Design Improvement in a Pump Intake in Prototype Gen-IV Sodium Cooled Fast Reactor using Computational Fluid Dynamics

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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. Preliminary Heat Transfer System (PHTS) transfer heat from the core to the Intermediate heat transfer system through the Intermediate Heat Exchanger (IHX) and there are two pumps to form the flow path. The schematic view of PHTS is shown in Fig. 1. In this study flow analysis was performed on the detailed shape of the pump intake in PHTS using CFD. The pressure drop and flow uniformity according to the length and bending of pump intake were evaluated and reflected in the design of PGSFR [1].

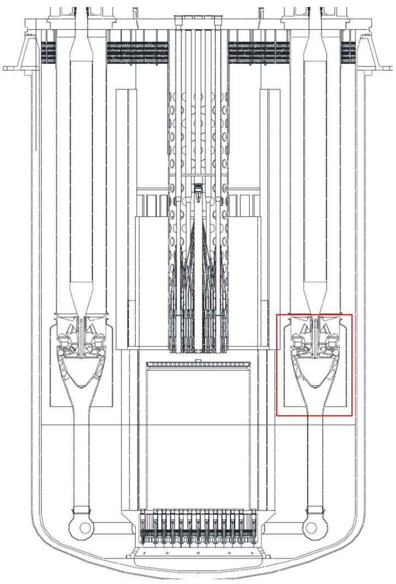
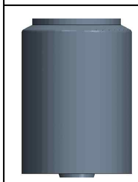
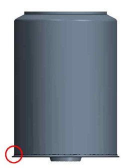
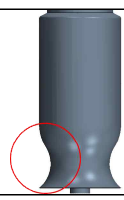


Fig. 1. Schematic view of PHTS

Table I: Tested pump intake geometries

Case 1	Case 2	Case 3	Case 4
			

2. Methods and Results

To Analysis the fluid characteristics depends on the pump intake design four cases are selected as shown Table I. Case 1, is the existing straight intake shape, case 2 has the radius of curvature of 0.05m, and case 3 is the shape along the recommended radius of 0.5D from HI standard [2], case 4 is a shape using the radius of curvature of reference [3].

2.1 Analysis Methods

Analysis region shown in Fig. 2 is cold pool area of 390℃rom the IHX outlet to the inlet of the pump impeller. The 1/2 shape is used for economical calculation and the circumferential boundary is the symmetry boundary condition. Numerical simulations were conducted at sodium flow path using the commercial computational fluid dynamics package, STAR-CCM+ v11.02.009. The polyhedral mesh is used, and three prism layers are applied at near wall region. Depending on the analysis case, about 11~13 million mesh were used. The assumptions and analysis method used for analysis are as follows.

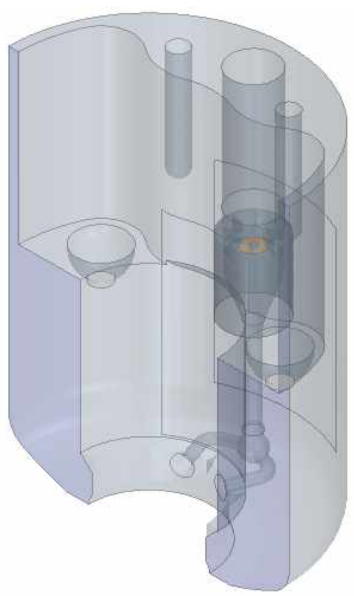


Fig. 2. 3D view of analysis region

- 1/2 symmetric 3D steady state calculation
- Turbulent model: Realizable k-ε Two-Layer Model

- Fixed Temperature at 390℃

The boundary conditions are as follows.
- Inlet Mass flow rate: 496.05kg/s
- Pressure Outlet (0 pa)

2.2 Results

The CFD simulation results are shown in Fig. 3 and 4. Fig. 3 shows vertical flow velocity distribution for each case, and Fig. 4 shows pressure drop and flow uniformity for each case. In all cases, vortex is generated, but in case 2, the smallest vortex occurs.

Typically, the flow uniformity of intake is designed to be more than 95%. Here, the flow uniformity is defined as follows.

$$Velocity\,uniformity\,[\%] = \left\{1 - \frac{\left(\sum_f |u_j - \overline{u_j}| A_f\right)}{2|\overline{u_j}|\sum_f A_j}\right\} \quad (1)$$

Four cases are satisfied the flow uniformity of 95% or more. The shape of case 2 was reflected in design, it shows smallest vortex and pressure drop, and most uniform flow.

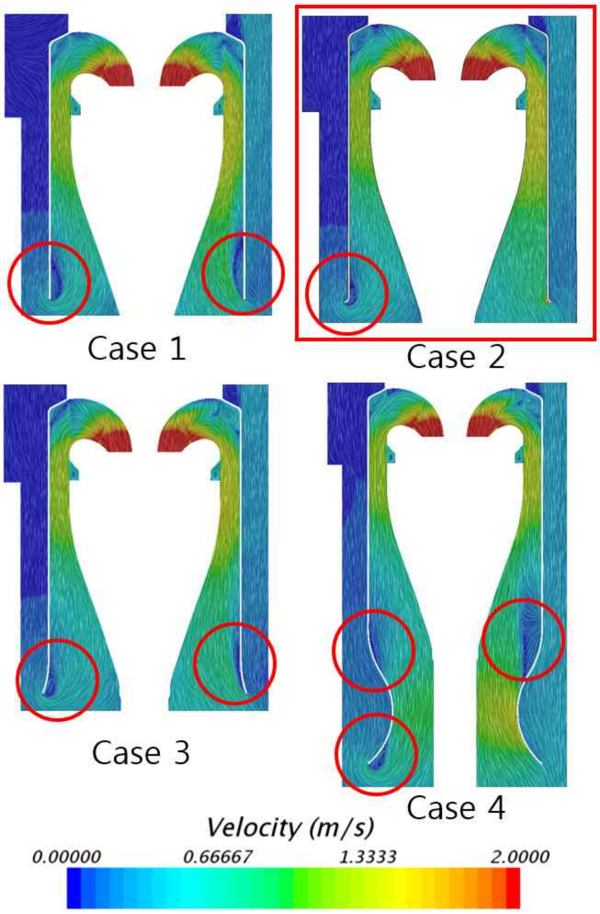


Fig. 3. Vertical distribution at vertical plane

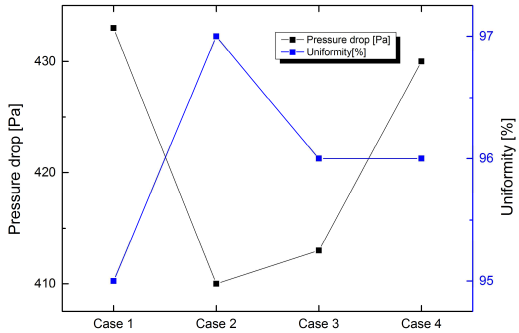


Fig. 4. Pressure drop and uniformity comparison

3. Conclusions

This paper the flow characteristics of PHTS pump is evaluated using CFD simulation for optimum design of pump intake. Four different pump intake were applied and flow characteristics were compared. By considering pressure drop and flow uniformity, the optimum design was chosen as case 2. It is expected that this results will be applied to the PHTS pump intake design of PGSFR.

ACKNOWLEDGEMENT

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