Sensitivity Analysis of Thermal Conductivity on Thermal Dimensioning of SNF Direct Disposal System

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1. Introduction

For safe disposal of SNFs in Korea, the KRS system had been developed. Since then, the KJ-II bentonite was adopted and several important THM properties of bentonite and rock are evaluated and revised. However, these results are not applied to the design of KRS system because of interruption of research on direct disposal. In this study, sensitivity of thermal conductivity on thermal dimensioning is studied by calculating temperature difference between base case and thermal properties variation case.

2. Methods and Results

2.1 Thermal Analysis Model

To evaluate sensitivity of thermal conductivity, the KRS direct disposal system depicted in Fig. 1 is adopted [1]. The plus7 type fuel which has 4.5wt.% of initial enrichment, 55 GWd/MtU of discharge burnup, 40 years of cooling time is selected as a reference fuel [2]. Decay heat of reference fuel is calculated using ORIGEN-ARP. Quarter region FEM model for thermal analyses is developed using ABAUS considering symmetry condition. 40 m of tunnel spacing and 9 m of hole pitch are considered [2]. Geothermal gradient is assumed to be 30°C/km based on KURT data.

Thermal properties of the repository materials used in this study are listed in Table 1. Thermal conductivity of bentonite is assumed to be varying between 0.6 W/mK to 1.3 W/mK based on research of KJ-II bentonite [3]. Thermal conductivity of KURT granite is assumed to be between 2.0 W/mK and 3.5 W/mK according to KURT rock measurement data [4].

2.2 Results

Table 1. Thermal properties of system materials [1~4]

<table>
<thead>
<tr>
<th>Material</th>
<th>Density [kg/m³]</th>
<th>Thermal conductivity [W/mK]</th>
<th>Specific Heat [J/kgK]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Iron</td>
<td>7,200</td>
<td>52</td>
<td>504</td>
</tr>
<tr>
<td>Copper</td>
<td>8,900</td>
<td>386</td>
<td>383</td>
</tr>
<tr>
<td>Ca- bentonite</td>
<td>1,970</td>
<td>base case: 0.8</td>
<td>this study: 0.6 – 1.3 [3]</td>
</tr>
<tr>
<td>Backfill</td>
<td>2,270</td>
<td>2.0</td>
<td>Base case: 3.0</td>
</tr>
<tr>
<td>Rock</td>
<td>2,600</td>
<td>Base case: 3.0</td>
<td>this study: 2.0 – 3.5 [4]</td>
</tr>
</tbody>
</table>

Fig. 1. EBS of the KRS PWR SNF disposal system [1].
determined to maintain bentonite peak temperature under 100°C. Bentonite peak temperature is highly affected by thermal conductivity as shown in Fig. 2 and Fig. 3, though thermal conductivity assumed in this study are extensive than expected ones in real disposal system. Therefore, peak bentonite temperature criteria or thermal loading criteria for canister should be modified to consider thermal conductivity changes in accordance with thermal evolution of repository.

thermal dimensioning is analyzed by calculating temperature difference between base case and thermal property variation case. Thermal properties are assumed based on measurements ranges for KJ-II and KURT granite. From sensitivity analyses, it is clarified that bentonite peak temperature is strongly affected by thermal conductivity. To consider thermal evolution of repository and uncertainty in material properties, criteria on bentonite peak temperature or canister maximum thermal loading criteria should be modified.

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REFERENCES