Thermal Analyses for the Design Parameters in the Geological Disposal of HLW

Yang Lee, Heui-Joo Choi, Jong Youl Lee, Jhinwung Kim, Jongwon Choi
KAERI, Disposal System Development, 105 Yuseong, Daejeon, ex-neroyang@kaeri.re.kr

1. Introduction

The thermal analyses for the geological disposal of spent PWR fuel are performed. The purpose of this study is to investigate possible variations of design parameters, and to determine thermally suitable parameters. FLAC^{3D}, which is a 3-dimensional finite-difference code, is used for the thermal analyses[1]. In this study, thermal conductivity and thickness of bentonite buffer, spacing between disposal tunnels, and spacing between disposal holes are used as the varying design parameters.

2. Methods and Results

For the thermal analyses a disposal model with 6 meter of the hole spacing, 40 meter tunnel spacing and 0.5 meter buffer thickness is used as a reference case. The parametric study with the reference model is performed.

2.1 Thermal Option of FLAC^{3D}

The thermal option of FLAC^{3D} that is a 3-dimensional finite-difference program for engineering mechanics computation allows the simulation of transient heat conduction in material and the subsequent development of thermally-induced stresses. The variables involved in heat conduction in FLAC^{3D} are the temperature and three components of heat flux. These variables are related through the energy-balance equation (1) and transport laws derived from Fourier's law (2) of heat conduction. Substitution of Fourier's law into the energy-balance equation yields the differential equation of heat conduction which may be solved for particular geometries and properties under the given specific boundary and initial conditions.

$$-q_{i,i} + q_v = \rho C_v \frac{\partial T}{\partial t} \tag{1}$$

$$q_i = -kT_{,i} \tag{2}$$

2.2 Analysis Model

It is assumed that the repository is placed in the granite rock bed at 500 meters depth[2]. Because of the symmetry of the disposal system a quarter of the model is used and the properties used are the same as in the reference by Kwon and Kim[3]. Also, the temperature at the ground surface is kept at 20□ and the initial underground temperature is set to increase 3□ per 100 meters.

2.3 Comparison of the FLAD^{3D} and the NISA

The thermal results of the reference case using the FLAD^{3D} and the NISA computer program were compared. For the period of 100 years the temperature changes at the 4 points-fuel center, canister center, canister outer surface and buffer outer surface are estimated. The temperature differences between the two models are below 3□ at the fuel center and 2□ at others points. The reference case meets the thermal criteria of peak temperature at the canister surface below 100□.

2.4 Effect of Thermal Conductivity of Bentonite Buffer

The thermal conductivity of bentonite buffer considered are 0.75 W/m□ and 1.3 W/m□. The effect of thermal conductivity is shown in Fig. 1. There are considerable temperature differences at the fuel center, canister center, and canister surface. It shows that the thermal conductivity of buffer is an important parameter, therefore, it should be selected carefully.

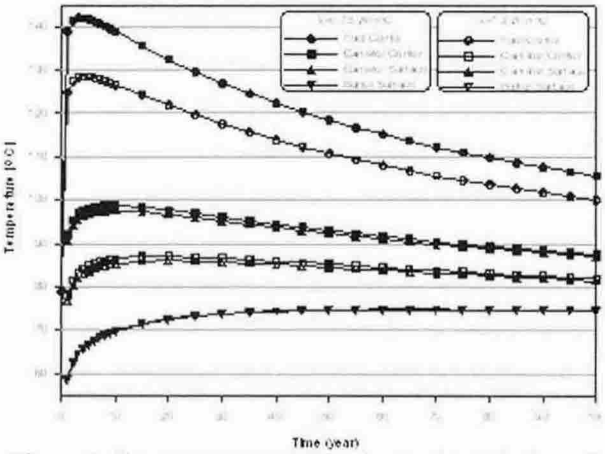

Figure 1. Temperature variation due to the variation of thermal conductivity of bentonite buffer.

2.5 Effect of Bentonite Buffer Thickness

Fig. 2 shows the effect of the buffer thickness variation. The cases with different buffer thickness are investigated. As the thickness of the buffer decreases, the peak temperature at the canister surface decreases. It shows that the thermal stability increases as the buffer thickness decreases. However, the thin buffer may cause some influence on the role as a buffer material and on the structural stability. Therefore, the buffer thickness should be determined after chemical and mechanical analyses, in addition to the thermal analyses.

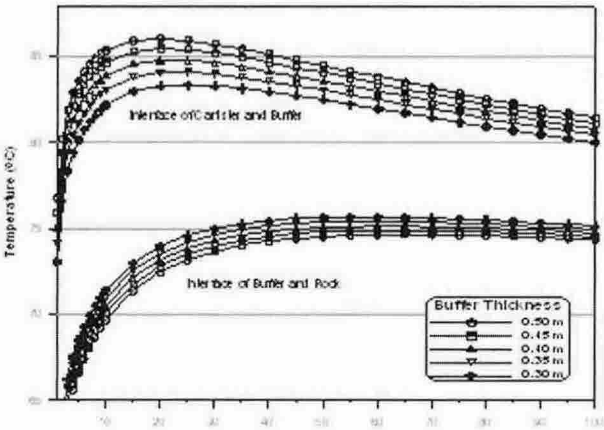

Figure 2. Temperature variations at the buffer surface and the canister surface due to the variation of buffer thickness.

2.6 Peak Temperature Change causing the Disposal Tunnel and the Hole Spacing

The case studies with the disposal tunnel spacing from 30 to 50 meters and the disposal hole spacing from 4 to 8 meters are performed. The points in Fig. 3 show the peak temperature at the canister surface. The shaded regions in Fig. 3 show the disposal tunnel arrangements satisfying the thermal criteria, which may not cause the properties change of buffer. It is recommended that the tunnel and hole spacings are 35m and 6m, or 30m and 7m. However, the repository arrangement should be determined after the mechanical behavior and excavation cost studies.

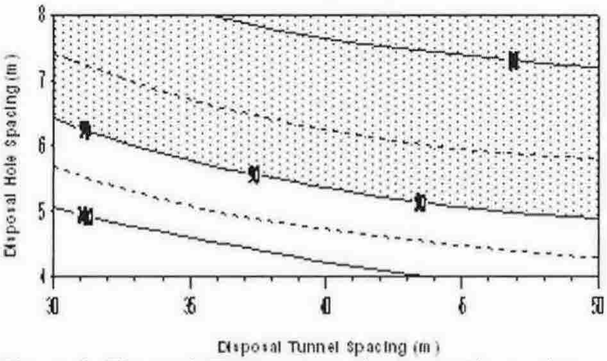

Figure 3. The peak Temperature changes at the canister surface according to the changes of disposal tunnel and hole spacing.

3. Conclusion

The thermal analyses are performed with variations of several parameters using a 3-dimensional finite-difference code FLAC^{3D}.

It is clear that the thermal conductivity affects the temperature of the fuel, the canister center, and the canister surface. That means that it is essential to obtain the exact thermal conductivity of bentonite buffer. If the buffer thickness is less than 0.5 meter, the thermal stability increases. However, the thickness should be designed after considering other aspects of bentonite buffer material and the structural stability. For the disposal of one PWR canister it was suggested that the disposal tunnel and the hole spacings are 35m and 6m, or 30m and 7m, respectively. The present study is performed by thermal analysis only. Thus, for more reasonable values of parameters, mechanical, chemical and cost analyses should be performed in addition to thermal analyses.

4. Acknowledgement

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