Autonomous Brayton Cycle (ABC) loop with S-CO_2 system components

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1. Introduction

The supercritical CO_2 Brayton cycle has high performance in power conversion. The S-CO_2 cycle has high efficiency at moderate temperature range, compactness and simple configuration[1]. This is because S-CO_2 has nonlinear property change without phase change near the critical point(7.38MPa, 31℃)[2]. However, the rapid property change of CO_2 near critical point also makes it difficult to develop the S-CO_2 power conversion system. The Autonomous Brayton Cycle loop (ABC loop) is being installed in KAIST to research the S-CO_2 Brayton cycle's performance and develop the design method of the components.

Through the installed ABC loop, those parts will be studied: automatic control of the S-CO_2 Brayton cycle's load operation, turbomachinery and magnetic bearing's operability, heat exchanger's performance. In this paper, the current state of the ABC loop and its key devices will be discussed.

2. Autonomous Brayton Cycle (ABC) loop

2.1 S-CO_2 Brayton Cycle

The S-CO_2 has nonlinear property changes near the critical point as Fig 1 without phase change. These characteristics makes the S-CO_2 Brayton cycle to have advantages of both the gas Brayton cycle and the steam Rankine cycle. It has compact turbomachinery size and simple configuration because of no phase change. In addition, it has less compression work, high efficiency. Fig 2 shows low compressibility of the S-CO_2 and Fig 3 [3] shows efficiency of various power cycles.

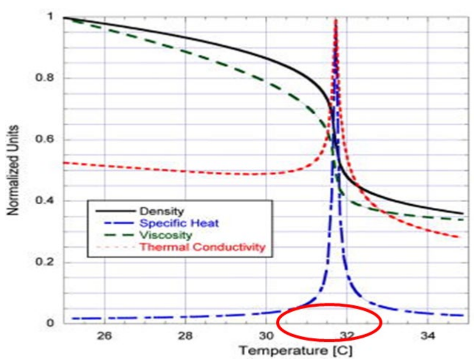

Fig 1. Nonlinear thermo-physical properties of CO_2 near critical point (7.4 MPa)

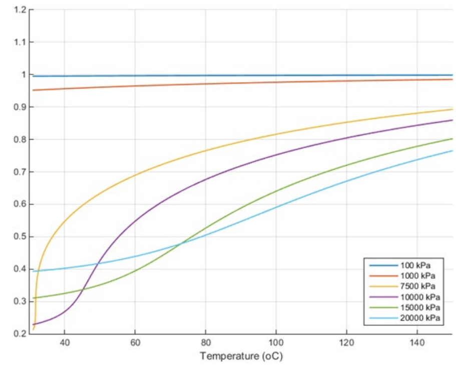

Fig 2. Compressibility factor of CO_2

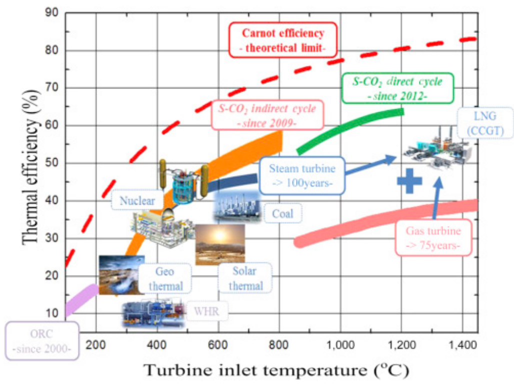

Fig 3. Efficiency of various power cycles

However, despite of these advantages, S-CO_2 Brayton cycle has technical challenges with rapid property changes of CO_2 near critical point. This high sensitivity of the CO_2 affects the controllability of the system. In addition, the component should handle the unexpected instability. The ABC loop is being installed to accumulate operational data to mature the S-CO_2 Brayton cycle technology.

2.2 ABC loop

The ABC loop consists of the key components of the S-CO_2 Brayton cycle: a turbomachine, recuperator, pre-cooler, heater as Fig 4. This system is designed to withstand more than 100 bar and 100 ℃ to test above the critical point.

