Experimental Setup for Supercritical CO_2 Compressor Performance Test Facility

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1. Introduction

The supercritical CO_2 (SCO_2) cycle has been extensively studied as the next power generation system because it has lots of advantages, compared to existing power generation systems. The advantage of the SCO_2 power generation system is the moderate operating temperature which can be used in various heat sources. In addition, the system has the compact size, because the SCO_2 cycle is operated above the critical point (31.1 ^oC, 73.8 bar). Korea Atomic Energy Research Institute (KAERI) has started to develop the SCO_2 power generation system [1-3]. Various experimental and theoretical conditions with different main components have been analyzed for optimizing cycle operation techniques.

Recently, KAERI has started a project which develops the SCO_2 power generation system for waste heat recovery [4]. The target of turbine inlet temperature is around 450^{o}C. Figure 1 shows the P&ID of the SCO_2 power generation system. The system consist of a simple-recuperated cycle. The first target of the project is to verify the performance of the SCO_2 compressor. After the SCO_2 compressor performance test, the power generation system will be installed. The present study shows the experimental setup for the SCO_2 performance test facility.

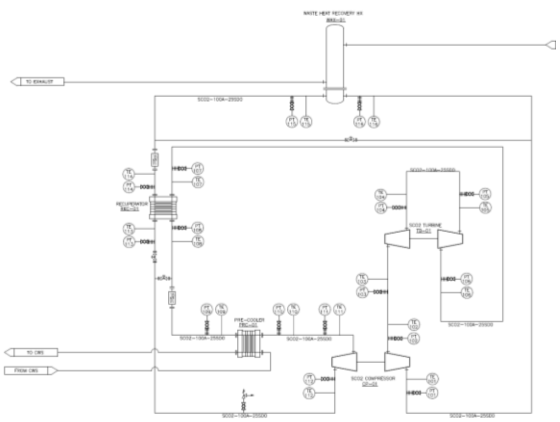

Fig. 1. P&ID of the SCO_2 power generation system.

2. Design Considerations of SCO_2 Compressor Test Facility

The present section describes design considerations of the test facility, such as heat exchanger, compressor, flow path, etc.

2.1 Heat Exchanger Design

In the SCO_2 compressor test facility, a precooler which is located in front of the compressor is needed. The precooler provides the required SCO_2 inlet temperature of the SCO_2 compressor. For the compact size of the precooler, printed circuit heat exchanger (PCHE) is selected. The design of the precooler is based on the heat load of SCO_2 power generation system, which will be used in waste heat recovery application (Fig. 1.). The amount of heat exchanger from the SCO_2 to the coolant is about 2 MW. To reduce the flow maldistributions in each flow channel, modified nozzle configuration was considered [5]. The core volume of the precooler is 1134 x 494 x 635 mm^3. The design pressure and temperature of the SCO_2 side and coolant is 150 bar and 150 ^oC, and 50 bar and 150 ^oC, respectively. Figure 2 shows the 3D structure of the precooler.

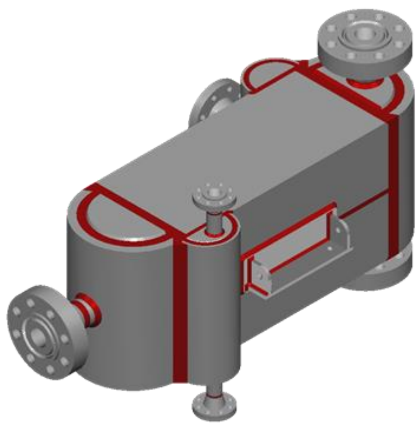

Fig. 2. 3D configuration of precooler.

2.2 Compressor Design

The SCO_2 compressor is the main component which provides the required system pressure to generate the desired power with waste heat recovery system. The mass flow rate of the present SCO_2 system is 12.55 kg/s. Based on the various SCO_2 compressor tests performed in the KAERI, the active magnetic bearing system is selected. The structure integrity and the rotor dynamic safety were considered based on the yield strength and the separation margin, respectively. The actual SCO_2 compressor used in the power generation system has driving turbine, but it is difficult to produce the desired performance with driving turbine in the SCO_2 compressor test. Therefore, the present compressor is operated by high speed inverter and high speed electric motor. Figure 3 shows the 3D structure of the SCO_2 compressor.

