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CFD Analysis of Dry Storage System for CANDU Spent Fuel using Fluent 6.2

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1. Introduction

To obtain the licensing for MACSTOR/KN-400 developed by KHNP, 3-D CFD analysis was demanded to prove that the maximum temperature was not over the limited temperature (93°C locally and 66°C averagely for concrete). Though the thermal-hydraulic prediction by CATHENA-code show the reliable results, that could not the temperature distribution. That is, that could not predict the location of maximum temperature well. In this study, the analysis of the temperature distribution on the natural convection flow with thermal radiation shows the concrete temperature distribution. It was different from the predicted results by CATHENA-code. Therefore, to obtain the licensing for AMCSTOR/KN-400, CFD analysis should be performed by 3-D CFD code like FLUENT at the same time. Figure 1 shows the structure of MACSTOR/KN-400.

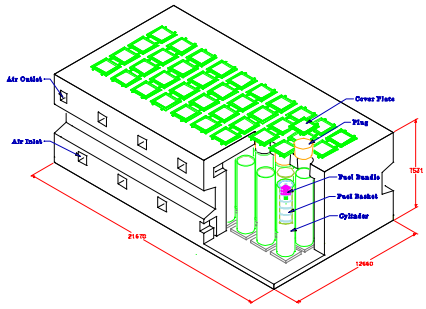

Figure 1 Numerical Model with hexagonal mesh [1]

2. Methods and Results

2.1 Numerical Method

Figure 2 shows the numerical model with 1,700,000 hexagonal meshes for the analysis of MACSTOR/KN-400. An averaged amount of heat was 364.8 W per basket and a maximum amount of heat was 390.6 W per basket. One cylinder was composed of 10 baskets. And 4 cylinders at center included 3 hot baskets and 7 averaged basket. Due to large size of the system and needed minimum mesh size, the analysis was performed for 4x4 cylinders. And the boundary condition of cut wall was set to symmetry without heat transfer.

To find the initial field of natural convection flow, CFD analysis of forced convection was performed first. After the analysis of forced convention, the boundary conditions of flow inlet and outlet were set to pressure inlet/outlet. And wall boundary condition was applied for other boundary conditions with shell conduction.

The working fluid was air. And the density of air had Boussinesq approximation. Applied thermal hydraulic models were standard k-e model as turbulent model and DTRM model as thermal radiation model. The atmospheric temperature was 40oC as severe conditions. And gravity effect was also considered.

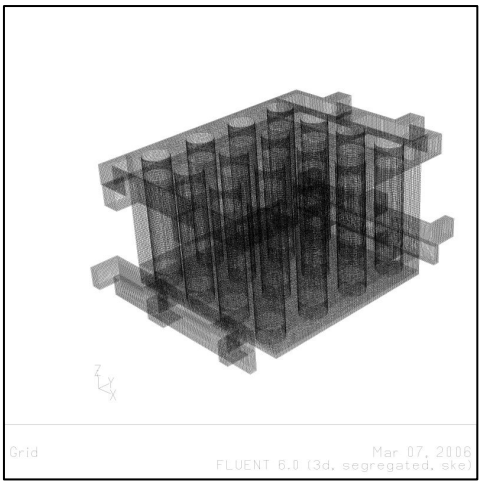

Figure 2 Numerical Model with hexagonal mesh

2.2 Normal Condition

At normal condition, temperature distribution shows the symmetry in figure 3. The location of maximum temperature was the side of the upper slab due to the stagnation of cooling air. The maximum temperature was 75.7 °C. In this case, the effect of hot basket was not important. The difference of maximum temperature between the case with the hot basket and without hot basket was just 1°C. Therefore, the key factor to decide the maximum temperature was the flow stagnation.

