The Thermal Effect of Gaps in the Engineered Barrier System(EBS) of HLW repository

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1. Introduction

Gaps may exist between the canister and the buffer material and buffer material and rock in the engineered barrier system(EBS) of high level waste repository. The gaps have various characteristics with size, condition and other properties. In this study, it is conducted that the effect of the gaps on the temperature distribution in the near field of HLW repository.

2. Analytical Condition

In order to estimate precisely the temperature in the near field, the coupled thermo-hydro-mechanical analysis is needed. However, both a slow water flow at great depth and the convection of water should have only a slight effect on the heat transfer of the EBS. According to the previous study, non-coupled thermal analysis using the thermal properties of buffer material of dry condition is likely to provide conservative results[1]. Therefore, in this study, non-coupled thermal analyses are performed to assess the effect of gaps on the temperature in EBS.

It is assumed that the repository is placed at 500 meters depth and the analysis model is contained from the ground surface to the 200 m below the disposal depth. The disposal tunnel spacing and deposition hole spacing are 40 m and 6 m, respectively. Because of the symmetry of the disposal system a quarter of the model is used and the properties used are the same with those used by Kwon and Kim[2]. Also, the temperature at the ground surface is kept at 20℃ and the initial underground temperature is set to increase 3℃ per 100 meters and the initial temperature of the PWR spent fuel and the canister are set 79℃ and 28.5℃, respectively[2].

The heat generation rate from PWR spent fuel was obtained as follows:

$$q(t) = 14548.7t^{-0.76204} \text{ W/m}^3 \text{ (for } 30 \le t < 10^6 \text{ years)}$$

It is assumed that the thickness of the gap between the canister and the buffer is 2 cm and between the buffer and rock is 3cm. Table 1 shows several analytic cases varying the characteristics of gap. Except case C, it is considered that heat transfer is caused by conduction through the air in every air gap. Only case C is considered the radiation and the convection of air is ignored in all cases. In case G, it is considered that the canister and the buffer are partly contacted. The gap model is described in figure 1.

Table 1. Analysis Cases

Analysis Case	Gaps		Remark
	Between canister and buffer	Between buffer and rock	
A	-	-	No gap
B	Air	Water	
C	Air	Water	Radiation in air gap
D	Air	Air	
E	Water	Water	
F	Bentonite powder	Bentonite powder	Bentonite powder is injected into gaps
G	Air	Water	Canister and buffer is partly contacted

3. Thermal Analysis

The maximum temperature of the buffer and the time when the temperature in the buffer reaches the maximum temperature for all cases are shown in Table 2. In the results of the calculation, the maximum temperature of the buffer is estimated 86.4℃ in the case A, no gap model, which is a very close to the result, 86℃, assessed by FLAC^{3D}[3].

As shown in Table 2, in terms of the maximum temperature of the buffer, the case B considered the conduction through the air is high by about 10℃ than the case C considered the radiation in air gap. Therefore, it is expected the more conservative results if the conduction in the air gap is only used.

From case B to case F show the effects of the filling material. The water filled gap has only a slight effects on the heat transfer of the near field. However, the air filled gap extremely interferes with the transfer of the decay heat from the spent fuel. In that case, the thermal criteria of the peak temperature at the buffer below 100℃ is not satisfied. Actually, it is expected that the buffer temperature will be lower than that because the radiation and the convection as well as air conduction will act together in the air gap. In addition, even though the deposition hole is drained at the initial disposal stage, the deposition hole below ground water level will start to resaturate. And also the swelling of the buffer will improve the thermal conductivity. The result shows that the method to inject bentonite powder into the air gap has a little improvement the thermal conductivity.

Table 2. Results of heat transfer analyses

Analysis Case	Max. Temperature of buffer (°C)	Reaching Time (year)	Position (inner surface)
A	86.4	20	Side wall
B	109	7	Bottom
C	98.2	9	Bottom
D	128.2	4	Top
E	87.6	18	Bottom
F	94.9	15	Top
G	105.8	7	Side wall

Figure 1 and 2 show the temperature profile on the buffer for the case B and G, respectively, at the time when the temperature meets the peak value.

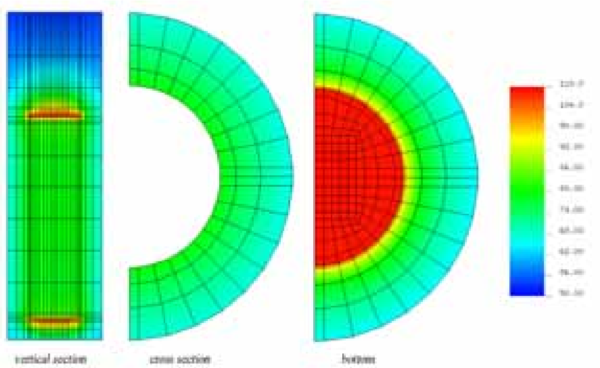

Figure 1. The temperature profile on the buffer for the case B at 7 years after emplacement.

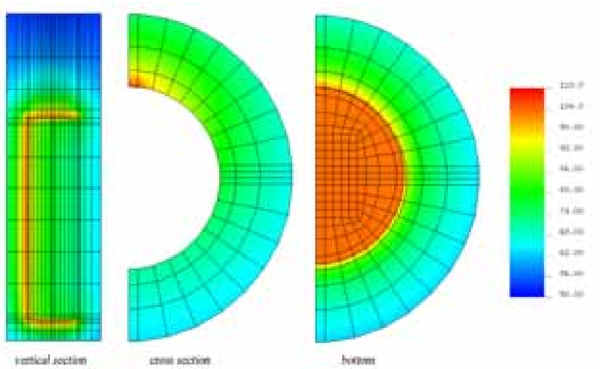

Figure 1. The temperature profile on the buffer for the case F at 7 years after emplacement.

4. Conclusion

Gap is considered as a great disadvantageous factor in the EBS. Especially, the gap filled air may cause temperature above 100°C, and only for a short period of time. In order to improve the heat transfer on the EBS, filling water or the bentonite powder into the gaps should be a good choice.

5. Acknowledgement

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