Measurement of flow uniformity in the heat exchanger design for a SFR steam generator

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1. INTRODUCTION

The Korea Atomic Energy Research Institute (KAERI) has performed research and development on the Sodium-cooled Fast Reactor (SFR) as a next generation reactor, and proposed the Copper Bonded Steam Generator (CBSG) as an optimal steam generator with the lowest Sodium-water Reaction (SWR) occurrence among the candidates: Double Walled Tube Steam Generator (DWTSG), Double Tube Bundle Steam Generator (DTBSG) and CBSG [1-2].

CBSG consists of cross flow heat exchanger modules, where heat transfer occurs between hot sodium flowing through horizontal channels and cold water flowing through vertical channels. Uniform sodium flows through horizontal channels are needed to improve the heat transfer performance.

Recently, Nguyen et al. [2] numerically showed that a perforated plate could yield considerable increase in the flow uniformity in the sodium channel side.

The purpose of this study is to show the effect of the perforated plate on the flow uniformity improvement with help of particle image velocimetry. Water is used for working fluid.

2. EXPERIMENTAL SETUP

Fig. 1. shows the 1/4 scale CBSG heat exchanger unit and the perforated plate. Water enters the inlet header and is distributed into 66x33 horizontal channels. Each channel is of 4.5 mm x 4.5 mm and the distance between two adjacent channels is 1.2 mm. The volume flow rate measured using a magnetic flow meter, and the pressure drop between the test section was measured using a differential pressure gauge.

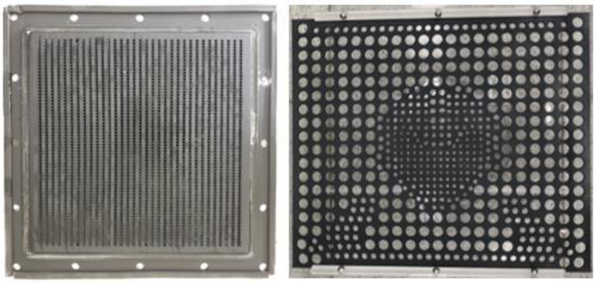


Fig. 1. Test section of CBSG heat exchanger unit and the perforated plate

Fig. 2. Experimental setup

3. RESULT AND DISCUSSION

Fig. 3 indicates the position of the vertical middle and side planes where measurement is made. Fig. 4 shows numerical simulation results of the velocity vectors for the original design, and Fig. 5 for the proposed design with a perforated plate.