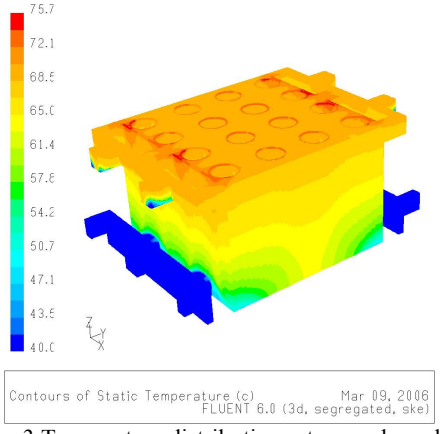

Figure 3 Temperature distributions at normal condition

2.3 Abnormal and Accident Condition

The definition of abnormal condition was the condition at which one air inlet is choked. In figure 4, the one left window of air inlet was choked. In this case, the maximum temperature was 79.17 ^{o}C. The location was the left side of upper slab. The maximum temperature was not over the limited temperature (93^{o}C locally for concrete).

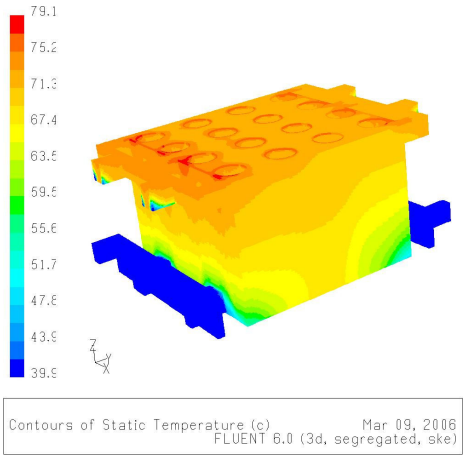

Figure 4 Temperature distributions at abnormal condition

The accident condition means that the all windows of onside of air inlet are choked. In figure 5, the windows are the left side windows. In this case, the maximum temperature was 84.03^{o}C. The location was the right side of upper slab. Figure 6 explain the change of the location of the maximum temperature. That is, the air at the right upper side was stagnated because the flow direction generated from right down windows to left upper windows by natural convection.

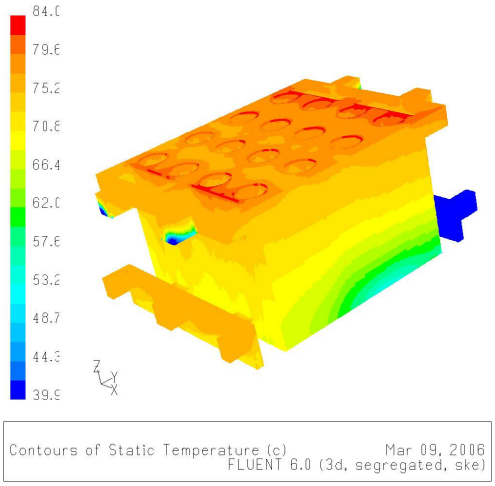

Figure 5 Temperature distributions at accident condition

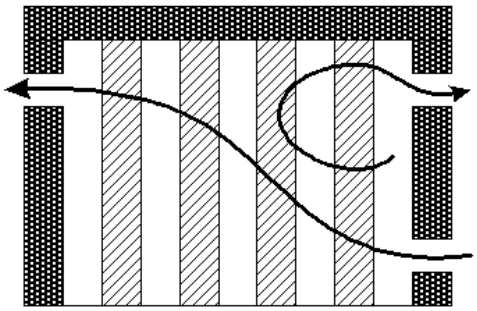

Figure 6 Flow directions at accident condition

3. Conclusion

From the thermal hydraulic analysis of MACSTOR/KN-400, the system satisfy temperature limit in the licensing requirement and design criteria. And, the analysis results by CATHENA are more conservative than by Fluent. But, for prediction of the concrete local temperature distribution, CFD analysis should be performed by 3-D CFD code like FLUENT.

REFERENCES

[1] Korea Nuclear Environment Technology Institute, Development of Consolidated Dry Storage System for CANDU Spent Fuel, 2004