Verification of Gas System Analysis Code GAMMA+ with S-CO_2 Compressor Test Data

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1. Introduction

A Supercritical Carbon dioxide (S-CO_2) Brayton cycle is receiving attention as a next generation power conversion system for Generation IV (Gen IV) reactors due to its high system efficiency, simplicity, compact components and so on [1-2]. It was identified that controlling CO_2 compressor near its critical point is the core technology for the S-CO_2 Brayton cycle achieving high system efficiency. To achieve CO_2 compressor operating technique and accumulate experimental data near the critical point of CO_2, KAIST research team is utilizing the CO_2 compressing test facility called SCO2PE (Supercritical CO_2 Pressurizing Experiment). Operating the SCO2PE, our research team is studying the S-CO_2 compressor and cycle under various compressor inlet conditions near the critical point.

Despite the growing interest in the S-CO_2 Brayton cycle, research on the cycle transient analysis, especially in case of CO_2 compressor inlet condition variation, is still in its early stage. Most of existing analysis methods are not proven to be accurate near the critical point of CO_2 [2-3]. Thus, in this study, the authors conduct a S-CO_2 loop transient study with the GAs Multidimensional Multicomponent mixture Analysis plus (GAMMA+) code, a transient analysis code for analyzing hypothetical transient cases in a High Temperature Gas-cooled Reactor (HTGR) systems [4]. Some updates in the GAMMA+ code were carried out to apply to the S-CO_2 system [5].

For the selected transient scenario, the loss of cooling water event was assumed, so a test was conducted in the SCO2PE by decreasing the mass flow rate of cooling water line. Before the whole SCO2PE loop is simulated, major components, the compressor and the heat exchanger, were separately modeled [5].

2. Verification and Validation of the GAMMA+ code with SCO2PE data

Fig. 1 shows the nodalization of the SCO2PE loop. The SCO2PE nodalization can be separated into two systems, the primary side is a closed CO_2 loop while the secondary side is an open water loop for heat rejection. The nodalization consists of fluid blocks, external junctions and boundary volumes.

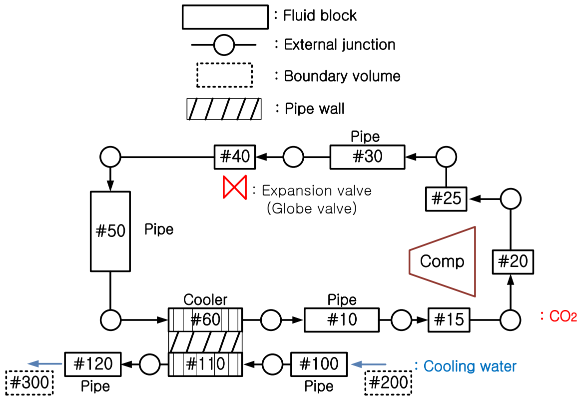

Fig 1. Nodalization of the whole SCO2PE loop for GAMMA+ code

Table I: The steady state operating conditions before the transient state

For steady state		
Compressor Inlet and outlet temperature of CO_2 side (°C)	Inlet	40.0
	Outlet	42.0
Compressor Inlet and outlet pressure of CO_2 side (MPa)	Inlet	8.29
	Outlet	8.60
Mass flow rate (kg/s)	Inlet	1.58
	Outlet	0.25
Compressor Inlet and outlet temperature of water side (°C)	Inlet	25.4
	Outlet	37.5

In this study, a scenario that models the cooling water flow rate reduction over time was investigated to simulate the postulated loss of cooling water accident. The steady-state condition before beginning of the transient state was first calculated and the results are summarized in Table I. This test condition was chosen in consideration of the previous results [5]; to avoid the narrow region where the uncertainty is high due to the critical point. The mass flow rates of CO_2 and cooling water are shown in Fig. 2 for 100 seconds. Under this condition, the results of the pressure and temperature variations at the heat exchanger inlet, compressor inlet (almost the same with the heat exchanger outlet) and compressor outlet are respectively shown in Figs. 3, 4 and 5.

