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DEVELOPMENT OF DEVICE FOR DETECTING HELIUM LEAK FROM CANISTER -ANALYTICAL STUDY FOR TEMPERATURE BEHAVIOR DURING GAS LEAK FROM SMALL PRESSURIZED VESSEL-

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Spent nuclear fuel from nuclear power reactors is stored inside a cask for a certain period of time. In a metal cask, monitoring of helium pressure between lids is always required. On the other hand, in a concrete cask, a loss of sealing performance of canisters, which is caused by stress corrosion cracking (SCC), is concerned in the case of long-term storage. However, helium leak detectors have yet to be installed to the concrete casks. Therefore, development of the helium leak detector is important to improve safety of concrete casks. The phenomenon that the temperature at the top of the canister (T_T) decreases and the temperature of the bottom (T_B) increases during helium gas leak from the canister has been confirmed by experiments in the previous study. Takeda,H., Wataru,M., Shirai,K. and Saegusa,T. [2008] have proposed a helium leak detection method using the temperature difference between the top and the bottom of the canister. However, the temperatures at the top and bottom surfaces of the canister are required in this method. It would be difficult for some casks which have complex cooling air duct structures to install two thermal sensors to each side. To resolve this problem, Takeda,H., Toriu, D. and Ushijima, S. [2015] proposed easier detection methods using temperature information at either the top or bottom of the canister.

In order to realize the device of helium leak detection for concrete casks, the authors perform experiments and analyses. Experiments using a small pressurized vessel were performed to investigate the relationship between temperatures and inner pressure by Arya, M.S. and Keyhani, M. [1990]. And the analysis for the experiments was performed by Chalasani, N.R. and Greiner, M. [2009]. As part of the development of the device for detecting helium leaks from canisters, the authors performed gas leak tests on a small pressurized vessel with 12 electric heaters. The vessel is a one-eighteenth scaled model of the storage canister in the concrete cask. The diameter of the vessel is 100mm and the height is 260mm. Inner pressure (from 5atm to 1atm), heat rates (from 11.9W to 47.8W) and the kind of gas in the vessel (Air or Helium) were changed as parameters. The phenomenon that T_T decreases and T_B increases during gas leaks was observed in this experiment.

In order to elucidate the phenomenon observed in this test and evaluate the applicability of the result to actual equipment, test analyses were conducted. In this study, benchmark analysis was conducted by using two CFD solvers: CD-adapco™ STAR-CCM+® (ver.11.02.010) and ANSYS® Fluent® (ver.17.1). In the benchmark analysis, physical properties, boundary conditions and turbulence models were set under the same conditions. The numbers of mesh are 3,190,862

(Fluent®) and 3,963,389 (STAR-CCM+®) respectively. The mesh used in Fluent® is mainly tetra mesh, which has advantage about flexibility to complex geometries and that of STAR-CCM+® is mainly polyhedral mesh, which has advantages of robustness and convergence speed of solution against tetra mesh. In STAR- CCM+®, prism layer meshes are created near the wall, basket and heaters, so the number of meshes has increased compared to Fluent®. Fig. 1 and Fig. 2 show the contour plots of the temperature distribution of the outer surface of the canister in the case of Air 36.4W. In the leak test, it was observed that the temperature at the bottom of the vessel (T_B) is increased and the temperature at the top of the vessel (T_T) is decreased when canister internal pressure is decreased. This phenomenon was reproduced by both CFD solvers. It was confirmed that both solvers can analyze this phenomenon appropriately and there is no problem with applying these CFD solvers to this phenomenon. The maximum difference of surface temperature of the canister between analysis results of the solvers was 6.1 K (1.57%) or less.

The test results were compared with analysis results by STAR-CCM+® in the cases of Air 36.4W and Helium 36.2W. Fig.3 shows the comparison between the test and the analysis in the case of Air 36.4W. Fig.4 shows the comparison between the test and the analysis in the case of Helium 36.2W. It was confirmed that the temperature at the bottom of the vessel (T_B) and the temperature at the top of the vessel (T_T) are almost matched between the test and the analysis. It was found that the heat transfer rates have dependency on pressure in the air test and there is difference between the test and the analysis. In the analysis, the heat transfer coefficient is calculated from the correlation equation by Vliet,G.C. and Liu,C.K [1969]. However, in the comparison between the test and the analysis, the difference in the value of heat transfer rates is large at the top and bottom of the vessel. Therefore, this should be reviewed. The heat transfer rate should be obtained from analysis results calculated under the condition of coupling atmosphere air.

REFERENCES

・Arya, M.S. and Keyhani, M. [1990]. Convective heat transfer in a sealed vertical storage cask containing spent fuel canister, *Nuclear Sci. Eng.*, 105, pp391-403.

