Autonomous Brayton Cycle (ABC) loop with $S\text{-}CO_2$ system components

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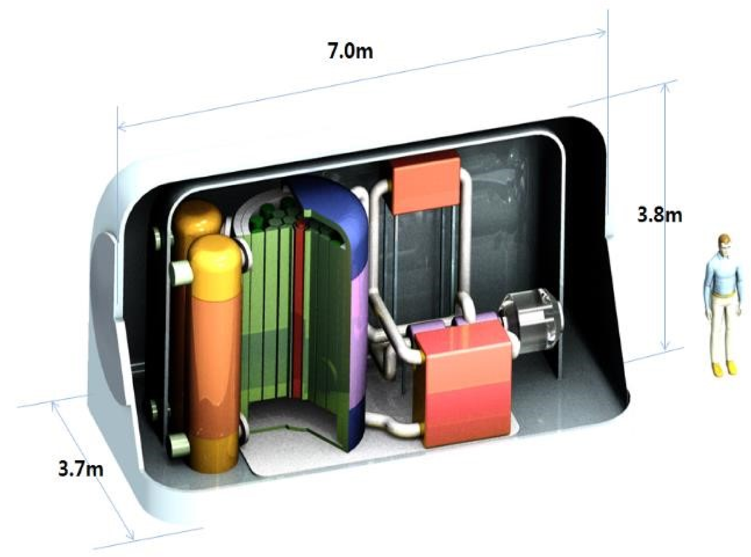
Introduction & Background

▣ Supercritical CO_2 Brayton Cycle

Brayton cycle consists of adiabatic compression and expansion & constant pressure heat addition and rejection. $S\text{-}CO_2$ Bryaton cycle uses Supercritical CO_2 (CO_2 above critical point, 7.38 Mpa and 31℃) as working fluid. This concept is adapted to the KAIST-Micro Modular Reactor (MMR).



▲ Configuration of MMR

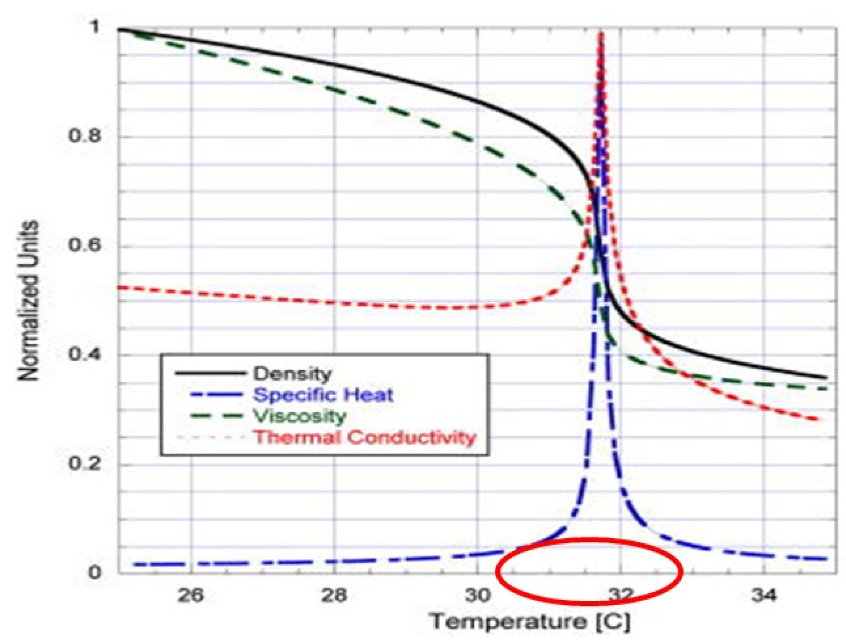
▣ KAIST-MMR's Advantages

- MMR (fully modularized fast reactor with super critical CO_2) has high power density with moderate heat source temperature.
- MMR can replace the diesel engine to avoid violating the newly released IMO regulation.

