Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Structural Analysis for the Canister Handling Accident

Heui-Joo Choi[a], Yang Lee[a], Jong Youl Lee[a], Jongwon Choi[a], and Young Joo Kwon[b]
[a]*Korea Atomic Energy Research Institute, 150 Dukjin-Dong, Yuseong, Daejon*
[b] *Hongik University, 300 Shinanri, Chochiwon, Yeonki, Choongnam*
HJCHOI@Kaeri.re.kr

1. Introduction

The high level radioactive waste disposal system consists of the engineered barrier system and natural barrier system. The engineered barrier system is composed of spent fuel itself, the canister, buffer and backfill. The canister functions as the first barrier to prevent the radioactive material from leaking from the spent fuels. From the point of economics the cost for the manufacture of the canister is one of the most expensive elements in the disposal system. In most countries the price of the canister for HWL is estimated to be even more than $100,000 [1].

A Korean Reference Disposal System for the high-level radioactive wastes has been developed by KAERI for several years [2]. Several concepts of disposal canister have been proposed by the authors, and three different kinds of canisters were designed, two for PWR spent fuels and one for CANDU spent fuels. All the canisters consist of two layers. One is an outer shell for the corrosion resistance and the other is an insert for the mechanical strength. Since the main function of the canister is the containment of the radionuclides during the specified period, the canister is designed with an outer layer of copper for corrosion protection, and the canister is supported by the pressure-bearing insert.

The determination of the canister diameter is very important in the design of the repository. The diameter of the canister was reduced from 122cm to 102 cm through the structural analysis [3]. The insert was optimized to withstand the hydrostatic pressure and the swelling pressure from the bentonite buffer.

The canister should be transported from the encapsulation plant to the final deposition hole containing the spent fuels. The weight of the canister with the spent fuels is around 25 tons. Many difficulties are expected during handling the heavy canisters. While the previous analysis focused on the normal case of handling the canister, two scenarios of handling accidents were assessed in this study. Two cases were considered regarding the design of the handling equipments and the canister itself in one scenario. According to the current design the canister is lifted using the handling machine with four grippers. In this paper the effects of the failure of one or two grippers were assessed during the operation of the handling machine. The other scenario is regarding the accident of dropping the canister in the deposition hole.

The main purpose of this study is to assess the handling accident related to the development of the canister for PWR spent fuels. The structural analysis was carried out for two scenarios related to the handling accident scenarios. The results were compared in terms of safety factors.

2. Canister

KAERI prepared several requirements for the canister design instead of the regulatory body in Korea. Table 1 compared the requirements with those in Finland. The shape of the canister (KDC-1) for PWR fuels were given in Figure 1. It is one of two canisters designed for the PWR spent fuels. The nodular cast iron was selected as material for the insert because it shows the best properties [4].

Table 1. Canister design requirements

	KAERI	Finland
Duration of corrosion resistant	1,000 years or 100,000 years	100,000 years
Maximum dose rates	1 Gy/y	1 Gy/y
Criticality	$K_{eff} < 0.95$	subcritical
Temperature at the canister surface	< 100°C	< 100°C
Load (Pressure) condition	Qualitatively stated	7 MPa + 7 MPa
Drop test condition	2.0 m	Not mentioned
Handling	**Qualitatively mentioned**	**Strength of copper**
Remaining	Initial defects less than 0.1 %	Gap between outer shell and insert: <5%

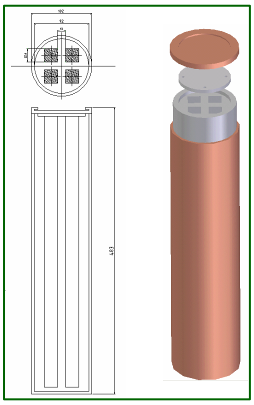

Figure 1. Schematic of PWR canister.