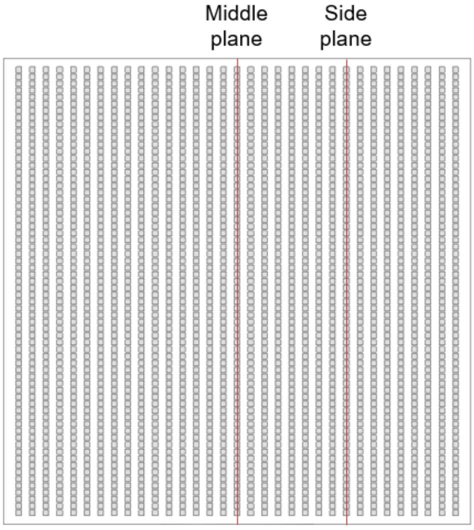


Fig. 3. The position of middle and side plane

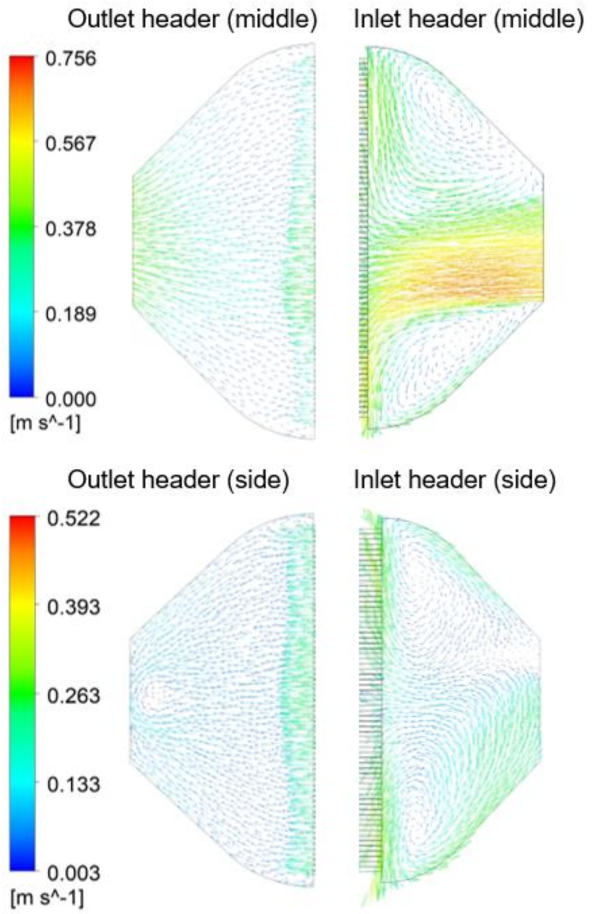


Fig. 4. The velocity field in the vertical middle and side planes in the inlet and outlet headers for original design

Because the perforated plate distributes the flow from the center to the side, the flow velocity at the outlet becomes more uniform than before.

Particle image velocity (PIV) was used to measure the planar velocity fields. For this, a high-speed camera and a green continuous laser (8W) were used. The PIV images were analyzed using correlation-based correction [3] and multigrid method [4] based on C++ code developed by Chungnam National University.

A velocity profile was measured at a distance of 20 mm from the channel outlet. Comparison of horizontal velocities between simulation and experiment are shown in Fig. 6 and 7. In the original design, the middle plane shows a higher velocity compared to the side plane. The average velocity at the middle and side planes are about 0.0733 m/s and 0.0543 m/s, respectively. This large difference means the non-uniformity of the flow. On the other hand, it is shown in Fig. 7 that the average velocities in the middle and side planes are 0.0546 m/s and 0.0655 m/s, respectively. The velocity difference becomes smaller compared to the original design. This means that the flow uniformity is improved.

A detailed discussion on flow uniformity will be presented in the conference.

