A CFD investigation of Using an Isothermal Compressor in a Supercritical CO_2 Cycle for SMART Applications

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Introduction

▣ To maximize the benefits of SMART, the supercritical CO_2 (S-CO_2) power cycle can be adopted to improve the performance of power conversion systems.

▣ Adopting an isothermal compressor in the S-CO_2 cycle can be advantageous, and can improve the efficiency by 1-2% points.

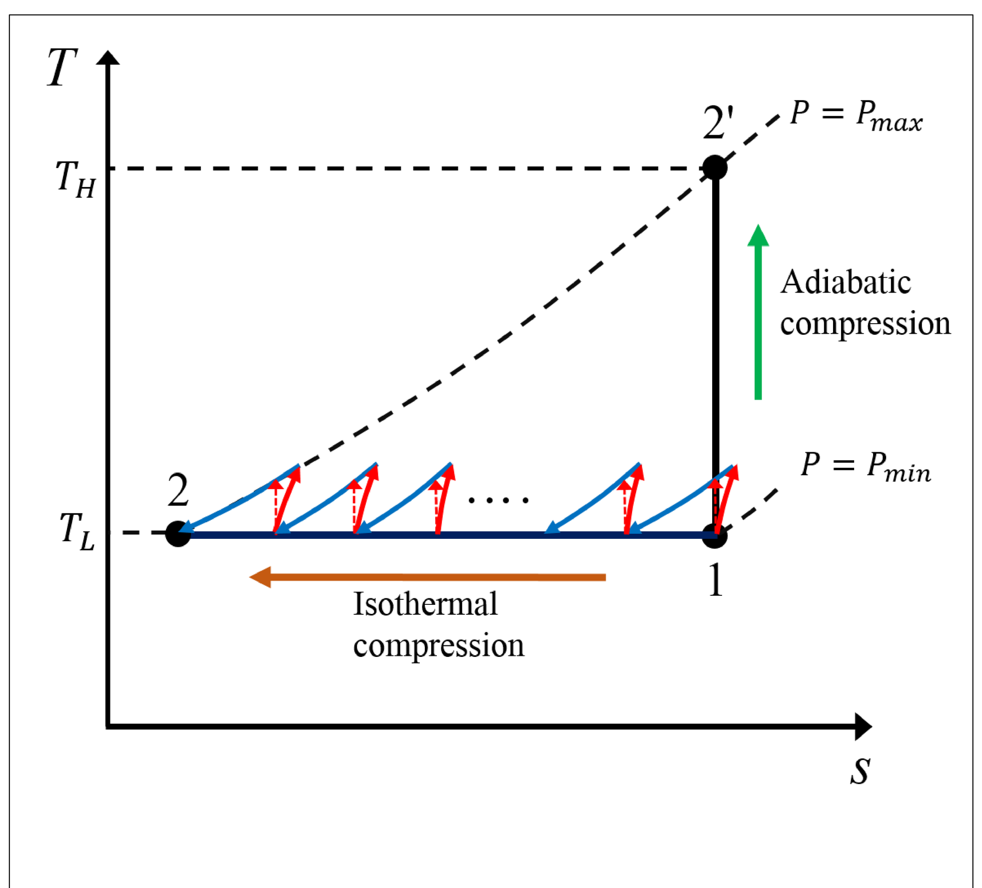
▣ In order to investigate the possibility of using an isothermal compressor, a CFD analysis on the basic operating feasibility of the suggested turbomachine is performed.

