Thermal Dimensioning of SiC Canister Applied A-KRS

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1. Introduction

Reducing toxicity and volume of SNF and reusing valuable fissile materials, pyro-processing connected with SFR is under-developing. Accordingly the Advanced Korean Reference disposal System (A-KRS), a deep geological disposal system concept for HLW from pyro-processing, had been developed by KAERI. The A-KRS is composed of 1 cm thick copper cold-spray-coated cast iron canisters, buffer blocks, disposal holes and disposal tunnels, etc. To manufacture disposal canisters, massive un-reusable copper and iron resources are required. Recently, SiC which has high thermal conductivity and good mechanical properties is investigated as a substitute material of metal canister to save metal resources. In this study, thermal performance of SiC canister is investigated and thermal dimensioning of SiC canister applied A-KRS is conducted to estimate thermal applicability of SiC canister in repository.

2. Methods and Results

2.1 Methods for thermal evaluation

After pyro-processing of spent nuclear fuel, five kinds of waste, metal; monazite/LiCl+KCl; filter/off-gas; SAP/LiCl; fly ash/off-gas, are produced. Among these waste the metal waste containing U and TRU is disposed in -200 m level and the monazite/LiCl+KCl waste containing rare earth element and TRU is disposed in -500 m level according to the A-KRS concept [1]. The footprint of repository is depending on the monazite waste due to its high decay heat. Therefore, thermal performance estimation and dimensioning are conducted only for the monazite waste in this study.

The Fig. 1 represents specification of monazite waste disposal system in the A-KRS concept. Four disposal canisters containing 14 monazite wasteform are disposed in one disposal hole. The maximum temperature of bentonite is limited not to exceed 100 ˚C to prevent bentonite degradation [1].

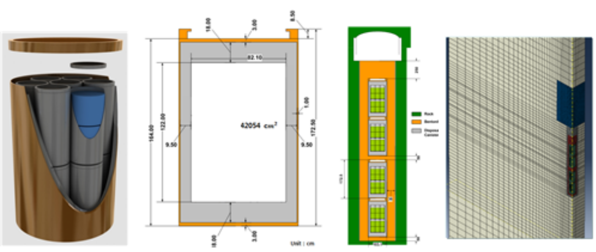

Fig. 1. Specification of A-KRS and FEM models

Heat transfer strongly depends on the heat source, material properties, initial condition, and boundary conditions. To calculate heat source, the Plus7 spent fuel with an initial enrichment of 4.5 wt.% and discharge burn-up of 55 GWd/MtU was considered a representative fuel and cooling period was assumed to be 10 years and 30 years for SF and HLW respectively. The material balance 2.6.0 is assumed and decay heat is calculated using ORIGEN-ARP code. The thermal properties of the repository materials are given in Table 1. For heat transfer analysis, ABAQUS FEM models are developed and it is assumed that every disposal canisters disposed at once and every bentonite are saturated to use symmetry condition. The geothermal gradient is assumed to be 30˚C/km based on measurement at KURT [1].

Table 1: Thermal properties of system materials [1]

	SiC			Ca-bentonite	Backfill	Rock
Density [kg/m3]	3,158			1,970	2,270	2,600
Thermal Conductivity [W/m˚C]	29.3˚C 173.9	51.4˚C 146.4	99.4˚C 117.2	0.8	2.0	3.0
Specific heat [J/kg˚C]	800			1,380	1,190	900

2.2 Effect of thermal conductivity on bentonite peak temperature

Thermal conductivity of SiC is highly varying on the material temperatures. The measured thermal conductivity of SiC is 173.9 W/m ˚C at 29.3 ˚C, 146.4 W/m ˚C at 51.4 ˚C and 117.2 W/m ˚C at 99.4 ˚C. The thermal conductivity of SiC at 99.4 ˚C is about 67 % of room temperature. The Fig. 2 represents effect of thermal conductivity of SiC on peak bentonite temperature. The dot line in the Fig. 2 means peak bentonite temperature calculated using varying thermal conductivity and the data points represent peak bentonite temperatures calculated fixed thermal conductivity at specific temperature. The Fig. 2 shows that the maximum difference in the peak bentonite temperature is less than 0.3 ˚C and thermal conductivity at higher temperature represent more practical results. Based on this sensitivity study, interpolated varying thermal conductivity is determined to be used on thermal analyses.

