CFD Analysis of a Dry Storage System for MACSTOR/KN-400

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1. Introduction

There are four nuclear power plants in operation at Wolsong and, annually, more than 5,000 assemblies of spent nuclear fuels are released from each plant. Thus the concrete silo type dry storage system was constructed from '90. However, after 2006, another dry storage facility is required to accept the all amount of spent nuclear fuels from the plants. Instead of the concrete silo type, MACSTOR/KN-400 was developed to store the CANDU spent nuclear fuel more densely.

In this study, computational fluid dynamics (CFD) analysis of the MACSTOR/KN-400 model was performed to confirm the thermal integrity of the facility, especially for the concrete structure, using the commercial CFD code, FLUENT. The MACSTOR/KN-400 which has Thermal Insulation Panel (TIP) and IAEA Re-verification Pipe (RVP) was modeled and analyzed in the view point of the thermal integrity of the concrete structure.

2. Geometry Modeling

MACSTOR-400 has forty cylinders inside its concrete structure. The decay heat from the cylinder is cooled by the natural convection of the air that comes in from 10 air inlets at the bottom and goes out through 12 air outlets at the top of the facility. There is a TIP on the inner wall of the concrete structure. This TIP has a stainless-steel surface filled with the insulation material and prevents that heat goes to the concrete by not only convection but also radiation. There are four RVPs which are located on the center line of the forty cylinder array in the module.

3. CFD Modeling

The geometry, which contains only eight cylinders, was drawn using Gambit 2.2.30. Mesh type used is the Tetra/TGri and the total number is about 2.13 millions. The commercial CFD code, Fluent 6.2.30 was used to modeling MACSTOR/KN-400 module. For the natural convection, the density of the air was set for the boussinesq condition and the pressure inlet/outlet conditions were selected for the air inlet and outlet. Surface to Surface (S2S) model was used for the radiation modeling.

The input material properties for the air were selected at the 40℃ and the heat transfer coefficient of the concrete outer surface was calculated as 3.9129($W/m^2.K$) using these properties and the properties of the other structural material were also selected at 40℃.

The thermal conductivity of the TIP was set 0.042 (W/m.K) as mentioned in the technical reports form the AECL. Heat flux of the cylinder surface was calculated based on the heat capacity 3648W and the surface area of the cylinder. For the hot basket, the second basket form the top of the cylinder, 3725.4 W was used.

4. Result

The local maximum and the are-weighted average temperature of the several important points were listed in Table.1. Both cases satisfy the concrete temperature limit of local maximum, 93℃. The local maximum concrete temperature with RVP is about 67℃. This is lower temperature than the case without RVP, 71℃. The other local temperatures with RVP show lower result than without RVP. This result comes from that RVPs play a role like obstacles against the inlet air. The inlet air penetrates deep inside to the bottom part of the module from the inlet in the case without RVP. However, in the case with RVP, the air goes up more easily in the vicinity of the RVP so that the cold air from the inlet cools down the hot cylinder surface.

5. Conclusion

The MACSTOR/KN-400 module was modeled using the commercial CFD code, Fluent 6.2.30. Result shows that the MACSTOR/KN-400 satisfies the temperature limit in the both cases, and w/o and w/ RVP. Especially, in the consideration of the effect of RVP, temperature distribution of the case with RVP shows lower results than the case without RVP. Therefore, RVP gives a good effect to keep the thermal integrity of the module.

	Without RVP		With RVP	
	Maximum	Average	Maximum	Average
Cylinder surface(℃)	90.41	81.84	86.88	79.14
Concrete inner wall(℃)	71.02	58.07	67.73	55.74
Concrete outer wall(℃)	55.98	41.53	54.06	41.27
Air-inlet temperature(℃)	40.05	40.00	40.00	39.97
Air-outlet temperature(℃)	65.63	55.93	63.15	54.72
Air-inlet velocity(m/s)	0.64	0.52	0.59	0.47
Air-outlet velocity(m/s)	1.49	0.70	1.45	0.66
RVP Surface(℃)	-	-	71.78	65.24

Table.1. Temperature distribution of MACSTOR/KN-400

REFERENECS

[1]. Fluent User's Guide 6.2

[2]. 고연소도 PWR 사용후연료 건식저장 기술개발 (최종보고서), 2005, 산업자원부.

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