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Experimental study of a straight channel printed circuit heat exchanger on supercritical CO₂ near the critical point with water cooling

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ABSTRACT

The study presents an experimental examination of heat transfer of straight printed circuit heat exchanger (PCHE) for a precooler of supercritical carbon dioxide (sCO₂) Brayton cycle. To perform heat transfer experiment, experimental loop for thermal hydraulic of CO₂ in supercritical (ETHICS) was constructed at POSTECH. The straight PCHE was independently manufactured by photochemical etching and diffusion bonding process. An experiment for CO₂ cooling with water was conducted via the ETHICS. We focused on heat transfer and flow characteristics of CO₂ in the printed circuit heat exchanger. The experiments were conducted at three operating conditions for CO₂ 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 CO₂ near the critical point. Instead of that, we propose to use discretization method in data reduction of experimental data of CO₂ near the critical point. It is difficult to predict heat transfer performance near the critical point of CO₂ in PCHE. Hence, the data from this experiments and discretization method for data reduction are useful in designing a precooler for the sCO₂ Brayton cycle.

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1. Introduction

The supercritical carbon dioxide Brayton cycle (sCO₂ 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 sCO₂ near the critical point of CO₂ (30.98 °C, 7.38 MPa) due to wide and rapid variation in the thermodynamic properties of sCO₂ near the point [1,2]. Given the advantages, the sCO₂ 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 sCO₂ BC can be compact. However, conventional heat exchangers such as shell and tube type are large. Therefore, to attain compactness of whole system in sCO₂ 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 sCO₂ 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 sCO₂ 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 sCO₂ BC, which requires intensive heat transfer and durability for harsh conditions of high temperature and

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