Numerical Simulation on Intermediate Heat Exchanger at Low Flowrate Condition in PGSFR

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) has been developing a conceptual design of the prototype gen-IV sodium-cooled fast reactor (PGSFR), the pool type sodium cooled fast reactor. Primary Heat Transfer System (PHTS) transfer heat from the core to the Intermediate Heat Transfer System (IHTS) through the Intermediate Heat Exchanger (IHX), isolating the PHTS radioactive sodium from the non-radioactive sodium of the IHTS. Figure 1 shows schematic of IHX.

KAERI developed the SHXSA code, a one-dimensional design and performance analysis code, for the design of heat exchanger. The CFD was used to preliminarily analysis for the heat transfer characteristics and pressure drop, and the heat transfer characteristics and the pressure drop were verified by performing the heat transfer experiment and the flow characteristics experimental test[1~3]. The problem caused by the local temperature variation that can not be verified by the one-dimensional code was raised, that problem was solved by the flow mixer designed by three-dimensional CFD analysis [4].

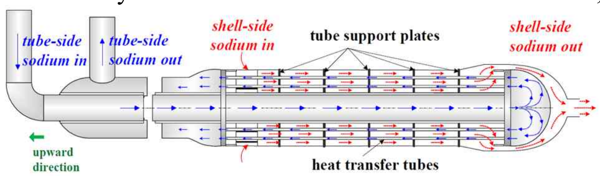

Fig. 1. Schematic view of IHX

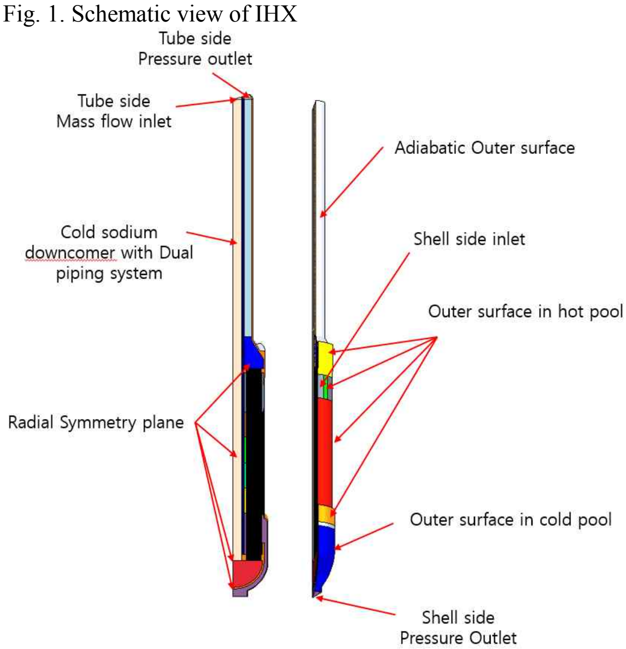

Fig. 2. Boundary conditions of analysis region

In this paper, we compare the CFD analysis results with the flow characteristics test results at low flowrate condition including normal operating condition, and examine how the design of the flow mixer affects the wall temperature under low flowrate conditions.

2. Methods and Results

In this section the analytical method used for CFD analysis and comparison with the CFD analysis results with the flow characteristics test results at low flowrate conditions are described.

Table I: Boundary conditions

Boundary	Boundary Condition
Inlet(Tube side)	332.3℃, 9.8~36.8 kg/s (30~113%)
Inlet(Shell side)	545℃, 12.4~46.7 kg/s (30~113%)
Ar layer	Radiation
Shroud surface (Outer surface in hot pool)	545℃
Shroud surface (Outer surface in cold pool)	390℃
Outlet(Tube side)	0 Pa
Outlet(Shell side)	0 Pa