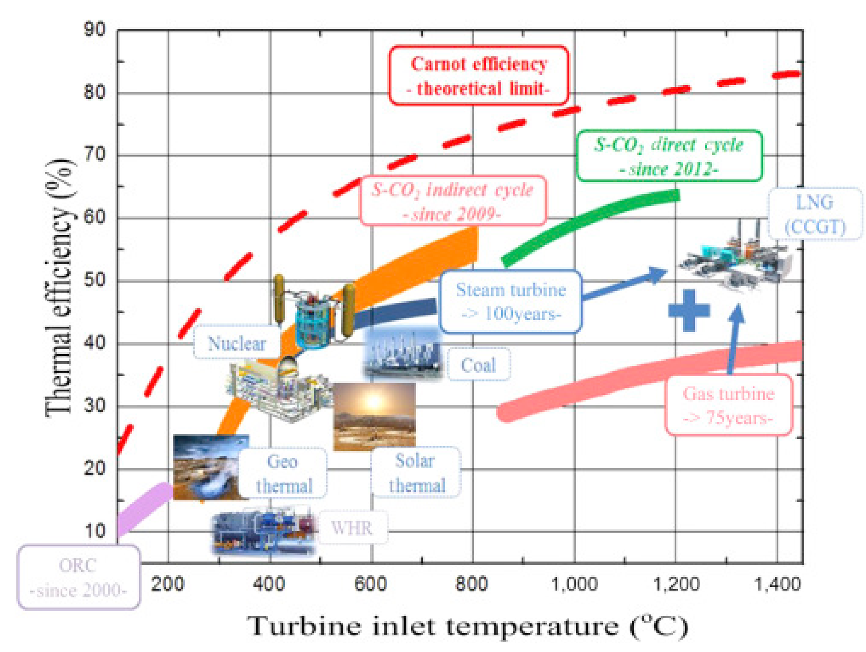
▣ Advantages of $S\text{-}CO_2$ Brayton Cycle

$S\text{-}CO_2$ has nonlinear property changes near the critical point. These characteristics make the $S\text{-}CO_2$ Brayton cycle have advantages of both the gas Brayton cycle and the steam Rankine cycle.

- Compact turbomachinery size and simple configuration because of no phase change
- Less compression work
- High efficiency with recuperator



▲ Nonlinear thermo-physical properties of CO_2 near critical point



▲ Efficiency of various power cycles

▣ Technical issues of $S\text{-}CO_2$ Cycle

Rapid property changes of CO_2 near critical point is the main reason of the technical issues

- It affects to the controllability of the system
- The component should handle the unexpected instability

→ **The Autonomous Brayton Cycle (ABC) loop** is installed to research the performance improvement of the $S\text{-}CO_2$ cycle, its components and operation strategy like automatic control

In this poster, the current state of the ABC loop and its key devices will be discussed. Also, the trail test results will be introduced.

Autonomous Brayton Cycle (ABC) loop

▣ ABC loop installation

- Consists of key components:

turbomachine, recuperator, precooler, heater and control valve

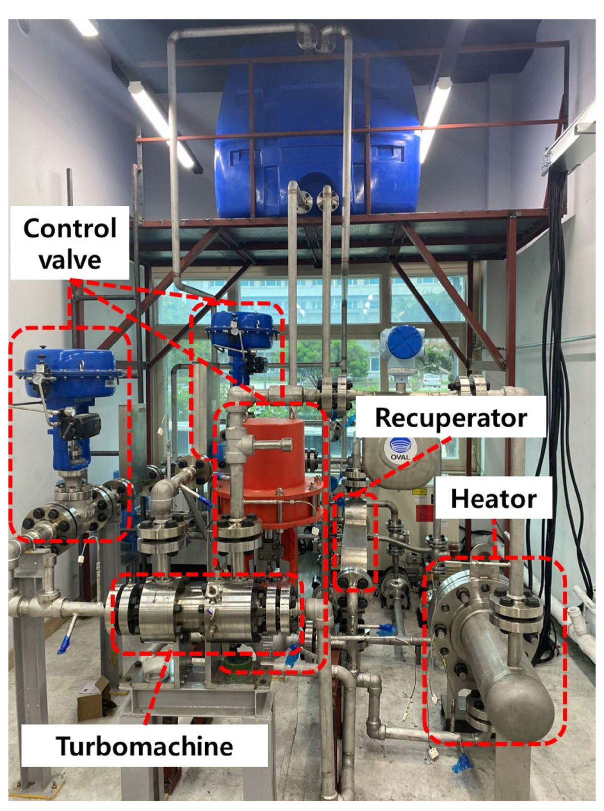
- Designed to withstand more than 100 bar and 100 ℃