・Chalasani, N.R. and Greiner, M. [2009]. Natural convection/radiation heat transfer simulations of enclosed array of vertical rods, *Packaging, Transport, Storage & Security of Radioactive Material*, VOL 20, NO 3, pp117-125.

・Takeda,H., Wataru,M., Shirai,K. and Saegusa,T. [2008]. Development of the detecting method of helium gas leak from canister. *Nucl. Eng. Design*, Vol. 238, pp1220-1226.

・Vliet, G. C. andLiu, C.K. [1969]. An Experimental Study of Turbulent Natural Convection Boundary Layers, *J.Heat Transfer,* 91, pp517-531.

・Takeda,H., Toriu, D. and Ushijima, S. [2015], *Development of Evaluation Method of Long-term Confinement Performance for Canister (Part 2) –Helium Leak Analysis and Proposal of Simpler Helium Leak Detection Method–*, CRIEPI Research Report, N15006, (In Japanese)

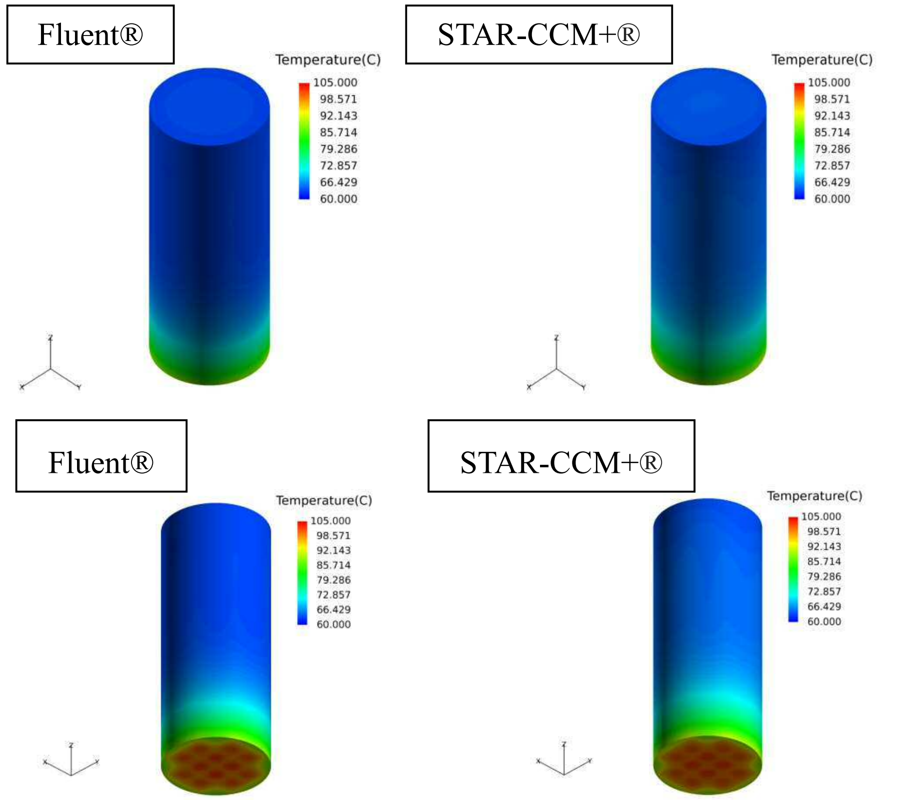

Fig. 1 Contours of surface temperature (Air 36.4W 1atm).

