Design of Supercritical Carbon Dioxide Compressor Testing Loop

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1. Introduction

For small and medium-sized reactors and Generation IV reactors such as sodium-cooled fast reactor are recently under development actively. The supercritical CO_2 Brayton cycle is considered as an attractive cycle for the abovementioned nuclear systems. This is because the supercritical CO_2 Brayton cycle (S-CO_2 cycle) is especially effective to reduce the volume of power generation system, which occupies 1.5~2times more space than the primary nuclear system in general. Comparing to traditional water-vapor cycle and helium cycle, the S-CO_2 system has relatively much less volume and component size. Therefore, S-CO_2 cycle can be used for many purposes such as nuclear ship propulsion where volume requirement is strict, or a small nuclear reactor when it is constructed on geographically limited area.

2. Supercritical CO_2 brayton cycle testing loop

2.1 Previous studies of S-CO_2 brayton cycle

Due to the compact heat exchanger technology such as PCHE[1] (Printed Circuit Heat Exchanger) technology, fluid with mediocre heat transfer capacity such as gas or supercritical fluids can be used for working fluid of a thermal system. The compact heat exchanger technology is one of the key factors for reducing the size of cycle total volume.

One of the main factors for determining the supercritical Brayton cycle thermal efficiency is the turbomachinary. KAERI conducted conceptual design and numerical analysis of S-CO_2 turbine and compressor. SNL(Sandia National Laboratory) and JAEA(Japan Atomic Energy Agency) already obtained preliminary experimental data of S-CO_2 cycle components. However, the amount of experimental data is still insufficient for design optimization of the S-CO_2 turbomachineries.

2.2 S-CO_2 compressor testing loop

KAIST and Khalifa University joint research team is conducting S-CO_2 compressor test to obtain basic data for the compressor design optimization and measure the overall performance of the compressor near the critical point. Design of the testing loop is finished and it is under construction now. The S-CO_2 compressor testing loop is designed to test main compressor of the cycle. The compressor testing loop configuration [2] is similar to SNL and JAEA testing loop. However, the operating conditions and focus of the test are different from them.

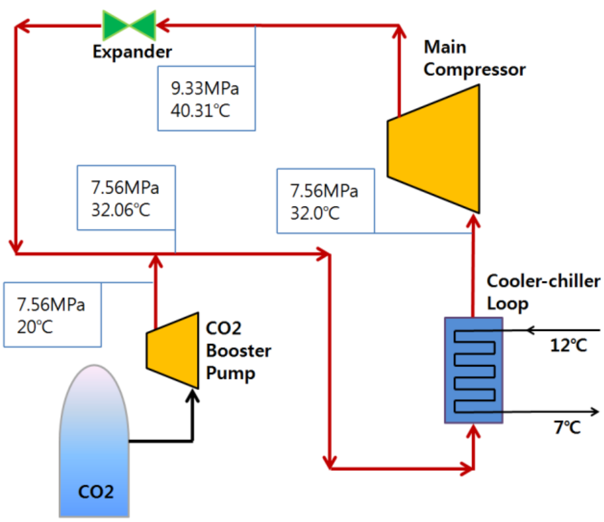

Fig.1. Schematic diagram of S-CO_2 compressor testing loop.

The loop is equipped with an expander (simply a valve in our case) which reduces the pressure to maintain the steady state operation of the loop. The added heat from the compressor is rejected from a heat exchanger connected to a chiller. The booster pump is located on the point where the total CO_2 inventory is controlled. The booster pump maintains the loop pressure above the CO_2 supercritical pressure. The main compressor compresses S-CO_2 from just above supercritical pressure (around 7.5MPa) up to 10.0MPa

2.3 Operating condition of S-CO_2 compressor test loop

The inlet temperature of compressor is especially important to achieve high thermal efficiency of the cycle. This is because the S-CO2 cycle takes advantage of property change near the critical point.

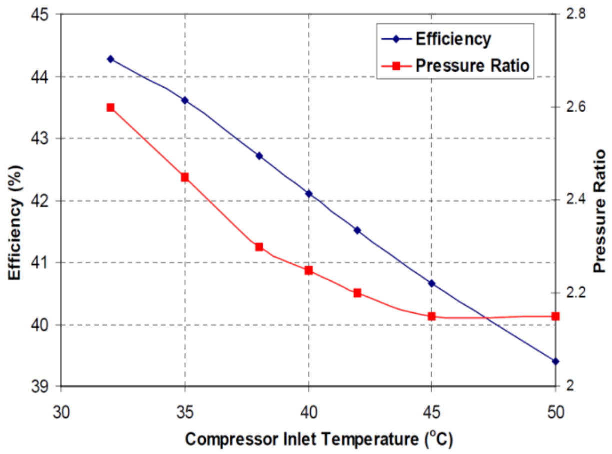

Fig.2. Effect of compressor inlet temperature on S-CO_2 cycle efficiency[3].

As shown in Fig.2, increase in compressor inlet temperature consumes more power and result in efficiency reduction. The cycle efficiency decreases linearly with compressor inlet temperature. To achieve high efficiency of the cycle, it is important to control the inlet temperature near 32℃ before entering the compressor.

Because operating experience with compressor near the supercritical point is insufficient, this test will have an important clue in future research.

3. Summary

Obtaining experimental data of a turbomachinery when the operating fluid is at supercritical state is essential for realizing and commercializing the S-CO_2 Brayton cycle. The data will be very useful for verifying the accuracy of a design tool as well as understanding the phenomena inside the turbomachinery with a numerical approach.

After construction of the test loop is finished and obtain preliminary compressor data, we are planning to attach heater and turbine on the test loop to complete the whole cycle. This upgrade will enable us to verify the calculation result of the S-CO_2 Brayton cycle efficiency and at the same time we can observe the transient behavior of the system as well.

REFERENCES

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