International Journal of Heat and Mass Transfer 150 (2020) 119364

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/hmt

Experimental study of a straight channel printed circuit heat exchanger on supercritical CO_2 near the critical point with water cooling

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ARTICLE INFO

Article history:
Received 25 November 2019
Revised 10 January 2020
Accepted 10 January 2020
Available online 21 January 2020

Keywords:
Carbon dioxide (CO_2)
Brayton cycle
Heat transfer
Supercritical

ABSTRACT

The study presents an experimental examination of heat transfer of straight printed circuit heat exchanger (PCHE) for a precooler of supercritical carbon dioxide (sCO_2) Brayton cycle. To perform heat transfer experiment, experimental loop for thermal hydraulic of CO_2 in supercritical (ETHICS) was constructed at POSTECH. The straight PCHE was independently manufactured by photochemical etching and diffusion bonding process. An experiment for CO_2 cooling with water was conducted via the ETHICS. We focused on heat transfer and flow characteristics of CO_2 in the printed circuit heat exchanger. The experiments were conducted at three operating conditions for CO_2 cooling, namely the trans-critical case (cooling from supercritical state to subcooled liquid), near the critical case (cooling from gas-like supercritical state to liquid-like supercritical state), and far critical case (cooling just in gas-like supercritical state). Nusselt numbers for different pressure and different operating conditions were compared by following typical analysis used in previous which is using averaged enthalpy based on inlet and outlet data but we conclude that the method of average value using inlet and outlet data is not appropriate for data reduction due to significant changes in the properties of CO_2 near the critical point. Instead of that, we propose to use discretization method in data reduction of experimental data of CO_2 near the critical point. It is difficult to predict heat transfer performance near the critical point of CO_2 in PCHE. Hence, the data from this experiments and discretization method for data reduction are useful in designing a precooler for the sCO_2 Brayton cycle.

1. Introduction

The supercritical carbon dioxide Brayton cycle (sCO_2 BC) is a promising power conversion system with advantages of high thermal efficiency, simple cycle layout, compactness of components, and wide operation range [1]. The aforementioned advantages are the result of high density and low compressibility of sCO_2 near the critical point of CO_2 (30.98 °C, 7.38 MPa) due to wide and rapid variation in the thermodynamic properties of sCO_2 near the point [1,2]. Given the advantages, the sCO_2 BC is evaluated as a power-conversion system for numerous applications including nuclear, geo-thermal, solar, and thermal power plants.

Due to low compressibility, the size of turbomachinery of sCO_2 BC can be compact. However, conventional heat exchangers such as shall and tube type are large. Therefore, to attain compactness of whole system in sCO_2 BC, compactness of heat exchanger should be attained. Among the compact heat exchanger, a printed circuit heat exchanger (PCHE) take an attention for heat exchanger of sCO_2 BC. Specifically, PCHE exhibit the advantages of small size and structural rigidity. They are widely chosen as a heat source and sink for a compact sCO_2 power conversion system [3,4]. The PCHE typically exploits a diffusion-bonded array of plates on which semicircular channels are engraved via etching [5]. The densely-stacked structure allows high compactness, and the diffusion-bonded junctions enables high rigidity. The PCHE is suitable for supplying heat to the sCO_2 BC, which requires intensive heat transfer and durability for harsh conditions of high temperature and

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https://doi.org/10.1016/j.ijheatmasstransfer.2020.119364