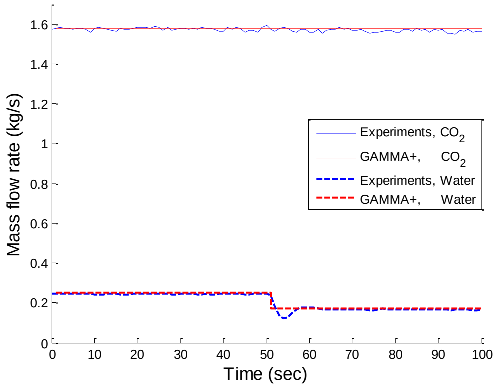

Fig 2. Transient mass flow rate data comparison between experiments and GAMMA+ code for transient state

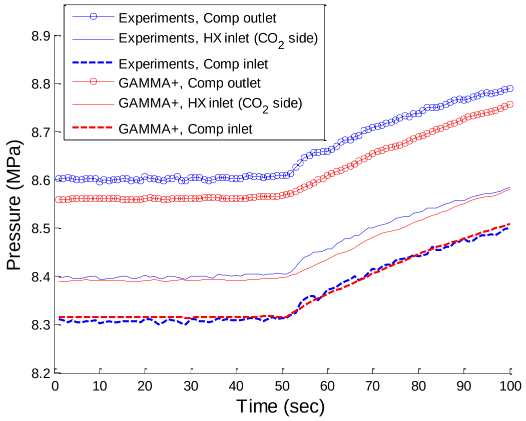

Fig 3. Transient pressure data comparison between experiments and GAMMA+ code for transient state

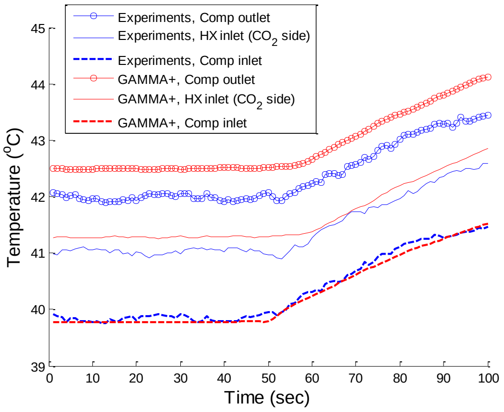

Fig 4. Transient temperature data comparison between experiments and GAMMA+ code for transient state at the CO2 system of SCO2PE

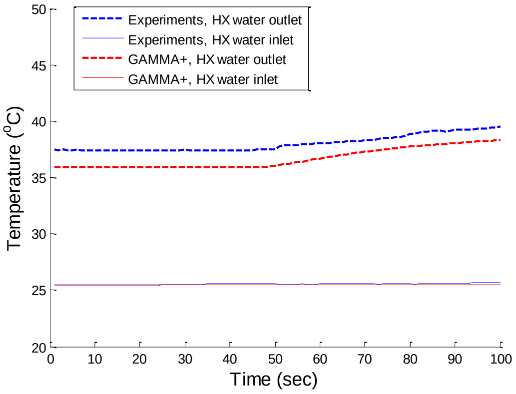

Fig 5. Transient temperature data comparison between experiments and GAMMA+ code for transient state at the cooling water system of SCO2PE

3. Results and Conclusions

In this study, the validation and verification of the GAMMA+ code, which is gas system transient analysis code was conducted by using the obtained SCO2PE experimental results.

Before performing a SCO2PE loop transient simulation with the updated GAMMA+ code, major components, the compressor and the heat exchanger, were separately modeled. For the transient experiment, the reduction in cooling event was experimented in the SCO2PE. The results of GAMMA+ code show reasonable agreement with SCO2PE experimental data. However, there is a minute difference between the GAMMA+ prediction and the experimental data, especially at the compressor outlet condition because the heat transfer value from the experimental data was uncertain due to the measurement uncertainties and the CO_2 properties near the critical point.

To reduce the difference between the experimental data and GAMMA+ results, the modeling of SCO2PE and the methodology for turbomachinery analyses will have to be updated in the future.

ACKNOWLEDGEMENT

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