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Installation of the Supercritical CO_2 Brayton Cycle Experiment Loop

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1. Introduction

Nowadays, the development of supercritical CO_2 Brayton cycle technology is a hot technology in various fields such as nuclear power plant, waste heat recovery, renewable energy. In nuclear energy field, the S-CO_2 Brayton cycle is one of the candidates for the next generation nuclear power plants since the S-CO_2 Brayton cycle has relatively high efficiency and compactness.

KAERI, KAIST and POSTECH joint research facility SCIEL has been started to develop Korean S-CO_2 Brayton cycle and to demonstrate both of components and system verification of the S-CO_2 Brayton cycle. In this paper, the overview of SCIEL facility is discussed with current activities.

2. Full Scope Description of SCIEL

One of the main purposes of SCIEL is technology independence of S-CO_2 Brayton cycle technology. Thus, designing and manufacturing of all main components such as compressor, heat exchanger and heater are cooperated with domestic vendors and SCIEL facility will serve them for technology verification.

For actual outcomes, final goal of the SCIEL is to demonstrate a few hundred kW electricity generation with simple recuperated or recompressing S-CO_2 Brayton cycle layout. Previous research said that the recompressing S-CO_2 Brayton cycle has higher efficiency than simple recuperated S-CO_2 Brayton cycle [1]. KAIST research team found out that the efficiency benefit from recompressing S-CO_2 Brayton cycle layout can be obtained when the compressor efficiency is high enough [2]. Thus, the SCIEL facility adopted step by step development. First step is to demonstrate high efficiency S-CO_2 compressor to decide research direction. At this step, various compressor types will be tested to find out the most suitable compressor type for S-CO_2 Brayton cycle. Currently two different types of compressor tests are planned and first type of compressor will be tested within September 2013. The reason why various compressor types should be tested at this point is the technical uncertainty of element technologies involved in S-CO_2 compressor. The S-CO_2 in the vicinity of the critical point has non-linear property variation and its variation quantity is very large. The S-CO_2 compressor is inherently small so that mechanical design and machining tolerance management are challenges. Thus, a verification of S-CO_2 compressor performance will be a key issue. Another uncertain component is domestic manufactured PCHE (Printed Circuit Heat Exchanger). Chemical etching and diffusion bonding for PCHE manufacture was successfully finished and pressure withstand test was finished up to 250 bar. But, its performance is still uncertain since PCHE performance verification can be a serious issue for cycle analysis and design. Recuperator which will adopt PCHE governs overall cycle efficiency and heater capacity. So, performance verification of PCHE will be performed during compressor experiment loop operation.

After compressor test is done, electricity generation phase will be started.

3. Current State of SCIEL Facility

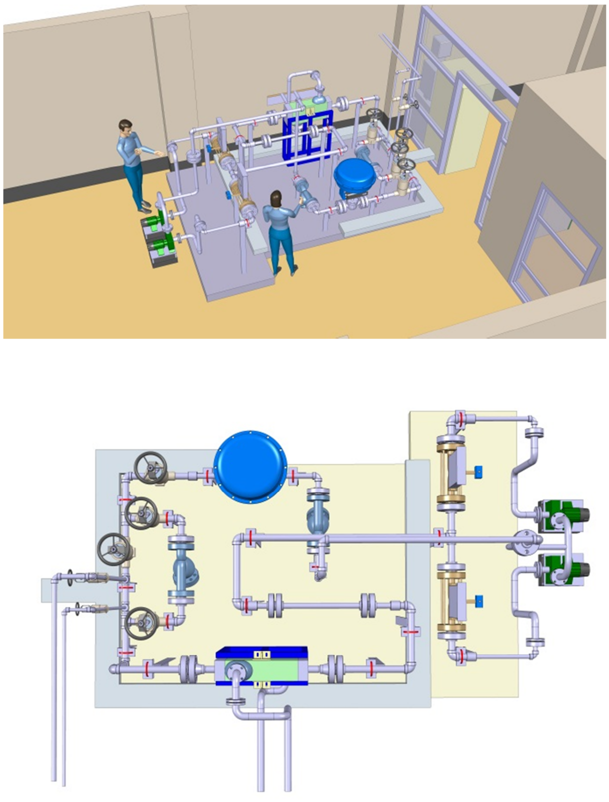

Fig.1. Current State of SCIEL facility (S-CO_2 compressor experiment facility, water pumps are temporarily installed for the pressure drop test)

