Development of Supercritical CO_2 Compact Heat Exchanger for a Gen-IV SFR

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1. Introduction

KAERI has conducted a systematic study for a supercritical carbon dioxide Brayton cycle energy conversion system coupled to the Gen-IV Sodium cooled Fast Reactor. A new configuration of a compact heat exchanger was developed by using a CFD flow analysis, which shows a very small pressure loss compared with a previous compact HEX while maintaining its heat transfer rate. A test apparatus was also installed to investigate a new compact HEX performance. Two types of HEX test samples were prepared with a diffusion-bonded method. This paper contains the current preliminary test results of the supercritical CO_2 compact HEX of KAERI.

2. Supercritical CO_2 Compact Heat Exchanger Experiments

To enhance the safeties and economics, various kinds of heat exchangers were investigated and the Printed Circuit Heat Exchanger^{TM} (PCHE^{TM}) was selected for the supercritical CO_2 Brayton cycle energy conversion system. For the evaluation of diffusion-bonded heat exchangers similar to PCHE models, a one-dimensional analysis computer code was developed to evaluate the performance of the heat exchangers and design data for the typical type PCHE was produced.

In parallel with the PCHE-type heat exchanger design, a diffusion-bonded airfoil shape fin heat exchanger has been newly designed. The new design concept was evaluated by three-dimensional CFD analyses, which have showed that the airfoil shape fin heat exchangers conserves the total heat transfer rate and reduces the pressure drop by a factor of 14 (Figure 1). Figure 2 shows the heat transfer area of a new air-foil type HEX. The main design concept of a new configuration HEX is a reduction of pressure drop and an increment of a conduction heat transfer area with an adoption of a streamlined-airfoil fin in the channel. If we use this kind of compact HEX, we can more freely control the pressure drop by using the change of fin density in the channel while maintaining the heat transfer rate.

The two-types of compact HEX test samples were prepared to evaluate their thermal hydraulic performance by diffusion bonding method. A total of fifteen etched HEX plate were bonded with a single banking layer. The depth of the channel etching is around 0.5mm. Figure 3 shows the test compact HEX test sample which is made by a stainless steel SUS316 plate with 1mm thickness, 200mm(L) x 80mm(W) x 20mm(T). Figure 4 and Figure 5 show the HEX test apparatus to evaluate the performance of new compact HEX. After then a preliminary test such as a leak test and a sensor calibration, the performance test has been recently conducted. The S-CO_2 coolant is circulated with a magnetic gear pump in the HEX loop and the flow rate is measured with a mass flow meter. The system pressure is controlled by a boost pump and a pre-heater is used to heat the CO_2 gas before entering the test section.

