A Study of HANARO Flow Fields

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1. Introduction

HANARO is an open-tank-in-pool type research reactor. Recently, it is necessary to develop a three-dimensional computational fluid dynamics (CFD) model for predicting the coolant flow patterns and investigation of the thermal-hydraulic conditions inside the reactor pool of HANARO. In this study, the steady state simulation for the coolant flow behavior is performed by CFX-5, a commercial CFD code developed by AEA technology. As a result of the CFD computation, the velocity field of HANARO under normal operating conditions is presented and the change of the flow pattern inside the reactor pool is reasonable.

2. Calculation Method and Results

2.1 HANARO Reactor Cooling System

HANARO reactor pool is cylindrical and its size is 4m in diameter and 12.2m in depth filled with demineralized water. The structure assembly is submerged in the reactor pool. It consists of five major components which are the inlet plenum, the lower grid plate, flow tubes, the reflector tank, and the chimney [1,2]. Figure 1 illustrates the main features of the HANARO reactor structure assembly.

The 2m diameter and 60cm height, stainless steel inlet plenum, bolt-jointed to the bottom of pool, supports weight of the other reactor structure components and uniformly distributes cold inlet coolant to each flow channels. The grid plate made of stainless steel holds fuel assemblies and in-core experimental facilities. The 2m diameter and 1.2m height zircaloy tank containing D_2O surrounds the reactor core and accommodates various vertical and horizontal experimental holes. In the aluminum outlet chimney in the hexagonal form, heated core up-flow is mixed with cold down-coming bypass flow and sucked out through a pair of angled outlet nozzles. Circular or hexagonal shaped zircaloy flow tubes function as either fuel channels when fuel assemblies are loaded, or flux traps when vacant. Total 31 removable flow tubes arranged in honeycomb lattice form in the inner core. Eight fixed flow tubes embedded in the reflector tank are available for additional fuel loading, which is called the outer core.

Inside the reactor pool, the primary cooling system circulates demineralized water to the reactor inlet plenum. The water from the inlet plenum then flows vertically up through the reactor fuel channels removing the heat produced by fission in the fuel. It exits from the core into the chimney, rises vertically to the two primary coolant pump suction pipe nozzles, one on each side of the chimney wall just above the core outlet. In the chimney the core coolant merges the bypass flow coming down through the chimney opening from the reactor pool.

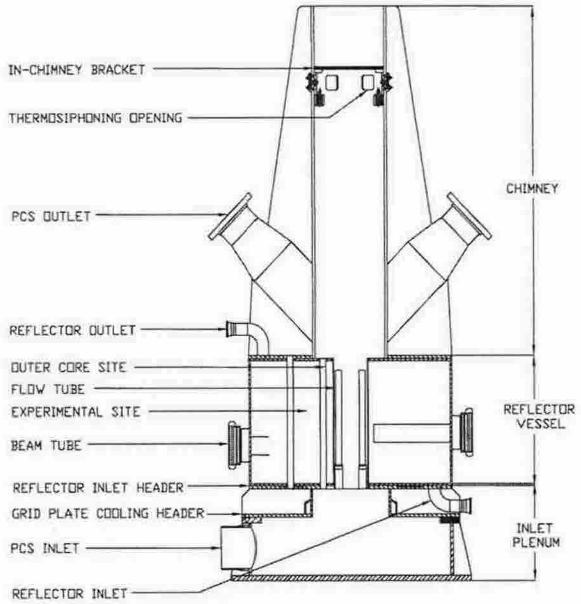

Figure 1. Vertical cross sectional view of the HANARO reactor structure assembly.

2.2 CFD Analysis Model

For the computational model, it is necessary to generate two calculation domains; one is a IC with the inlet plenum, lower grid plate and chimney, and the other is a FT with the flow tubes. The reflector tank model is excluded in this work. Because heavy water (D_2O) is circulated in the reflector tank as a different loop. The number of total computational elements is 2,296,000. In order to accomplish these computations, first it is essential to determine certain boundary conditions. Numerical and physical parameters are set to the model. The inlet plenum is defined as INLET type patch with the inlet mass flow rate of 703 kg/s and the each outlet nozzle is defined as OUTLET type patch with the mass flow rate of 390 kg/s uniformly. The wall of the inactive part of the chimney is defined as WALL type patch with the smooth and no slip.

For the analysis of a turbulent flow, the standard k-εmodel is used in this study. The convergence criteria are the enthalpy residual reduction of 10^{-4} and the largest mass residual of 10^{-5}. The physical timescale is 0.05sec. The maximum number of steady computation iterations is 200. In this simulation, the working fluid is water at 1atm. The properties are set as uniform and constant. The steady state computation using CFX-5 [3,4] is performed on a PC.

Figure 2 shows the flow pattern of the HANARO under normal operating conditions in the x-y cut plane (z = 0 plane). In the bottom of the pool, relatively large velocity flow compared to other part of the pool is induced at the inlet plenum. Pool water is merged inside the chimney and then exits through the outlet with relatively large speeds. Otherwise, some pool water is seen to go down slowly through the top opening of the chimney. The bottom of the flow tubes is shown that the velocity distribution is the most significant of the 12.2 m/s compared to the other region. Pool water from the inlet plenum is passed through the each fuel channel rapidly for the narrow gaps.

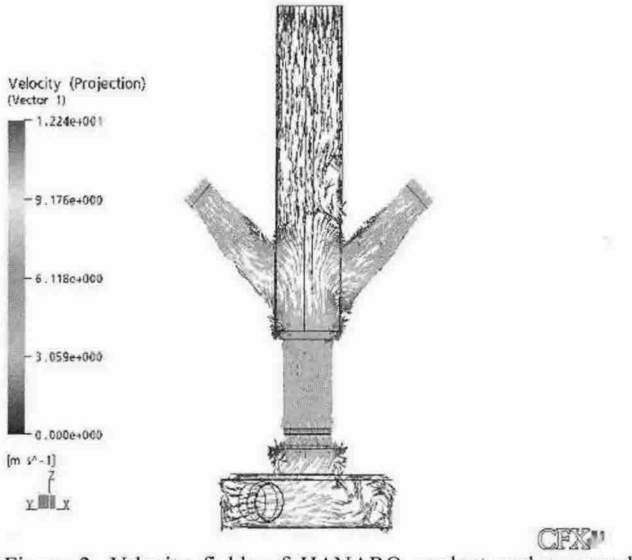

Figure 2. Velocity fields of HANARO coolant under normal operating conditions.

3. Conclusions

In this study, the HANARO analysis model using CFX-5 is established and the simulation for predicting the flow field in the reactor cooling system is performed. The velocity field of the simulation result is presented. The simulated result is well predicted the flow patterns for the velocity distributions.

Acknowledgement

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