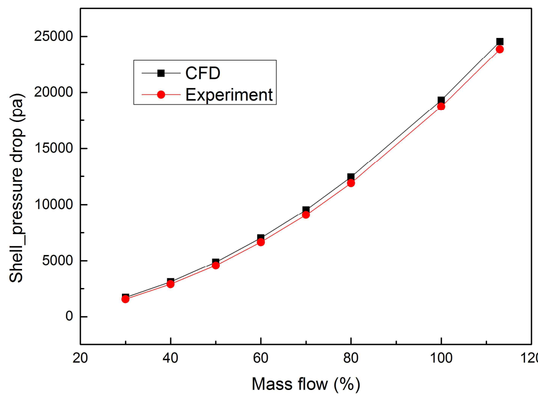

Fig. 3. IHX shell side pressure drop with mass flowrate variation

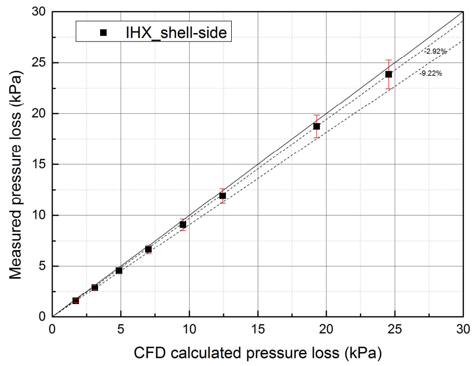

Fig. 4. IHX shell side pressure drop comparison CFD result and Measured

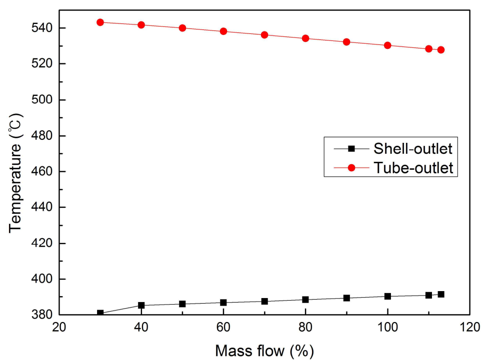

Fig. 5. IHX outlet temperature

2.1 Methods

The CFD model for the analysis was made by modifying the boundary conditions in the model made for the flow mixer design [4]. The analysis region and boundary conditions are shown in the Fig. 2. The analysis region is 1/12 of IHX, and about 40million meshes generated through the mesh test are used. CFD analysis was performed using STAR-CCM+ 11.02.009 commercial software. Table I shows the specific boundary condition.

2.2 Results

The shell side pressure drop data obtained by the CFD analysis are compared with experimental data and shown in Fig. 3 and Fig. 4. Figure 3 compared the pressure drop according to the flowrate, Figure 4 compared the CFD analytical pressure drop and the experimental pressure drop. The error between the experimental data and the CFD analysis was found to be similar from the lowest of 2.92% to the maximum of 9.22%, all of which were within the error range that can be measured.

Figure 5 shows the outlet temperature of the shell side and tube side according to the mass flowrate, and Fig. 6 shows the temperature difference between the inside and

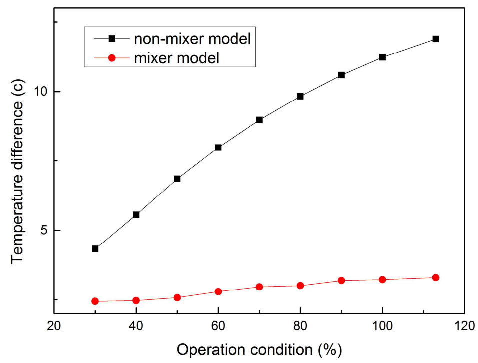

Fig. 6. IHX tube outlet temperature difference between inside and outside wall

outside wall of the tube side outlet according to the operating conditions when the mixer was exist or absence. At the smaller flow rate, sodium stagnates in the heat transfer region longer time than the larger temperature difference becomes between the tube side outlet and the shell side outlet. This is also related to the temperature difference between the inside and outside wall of tube outlet. As the flowrate becomes smaller, the flow velocity becomes slower and the heat transfer rate per mass flow rate becomes faster, so that the temperature difference between the inside and outside wall of the tube outlet is reduced. It can be seen from Fig. 6, the existence of a flow mixer greater effect on the temperature difference between the inside and outside of the tube outlet at higher flow rate than at lower flow rate condition.

3. Conclusions

In this paper, the heat flow characteristics of the intermediate heat exchanger under low flowrate conditions are evaluated by CFD simulation. The verification of the analysis was confirmed by comparing with the results of the flow characteristic experimental test, and CFD results shows that the flow mixer of tube outlet had a significant influence to the temperature difference between the inside and outside wall of the tube outlet at high flow rate condition.

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