Transactions of the Korean Nuclear Society Autumn Meeting
Goyang, Korea, October 24-25, 2019

Flow Visualization of Inlet and Outlet of Intermediate Heat Exchanger for PGSFR

Woo Shik Kim, Yong Seok Choi, and Dong-Jin Euh
Korea Atomic Energy Research Institute
wooshik@kaeri.re.kr, cys@kaeri.re.kr, djeuh@kaeri.re.kr

1. Introduction

In order to quantify the flow distribution characteristics of Prototype Gen-IV Sodium-cooled Fast Reactor (PGSFR), a test facility, named "Pressure and Core Flow Distribution for PGSFR" (PRESCO) had been constructed, and hydrodynamic tests were conducted under several inlet flow conditions. [1] The test facility was designed based on the 1/5 linear scale, shape and Eu number preservation. In the present study, the Particle Image Velocimetry (PIV) technique was used for visualization inside of the PRESCO test section. Visualization windows and laser guides were installed to measure the velocity fields of the two regions; inflow inside IHX (Intermediate Heat Exchanger) inlet windows; IHX outlet discharging flow. The flow visualization results were compared with CFD results. [2]

2. Methodology for flow visualization of inlet and outlet of IHX

There are 4 IHXs in the PGSFR as well as PRESCO test section. The flow visualization was conducted one of the IHX simulators of PRESCO test section. The upper wall of the IHX simulator has been modified and installed to visualize the flow inside the IHX window as shown in Fig. 1. The laser beam was delivered through optical fiber and the laser sheet was generated at the center height position of the inlet window. The laser sheet is illuminated in a radial direction, utilizing the space protruding lower into the center, and the flow area between the protruding and the inner wall of the IHX windows is photographed with a CCD camera to obtain velocity field data. When performing the visualization in this way, the angle of the laser sheet and the field of view of the CCD camera were limited, so the laser and camera were rotated in a circular direction and visualized images were taken sequentially to measure the velocity field for whole cross-sectional area.

For the visualization of IHX exit discharge flow, two transparent windows were installed perpendicular to each other at the bottom of the reactor vessel as shown in Fig. 2. These two windows are used for laser emission and CCD camera imaging respectively. The windows are made of polycarbonate material with a thickness of 20 mm. The PIV system consists of pulse laser, CCD camera, synchronizing device, tracer particle and optical devices. The laser is a dual-head type Nd-YAG pulsed laser with a wavelength of 532 nm and an energy output per pulse is about 200 mJ. Each head of a laser is independently capable of repetitive laser oscillations up to 15 Hz per second. A high-resolution CCD cameras equipped with double frame acquisition function so that PIV method can be applied. The resolution of the CCD is 2048×2048 pixels. The synchronizing device allows the acquisition of two consecutive particle images by separating each head of the pulse laser by a short time internal of Δt and synchronizing the frame action of the camera with the laser emission. The minimum time resolution of the synchronization device used is 1 ns. The fluorescent polymer particles of about 24 μm in diameter were used as the tracer particle. The surface of the particles is coated with Rhodamine B, which is fluorescent with a wave length of more than 550 nm after being excited by a wave length with 532 nm. The lens of the CCD camera is equipped with a band filter that passes only over 550 nm of wavelength, recording images of fluorescent particles, which allows the removal of background images and laser scattering light caused by reflection on the surface of the test section, and the acquisition of high quality particle images. The optical unit extends the laser beam with a diameter of approximately 1 mm to the sheet beam to excite the particles in the flow on a 2D plane. The circumferential convex lens and concave lens are properly positioned to control the thickness and width of the laser sheet, and the optimal laser sheet beam is formed through fine adjustment.

3. Results

Flow inside the IHX inlet is visualized for a total 12 IHX inlet windows. Fig. 3 shows the measured velocity fields. The velocity across the inlet windows ranged from 0.2 m/s to 0.3 m/s. In the region oriented to the core (windows 1, 2, 9~12), the magnitude of velocity tended to higher than the other region. The deviation of the velocity was about 0.1 m/s. Similar trend was observed in the CFD calculation results. Fig. 4 shows the magnitude of radial velocity estimated from CFD data. The CFD data also shows about 0.3 m/s and 0.2 m/s of velocity magnitude in maximum and minimum, respectively.