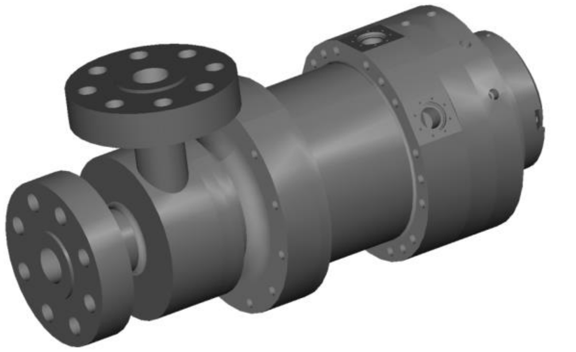

Fig. 3. 3D configuration of SCO_2 compressor.

2.3 Flow path and measurement instruments

The maximum pressure and temperature of the SCO_2 power generation system is calculated as 138.5 bar and 450 ºC, respectively. To endure high-pressure and high-temperature condition, appropriate pipe specification and measurement instruments should be considered.

It is important to determine the pipe diameter because it is related to the cycle efficiency and the cost. When the diameter of pipe is increased, the pressure drop can be decreased thus the system efficiency will be increased. But excessive cost may arise if inappropriate (excessive large) pipe diameter is selected. Therefore, the pipe specification was analyzed based on optimum SCO_2 velocity along the system: 4 inch diameter of the pipe is considered. The thickness of tube diameter was analyzed based on ASME B 31.1 [6]. The required pipe thickness was 8.46 mm using SS316L. Finally, schedule 160 pipe specification was selected by considering additional stress due to the thermal expansion and off-design operation.

Major measurement instruments for the compressor test facility are flowmeter, control valve, pressure transmitter, RTD, etc. Venturi type flowmeter is selected for the SCO_2 side because of its low pressure drop and inexpensive. The disadvantage of the venturi flowmeter is the limited flow measurement range: the limited flow range can be compensated by using two differential pressure transmitters. An electromagnetic flowmeter is used in the coolant side. A control valve is needed in the SCO_2 compressor test facility because there should be a pressure drop device after the SCO_2 compressor for providing required inlet pressure condition of the SCO_2 compressor. Pneumatic piston actuator is selected and the size of the control valve system is same as the pipe specification. Pressure transmitters and RTDs were selected based on the maximum operating condition of the SCO_2 power generation prototype.

2.4 SCO_2 compressor test facility

Figure 4 shows the SCO_2 compressor test facility. The compressor test facility is based on the SCO_2 power generation system. After the SCO_2 compressor performance test, additional major components such as turbines, a recuperator, a flowmeter, and a control valve will be installed on the test facility.

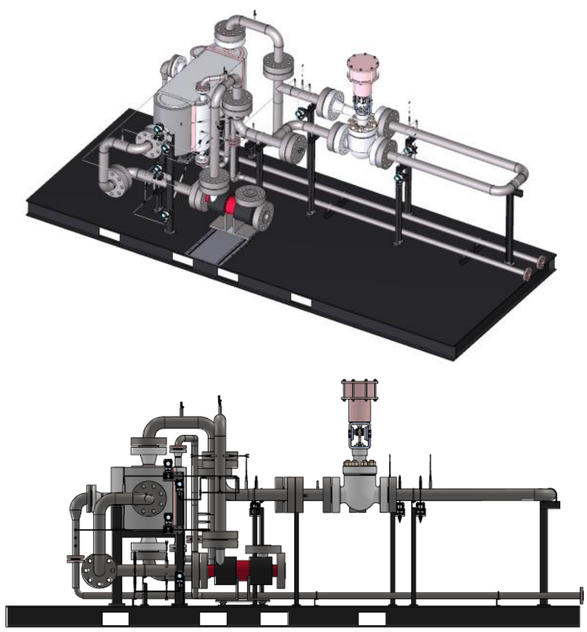

Fig. 4. SCO_2 compressor performance test facility.

3. Conclusions

Performance test of the SCO_2 compressor is important because it is related to the cycle performance and efficiency. The target of the pressure ratio is 1.75 with having 68% compressor efficiency. The SCO_2 compressor performance test facility is under construction and the performance test will be started on October, 2018.

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