▣ Key components of the ABC loop

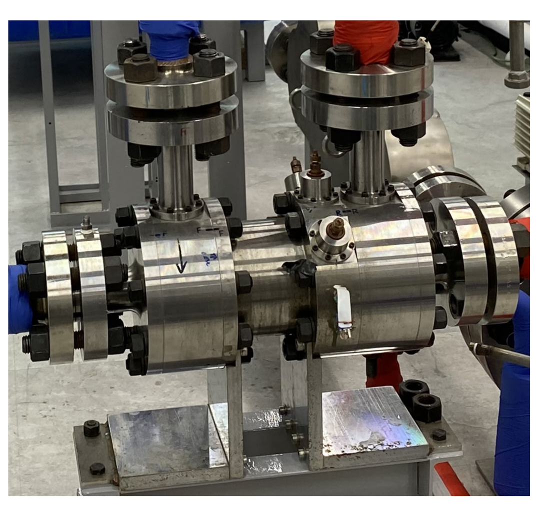
- Turbomachine

Turbine-Alternator-Compressor(TAC) and Active Magnetic Bearing (AMB) test rig

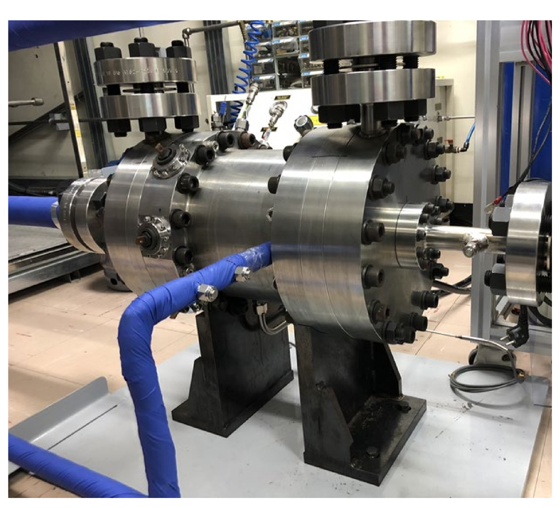
Compressor inlet : closest to the critical point