Isothermal Compressor Performance Analysis

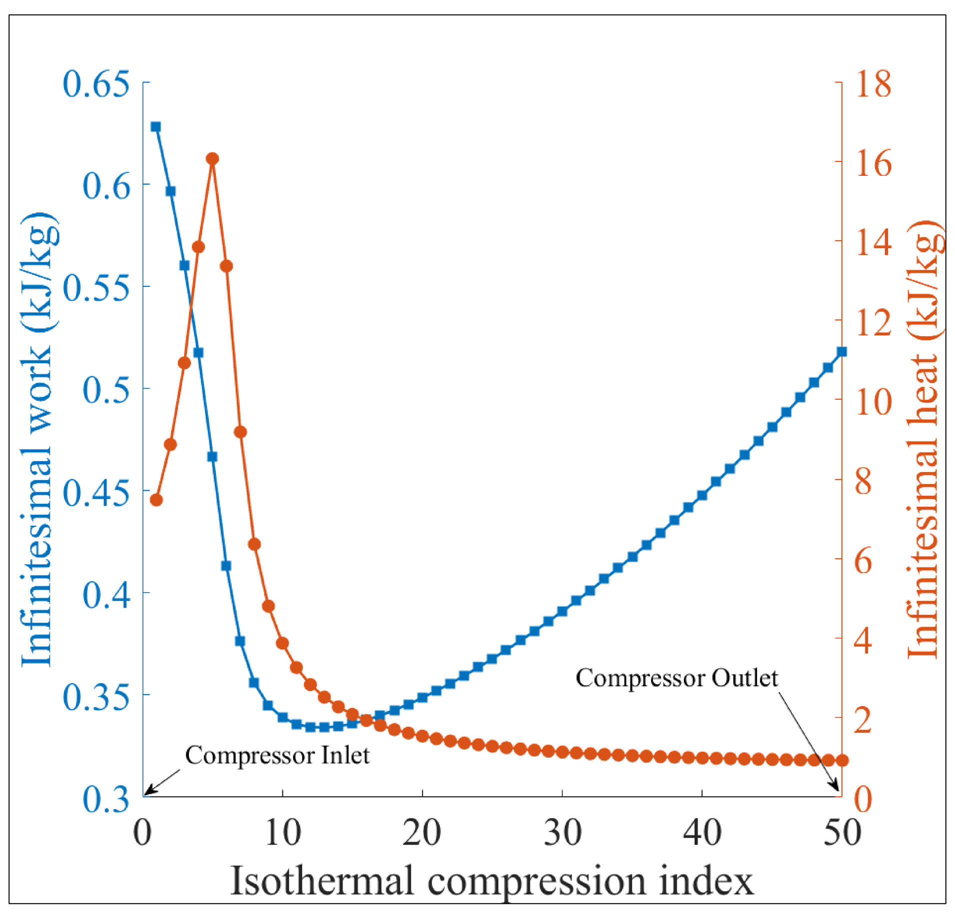
▣ Isothermal compression allows the working fluid to become compressed at constant temperature, and can minimize the compression work required.

▣ The 'infinitesimal approach' is suggested in order to defined the real work to calculate the efficiency of the isothermal compressor.

▣ The framework divides the isothermal compression into a series of infinitesimal isentropic compression and cooling processes to calculate the amount of heat required to be removed during compression.



▲ *T-s diagram of Brayton cycle with isothermal compression*



▲ *Graph showing the heat removal required for isothermal compression at each infinitesimal process*

CFD Analysis Conditions and Setup

▣ The geometry and design variables are taken from the S-CO_2 compressor from the SCIEL loop facility in KAERI. This is to compare with previously conducted results and to create the geometry model from preexisting compressor.

▣ The study has utilized the commercial code STAR-CCM+, under $k-\omega$ SST (Shear Stress Transport) model with wall function. The properties of S-CO_2 have been stored under data tables from NIST REFPROP.

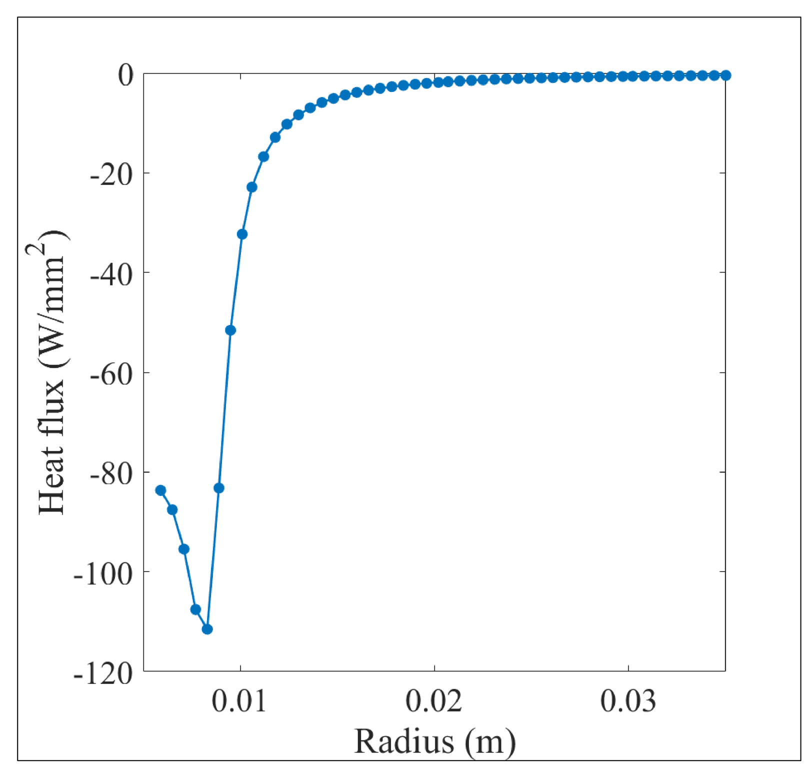
▣ The mesh scheme consists of polyhedral elements with 10 prism layers.

▣ Design variables for the SCIEL compressor are given as the following in the table below. Some variables are altered from the reference values for better CFD convergence.