Fig. 5 shows the velocity field for the IHX outlet discharging flow. The discharging velocity was about 1.6 m/s in maximum. As shown in the direction of the velocity vector in R2 and L2 plane, weak rotating flow motion was observed. In the CFD results, magnitude of the discharging velocity was also 1.6 m/s in maximum, and also the rotating motion and its direction was well agreed with the PIV measurement data.

4. Conclusion

In the present study, flow visualization was conducted for IHX inlet window inflow and IHX outlet discharging flow using PIV technique.

The deviation of the velocity passing through each IHX inlet window was revealed to be about 0.1 m/s, which could be observed from both PIV measurement and CFD results. It is necessary to investigate the effect of this amount of deviation on the performance of the IHX.

The magnitude of the discharging velocity in the IHX outlet region was about 1.6 m/s, and the weak rotating motion was observed. This flow characteristic showed good agreement between PIV measurement and CFD results.

REFERENCES

[1] Kim, W.S., Chang, S.K., Youn, Y.J., Park, J.K., Choi, H.S., Kim, J.U., Hong, S.H., Seol, H.S., Euh, D.J., Report of SFR Reactor Flow Distribution Test, KAERI/TR-6952/2017, KAERI, 2018.

[2] Kim, W.S., Chang, S.K., Euh, D.J., Jeon, C.H., Ryu, J.B., , CFD Calculation for Preliminary Analysis of SFR Reactor Flow Distribution Test, KAERI/TR-6954/2017, KAERI, 2017.