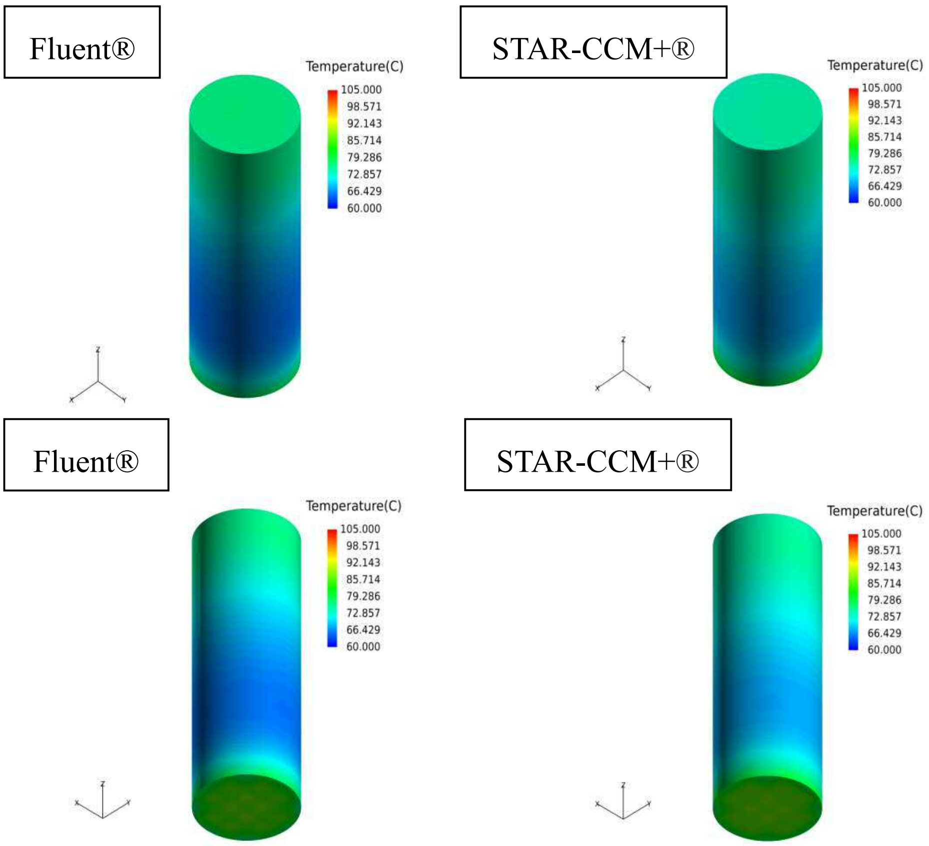

Fig. 2 Contours of surface temperature (Air 36.4W 5atm).

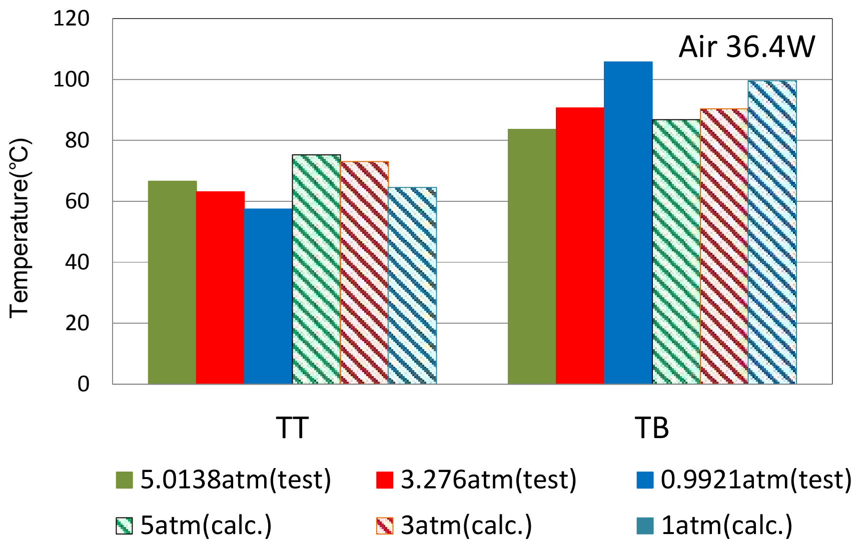

Fig. 3 T_T and T_B (Air 36.4W).

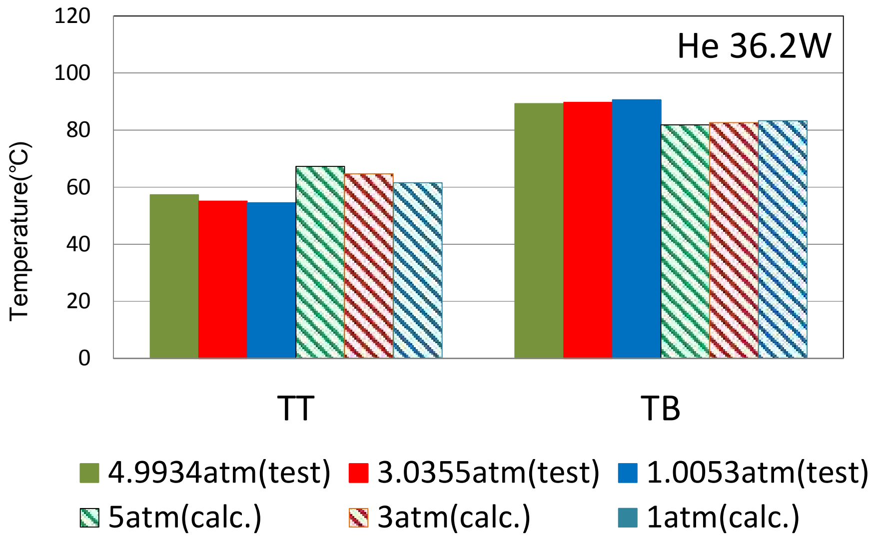

Fig. 4 T_T and T_B (Helium 36.2W).