Thermal Design Concept of Gap Between Canister and Buffer in an HLW Repository

Jae Owan Lee* and Geon Young Kim

Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea

*jolee@kaeri.re.kr

1. Introduction

When the buffer is installed in the excavated deposition borehole in the HLW repository, there will be an empty space, i.e. gap between the canister and the buffer and between the buffer and the deposition borehole. These gaps around the buffer may give a significant influence on the release of decay heat from the waste through the canister and buffer into the surrounding host rock.

This study presents the influence of the gap between the canister and buffer (hereafter, referred to as the inner gap) on the peak temperature of the buffer and its thermal considerations in the buffer design of Korean Reference disposal System (KRS).

2. Numerical model

The present KRS design concept has no consideration of gaps between the canister and the buffer and between the buffer and the deposition borehole: The high-level waste encapsulated in the canister is deposited in the deposition borehole, and after its emplacement, the empty space between the canister and the wall of the deposition borehole is filled with compacted bentonite buffer without any gaps (Fig. 1). This study assumes there are gaps between the canister and the buffer and between the buffer and the deposition borehole, analyzing the change in the buffer thermal performance by gap-filling options of the inner gap when the outer gap between the buffer and the surrounding host rock is filled with bentonite pellets.

Numerical simulations are carried out for a 3-D quarter of model geometry using the Heat Transfer Module of COMSOL Multiphysics Ver. 5.1, which is a finite element computer code. The Heat Transfer Module is expressed by the following governing equation which is applicable to a conductive heat transfer in a porous medium:

$$\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot (-\lambda \nabla T) = Q, \qquad (1)$$

where T is the temperature as a dependent variable, ρ is the density of porous media, C_p is the specific heat capacity, λ is the thermal conductivity, t is the time, and Q is the heat source. The meshes for the numerical simulation are made using free tetrahedral elements, and more elements are made near the buffer and its surrounding gaps.

For model simulation, the thermal conductivity of bentonite pellets used as gap-fills is calculated from Beziat et al.'s equation [1]:

$$\lambda_{pellets} = {\lambda_s}^{1-n} \cdot {\lambda_w}^{n \cdot s_r} \cdot {\lambda_a}^{n \cdot (1-s_r)} \qquad (2)$$

where $\lambda_s, \lambda_w, \lambda_a$ are the thermal conductivities of solid, water, and air, respectively. n is the porosity of the bentonite pellets and s_r is the degree of saturation.

3. Results and conclusions

The location of the peak temperature in the buffer was determined by examining the temperature distribution along the interface boundary between the inner gap and the buffer. The highest temperature in the buffer was located at the central point of the inner gap which is in contact with the buffer in the axial direction of the deposition borehole.

The peak temperature in the buffer, when the inner and outer gaps were left unfilled with gap-fills, was much higher than when no gap around the buffer was considered. This is probably because air significantly interferes with the release of decay heat from the canister containing waste to the surrounding host rock.

However, when both the outer gap and inner gap were filled with the gap-fills of bentonite pellets, the peak temperature was much reduced to 110℃ (Fig. 2), which suggests that the bentonite pellets are effective in improving the heat release through the gaps. Fig. 2 also shows the calculated peak temperature when the outer gap is filled with the gap-fills of bentonite pellets and the inner gap is left empty without gap-fills. We knew in this figure an interesting fact unlike our expectations: the peak temperature for the case of no gap-fills in the inner gap (107.5℃) was lower than that of the case of gap-fills (110℃). This suggests that it is favorable for the heat release to leave the inner gap empty without filling it with gap-fills.

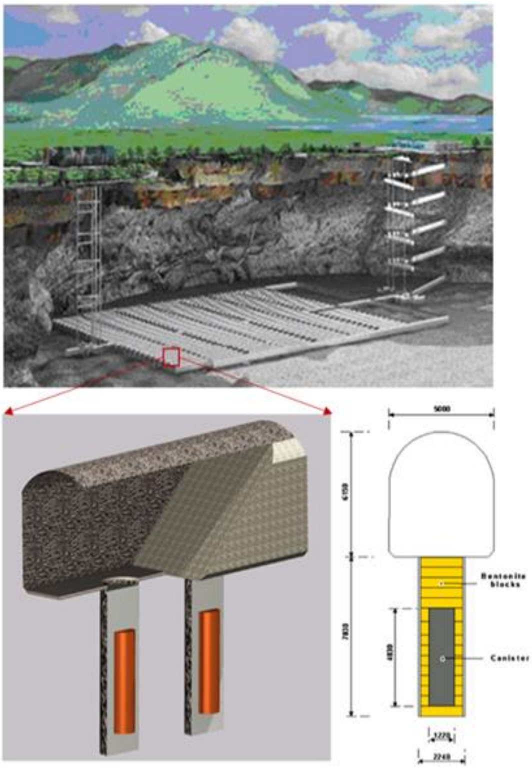

Fig. 1. Schematic picture of Korean Reference disposal System (KRS) and engineered barrier system.

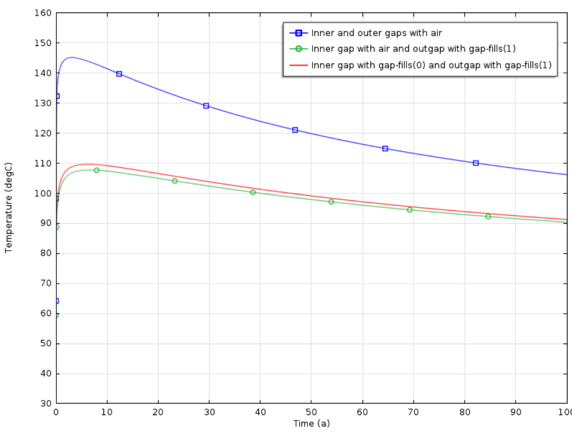

Fig. 2. Temperature evolution curves at peak temperature point for three gap-filling options of the inner gap.

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