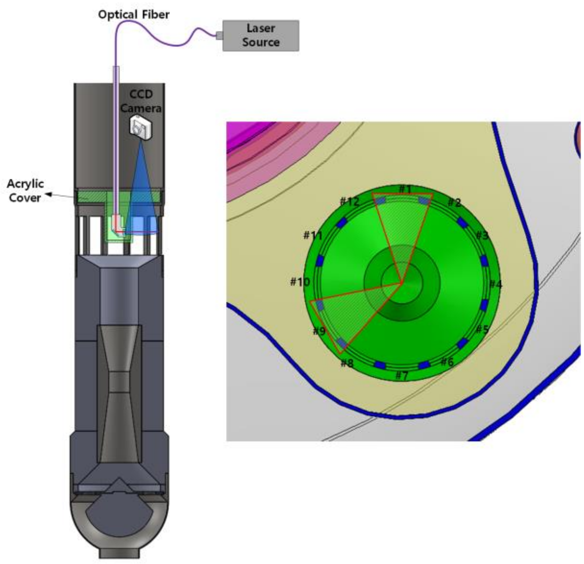


Figure 1 Visualization method for IHX inlet window inflow

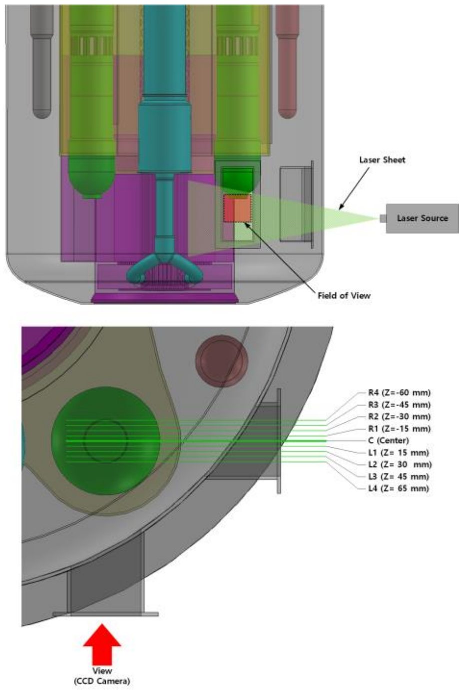


Figure 2 Visualization method for IHX outlet discharging flow

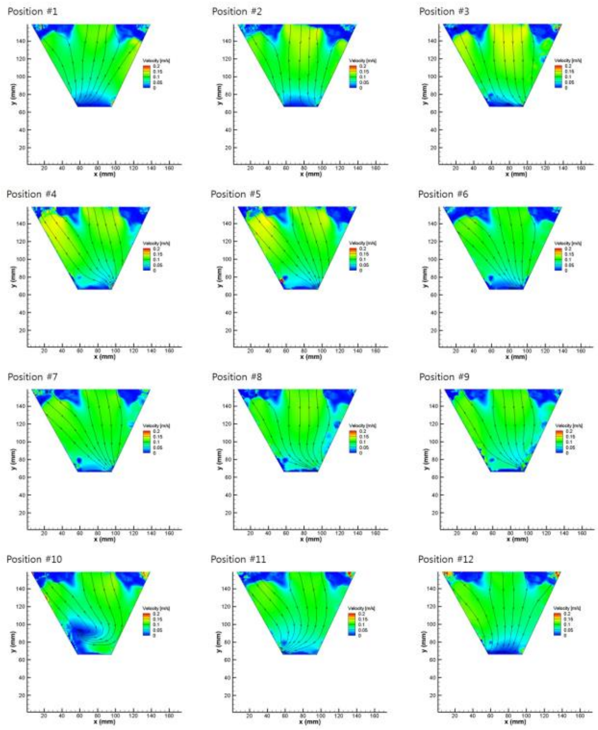


Figure 3 Velocity field for IHX inlet window inflow

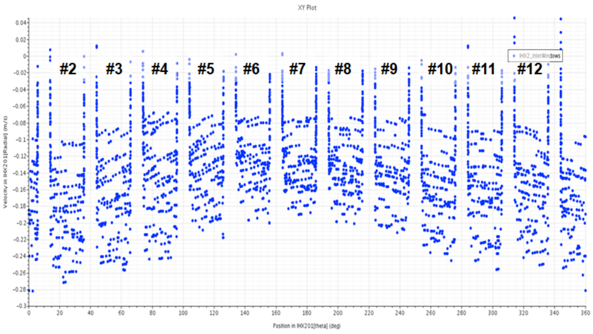
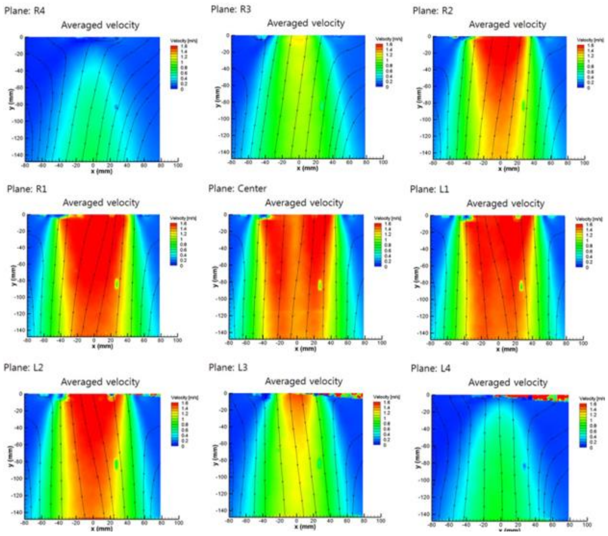
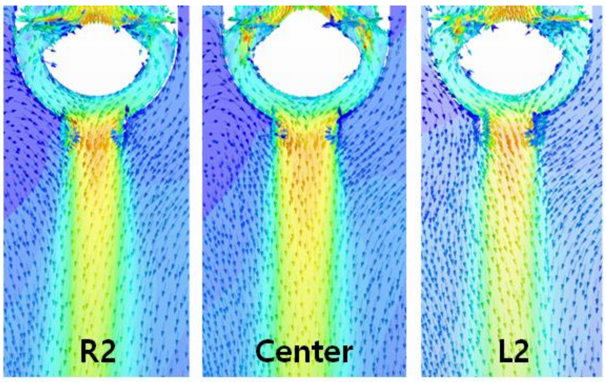


Figure 4 Velocity distribution across IHX inlet windows (CFD results)



(a) PIV



(b) CFD

Figure 5 Velocity field for IHX outlet discharging flow