Preliminary Design of a Compressor for the Supercritical CO_2 Brayton Cycle coupled to KALIMER

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1. Introduction

The supercritical CO_2 Brayton cycle has recently been suggested as an advanced power conversion system for a liquid-metal reactor in view of its economic design and operation. The efficiency and the size of the turbomachinery are considered as important parameters for the S-CO_2 cycle economic efficiency. The preliminary performance analysis of the compressor was conducted for the S-CO_2 Brayton cycle coupled to Kalimer-600 with a one-dimensional analysis code.

2. Design of S-CO_2 compressor

2.1 Conceptual design of the S-CO_2 compressor

Figure 1 is the conceptual diagram of the S-CO_2 Brayton cycle coupled to the KALIMER-600 liquid-metal reactor which has been developed in the KAERI. The analysis of the cycle performance was conducted with one-dimensional S-CO_2 Brayton cycle analysis code, named RECOBA, which was developed at KAERI [1]. The cycle efficiency was estimated as around 42.8% under the assumption of the efficiencies of the two compressors and a turbine, 89.1%, 87.5%, and 91.7%, respectively. The design of the compressor is most important to enhance the S-CO_2 Brayton cycle efficiency since the properties of S-CO_2 are drastically varied near its critical point.

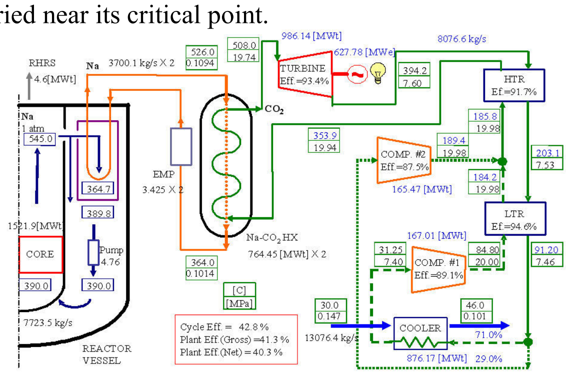

Figure 1. The schematics of S-CO2 Brayton cycle coupled to the KALIMER-600 liquid-metal reactor

The development process of a compressor can be roughly divided into a conceptual design, a preliminary design, a detail design, and a performance evaluation. Based on the physical properties, the basic design parameters such as a specific speed and a specific diameter are established in the conceptual design step. In this step, the compressor type and stage number are determined to maximize the efficiency. In the case of a preliminary design, the major design parameters of the compressor are determined with the methodology of one-dimensional analysis such as a meanline analysis method.

The configuration parameters such as an impeller and diffuser and an inlet guide vane are designed on a detail design stage by using lots of correlations and experimental tables. And the designed compressor is estimated with the help of a commercial computational code and an experiment of a prototype.

Table 1. Conceptual design parameter of the compressor

	Unit	Compressor #1	Compressor #2
Average density	kg/m3	466.3	200.8
Pressure difference	MPa	6.30	3.13
Head	m	1378	1589
Rotational speed	rpm	3600	3600
Diameter	m	0.90	0.80
Volume flow rate	m3/s	12.30	11.66
Specific speed	–	55.83	48.84
Specific diameter	–	1.564	1.479
Stage		2	3

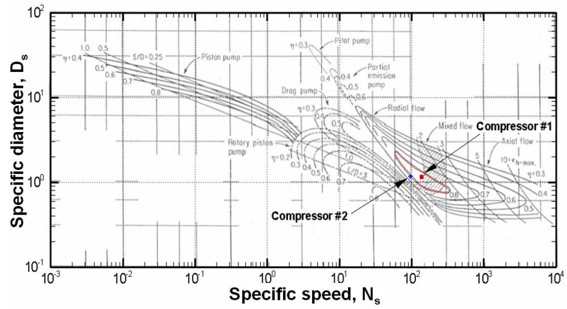

Figure 2. Design points of the compressor #1, #2 in the conceptual design process

The design parameters of the two compressors are summarized in Table 1 for the S-CO_2 Brayton cycle coupled to the KALIMER-600 and its schematics is shown in Figure 1. The maximum diameter and the head of the compressor were determined to maximize the efficiency in the diagram of the specific diameter and the specific speed [2]. From Figure 2, the stages of the two compressors #1 and #2 were determined as two and three, respectively and the efficiency was estimated as more than 80% in the process of the conceptual design.

