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Experimental investigation of a cryogenic printed circuit heat exchanger

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With the growing demand for compact and large-capacity cryogenic refrigerators nowadays, large-temperature-span cryogenic heat exchangers (HX), as the key and bulky components, are studied to achieve performance and volume advantage. The printed circuit heat exchangers (PCHE) are supposed to a promising candidates for compact HX for their lower resistance, and flexible design, which have been widely applied in normal and high-temperature fields such as fuel cells and supercritical carbon dioxide Brayton cycles.
However, relatively little research has been developed on PCHE application in cryogenic zones, especially in situations with large-temperature-span. This research deficiency of the large-temperature-span cryogenic HX seriously drags the compactness of cryogenic refrigerators. Thus, a cryogenic PCHE for reverse Brayton refrigerators, working between 80 K - 300 K, is proposed and tested in this article, whose heat transfer efficiency is designed to 97.5%. Arranging the proposed micro-fins channel, the cryogenic PCHE achieved a high heat transfer area density (≈2200 m2/m3), demonstrating a good thermal-hydraulic performance and high compactness. Then, a cryogenic test is designed and set up to investigate the thermal-hydraulic performance of the proposed PCHE. The experimental platform in the designed vacuum chamber can achieve the calculated relative uncertainties of the key heat transfer coefficient and pressure drop at 6.3% and 0.25%, respectively. Nitrogen as the experimental working fluid flows through the hot side and cold side. For the hot side, inlet temperature and mass flow vary from 290 K to 300 K and 1.2 g/s to 1.9 g/s, respectively. For the cold side, inlet temperature and mass flow vary from 290 K to 300 K and 1.2 g/s to 1.9 g/s, respectively. The effect of the key operation parameters on the thermal-hydraulic performance of the proposed PCHE is revealed, while the compactness and effectiveness of the proposed PCHE structure are validated.
Considering the high difficulty of compact HX fabrication and cryogenic experimental conduction, the experimental investigation proposed in this paper is useful for further theoretical design and optimization.

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