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Research Paper

Study on CO_2 – water printed circuit heat exchanger performance operating under various CO_2 phases for S-CO_2 power cycle application

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HIGHLIGHTS

- Development and validation of PCHE design methodology for S-CO_2 power cycle application.
- Performance evaluation of designed PCHE under various CO_2 phases.
- Development of friction factor and heat transfer correlations with CFD obtained experimentally validated results.

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ABSTRACT

The supercritical CO_2 (S-CO_2) power cycle is receiving worldwide attention as one of the promising advanced future electricity generation technologies. Since the S-CO_2 power cycle can achieve high efficiency with simple system configuration, the role of compact heat exchanger becomes more important to achieve smaller system footprint. As an example of successful compact heat exchanger, the printed circuit heat exchanger (PCHE) was recently suggested for the S-CO_2 power cycle application due to the capability of enduring high pressure difference while providing large heat transfer area within a small volume. However, the S-CO_2 precooler operates very close to the critical point of CO_2 where the conventional design methodology may not be suitable due to substantial variation of the thermo-physical properties near the critical point. Thus, in this paper the design and operation issues of PCHE as the precooler are addressed. In this study, the verification of developed PCHE core design code and experimental test results are presented. The test conditions were 26–43 °C and 7.3–8.6 MPa in temperature and pressure, respectively. In terms of non-dimensional numbers, the Reynolds number range is 15,000–100,000 and the Prandtl number range is 2–33. Friction factor and heat transfer correlations were developed with the experimental data and computational analysis for the future PCHE design as a precooler in the S-CO_2 power cycle.

1. Introduction

Recently, the efficiency of the power conversion system became more important due to the increasing energy demand and global warming issues. At this point, the supercritical CO_2 (S-CO_2) power cycle is receiving more attention as a key technology for resolving energy problem. The main advantages of S-CO_2 power cycle are having a large potential to be highly efficient and can be constructed in compact system configuration. Due to the remarkable fluid characteristics of supercritical state CO_2, e.g. liquid like high density, low compressibility factor and gas like low viscosity, the cycle can achieve high efficiency by reducing compression work [1,2].

Another advantage is the S-CO_2 power cycle can achieve high thermal efficiency at moderate turbine inlet temperature (450–650 °C) compare to the conventional power cycle, so the S-CO_2 power cycle technology can be utilized with various heat source applications such as the next generation nuclear reactor, waste heat recovery system, fuel cell bottoming system [3,4]. For these reasons, the S-CO_2 power cycle has been studied as the next generation power conversion cycle which can exceed conventional steam Rankine or gas Brayton cycles [22,23].

The promising S-CO_2 system configuration for the next generation nuclear reactor and concentrated solar power applications was introduced by Dostal [1] as shown in Fig. 1. The temperature-entropy diagram and the recompression S-CO_2 Brayton cycle layout show that the compressor inlet condition (5) is near the CO_2

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