Structural Evaluation under Off-normal Condition for Concrete Storage Cask of Spent Fuels

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1. Introduction

The concrete storage cask is under development with containing canister loaded with spent fuel and vertically placed on storage pad as free-standing type. The structural evaluation of the concrete storage cask must show that it secures the confinement and structural integrities under normal, off-normal and accident conditions. 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 off-normal 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.

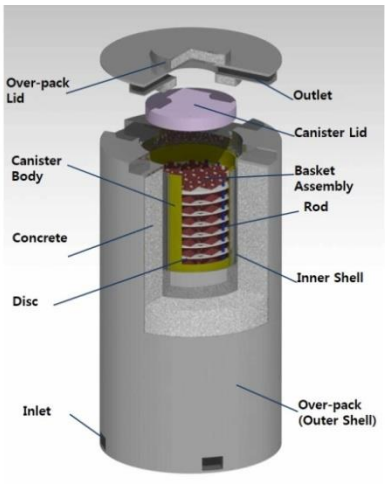


Fig. 1. The cross-section of concrete storage cask.

2.2 Load combinations of off-normal condition

The structural analysis of the concrete storage cask considered pressure load, wind load and thermal load for off-normal condition. The load combinations regarding the concrete storage cask were set according to the NUREG-1536, ANSI/ANS 57.9 and ACI criteria based on the structural analyses results on each load to conduct a stress evaluation of the concrete storage cask. The design criteria under off-normal condition are listed in Table 1.

Table 1. Design criteria under off-normal condition

Type	Criteria	Basis
Ambient temp. (Max./Min.)	35.0℃/ -25.0℃	ANSI/ANS57.9, NUREG-1536
Partial blockage of air inlets	50% (two air inlet blocked)	10CFR72,128(a)
Wind load	45m/sec (avg. 10 min)	Korea building code-Structural

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.

2.4 Structural analysis

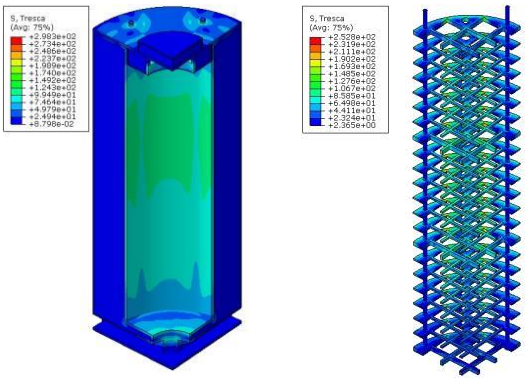
For the finite element analysis model used in the structural analysis of the concrete storage cask, one structural model was prepared and the initial condition and boundary condition were varied to apply to every analysis. Considering the symmetry of the cask, the analysis model was composed of a 1/2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

3. Results and discussion

The internal pressure of the canister with 10% of the internal fuel rods damaged was set as the load, and 0.09972 MPa, pressure under the off-normal condition computed from the thermal analysis results, was applied to the inside the canister. The internal elements were excluded from the analysis because the pressure load acts only inside the canister. Analysis results showed a maximum stress 15.9 MPa on the canister body.

The wind load was set with the consideration of the natural environment of Korea according to the Korean Building Code, the wind load was set as 1.831 kN/m^2 and 2.464 kN/m^2 in horizontal and vertical directions, The analysis results revealed the stress of 1.6 MPa on the external surface of the concrete cask body, and almost no influence wind load was observed.

The stress evaluations due to the thermal load at the maximum temperature of 35℃ and the minimum temperature -25℃ were conducted for the thermal loads on the concrete storage cask under the off-normal condition. An air path condition of 50% blockage was additionally considered for the maximum temperature of 35℃. The highest temperature was observed at the upper part of the concrete cask body due to the internal air circulation, and the difference between the outside and inside temperatures of the cask body was approximately 50℃. The highest stress due to the off-normal condition was observed at the disc, and satisfied the allowable stress in every part. The stress distribution with respect to the maximum and minimum outside temperatures is illustrated in Fig. 2.



(a) (b)

Fig. 2. Thermal stress distribution; (a) concrete cask body, (b) disc and rod.

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 off-normal condition. the evaluation results show that the maximum stress was below the allowable stress under off-normal 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 off-normal condition.

REFERENCES

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