▲ *ABC loop and its components*



▲ *$S\text{-}CO_2$ TAC in ABC loop*



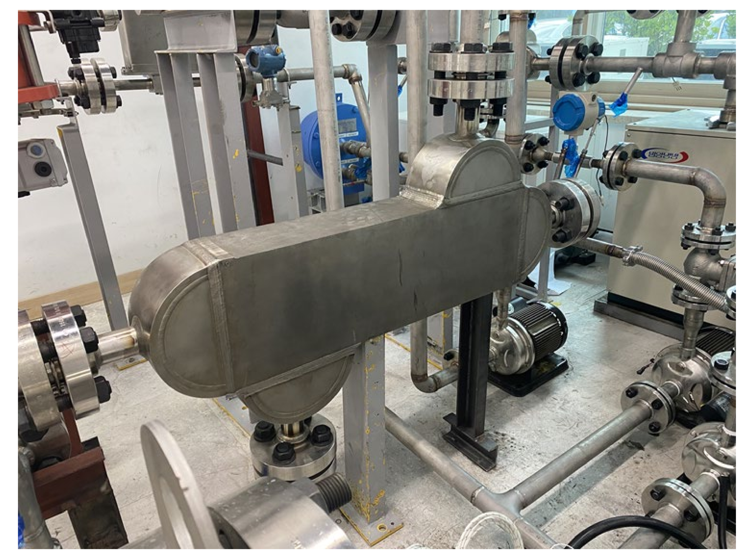
▲ *AMB test rig*

- Recuperator

Key component to commercialize the S-CO2 power conversion system

Directly affects to the high efficiency and the size of the system

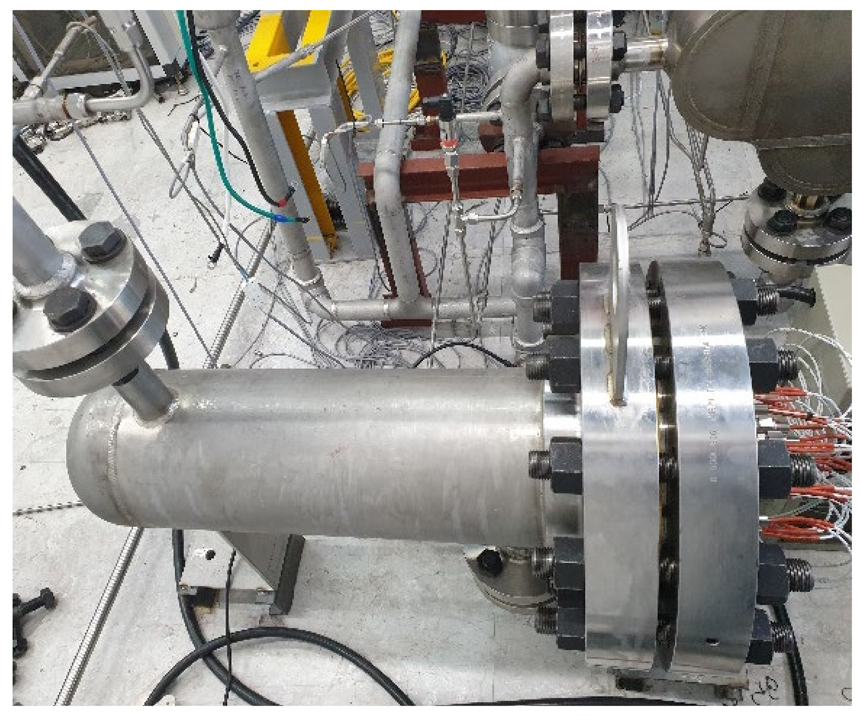
Printed Circuit Heat Exchanger (PCHE) type (micro fluid channel for compactness)



