A Numerical Study of the Pool Cooling in a Research Reactor

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1. Introduction

Most of the research reactors are submerged in a pool [1-3]. The pool is the most noticeable feature in research reactors and provides an inherent safety feature to research reactors. The pool temperature would increase due to the heat transfer from the hot reactor vessel unless it is cooled by a cooling system. The cooling of the pool is accomplished by suction of the hot water from the pool and injection of the cold water to the pool. To minimize the pump capacity in a pool cooling system, it is desirable to have the water temperature as high as possible at the suction region in a pool. For a better understanding of the pool cooling methodology, a numerical study has been done to investigate the temperature profile in a pool. This result would be helpful in designing a pool cooling system in a research reactor.

2. Simulation Methods and Results

In this section the computational domain, numerical methods and the results are described.

2.1 Computational Domain

Fig. 1 shows the computational domain. For the purpose of this study, the pool and vessel geometry were simplified to a cylindrical volume. The cold water is injected through a hole on the reactor vessel. The pool water suction pipe is located opposite to the pool injection hole. The dimensions of the computational domain used in the numerical simulation are summarized in Table I.

The boundary conditions are shown in Table II. The heat flux through the pool wall side and upper water surface were assumed to be negligible. The hot reactor vessel surface will be the heat source and its temperature was assumed to be constant. The cold water is injected from the hole with a mass flow rate of 100kg/s and its temperature is 35℃. All the gradient of the fluid property except pressure were assumed to be zero at the outlet of the suction pipe.

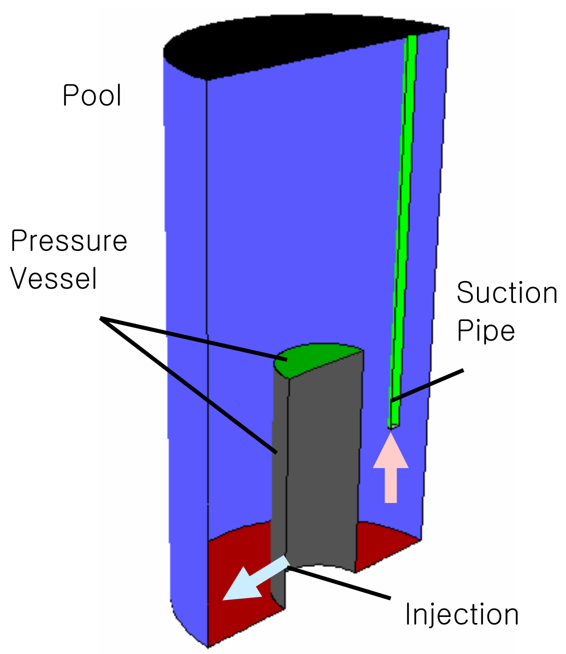

Fig. 1. Computational Domain

Table I: Dimensions of the Computational Domain

	Diameter(mm)	Height(mm)
Pool	6000	11000
Reactor Vessel	2000	5000
Injection Hole	254	-
Suction Pipe	254	-

Table II: Boundary Conditions

Pool Wall	Heat Flux (W/m^{2}K)	0
Reactor Vessel	Temperature (℃)	50
Injection Hole	Mass Flow rate (kg/s) Temperature (℃)	100 35
Suction Pipe outlet	Gradient except pressure	0

2.2 Numerical Methods

About 630000 hexahedral meshes were generated by using the commercial mesh generating program, GAMBIT 2.3. Only half of the pool was meshed since the geometry is symmetric. The simulation was conducted by using the commercial computational fluid dynamics code, FLUENT 6.3. Turbulent motion was simulated by using the standard $k-\varepsilon$ model [4] and the standard wall function [5] was used for the near-wall treatment. The buoyancy effect was also considered assuming piece-wise linear density variation with respect to the fluid temperature. SIMPLE [6] algorithm and second order upwind scheme were used for the simulation.

2.3 Results

Fig. 2 shows the temperature profile within the pool water. For a better view, the temperature range was adjusted to 35~36.5℃. The pool water temperature is in the range of 35~36.5℃ except very near the surface of the reactor vessel . The suction point temperature is 35.9℃.

It can be seen that the water temperature above the cold water injection hole is slightly higher than the other region. The flow directions due to the jet entrainment flow near the injection hole and the buoyancy driven flow on the hot reactor vessel surface are opposite. This would make the characteristic temperature field above the injection hole.

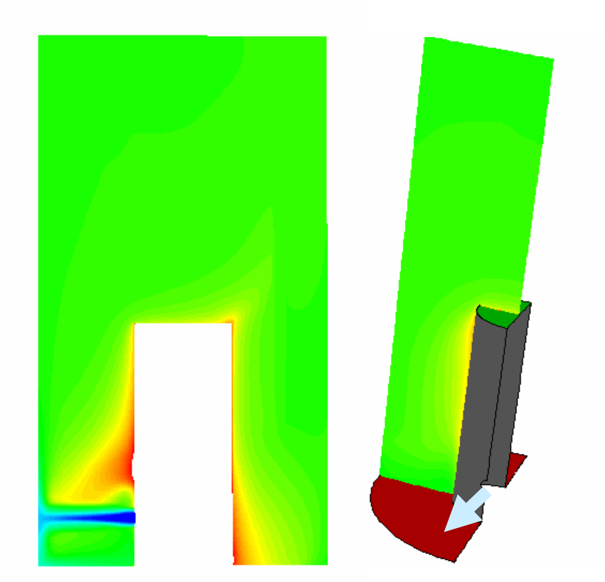

Fig. 2. Pool Water Temperature (Display Range: 35~36.5℃)

3. Conclusions

A numerical study has been done to investigate the temperature field in the pool water in which a research reactor is submerged. The calculation results show that the pool temperature variation is somewhat low except near the reactor vessel surface. This characteristic of the pool water temperature filed is established due to the heat balance between the pool cooling system's capacity and the heat transfer from the reactor vessel surface under the circumstance of pool water temperature distribution.

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