DESIGN OF A TEST RIG FOR THE EXPERIMENTAL CHARACTTERIZATION OF BRAYTON HIGH-TEMPERATURE HEAT PUMPS

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ABSTRACT

This study shows the conception and design of a test rig for the experimental charatecization of high-temperature heat pump based on a Brayton Joule cycle, which provides heat at more than 130°C, using small-size and off-the-shelf components. This facility will enable the testing of several models of Brayton heat pump systems and components, with the final goal of highlighting the technology's key features and overcoming the challenges that may hinder its wide deployment in industry.

INTRODUCTION

High-temperature heat pumps have the potential to play a crucial role in decarbonizing the heat demands of the industrial sector [1]. Heat pumps based on the Brayton cycle have gained increasing attention, especially for applications above 150°C [2], thank to their conceptual simplicity and high temperature compatibility. However, only a few examples of operating prototypes exist in the literature. Therefore, still research is necessary to investigate and optimaza the performance of these systems and their components in design, off design and transient conditions. In addition, a reduction of costs of high temperature heat pumps is necessary to promote their diffusion in industrial applications. To this purpose it is important to assess the suitability of components already existing on the market to be used in these systems.

This study propose the conception and realization of a test rig to test in different conditions the performance of high temperature heat pumps and their components. The test rig is designed to promote its flexibility and allows the testof four distinct operating conditions for the heat pump: closed- and open-loop and regenerated and non-regenerated layout. With a set of valves, it is possible to bypass the regenerative heat exchanger, transitioning from one operational state to another. In contrast, open loop operation is achieved simply by disconnecting the turbine outlet from the compressor inlet.

RESULTS AND DISCUSSION

Based on what is available on the market and considering the main limitations of available turbomachinery, the thermodynamic cycle is designed to evolve between a minimum pressure of 1 bar and a maximum of 2 bar and between a minimum temperature of -7°C and a maximum of 135°C. The arrangement of the test rig is reported in Figure 1, with a detail of the measurement points and control loops.

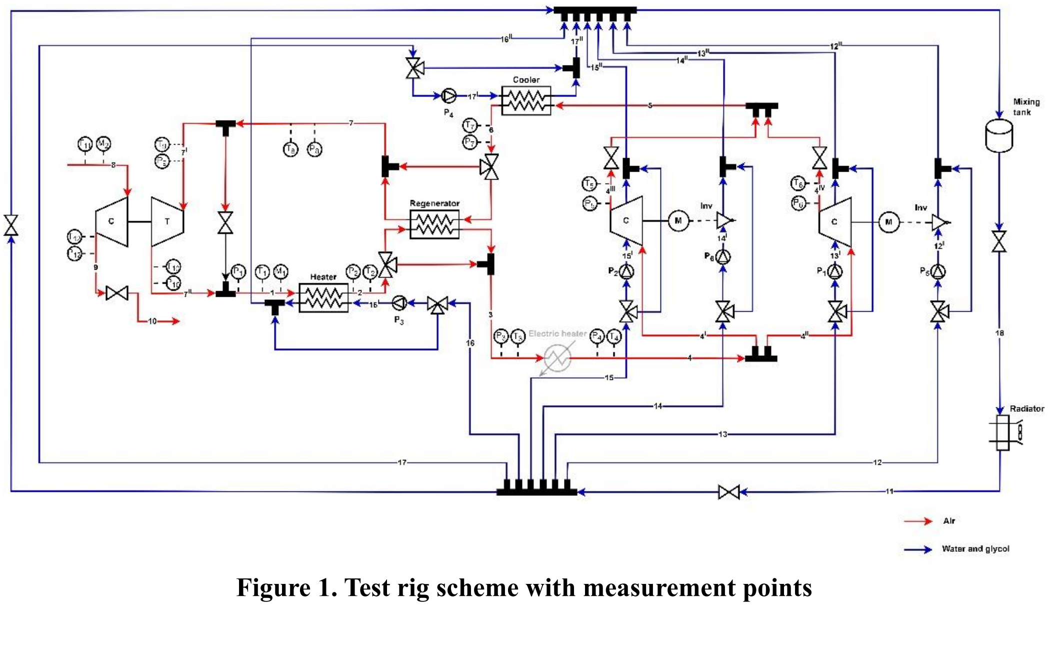

Figure 1. Test rig scheme with measurement points

For the expansion unity, an automotive turbocharger were selected, instead of a single turbine, thanks to greater availability of the former on the market. Two centrifugal compressors originally developed for fuel cell-related applications were considered for the compression section. The use of two compressors in parallel was necessary to match the expansion unit mass flow rates. The selected machines are reported in Table 1.

	Name	**Nominal power** [kW]	**Test rig power** [kW]	**Air flow rate** [kg/s]
Turbine (turbocharger)	Garrett GBC14-200	N/A	5	0.11
Compressor	Rotrex EK10C-0822	13	5.5	0.05

Table 1 – Turbomachine data

Once the test rig's operating conditions and components were selected (see Figure 1), particular attention was devoted to the coolant system design. This system has a twofold role: dissipate the heat pump output and cool the auxiliary components, such as compressor lubricant oil and compressor inverters. A closed-loop coolant liquid circuit is proposed to simplify the test rig. All the heat exchangers are operated in parallel and the excess thermal energy is dissipated into the environment. Seven heat exchangers are connected in parallel to the collectors, with five of them increasing the coolant temperature and two reducing it. The heat exchanger capacity is reported in Table 2.

	Heat [kW]	**Area** [m^2]
Heater	2.51	0.52
Cooler	8.72	1.39
Regenerator	2.56	2.86
Electric heater	2.50	/
Radiator	43.3	15.8

Table 2 – Heat exchangers data

REFERENCES

[1] Arpagaus, Cordin, et al. "High Temperature Heat Pumps: Market Overview, State of the Art, Research Status, Refrigerants, and Application Potentials." Energy, vol. 152, 2018, pp. 985-1010.

[2] Zühlsdorf, B., et al. "Analysis of Technologies and Potentials for Heat Pump-based Process Heat Supply above 150 °C." Energy Conversion and Management: X, vol. 2, 2019, p. 100011.