Preliminary Thermal Analysis for an Alternative Disposal System

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1. Introduction

Yucca Mountain repository type [1], which is a geologic repository, is being considered as one of alternative disposal concepts in KAERI. This disposal system has two types of cooling mode to remove decay heat generated from PWR spent fuels in the waste packages. For the first cooling phase, the decay heat is cooled by forced convection during a certain period (pre-closure). Then, it will be cooled by natural convection (the second cooling phase, post-closure). In the present work, thermal analysis was carried out using a commercial CFD code, CFX, to establish cooling concept of the alternative disposal system.

2. Methods

2.1 Numerical Model

The half model of the alternative disposal system was used in the present simulation as shown Fig. 1. This computational model consists of a waste package, a storage drift (tunnel), and rock. The 2 million computational meshes were generated in the fluid (tunnel, air) and solid domain (rock) for 3-dimensional conjugated heat transfer analysis.

2.2 Numerical Method

The 3-dimensional flow field of air flowing through a tunnel was solved using the steady-state RANS equation with SST turbulence model. Major heat transfer modes of conduction, convection, and thermal radiation were also considered in the present simulation.

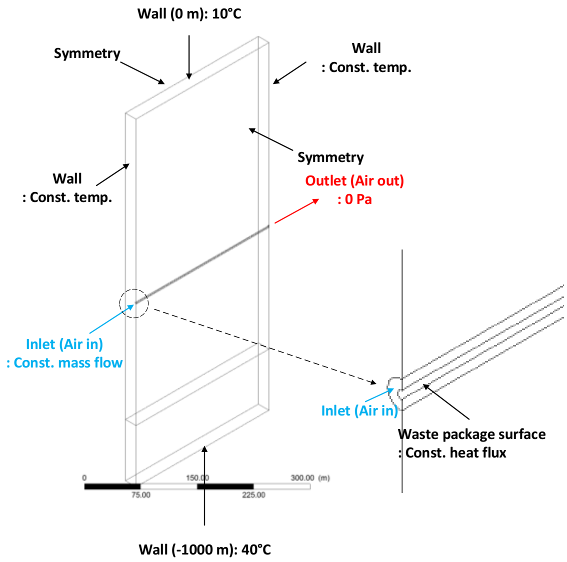

Fig. 1. Schematic of computational domain.

2.3 Initial and Boundary conditions

The inlet boundary condition was set constant mass flow rate (15 m^3/s) at the entrance of tunnel and the outlet boundary condition was modeled as a relative pressure of 0 Pa at the end of tunnel. The symmetry boundary condition was applied on two vertical side planes of solid computational domain (rock) as shown in Fig. 1. The rest of wall boundary was set as the constant temperature wall. The uniform heat flux at waste package surface was taken into consideration as shown in Fig. 1.

3. Results

Fig. 2 shows the maximum temperature variation during the forced convection cooling phase (0~100 years). The temperatures slightly decrease with decreasing decay heat. The maximum temperatures do not exceed temperature limits (waste package surface=300°C, tunnel wall=200°C, between tunnels=100°C) in the present simulation. Additional simulation was performed to assess the effect of air flow rate. Fig 3 shows the maximum temperatures after waste package placement (0 year) for various inlet conditions. If air flow rate is set to 5 m^3/s or more, the maximum temperature between the tunnels does not reach the temperature limit (100°C). Based on the numerical simulation on forced convection phase (air flow rate=15 m^3/s), the numerical simulation on natural convection cooling was performed to assess cooling capability for post-closure. Fig. 4 shows the maximum temperature variation for natural convection cooling phase (after 100 years). The temperature rapidly increases as the cooling mode change from the forced convection to the natural convection. The maximum temperature between the tunnels (106°C) slightly exceeds limit temperature (100°C) at this time.

4. Conclusion

The present study was carried out using CFD code to investigate thermal behavior of the preliminary conceptual design of the alternative disposal system. In present work, the predicted maximum temperature between tunnels exceeds temperature limit at the time of cooling mode conversion. Therefore, it is necessary to carry out further study on natural convection cooling of the alternative disposal system.

ACKNOWLEDGEMENT

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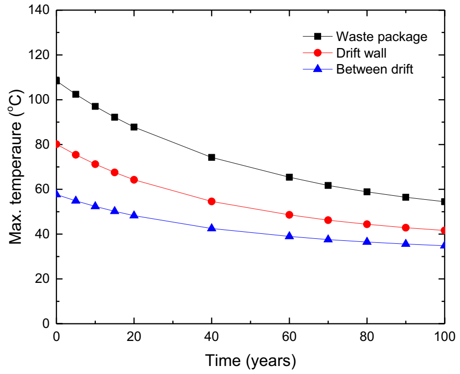

Fig. 2. Max. temperature variation during pre-closure (forced convection cooling phase).

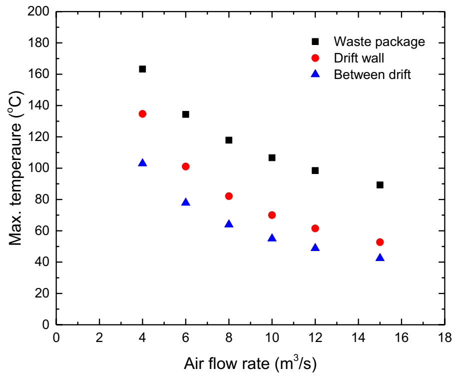

Fig. 3. Max. temperature in various air flow rates.

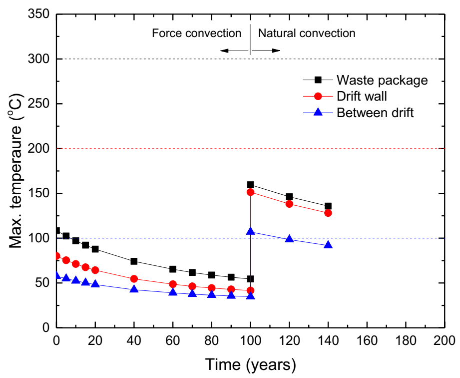

Fig. 4. Max. temperature variation during post-closure (natural convection cooling phase).

REFERENCES

[1] G.S. Bodvarsson et al., “Overview of scientific investigations at Yucca Mountain” Journal of Contaminant Hydrology, 38, 3-24, (1999).