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MARS-KS simulation for calculating the cooling capacity of spent fuel pool

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1. Introduction

The performance of MARS-KS (Multi-dimensional Analysis of Reactor Safety KINS Standard) code which has been developed for the realistic multi-dimensional system to estimate and evaluate the thermal hydraulic behavior of nuclear power plants was assessed in the present study by simulating the cooling capacity of SFP (spent fuel pool). Since the MARS-KS code can solve the multi-dimensional problem [1] unlike other system codes such as RELAP and TRACE etc., not only the averaged values like temperatures of outlet pipes but also the temperature and flow distributions can be obtained using that. The objective of this study is to evaluate the cooling capacity of the SFP in Ulchin NPP unit 3 in removing decay heat using MARS-KS code. An average temperature and temperature distribution were presented using multi-dimensional simulation in MARS-KS. To obtain an accurate representation of the couple flow and temperature fields, a 3-dimensional Computational Fluid Dynamics (CFD) analysis was normally used. [2] Therefore, the comparison between results from the MARS-KS and that of CFX was provided in this research.

2. Modeling Information

In order to evaluate the cooling capacity of spent fuel pool, the Ulchin NPP unit 3 which is one of the KSNP (Korea Standard Nuclear Plant) was simulated. Fig. 1 shows the schematic diagram of SFP in Ulchin unit 3. As shown in the figure, there are one inlet pipe which is located at the bottom of the pool and two outlet pipes which are located at 9.14m from the bottom. The region of fuel assemblies in the pool located bottom region of the SFP with a height of 4.7 m and it was segregated by two regions. Since the spent fuels are to locate in the region II in the normal operation, the region I simulated

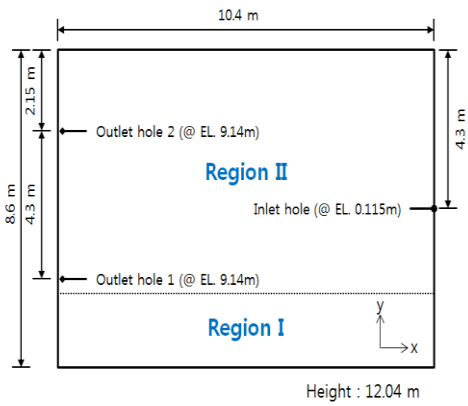


Fig. 1 Schematic (a sectional plan) of spent fuel pool in Ulchin NPP unit 3

as an empty racks. The fuel region is elevated to have its lower end 0.225 m above the pool bottom to describe the bottom space of the fuel racks. The spent fuel region was simulated as a porous media.

Figure 2 shows the nodalization diagram for the MARS-KS. The SFP is simulated as a multi-dimensional volume and there are three time dependent volumes and junctions to describe the inlet and outlet pipes. The SFP volume is divided by 8 volumes for x-direction, 9 volumes for y-direction, and 20 volumes for z-direction. The 56 heat structures are used for simulating the decay heat of the spent fuels only for region II. The number of spent fuel assemblies of the Ulchin NPP unit 3 is 824. The decay heat of the spent fuel assemblies was calculated by the ORIGEN-ARP code. [3] The k loss factors and frictions were input differently in order to simulate the flow resistance for the each region. The initial conditions were decided according to the FSAR [4]. Table 1 shows the initial conditions for the calculation. The simulations with 9 cases according to the flow rate of the inlet pipe were presented. (From 600 to 3000 gpm) In order to consider the heat and mass transfer from the top surface of the SFP, the heat transfer coefficient of a plane was input.

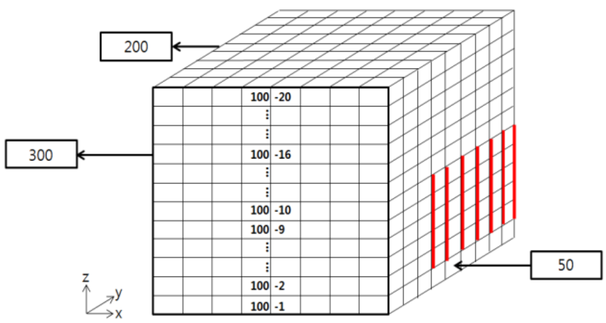


Fig. 2 Nodalization diagram of spent fuel pool in Ulchin NPP unit 3 for MARS-KS

Table 1 Initial conditions

Parameter	value
Water level of pool	12.04 m
Inlet flow rate	3000 gpm(standard) 600-3000 gpm(case study)
Inlet temperature	298.2 K
Initial pool temperature	303.2 K
Air condition (top surface)	308.2 K, 50% (RH)
Decay heat	1.51 MW

3. Simulation Results

Figure 3 shows the outlet temperature which is the average of temperatures from the two outlet pipes with various inlet flow rates. As shown in the figure when the flow rate reached more than certain amount, the outlet temperature was represented as cooled down lower than initial condition. Therefore, the SFP showed having enough cooling capacity with simulation conditions. These methods using MARS-KS code and its results could be applicable to verification for safety of the SFP.