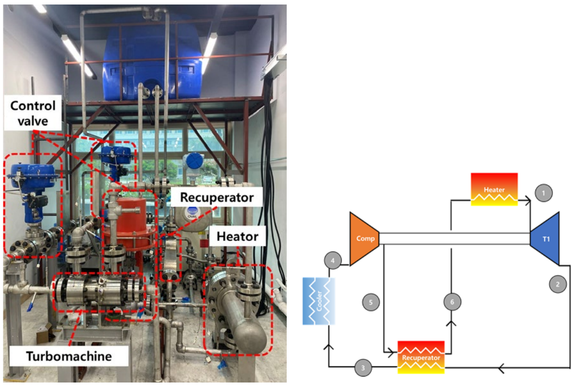

Fig 4. ABC loop and layout

The heater is designed to test the recuperator. The heater has an output of 30 kW and the 2 chillers each have a capacity of 20 kW. The pre-coolers will dissipates the generated heat from heater and turbomachine. The operability of the entire system will be tested by adjusting the control valve, speed of the turbomachine and power of the heater.

2.3 S-CO_2 TAC and Active Magnetic Bearing (AMB)

Turbine-Alternator-Compressor(TAC) with ball bearing in Fig 5 is the main turbomachinery of the ABC loop. TAC will be tested under various operating conditions for different impellers.

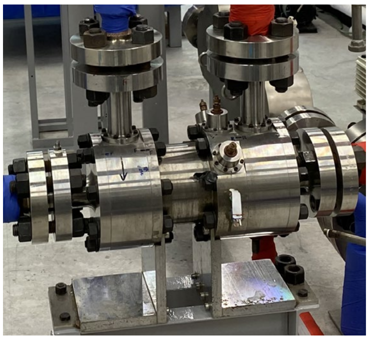

Fig 5. S-CO_2 TAC in ABC loop

Since the proper bearing is necessary for S-CO_2 system design [4], AMB test rig in Fig 6 will be added. This test rig is a turbomachine without impeller so AMB is the dominant factor of rotor-dynamics.

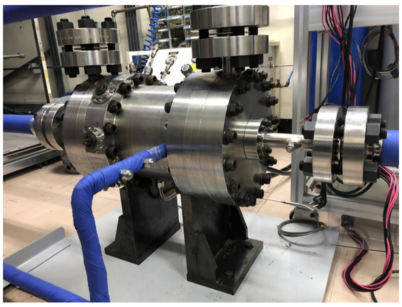

Fig 6. AMB test rig

After the AMB test, TAC with AMB will be added to the ABC loop. The AMB's operability with impellers will be compared with existing TAC.

2.4 Recuperator

Recuperator is a key component to commercialize the S-CO_2 power conversion system because the heat exchange is directly related with the high efficiency and the size of the system.

Recuperator in the ABC loop is shown in Fig 7. This is Printed Circuit Heat Exchanger (PCHE) which has printed micro fluid channel to be more compact. This recuperator will be tested through the ABC loop and a computational simulation of it will be verified.

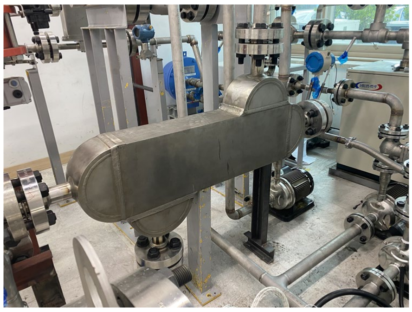

Fig 7. PCHE type recuperator in ABC loop

3. Summary and Conclusions

The ABC loop in this paper depicts the S-CO_2 power conversion system in experimental scale. With this system, the test for higher performance with stable load follow will be conducted. The operability of ABC loop and components' performance (TAC, PCHE, AMB etc) will be analyzed with experimental results in the poster.

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