3. Gripper Failure Accident Analysis

The scenario related to the failure of handling grippers was analyzed by FEM computer program, NISA. The previous safety assessment showed that the four grippers of handling machine were safe enough to lift the heavy canisters including the spent fuels. The length of a canister holder was 105 mm. The structural analysis for the canister holder was carried out for two cases of gripper failure, one or two of four grippers. The calculation was based on the canister weight of 25 tons. Figure 2 shows the analysis models used for the gripper failure accident in the case of normal condition and one gripper failure condition.

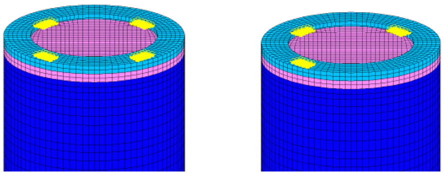

Figure 2. Analysis model for gripper failure accident.

The results of the structural analysis for the gripper failure accident were given in Table 2. As shown in Table 2, safety factors for three cases are above 1.0. This means the handling system can be used even in the case of one or two gripper failure accident during the operation. One of interesting results given in Table 2 is that the safety factor for 3 gripper case is lower than that for 2 gripper case.

Table 2. Results of grip failure accident analysis

	von-Mises stress (MPa)	Safety Factor	Displacement (mm)
4 grippers (normal)	12.6	4.76	0.015
3 grippers (one failure)	30.4	1.97	0.251
2 grippers (two failure)	25.2	2.38	0.026

4. Canister Drop Accident

It was assumed that the canister dropped from 1 meter above the surface of the deposition hole whose depth is 7.83 meters (Figure 3). For the conservative calculation, the buffer block was not considered. Also, the cylinder to surface contact was assumed between the bottom of the canister and the deposition hole. In the case of canister drop accident the calculation was carried out at two steps. Firstly, the impact force from the drop accident was obtained using the RecurDyn program. The simulation was carried out for 20 seconds. The first collision between the canister and the deposition hole was at 1.437 second after dropping. The impact force was about 5.73 MN. Secondly, the structural analysis was carried out to calculate the impact from the collision with the impact force of 5.73 MN. This impact force was assumed to be evenly distributed to the bottom of the canister. The calculation was carried out using NISA program. The maximum von-Mises stress was 0.762 MPa.

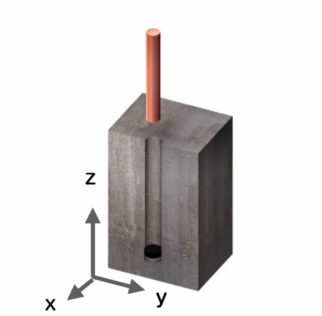

Figure 3. Schematic of the canister drop accident.

5. Conclusion

KAERI developed the canisters for PWR spent fuels for the Korean Reference Disposal System. The diameter of the canister insert for PWR spent fuels was set to 102 cm based upon the structural analysis. The structural analysis was carried out in the case of the canister handling accident. Two kinds of accidents, a gripper failure accident and a canister drop accident, were considered in this paper. The results showed that the canister handling machine and the canister could be used in the case of the accident considered in this paper.

Acknowledgement

This work has been performed under the Nuclear R&D Program by the Ministry of Science and Technology.

REFERENCES

[1] G. Poon and P. Maak, Preliminary Estimated Costs of Cast Inner Steel Vessels, Ontario Power Generation, 06819-REP-01300-10081-R00 (2004).

[2] Heui-Joo Choi, Jongwon Choi, and Jong Youl Lee, Korean Reference Disposal System for High-level Radioactive Wastes, Proceedings of the 6th Korea-China Joint Workshop on Nuclear Waste Management, Kyeongju, Korea (2005).

[3] Heui-Joo Choi, Yang Lee, Dong-Keun Cho, Jong Youl Lee, and Jongwon Choi, Mechanical Dimensioning of the Canister Insert for PWR Spent Fuels, KNS 2005 Spring conference (2005).

[4] Lars Werme, Design premises for canister for spent nuclear fuel, SKB Technical Report TR-98-08, SKB (1998).