▲ *PCHE type recuperator*

- Heater & Control valve

Purpose: Control of the ABC loop system

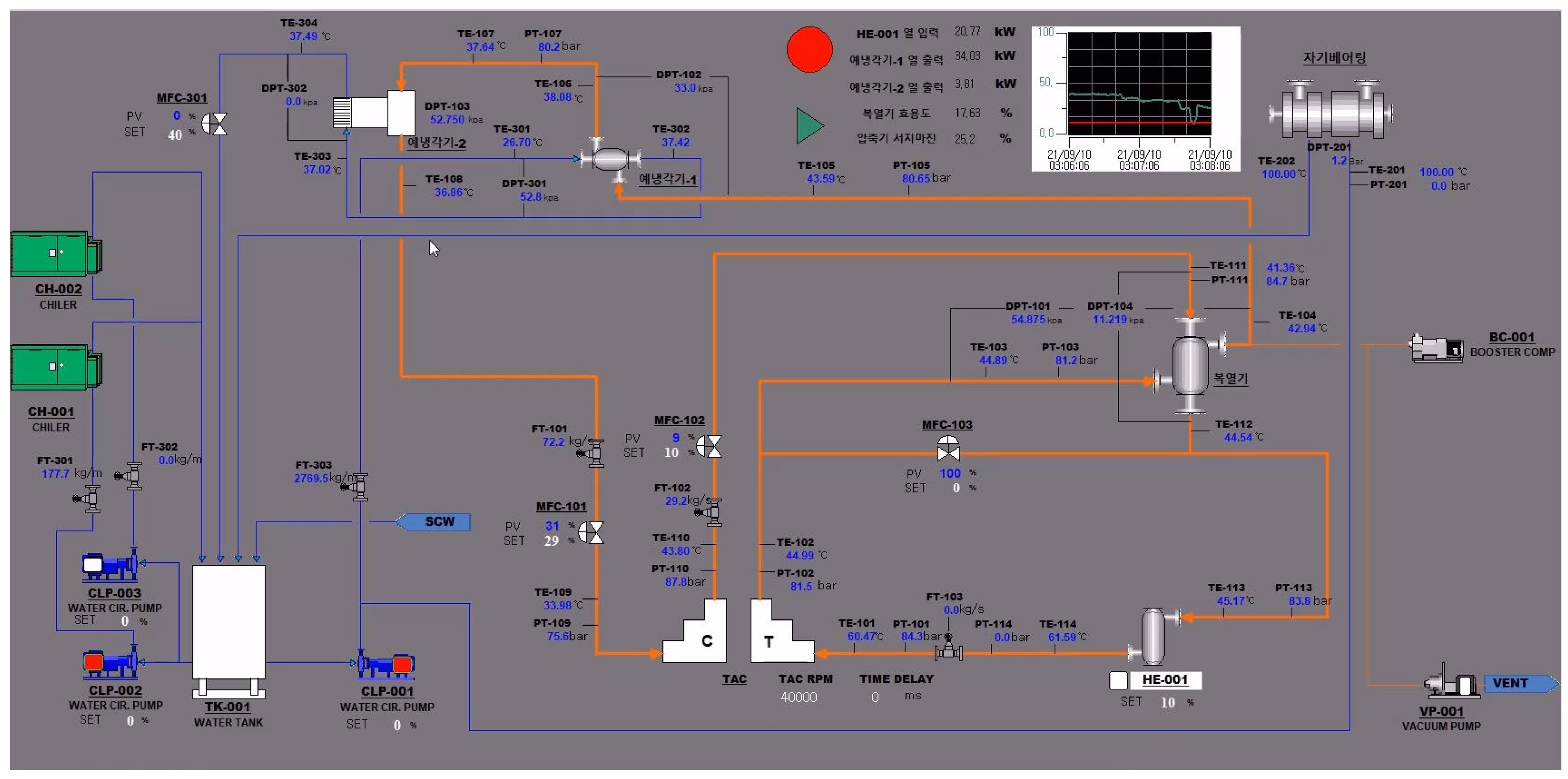


▲ Heater with controller

▲ Control valve for bypass control

Trial Test Results

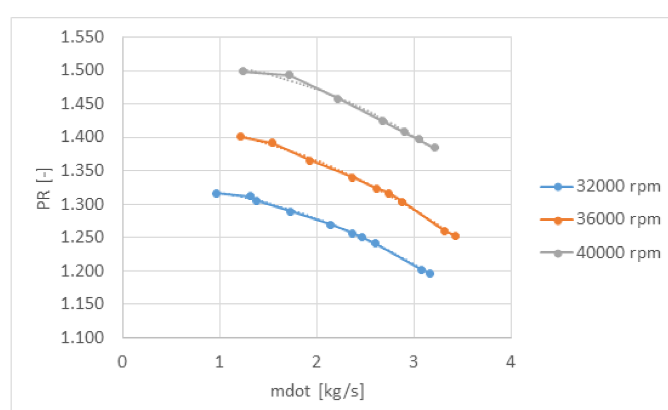
▣ Performance test



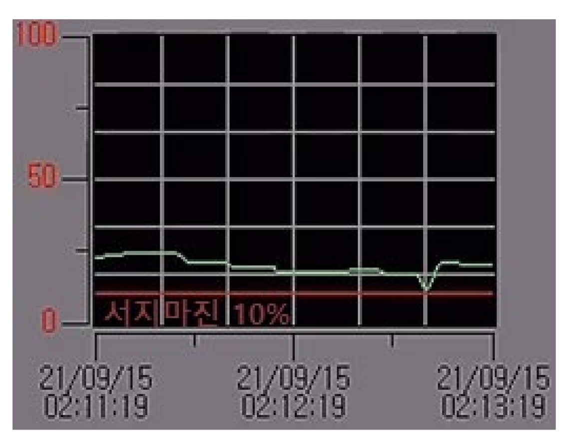
▲ Test results with achievement of target performance

- Newly installed cooler capacity more than 20kW ……………………………………………✓
- Securing heat source 20kW or more……………………………………………………………..✓
- Motor controllable range over 35,000 RPM……………………………………………..…✓
- Recuperator effectiveness over 80%……………………………………………………...………✓

▣ Compressor surge test



▲ TAC performance curve



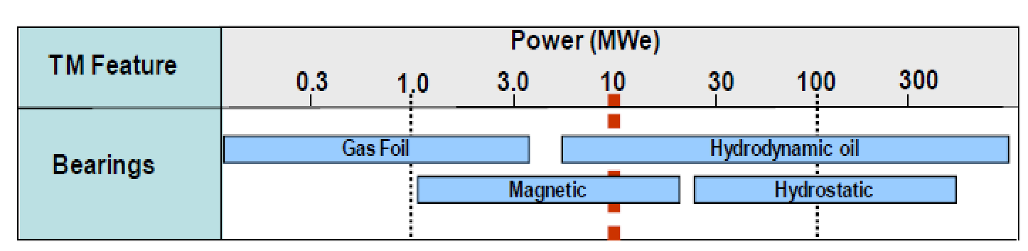
▲ TAC surge control with bypass

Surge margin[%] = 100% $\times \frac{m_w - m_s}{m_w}$, m_w : working mass flow rate, m_s : surge mass flow rate

Conclusions & Future work

▣ Magnetic bearing test

From the power scale of the MMR, magnetic bearing is well applicable. AMB test rig is added to research the instability of AMB under $S\text{-}CO_2$ condition.



▲ Bearing options for $S\text{-}CO_2$ Brayton cycles with various power scales

▣ Automatic control research

Operation strategy (ex. Bypass control, inventory control) for different goals (surge margin, load following etc.) of $S\text{-}CO_2$ Brayton cycle will be tested with ABC loop.