Thermal Analysis of KORAD21 CASK Using COMSOL MULTIPHYSICS

Sunwoo Park and Kwangheon Park*

Nuclear Engr. Department, Kyung Hee Univ., 1732 Deogyeong-daero, Giheung-gu, Yongin-si, Gyeonggi-do 17104, Republic of Korea

*kpark@khu.ac.kr

1. Introduction

Spent fuel is the most important waste to be carefully managed after the release from the nuclear power plants. Due to the decay heat and radiation emitted from the spent fuel, it must be handled carefully for a long time. In Korea, spent fuel has been stored in a wet storage tank located in a nuclear power plant. However, as the wet storage tank becomes saturated, the necessity of using other methods is increasing. The dry storage method is preferred as a substitute for the wet storage method. Dry storage is relatively safe from degradation of the cladding could occur during the wet storage. Dry storage is known to be cheaper to operate than the wet storage facility. In general, Safety analysis of dry storage cask is done in four fields. Thermal analysis, Structural analysis, Radiation shielding analysis, and Criticality analysis are included in four fields. In this study, thermal analysis of KORAD21 CASK designed and fabricated by KORAD was carried out.

2. Methods and Results

2.1 COMSOL MULTIPHYSICS Program

COMSOL MULTIPHYSICS is a multiphysical phenomena analysis program that analyzes various complex phenomena using finite element method. In this study, thermal evaluation of KORAD21 CASK was performed using thermal analysis and flow analysis module of COMSOL MULTIPHYSICS program. In the COMSOL MULTIPHYSICS program, time-dependent analysis method and stationary analysis method are supported. In this study, stationary analysis method was used.

2.2 Modeling and material setup

The KORAD 21 CASK modeled in this study consists of a concrete cask and a metal canister. The basket is supported by the 22 discs inserted inside of the canister. The air entering through the lower passageway is expanded by the heat released from the metal canister and form natural convection. As the expanded air release through the passageway at the top of the cask, cooling effect appears. Cooling by natural convection is also occurs on the outer surface of the cask. The homogenized fuel assemblies inserted inside the canister reflect the properties of Zircaloy cladding, UO_2, and Helium. The nuclear fuel burns 50GWD/MTU and has a cooling period of 10 years, resulting in an average heat output of 758.3W and a maximum of 796.2W per assembly. Inside the canister, helium gas was injected with 1atm. Excluding air, the density property is a constant value. The heat transfer coefficient and the specific heat value of materials are described as a function of temperature. In the case of air, density, heat transfer coefficient, and specific heat values were described as functions of temperature.

2.3 Calculation results and analysis

A practical temperature evaluation of KORAD21 CASK using electric heaters was performed. The inside of the KORAD21 CASK is divided into six part in the z-axis direction. Temperature evaluation was performed by an inserted thermocouples. Each thermocouple measure the temperature of the canister shell, cask inner liner, concrete, and cask outer liner at each height. Based on the above experimental results, KORAD verified the thermal analysis result by FLUET code. In this study, the thermal analysis was performed using the COMSOL MULTIPHYSICS program and the results were verified in the same way as KORAD did. From the bottom, the heights of 1630.8 mm, 2630.8 mm, 3630.8 mm, 4130.8 mm, 4630.8 mm and 4970.8 mm were designated as Level 1 through Level 6 in order. In this article, only the results of Level 4, 5, and 6 are shown.

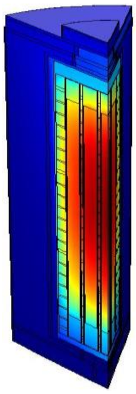

Fig. 1. Thermal analysis result of KORAD21 CASK using COMSOL MULTIPHYSICS.

In the graphs below, the results of the code analysis performed by KORAD, the actual measured results, and the results analyzed by COMSOL MULTIPHYSICS program are compared at the points of Level 4, 5, and 6.

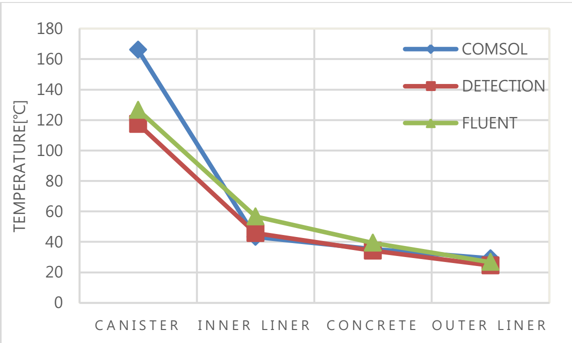

Fig. 2. Temperature profile at Level 4.

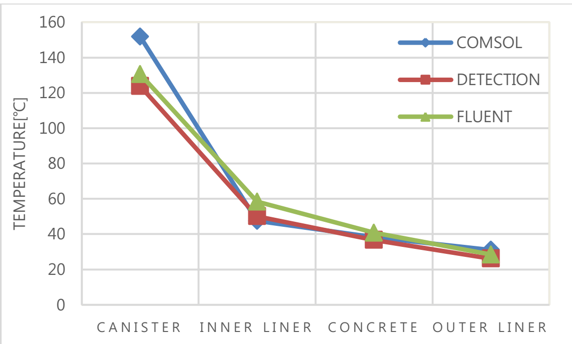

Fig. 3. Temperature profile at Level 5.

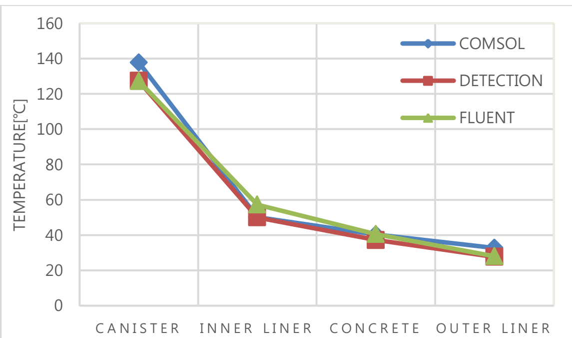

Fig. 4. Temperature profile at Level 6.

Except for the canister part, the analysis results using COMSOL show a tendency to be more consistent with the DETECTION results than the FLUENT code results. In addition, the analysis results of concrete, canister, neutron absorber, and cladding were evaluated to satisfying the temperature limit criteria.

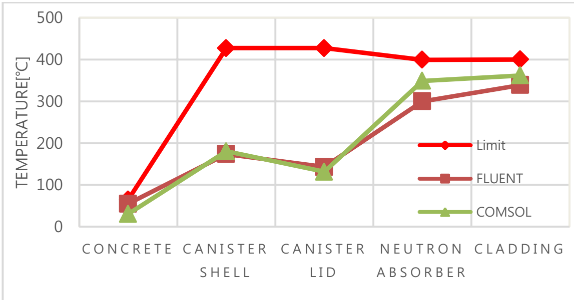

Fig. 5. Comparison of Code Analysis Results and Temperature Limit criteria.

3. Conclusion

The thermal analysis results of the KORAD21 CASK using COMSOL MULTIPHYSICS program were similar to those of code analysis results and the actual measurement results from KORAD. In addition, thermal analysis results of KORAD21 CASK have been found to meet the temperature limit criteria.

REFERENCES

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