Mixture Gas-Water Loop Design to Investigate Thermal Hydraulic Performance of a PCHE

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1. Introduction

Heat exchangers in the High-Temperature Gas Cooled Reactor (HTGR) are important components for heat applications. The Printed Circuit Heat Exchanger (PCHE) is a highly feasible candidate with great performance of high effectiveness, high structural integrity, and compactness. Helium-Helium experiments [1] were performed to investigate thermal-hydraulic performance of the PCHE as an intermediate heat exchanger (IHX) or a recuperator in the HTGR. Helium-Water experiments [2] were also performed to investigate thermal-hydraulic performance of a PCHE as a pre-cooler.

The cycle efficiency of nuclear power plants can be increased by using mixture working fluid. Improvement of the supercritical CO_2 Brayton cycle using mixture gas was investigated [3].

In this study, a He-CO_2 mixture gas-water test loop is designed to investigate the thermal-hydraulic performance of mixture gas in a PCHE.

2. Methods and Results

2.1 Mixture-Water loop design

A large reservoir to mix helium and CO_2 evenly is not necessary, if we confirm that helium and CO_2 in our test loop are mixed well by driving force of a circulator. Therefore, we performed the numerical simulation on gas mixing using CFD code to see whether helium and CO_2 were well-mixed or not.

The construction of the numerical model for the entire geometry was very difficult due to complex geometry and limited computer resources. The simplified geometry including one heater and 1 inch pipes was constructed using GAMBIT to check mixing time. The flow velocity of 20 m/s same with experimental measurement was maintained.

Transient numerical solutions were obtained by using a CFD code, FLUENT. Fig.1 is a transient state of gas mixing at 6 seconds. It took 6 seconds to mix helium and CO_2 evenly. It is short enough we safely assume the complete mixing of the mixture, because 30 minutes is needed to reach a thermal steady-state during experiments.

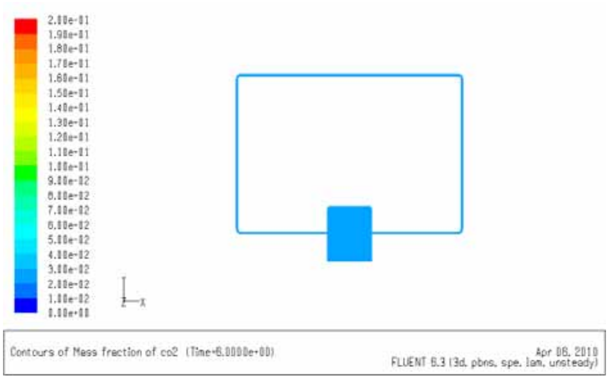

Fig. 1. CFD numerical solution of gas mixing at 6s

Figure 2 is a mixture-water test loop. The mixture side is a closed loop and the water side is an open loop. It consists of many components such as a heater, a PCHE, a cooler, and etc. All components are connected by a 1-inch stainless tube. 1/16 inch thermocouples are used at the inlet and the outlet of the PCHE to increase sensitivity. The others are 1/8 inch thermocouples. The vacuum pump is operated for loop purification. Helium and CO_2 gas are charged into the mixture loop. The mixing ratio is figured out by using the gas-analyzer. Mixture gas is heated up in the heater. The gas flow is driven by the circulator. Water flow is driven by the water pump. The thermal-hydraulic performance of the PCHE is investigated through measuring pressures and temperatures at the inlet and the outlet of the PCHE.

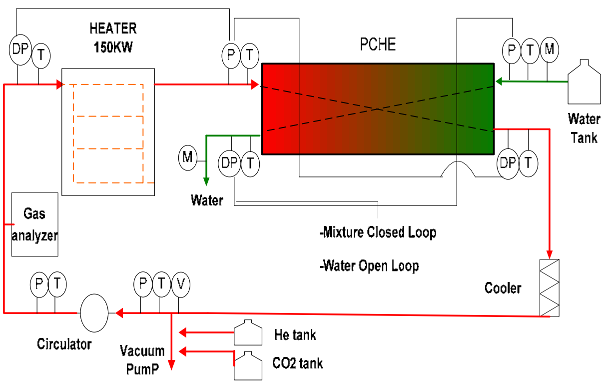

Fig. 2. He/ CO_2 mixture gas- water test loop

2.2 Mixture properties and test ranges

Pure gases have inherent critical points and properties at a specific point of pressure and temperature. However, critical points and properties are varied according to the different mixing ratio of mixtures. The program of REFPROP developed by NIST provides mixture properties based on experimental data about gas mixing at specific pressure and temperature. The design limitation of the test loop is less than 2 MPa and 550℃. We need to find appropriate ranges in which mixture properties are obtained and the design limitation of the test loop is satisfied. Table 1 shows the test ranges of pressure and temperature to satisfy those requirements.

Table I: Available test ranges

He Mole Fraction	CO_2 Mole Faction	Pressure	T1*	T2**
x	1-x	(Mpa)	(K)	(K)
0.80	0.20	1~1.7	280~427	427~
0.84	0.16	0.4~1.7	280~348	348~
0.88	0.12	0.1~1.6	-	280~
0.92	0.08	0.1~1.2	-	280~
0.96	0.04	0.1~0.7	-	280~
0.99	0.01	0.1~0.3	-	280~

In T1* ranges, properties are obtained from the experimental data of gas mixing. In T2** ranges, properties are provided from fitting of experimental data, in spite of no experimental data about gas mixing.

Mixture properties provided by REFPROP in the range of table1 will be used for the analysis of experiments and numerical simulations.

3. Conclusions

We designed the mixture gas-water test loop to investigate thermal hydraulic performance of mixture gas in the PCHE. Properties are varied as the change of the mixing ratio. Mixture properties are provided from the program of REFPROP developed by NIST. We will perform both experiments and numerical analysis. Mixture properties will be used for the analysis of them. Details of experimental results will be published next year.

REFERENCES

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