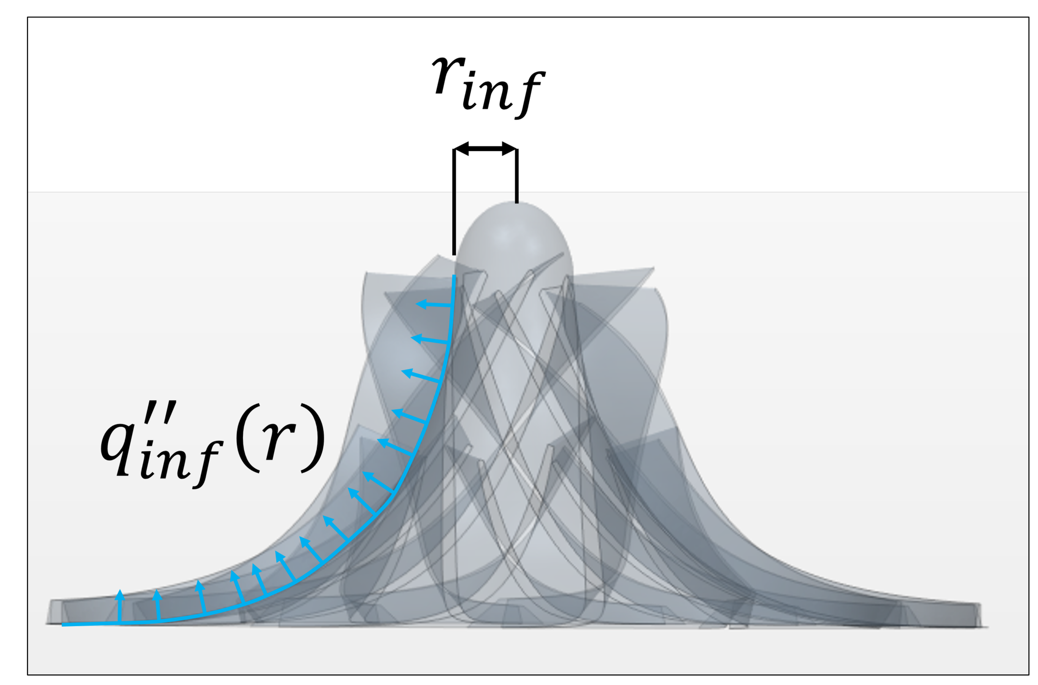
▣ Heat flux profile with increasing radius has been obtained.

Design Variables	
Compressor inlet temperature (°C)	38°C
Compressor inlet pressure (MPa)	7.8MPa
Pressure ratio	1.13
Compressor small stage efficiency (%)	85%
Shaft speed (rpm)	70,000
Mass flow rate (kg/s)	1.1 (one side)

▲ *Modified compressor specifications based on SCIEL compressor operating and design conditions*



▲ *Figure showing the heat flux profile needed to create isothermal compression*



▲ *Figure showing the impeller surface diameter and surface cooling heat flux provided to create isothermal compression*