2.2 Preliminary design of the S-CO_2 compressor

The preliminary design code of the radial compressor for the S-CO_2 cycle, named COMP1D, was developed on the basis of the meanline analysis method, which is a one-dimensional analysis method to analyze the flow and the energy along a meanline path. During the design and analysis process, a delicate loss model, the internal and the external loss, was used to include the impeller configuration and the flow path parameter [3]. Figure 3 shows the major configuration parameters of the radial type compressor. Figure 4 shows the flow diagram of the COMP1D code, which includes a change of the operation condition and stage order to obtain the exit condition for the next stage. Figure 5 shows some results of the sensitivity analysis with the COMP1D code. From the sensitivity analysis, the tip diameter (dit) and the exit diameter (dod) has a large affect on the performance as well as the exit blade angle (alod). Figure 6 shows the characteristics of the off-design point of compressor #1 and compressor #2 with an analysis by the COMP1D code.

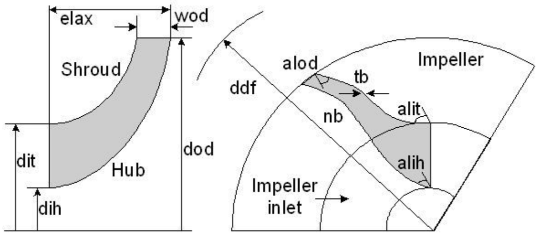

Figure 3. Configuration parameter of radial compressor

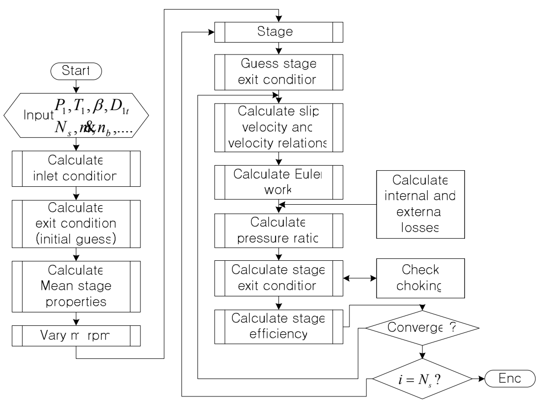

Figure 4. Flow diagram of the COMP1D code

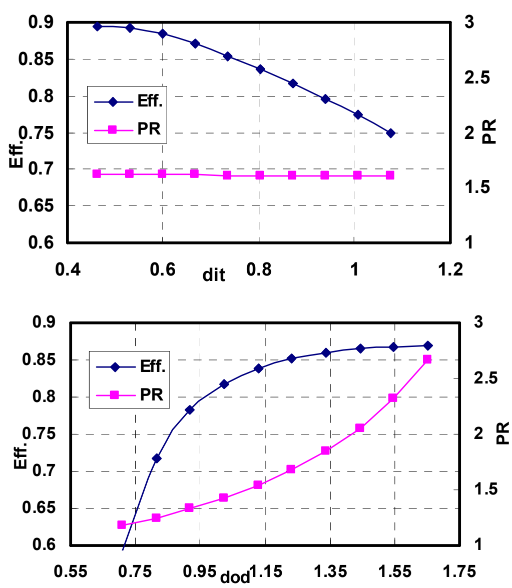

Figure 5. Sensitivity of radial compressor for the S-CO_2 cycle with COMP1D code

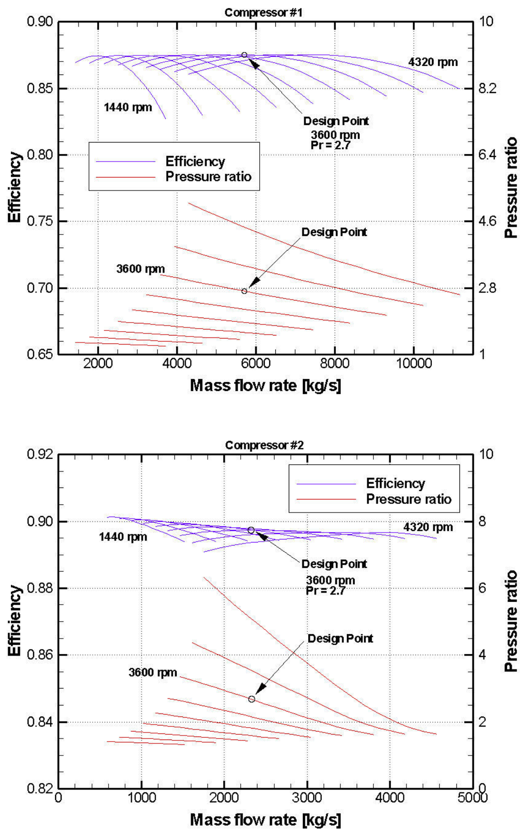

Figure 6. Off-Design Characteristics of the two compressors

3. Summary

A one-dimensional design and analysis code was developed to determine the compressor configuration parameter near an operation point on the basis of the meanline analysis method and Oh's loss model. The preliminary performance analysis of the compressor was conducted for the Kalimer-600 S-CO_2 Brayton cycle. The off-design characteristics and the sensitivity of the compressor configuration were analyzed with the code.

Acknowledgement

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