Thermal-hydraulic characteristics of the Printed Circuit Heat Exchanger (PCHE) in a Helium-Water Test Loop

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1. Introduction

Heat exchangers in High Temperature Gas Cooled Reactor (HTGR) are important components for heat applications. Printed Circuit Heat Exchanger (PCHE) is highly feasible candidate with great performance of high effectiveness, high structural integrity, and compactness. Helium-Helium experiments [1] were already performed to investigate thermal-hydraulic performance of an intermediate heat exchanger (IHX) or a recuperator in HTGR. In this study, a Helium-Water test loop was designed to investigate thermal-hydraulic performance of the PCHE for a pre-cooler in HTGR. A 3-dimensional (3-D) numerical model also was constructed and it was compared with helium-water experimental data.

2. Methods and Results

A Helium-Water test loop and a 3-D numerical model were constructed to investigate thermal-hydraulic performance of the PCHE. CFD simulations were performed to compare 3-D numerical model with experimental data of pressure drop and temperature difference in helium and water sides.

2.1 Helium-Water Test Loop

A helium-water test loop (Fig.1.) consists of a closed helium loop and an open water loop.

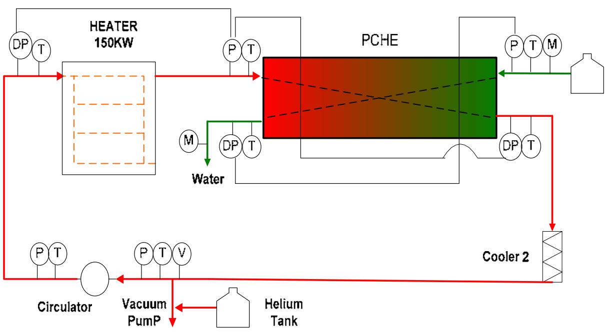

Fig. 1. A helium-water test loop

Helium gas was put into a helium loop after making a vacuum state. Helium gas was moved by a circulator. Volume flow rate was measured at inlet of the circulator. Demineralized water was supplied from a water tank. Mass flow rate was measured at inlet and outlet of the PCHE in the water side. Pressure drop and temperature in both the helium side and the water side were experimentally measured.

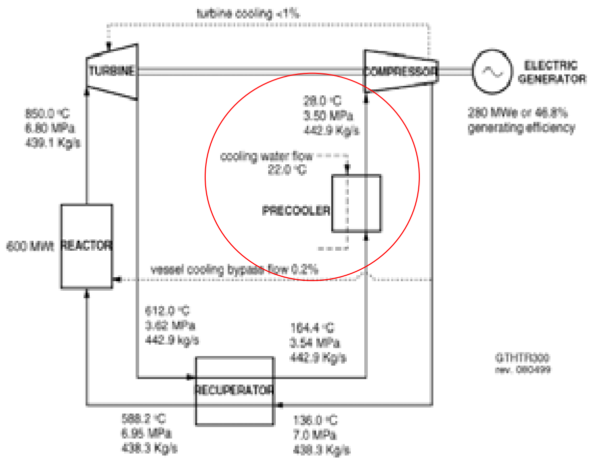

Fig. 2. GTMHR300 cycle of Japan

Laminar operation is selected because of a little consumption on pumping power. Experiment conditions of 18 bar and 80~160℃ were taken maintaining laminar region, even though a pre-cooler of Japanese GTMHR300 has high pressure of more than 3.5 MPa (Fig. 2.).

2.2 CFD approach

PCHE consists of micro-wavy channels (Fig. 3.).

Fig. 3. The angle of a wavy channel

A 3-D numerical model, selecting only a hot and a cold channel, was constructed (Fig. 4.). Top/down and left/right surface were linked meshes with a periodic boundary condition.

The boundary layer option was used at close wall surface. Five rows were generated with growth factor 1.2. The first layer was 0.01mm. Total depth was 0.0744mm. The total number of meshes was approximately 1,330,000. Simulations were done by FLUENT using a laminar option.

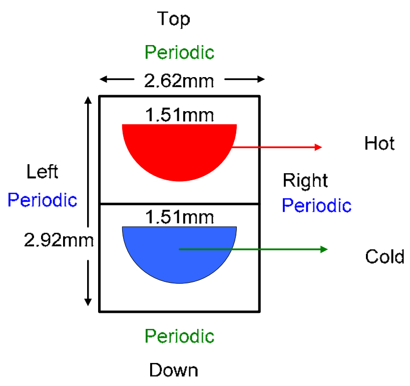

Fig. 4. Cross-section of the 3-D model

2.3 Pressure drop & Temperature difference

Measured Test data and CFD simulation results are compared in Fig. 5 and Fig. 6.

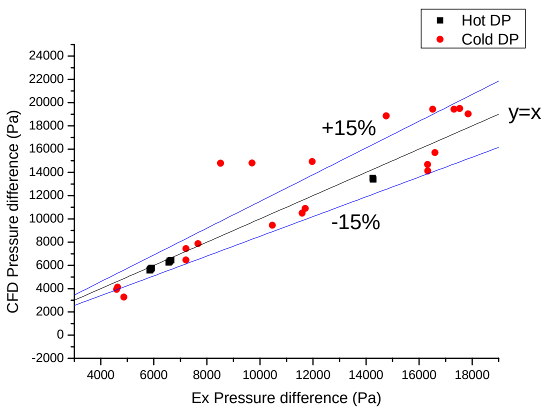

Fig.5. CFD Pressure difference vs. Ex Pressure difference

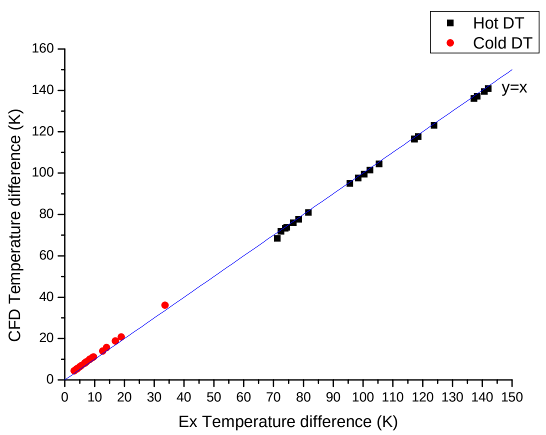

Fig.6. CFD Temperature difference vs. Ex Temperature difference

Temperature difference of CFD results has better agreement than the pressure difference. Most of data regarding pressure difference are predicted within ±15% and most data on temperature difference are predicted within the thermocouple uncertainty by CFD simulation results.

3. Summary and Conclusions

Thermal-hydraulic performance of the PCHE was investigated by a helium-water test loop and CFD simulations. The 3-D numerical model was validated against experimental data. The study range can be expanded using the validated numerical model. In the previous He-He test [1], it turned out that local correlation development is effective for large temperature difference between the inlet and outlet of PCHE. Therefore, we can propose the Fanning factor and Nusselt number correlations using local information from CFD results.

ACKNOWLEDGEMENTS

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REFERENCES

[1] In Hun Kim, Hee Cheon NO, and Jeong Ik Lee, Byong Guk Jeon, "Thermal-hydraulic performance analysis of the printed circuit heat exchanger using a helium test loop and CFD simulations", Article in Press Nuclear Engineering and Design (2009)