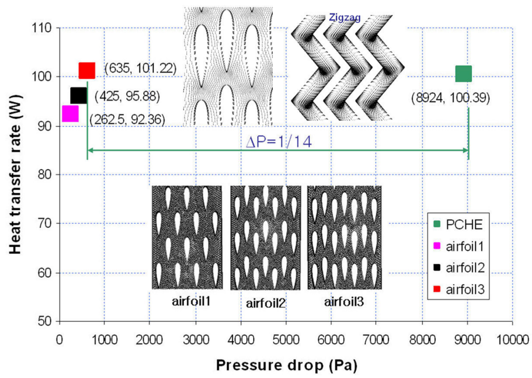

Figure 1. Performance of new configuration S-CO_2 compact heat exchanger

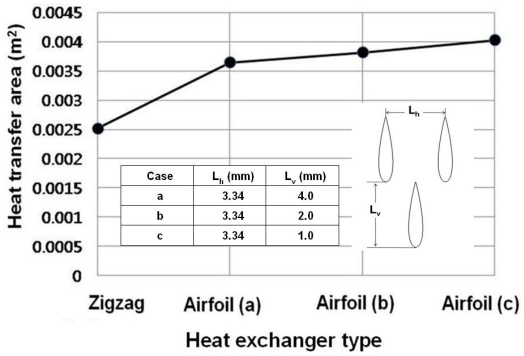

Figure 2. Heat transfer area of new configuration S-CO_2 compact heat exchanger

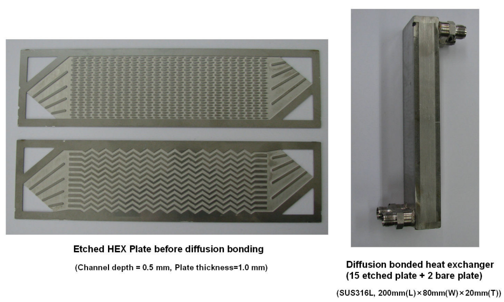

Figure 3. Diffusion-bonded S-CO_2 compact HEX test sample

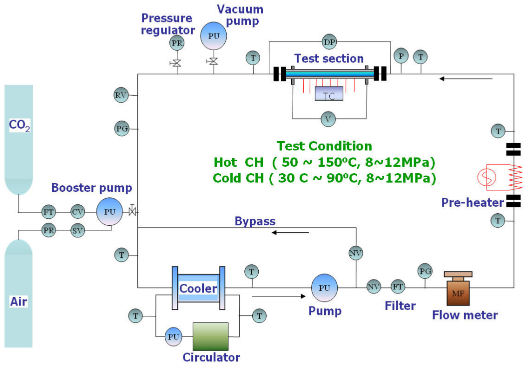

Figure 4. Schematics of S-CO_2 HEX test apparatus

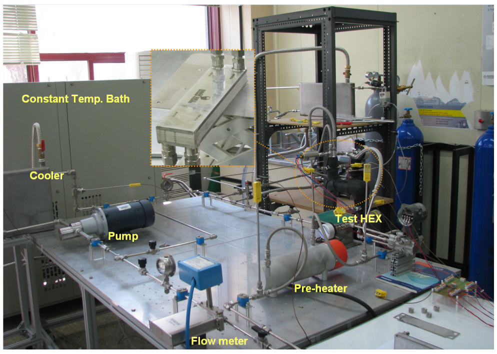

Figure 5. The S-CO_2 HEX Test Apparatus

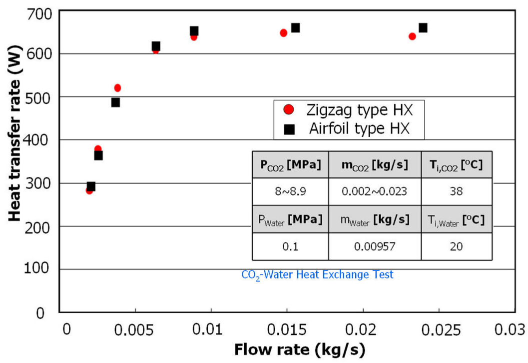

Figure 6. Heat transfer characteristics of the new configuration S-CO_2 HEX test sample

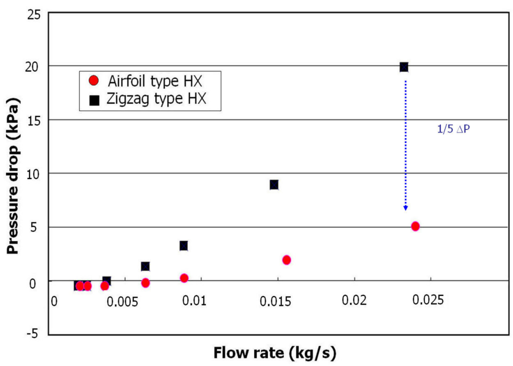

Figure 7. Pressure drop characteristics of the new configuration S-CO_2 HEX test sample

Figure 6 and Figure 7 show the preliminary test results which were recently conducted. The test was conducted in the supercritical CO_2 condition and the cold channel was cooled by a water circulator. The figures show that the pressure drop of new configuration compact HEX sample is less than 1/5 of that of the previous zigzag type compact HEX sample while maintaining the heat transfer characteristics. The measured pressure drop is larger than the CFD analysis value. After then a cross section investigation with a high resolution microscope, it seems that the channel area is smaller than the designed value owing to the poor etching process. Currently, the test samples are re-prepared to evaluate the TH performance more exactly. However, comparing with the TIT S-fin data, the new airfoil-type compact HEX of KAERI is similar pressure drop performance.

3. Summary

A systematic research has been conducted to develop a supercritical carbon dioxide Brayton cycle energy conversion system coupled with a Gen-IV sodium-cooled fast reactor. The new airfoil shape compact heat exchanger was developed by using the CFD analysis, which has a 1/14 of pressure loss compared with the previous zigzag type PCHE while maintaining the heat transfer characteristics. The measured pressure drop is around 1/5 of that of the previous zigzag type HEX.

ACKNOWLEDGMENTS

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