Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Proposal of a SiC disposal canister for very deep borehole disposal

Heui-Joo Choi, Minsoo Lee, Jong-Youl Lee, and Kyungsu Kim
Korea Atomic Energy Research Institute, 1045 Daeduk-daero, Yuseong, Daejeon
HJCHOI@kaeri.re.kr

1. Introduction

Recently, the government approved the national basic plan for the management of spent nuclear fuels in Korea. According to the national basic plan, the geological disposal like KBS-3 type that Swedish and Finnish developed was designated as a reference disposal concept. Also, the national basic plan asked to develop the alternative methods including the very deep borehole disposal through the international joint studies.

KAERI has been interested in developing a very deep borehole disposal (DBD) of HLW generated from pyro-processing of PWR spent nuclear fuel and supported the relevant RnD with very limited its own budget. KAERI team reviewed the DBD concept proposed by Sandia National Laboratories (SNL) and developed its own concept.

The SNL concept was based on the steel disposal canister. The authors developed a new technology called cold spray coating method to manufacture a copper-cast iron disposal canister for a geological disposal of high-level waste in Korea. With this method, 8 mm thin copper canister with 400 mm in diameter and 1200 mm in height was made. In general, they do not give any credit on the lifetime of a disposal canister in DBD concept unlike the geological disposal. In such case, the expensive copper canister should be replaced with another one.

In this paper authors proposed a silicon carbide, SiC, disposal canister for the DBD concept in Korea. A. Kerber et al.[1] first proposed the SiC canister for a geological disposal of HLW, CANDU or HTR spent nuclear fuels. SiC has some drawbacks in welding or manufacturing a large canister. Thus, we designed a double layered disposal canister consisting of a stainless steel outer layer and a SiC inner layer.

2. Properties of SiC

According to the current regulation, the primary barrier in a geological repository is a disposal canister. A disposal canister should withstand the high hydraulic static pressure and show a high corrosion resistance. Also, it should have a high thermal conductivity to dissipate the heat from HLW. Thus, copper or iron is considered as a candidate material than ceramic.

A. Kerber et al. proposed SiC as a disposal canister material due to its high strength, high corrosion resistance, high thermal conductivity, and extremely low diffusivity. Thus, we reviewed the basic material properties of silicon carbide and tried to measure the thermal conductivity of SiC.

The properties given in Table 1 were obtained by literature survey or via internet. One of interesting properties of SiC is its high thermal conductivity. In order to use SiC as a canister material, the thermal conductivity of SiC should be better than that of carbon steel. In this study, the thermal conductivity of SiC was measured. Several samples were taken from SiC block made by KSM company (Fig. 1). Thermal diffusivities of the samples at three temperatures were measured using NFA 4XX (NETZSCH) (Table 2).

Table 1. properties of SiC

properties	KSM	MAC	Accuratus
Density, g/cm^3	3.1 – 3.18	2.70 – 3.10	3.10
Modulus of elasticity, GPa	>320	420	410
Bending strength, MPa	350 -450	440	550
Compressive strength, MPa	>1,500	-	3,900
Thermal conductivity, W/mK	>80	35 - 124	120

Table 2. Thermal diffusivity of SiC

Sample No.	Temperature ℃	Diffusivity m^2/s	Density g/cm^3
1	29.3	68.82×10^{-6}	3.158
2	51.4	57.95×10^{-6}	3.158
3	99.4	46.40×10^{-6}	3.158

Fig. 1. Photos of SiC samples used for measuring thermal conductivity.

The corrosion resistance of SiC was tested with In-situ very long-term corrosion test in the simulated repository conditions at the KURT(KAERI Underground

Research Tunnel). As shown in Fig. 2, a coin-shaped SiC coupon inserted between two compact bentonite blocks was located within a corrosion cell made of titanium. The corrosion cell was designed for the bentonite blocks to contact with the flowing groundwater. Groundwater was taken from a borehole located in KURT and heated to 70℃. The corrosion rate will be measured in the near future.

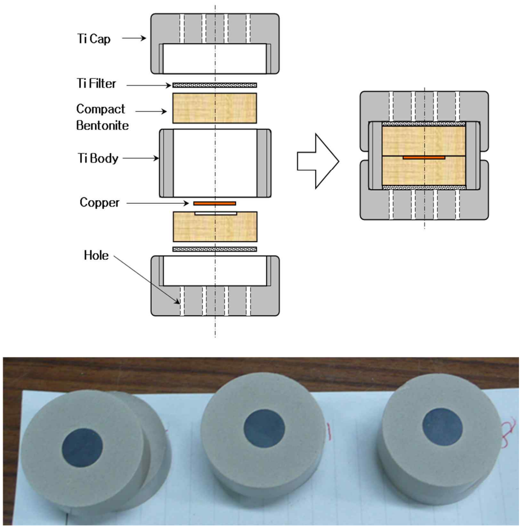

Fig.2. Corrosion cell in a simulated environment.

3. Design and manufacture of a SiC canister

A very deep borehole disposal is a concept to dispose of HLW including spent nuclear fuels into a 5 km deep borehole[2] (Fig. 3). A disposal canister for one PWR spent nuclear fuel was designed. It consists of double layers, outer layer made of stainless steel and inner layer made of SiC (Fig. 4). Inner layer was designed to withstand the hydrostatic pressure of 57 MPa using the following equation:

$$P = \frac{2\sigma t}{D}\left(1 - t/D\right)\text{: KS B 6734} \qquad (1)$$

With the equation (1), the thickness of the canister was determined to be 17 mm. Outer layer was introduced to handle the canister with ease.

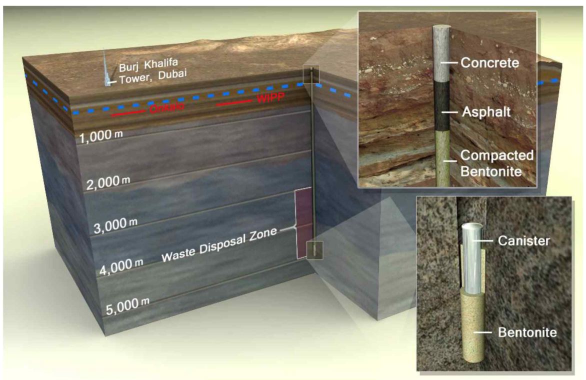

Fig.3. Concept of DBD for spent nuclear fuel[2].

Two small-size (about 1/10th scale) canisters with a 6 mm thick wall were manufactured with a pressureless sintering method (Fig. 5).

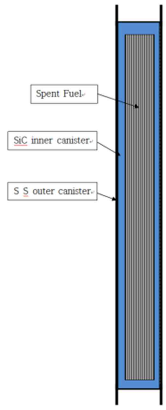

Fig.4. Structure of a disposal canister.

Fig.5. Manufacturing of a small-size canister.

4. Future plan and Conclusions

We designed a disposal canister using SiC for DBD. According to an experience in manufacturing a small-size canister, the fabrication of a large-size one is a challenge. Also, welding of SiC canister is not easy. Several pathways are being paved to overcome it. Applications of DBD concept with SiC canister to the disposal of CANDU SNF and wastes with a very long-lived radionuclide such as Tc-99 and I-129 generated from pyro-processing of SNF are some examples.

Acknowledgement

This work was supported by the Ministry of Science, ICT and Future Planning within the framework of the national long-term nuclear R&D program (NRF-2012M2A8A5025577).

REFERENCES

[1] Albert Kerber, Jena, and Juergen Knorr, atw 58, pp.8-13 (2013).

[2] Bill W. Arnold, et al., SAND2001-6749, p.13 (2011).