Results and Conclusions

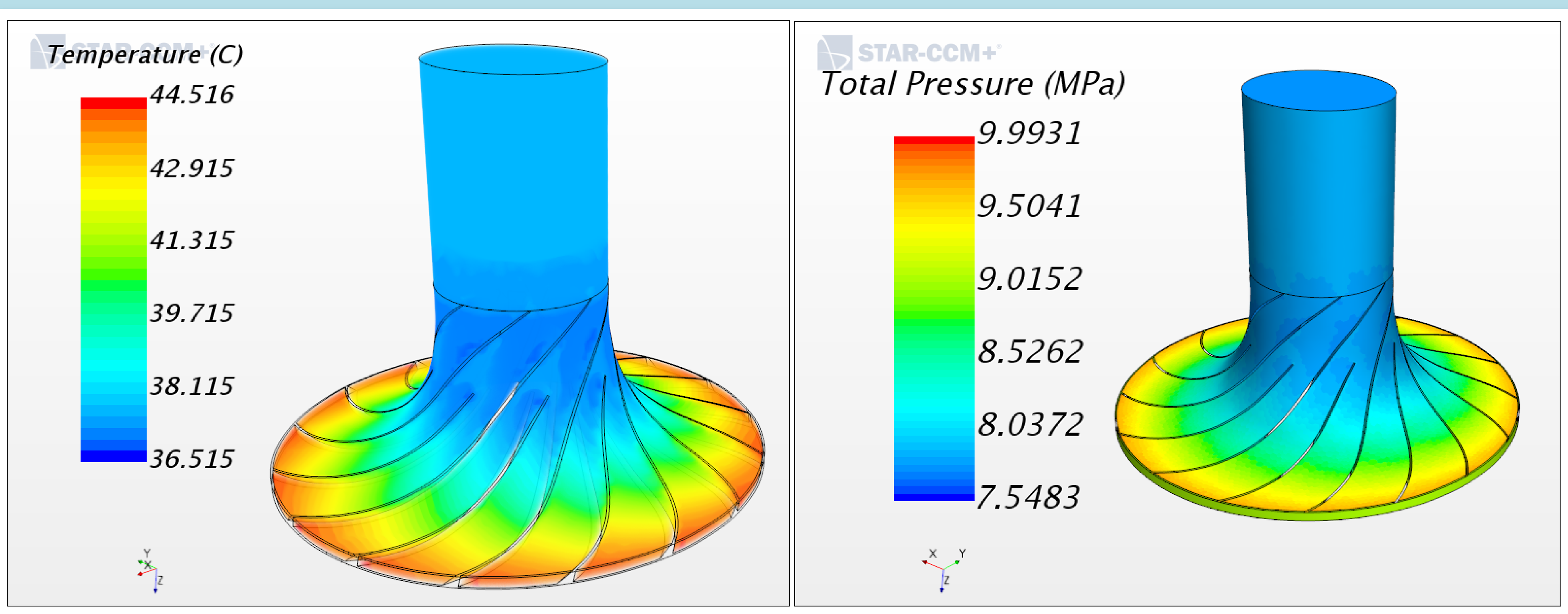


Fig. Temperature and pressure distributions inside the impeller under adiabatic boundary condition (**Outlet temperature = 48°C , outlet pressure = 8.8MPa**)

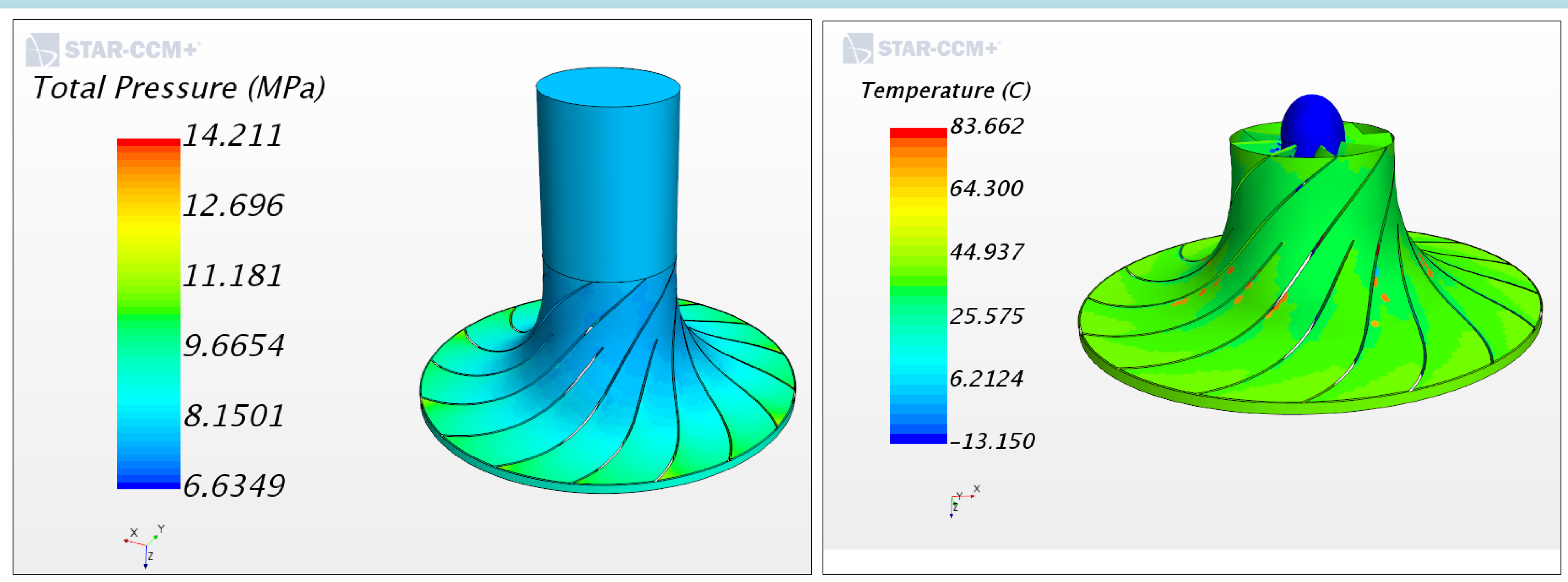


Fig. Temperature and pressure distributions inside the impeller under heat flux profile boundary condition (**Outlet temperature = 41°C, outlet pressure = 9.0MPa**)

▣ The results of which the isothermal compression is emulated show that the theoretical isothermal compression can be achieved by providing strong heat flux boundaries inside the impeller. However, due to the limited surface area that creates high heat fluxes, it would be more realistically feasible to incorporate shroud surface cooling as well.