Platform Design inside the Reactor Pool for Stable Flow of the Hot Water Layer in the Research Reactor

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1. Introduction

Many research reactors are generally designed as an open pool type and a reactor structure assembly is installed on the bottom of the pool in consideration of the radiation shielding and accessibility to the reactor as shown in Fig. 1. A reactor pool is filled with the demineralized water. Water quality is controlled by the pool water management system. A reactor hall is designed as a normal work area. Therefore, reactor operators, researchers and engineers can assess the reactor pool top area while the reactor is in normal operation. The radiation level of this area is an important design parameter in the point of radiation safety.

In the many open-pool type research reactors, the hot water layer (HWL) at the upper part of the reactor pool is formed and maintained while the reactor is in normal operation. HWL temperature is maintained to be about 5~15 Celsius degree higher than the temperature of the primary coolant near the reactor structure assembly. Temperature gradient will be established from the HWL to the lower pool water when the HWL is formed at the upper part of the pool. This temperature gradient suppresses the rise of lower pool water to the surface by natural circulation. Floating up of the ionized radioactive products with the primary coolant to the pool surface is prevented by this HWL so as to minimize the pool top radiation level. One of design objects of the HWL is that the radiation level near the pool top should be maintained as low as reasonably achievable (ALARA) which is a design principle of radiation protection. Therefore, the personnel can work safely near the pool top area while the reactor is in normal operation. Research reactors such as HANARO in South Korea, JRTR in Jordan, RMB in Brazil and OPAL in Australia adopt this system.

2. Reactor Pool and Platform

Design of the stable flow fields of the primary coolant at the lower part of the reactor pool is required because this flow fields affect the HWL and the radiation level on the pool surface. In the previous research [4]~[5], duct type discharge header is designed to dump the primary coolant into the reactor pool. Discharge header is the important design factor to make flow field stable at the lower part of the reactor pool.

The platform is installed at the middle of the reactor pool as shown in Fig. 1. Main purpose of the platform is to provide the working area when maintenance tasks are required. Other function of the platform is to confine the main flow field of the discharged primary coolant under the platform. But, the primary coolant can flow through the platform because there are a hole on the center of the platform for the reactor utilization and a gap between the pool liner and platform. The size of the gap is 100mm around the platform for the installation paths of the small pipelines and instrument cables. The effect of the platform on HWL formation is evaluated numerically in this research.

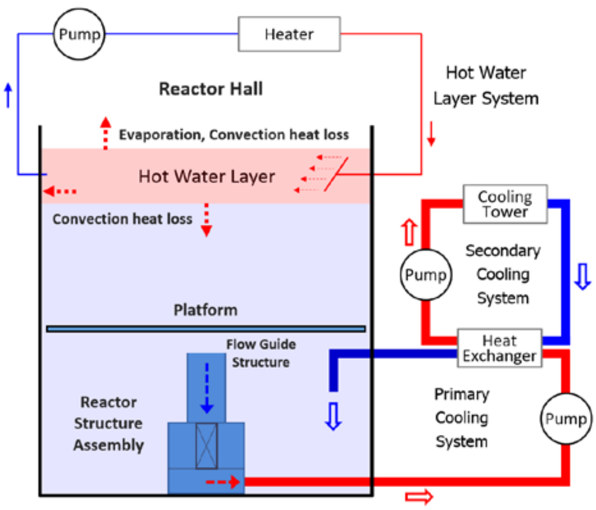

Figure 1. Schematic diagram of the reactor pool and related cooling system and the hot water layer system

3. Calculation Conditions

Heat balance, velocity and temperature fields are taken into consideration to evaluate the formation of the stable HWL and primary coolant based on the numerical simulation results. Commercial CFD tool, FLUENT 13, is used for thermal-hydraulic analysis in the reactor pool. Boundary conditions and the computational domain are shown in Fig. 2.

The unsteady 3-D flow fields are numerically simulated to observe thermal-hydraulic characteristics. Working fluid is the light water. Mass flow rate of 200kg/s and temperature of 37℃ are given on the inlet boundary condition of the pool inlet primary coolant. These conditions are determined based on the safety analysis results to cool the fuel assembly sufficiently. In the previous study, operating conditions of the HWL system are calculated and applied. Mass flow rate of 1kg/s and temperature of 48℃ are used for the inlet boundary condition of the pool inlet hot water to maintain the HWL. Pressure outlet conditions with the flow rate ratio are used for the outlet of the primary coolant and hot water, respectively. Free slip with the heat flux conditions is used for the reactor pool surface. The heat flux are calculated from the surface area and heat loss. Non-slip with adiabatic condition is applied to the other regions. The velocity of 0m/s and temperature of 37℃ are set as the initial conditions in the whole reactor pool.