Currently, SCIEL facility is installed to test the compressor performance and its construction was finished within September, 2013. The compressor experiment loop has a 100kW S-CO_2 compressor

(70,000rpm, 6.4kg/s), 300kW pre-cooler(680 x 320 x 170, SUS316) and precise measurement devices. For flexible depressurization, control valve and series of gate valves are installed on compressor experiment loop. These valves will also be used for compressor flow rate and turbine flow rate control at electricity generation test.

4. Preparation for Simple Recuperated S-CO_2 Brayton Cycle Experiment

Next step of SCIEL project is demonstrate simple recuperated S-CO_2 Brayton cycle. If the compressor performance test result is good enough, however, recompressing S-CO_2 Brayton cycle layout experiment will be seriously concerned for later step.

For electricity generation test with simple recuperated S-CO_2 Brayton cycle layout, compressor experiment loop will be modified and expanded with additional components such as heater, recuperator and required supporting and measurement devices.

Table 1. Component work capacities for simpler recuperated S-CO_2 Brayton cycle experiment

Component	Capacity (kW)
Compressor	55.1
Turbine	156.6
Recuperator	1572.5
Heater	645.2
Pre-cooler	543.7

Component work capacities are calculated with design target conditions with reasonably assumed component efficiencies. Cycle maximum pressure is on the range of 130bar to 200bar while above 500°C of target cycle top temperature is concerned.

4.1. Compressor

Compressor for simple recuperated S-CO_2 Brayton cycle experiment will be same with the compressor which will be installed on compressor experiment loop.

4.2. Turbine

Turbine will be manufactured by domestic vendor. At high temperature range of S-CO_2 doesn't have non-linear variation of thermodynamic properties. Thus, authors carefully guess that turbine design and manufacturing will be smooth. For turbine installation, compressor alternator turbine configuration and separated turbine-generator are concerned. Turbine configuration will be confirmed after compressor test result is obtained.

4.3. Recuperator

PCHE type recuperator will be designed and manufactured by domestic vendor. As shown in Table 1, heat capacity of recuperator is on MW order. Thus, small amount of efficiency prediction causes huge difference of its capacity. Thus, result of PCHE performance test from compressor experiment test will be reflected to recuperator design.

4.4. Heater.

About 750kW of heater will be designed and manufactured by domestic vendor. Shell and tube type electric heater is accepted and it will have serial form with multiple units.

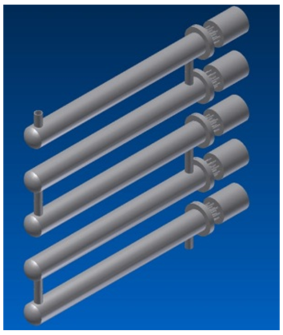

Fig.2. S-CO_2 heater array

4.5. Pre-cooler

Since 300kW of pre-cooler is installed on compressor experiment loop, pre-cooler will be modified to 600kW. Since 600kW of cooling capability is already secured, S-CO_2 cooling system will be finished after PCHE extension.

5. Summary

KAERI, KAIST and POSTECH research team is trying to demonstrate S-CO2 Brayton cycle for next generation nuclear power plant application. Currently, S-CO_2 compressor experiment facility is in construction and actual test will be started within September 2013. Depending on compressor test results, future experiment direction will be confirmed.

As a next step, simple recuperated S-CO_2 Brayton cycle experiment is planned and facility extension is on progress. After 100kWe electricity generation, final goal of SCIEL project will be rearranged and this work will be a seed for Korean S-CO_2 Brayton cycle technology development.

ACKNOWLEDGMENTS

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