Figure 4 provides temperature fields of the SFP. The case with enough flow rates such as case (a) showed lower temperature in the whole area than the case with less flow rates like case (b). As shown in the figure, water temperatures at the area near the entrance showed relatively lower. Moreover, the horizontally closer the distance is to the inlet pipe, the thicker cold water fields to the vertical direction showed. When the cold water flowed in the pool through the inlet pipe, the buoyancy driven by temperature differences induced the vertical flow. Therefore, the cold water flows to the horizontal direction at the bottom space of the pool were reduced by the buoyancy driven vertical flow. As shown in the figure 5 which represent the x-direction flow velocity on the line connected center of the inlet pipe and the opposite wall, when the distance from the inlet was getting farther, the flow velocity was sharply reduced by the buoyancy driven vertical flow especially in the near the entrance. The case with large amount of flow rate showed stronger buoyancy driven flow as shown in the figure 4(a) due to the bigger temperature differences. The results from MARS-KS showed fairly good agreement with that of the CFX.

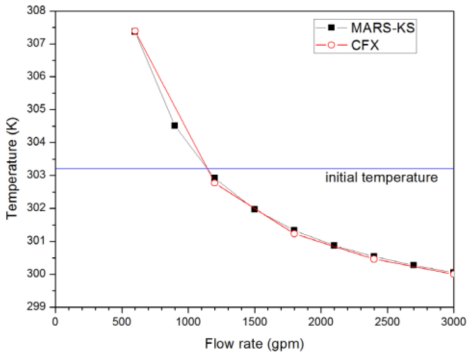
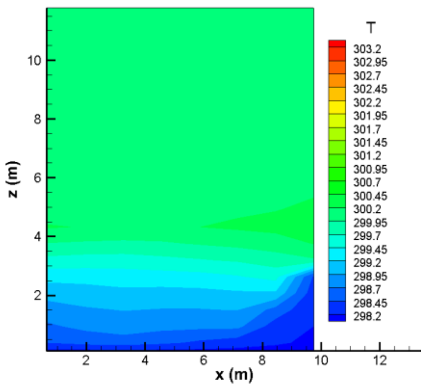
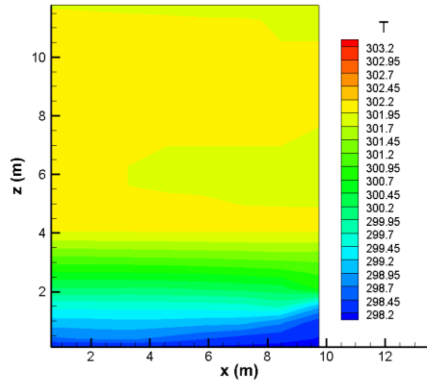


Fig. 3 Comparison of outlet temperature with various inlet flow rate



(a) 3000 gpm



(b) 1500 gpm

Fig. 4 Temperature contour of xz plane at y = 4.3m (center of inlet pipe)

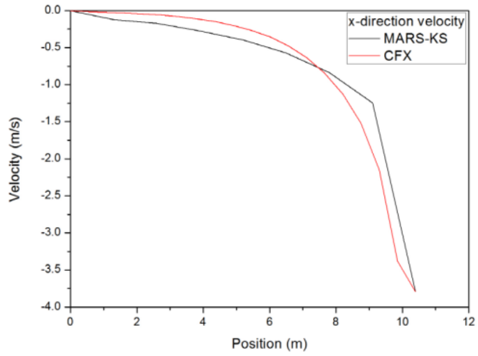


Fig. 5 X-direction velocity at y = 4.3m, z = 0.1125m (center of inlet pipe)

4. Conclusion

The cooling capacity and temperature field of SFP in Ulchin NPP unit 3 were simulated by the MARS-KS code. And the results were compared with CFD results. The cooling capacity with various inlet flow rates was provided, and the SFP showed having enough cooling capacity with the presented conditions. The temperature fields of the SFP were represented as influenced by the buoyancy driven flow. The results from MARS-KS showed fairly good agreement with that of the CFX. Therefore, it can be seen that the MARS-KS showed reasonable prediction for simulating the multi-dimensional thermal-hydraulic behavior in the SFP.

ACKNOWLEDGEMENTS

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