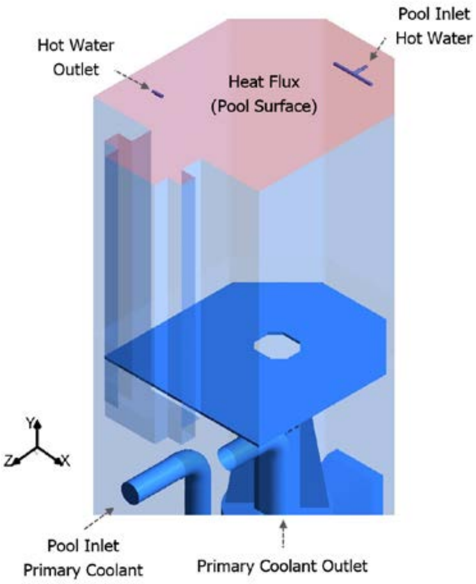

Figure 2. Boundary conditions and computational domain

4. Flow field analysis of the reactor pool

The flow field of the reactor pool is calculated without the primary coolant flow for 24 hours of the simulation time to form the HWL at the upper part of the reactor pool. The same results are calculated regardless of the different types of the platform because there is no HWL flow near the platform. The average velocity of about 0.03m/s and the average temperature of about 46℃ are developed at the upper part of the pool as shown in Fig. 3. This flow region is called HWL. It takes about 15 hours to form the stable HWL.

These results are used as initial conditions to study the effect of the primary coolant flow with the different type of the platform in the reactor pool. Primary coolant starts to flow while the HWL system flow with the constant mass flow rate and temperature are maintained.

Figure 4 shows the velocity and temperature fields on the middle plane of the reactor pool. When the platform is installed, HWL is well maintained. But, when the platform is not installed, the thickness of the HWL is about half time thinner than that of the HWL with the platform.

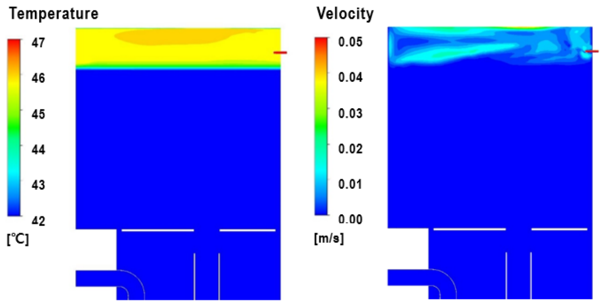

Figure 3. Velocity and temperature contours of the HWL

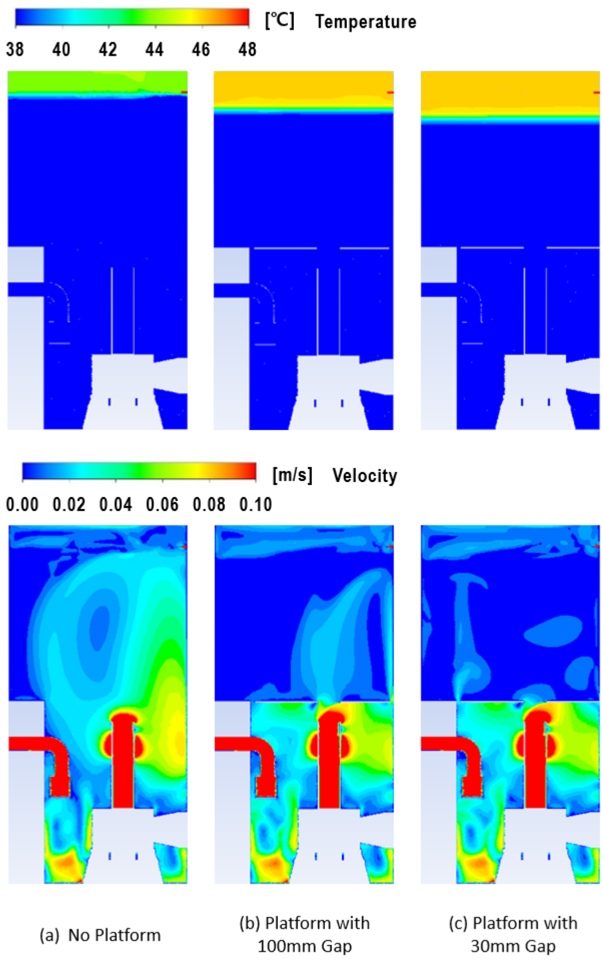

Figure 4. Velocity and temperature contours of the reactor pool with the different types of the platform

Gap size of the front side of the platform is adjusted to 30mm to suppress the main flow of the primary coolant. Adjustment of the gap size is possible in this region because there is no pipeline. Flow pattern of the reactor pool is changed when the gap size is adjusted from 100mm to 30mm. Primary coolant flow is suppressed through the front gap as shown in Fig. 4. Therefore, flow field above the platform is stabilized.

5. Conclusions

In this research, flow fields of HWL and primary coolant flow are simulated in the reactor pool. Geometry of the reactor pool, reactor structure assembly and primary coolant discharge header are taken into consideration for the calculation model. The platform designs are compared to determine the platform design requirements and design concept inside the reactor pool.

Platform with the thinner gap size is necessary to make flow fields of the primary coolant and HWL stable in the reactor pool.

ACKNOWLEDGEMENT

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