KOREA INSTITUTE OF MACHINERY & MATERIALS

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Experimental and theoretical investigation on avoiding freezing phenomena of Printed Circuit Heat Exchanger for cryogenic liquid hydrogen vaporizer

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1. Introduction

Whenever cryogenic fluid is used as the working fluid for heat exchanger, heat exchanger is exposed to the risk of freezing due to low temperature profile inside heat exchanger. Generally it is well known that a printed heat exchanger (PCHE) is one of the most popular solution for cryogenic liquid hydrogen vaporizer.

The purpose of this study is to experimentally identify the conditions under when freezing occurs and to present guidelines to avoid freezing when using a printed circuit heat exchanger (PCHE) for cryogenic liquid hydrogen vaporizers. To conduct laboratory-scale PCHE experiments prior to using liquid hydrogen, liquid nitrogen is used as the working fluid in cold channel. To determine the freezing conditions in PCHE, the heat transfer performance of laboratory-scale PCHE and the pressure drop in the hot channel is investigated. Furthermore, relatively large deviations in thermo-physical properties are taken into account to evaluate heat transfer coefficient and freezing conditions inside PCHEs.

2. Methodology

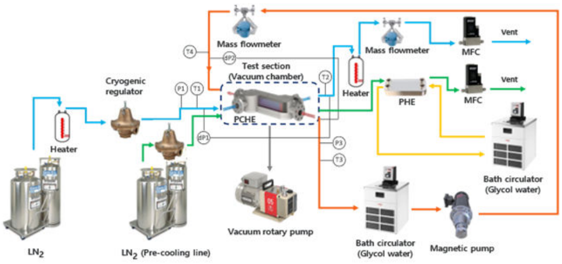
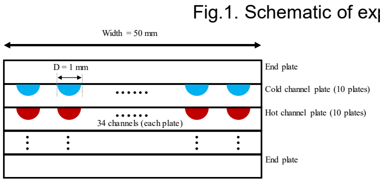


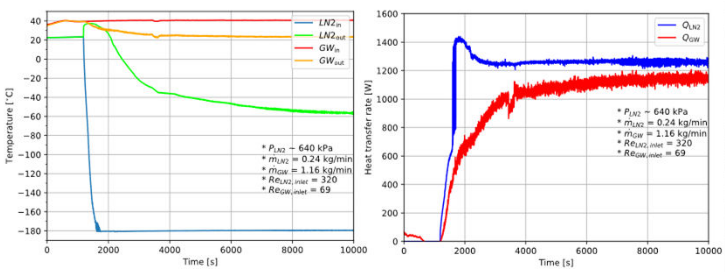
Fig.1. Schematic of experimental apparatus



	Cold channels	Hot channels
Working fluid	LN2	GW
# of plates [ea]	10	
# of channels [ea]	34	
Flow configuration	Co-flow	40
Plate type	I type	N type
Channel Configuration	Semi-circular	
Channel diameter [mm]	1	
Inlet temperature [℃]	-185 ~ -175	40
Inlet mass flow rate [kg/min]	0.15 ~ 0.31	0.4 ~2.4
Inlet Re [-]	170 ~ 400	24 ~142

Fig.2. Specification of fabricated PCHE and test conditions

3. Results and discussion



(a) (b)

Fig.3. Temporal data of (a) inlet and outlet temperatures and (b) heat transfer rate

3. Results and discussion

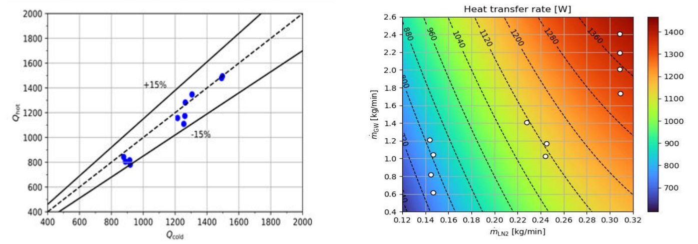
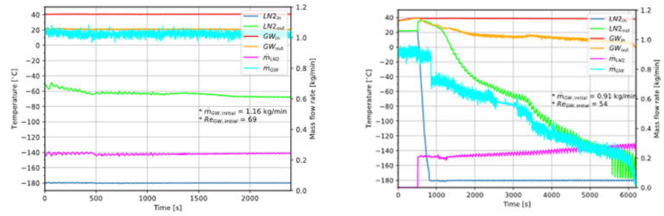


Fig.4. Heat transfer rate of the fabricated PCHE for various mass flow rates of LN2 and that of GW

Difference between heat transfer rate of cold channels and that of hot channels is less than 15% as shown in Fig. 4.



(a) (b)

Fig.5. Temporal data on temperatures and mass flow rates: (a) Non-freezing and (b) freezing condition

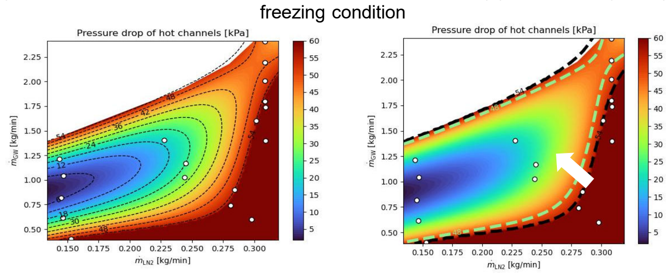


Fig.6. Pressure drop of hot channels for various mass flow rates of LN2 and that of GW

Fig. 6 shows the pressure drop hot channels and area for stable operation of PCHE. Green dotted contour lines represent the suggested area for stable operation of PCHE. Mass flow rate of hot channels should be further increased to avoid freezing phenomena in PCHE.

3. Conclusion

- Lab-scale PCHE experiment is conducted using liquid nitrogen. Glycol water is used as heating fluids for exchanging heat
- Freezing phenomena of PCHE is experimentally observed for various flow rates of LN2
- Since contour lines for stable operation of PCHE is suggested, further analysis is required to provide an universal correlation to avoid freezing phenomena

References

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[2] S. Baek, J. H. Kim, S. Jeong, and J. Jung, “Development of highly effective cryogenic printed circuit heat exchanger (PCHE) with low axial conduction”, Cryogenics 52, 2012, pp. 366-374