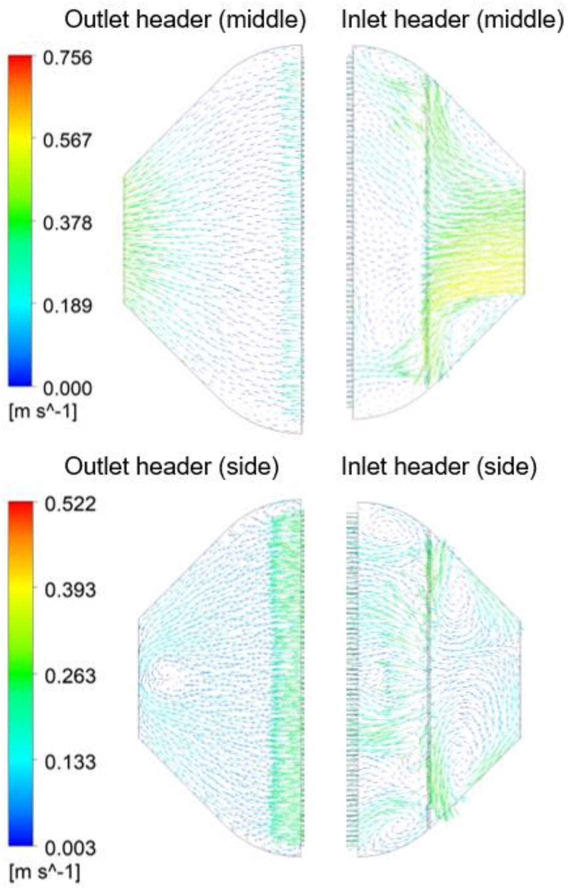


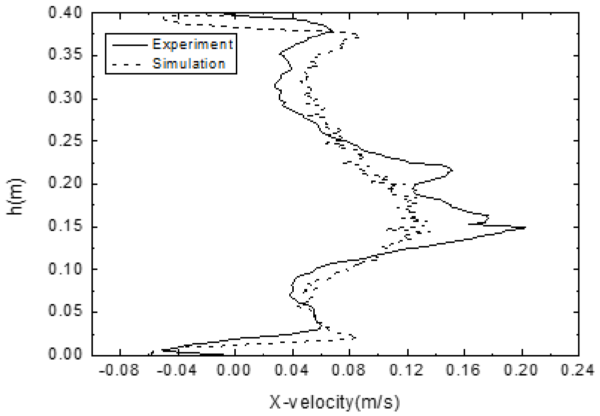
Fig. 5. The velocity field in the vertical middle and side planes in the inlet and outlet headers for proposed design with a perforated plate.

4. CONCLUSIONS

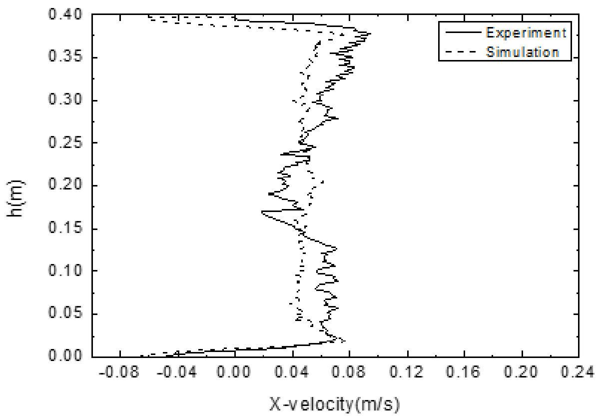
To improve the flow uniformity in the sodium channel side, a perforated plate was designed and its effect was validated with help of flow visualization. It was shown that flow uniformity was improved than original system by inserting the perforated plate.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (No. 2012M2A8A2025624).

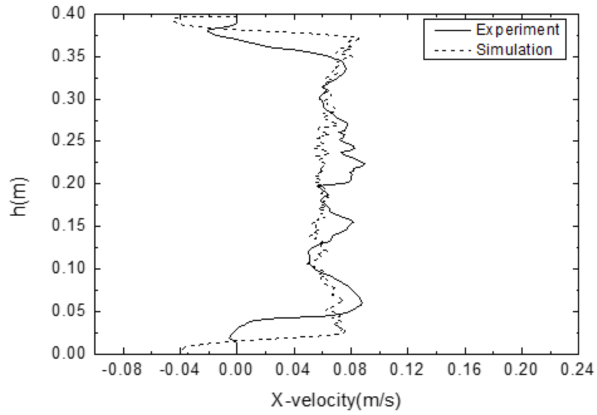


(a) Middle plane (original)

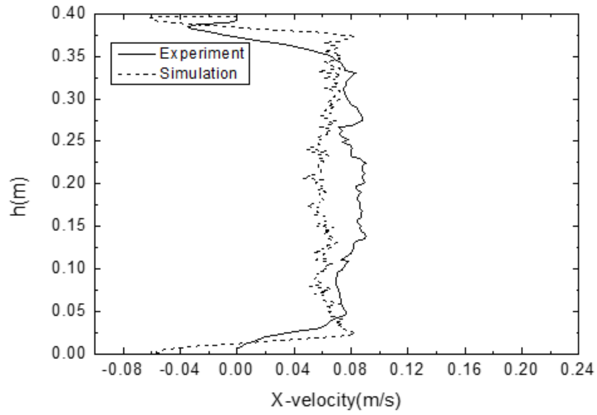


(b) Side plane (original)

Fig. 6. Comparison of simulation and experimental velocity in flow direction (original)



(a) Middle plane (plate)



(b) Side plane (plate)

Fig. 7. Comparison of simulation and experimental velocity in flow direction (insert perforated plate)

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