Plate-Fin Heat-Exchangers for a 10 kW Brayton Cryocooler and a 1 km HTS Cable

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Plate-fin heat exchangers (PFHX) are designed and fabricated for a cryogenic cooling system, serving for a 10 kW Brayton cryocooler and a 1 km HTS transmission cable under development in Korea. To achieve compactness and thermal efficiency at the same time, a recuperative HX for Brayton cycle and a sub-cooling HX of liquid nitrogen for HTS cable are designed as integrated parts. A key design feature is focused on the coldest part of sub-cooling HX, where the streams of liquid nitrogen and refrigerant (helium gas) are arranged as two-pass cross-flow so that the risk of freeze-out of liquid nitrogen can be reduced. Details of hardware PFHX design are presented and discussed towards its immediate application to the HTS cable system.

Introduction

Previous Studies for Cryocooler Development

Korean HTS Power Cable Project (2011 ~ 2016)

Install & Demonstrate at Jeju Island (2016)

Brayton cryocooler for 10 kW Cooling

Support by Korean Government (KEPCO)

Helium (He)

Proceedings of ICEC 24 - ICMC 2012,

Abstract

Plate-fin heat exchangers (PFHX) are designed and fabricated for a cryogenic cooling system, serving for a 10 kW Brayton cryocooler and a 1 km HTS transmission cable under development in Korea. To achieve compactness and thermal efficiency at the same time, a recuperative HX for Brayton cycle and a sub-cooling HX of liquid nitrogen for HTS cable are designed as integrated parts. A key design feature is focused on the coldest part of sub-cooling HX, where the streams of liquid nitrogen and refrigerant (helium gas) are arranged as two-pass cross-flow so that the risk of freeze-out of liquid nitrogen can be reduced. Details of hardware PFHX design are presented and discussed towards its immediate application to the HTS cable system.

Result and discussion

Plate-fin Heat Exchanger Design Concept

Two PFHX’s are re-designed with incorporation the anti-freezing schemes

HX-A : 1st stage : Cold gas is warmed-up → affect the thermodynamic efficiency

Pressure drop of refrigerant

Complete blockage of LN is avoided

Use commercial Software for evaluation (Aspen MUSE & HTRI-XPHE)

Multi-pass cross-flow → Counter flow (He-He)

→ Cross-flow HX’s more robust against the freeze out

Preparation for unusual decrease of thermal load

Cross-flow HX’s more robust against the freeze out

Counter-flow HX

Multi-pass cross-flow HX

Experimental Set-up

Cold layer

Warme layer

Counter-flow (He-HL)

Heat-exchanger Detailed Design (Chang et al., Proceedings of ICEC 24 -ICMC 2012, 2013)

Plate-Fin Heat Exchanger Design Concept

Counter-flow

→ Two-pass cross-flow

→ High effectiveness and Anti-freezing

Use 2-D temperature distribution

Multi-pass → Increase effectiveness

Use 2-D temperature distribution

Combined cross-flow and counter-flow HX

Temperature [K]

Cold part → Cross-flow

Warm Part → Counter-flow

High effectiveness and Anti-freezing

Cross flow HX

→ 5 is Coldest position of HX

Temperature [K]

→ Increase effectiveness

Use commercial Software for evaluation (Aspen MUSE & HTRI-XPHE)

Dimensions And Assembly

Heat-exchanger Detailed Design (Chang et al., Proceedings of ICEC 24 -ICMC 2012, 2013)

HX-A : Combination of HX-2 & remaining part of HX-1

→ Two piece of nearly the Same Size

HX-B : Combination of HX-1 & HX-2

→ Two-pass cross-flow

Size of HX could be excessively large

Complete blockage of LN is avoided

→ Counter-flow HX

→ Pressure drop problem

→ Multi-pass cross-flow

→ High effectiveness and Anti-freezing

Experimentally Verfication (Chang et al., Cryogenics 2013)

Two integrated PFHX are designed for recuperation of He in Brayton cryocooler and sub-cooling of LN supplied to HTS cable

Cryogenic expander Located between 4 and 5 → 5 is Coldest position of HX

The designed HX’s are successfully fabricated and ready for practical application