

2.4 Structural analysis

For the finite element analysis model used in the structural analysis of the concrete storage cask, one structural model was prepared and the initial condition and boundary condition were varied to apply to every analysis. Considering the symmetry of the cask, the analysis model was composed of a 1/2 model. The analysis model was composed of 809,046 nodes and 556,905 slid elements [4].

3. Results and discussion

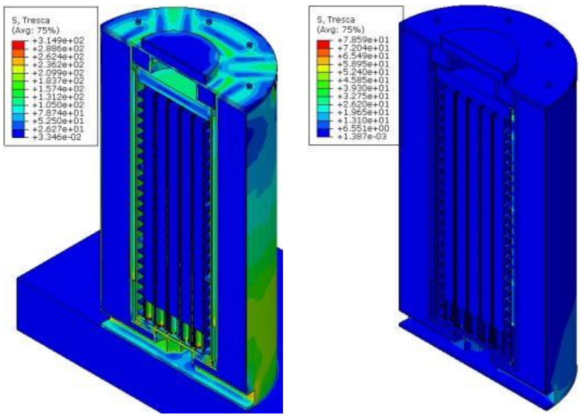
The internal pressure 0.335 MPa in the accident condition computed from the thermal analysis results was applied to the inside of the canister. The analysis results showed the highest stress of 70 MPa in the lower part of the canister body adjacent to the bottom plate of the canister.

The analysis results of vertical drop showed stress of 303 MPa at the bottom plate of the cask body, but it was evaluated to be below the allowable stress.

A tip-over analysis of the cask was conducted by applying the angular velocity 1.488 rad/sec at the moment the side of the cask body comes in contact with the bottom surface of the concrete pad. The analysis results showed that every part was evaluated to satisfy the allowable stress. The stress distribution regarding the tip-over analysis is shown in Fig. 2 (a).

The analysis results of flooding showed stress of 32 MPa at the bottom of the canister body and this was evaluated to be below the allowable stress.

In the analysis, the earthquake load was assumed to act simultaneously in the horizontal and vertical directions. The analysis results showed almost no stresses in the internal elements, and the highest stress observed in the canister was 32 MPa. However, stresses in every part were evaluated to be below the allowable stress. The stress distribution regarding the seismic is shown in Fig. 2 (b).



(a) (b)

Fig. 2. The stress distribution for accident condition (a) cask drop, (b) earthquake.

4. Conclusions

This paper verified the stabilities of the structural elements that influence the safety of the concrete storage cask for spent and summarizes the structural evaluation results of a concrete storage cask with respect to the design criteria under accident condition. The evaluation results show that the maximum stress was below the allowable stress under accident condition, and the concrete storage cask satisfied the design criteria. Therefore, based on the results of the stress evaluation, the design requirements were satisfied in the accident condition.

REFERENCES

[1] 10CFR Part 72, Title 10 (2006), Chapter 1 of the Code of Federal Regulations, Licensing Requirement for the Independent Storage of Spent Nuclear Fuel, High-level Radioactive Waste, and Reactor-Related Greater than Class C Waste, 1-1-06 Edition.

[2] NUREG-1536 (2010), Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility, Revision 1.

[3] Dassault Simulia (2010), ABAQUS 6.10 Documentation.

[4] TC Moon, CY Baeg, and CH Cho (2017), Structural Evaluation under Off-normal Condition for Concrete Storage cask of Spent fuels, Trans. of the Korean Radioactive Waste Society Spring Meeting, Pusan, Korea, May 24~26.