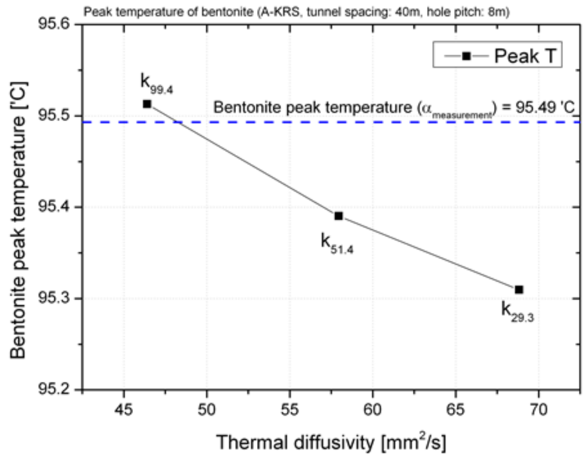

Fig. 2. Sensitivity study on thermal conductivity of SiC

2.3 Thermal performance of SiC canister and thermal dimensioning of SiC canister applied A-KRS

The Fig. 3 shows maximum buffer temperatures of original metal canister applied system (black) and SiC canister applied system (red). The maximum bentonite temperature of SiC canister applied system is lower than metal canister applied system due to higher thermal conductivity of SiC. Thermal conductivity of cast iron is 52 W/m ˚C and this value is about 1/2 of SiC.

Thermal dimensioning of SiC and metal canister applied A-KRS is shown in Fig. 4. To determine thermal dimensioning, tunnel spacing and hole pitch at which bentonite peak temperature complies with its limit must be determined. To determine proper spacing of disposal hole pitch without tunnel spacing is conducted in this study because it is determined that tunnel spacing of 40 m is most effective in the previous study [2]. The calculated minimum disposal hole pitches of SiC canister applied system and metal canister applied system are 6.86 m and 6.99 m respectively. The minimum hole pitch of SiC canister applied system is 98.1 % of metal canister system. However, decrease of disposal hole pitch is negligible considering engineering and safety margin.

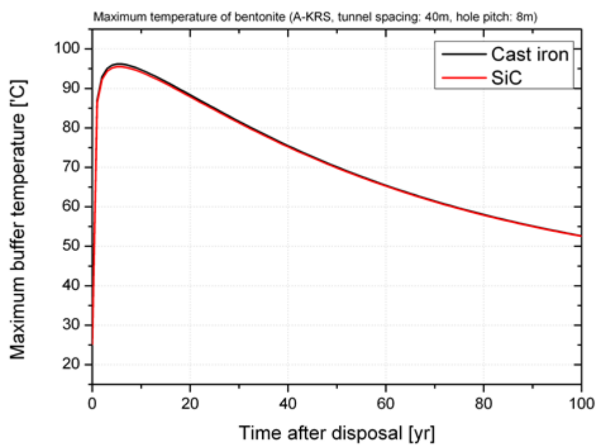

Fig. 3. Maximum temperature of bentonite buffer

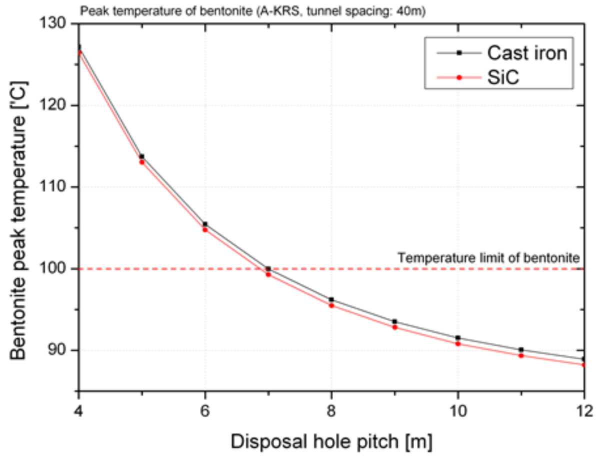

Fig. 4. Thermal dimensioning of SiC and metal canister applied A- KRS

3. Conclusions

In this study, thermal applicability of SiC as a substitute material of copper and cast iron canister is assessed. Due to higher thermal conductivity of SiC, calculated maximum temperature of SiC applied system is lower than original metal canister applied system and estimated minimum disposal hole pitch of SiC canister system is narrower than metal canister system. But decrease of distance between disposal hole pitch by adopting SiC canister is negligible considering engineering and safety margin. As a result, it is confirmed that SiC could be used as a substitute materials of metal in respect of thermal aspect.

To apply SiC canister in deep geological repository, however, thermal-mechanical assessment need to be conducted as future studies. Especially thermally induced stress and intactness of canister must be estimated because SiC is fragile material and its thermal conductivity is highly dependent on temperature.

REFERENCES

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