Preliminary Analysis of Supercritical CO_2 Compressor with CFD

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Introduction

▣ A supercritical CO2 Brayton (S-CO_2) Cycle is a variation of gas Brayton cycle, which utilizes supercritical CO_2 as a working fluid

▣ One particular advantage of S-CO_2 cycle is that compression process occurs near the critical point, and this reduces compression work significantly

▣ S-CO_2 cycle can be widely applicable to many heat sources such as concentrating solar power, fossil fuel, and nuclear. Especially, high density of S-CO_2 and simple layout of the system facilitate small scale power generation such as small modular reactor (SMR)

▣ A Compressor operating under S-CO_2 condition shows different behaviors with air compressor, and requires unconventional design and analysis methods

▣ It is necessary to conduct an experiment for a compressor operating under S-CO_2 condition

▣ However, due to high density of S-CO_2, the compressor tends to be considerably small, which makes it difficult to measure local flow variables. For this reason, CFD analysis should be applied

Experiment Facility

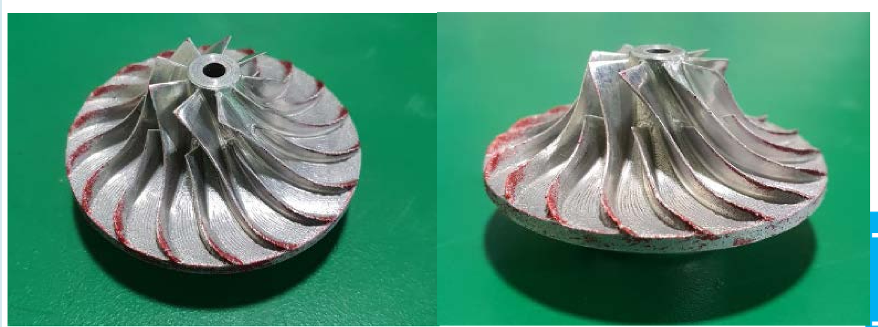
▣ Previously, Cho [1] Designed and performed a compressor testing based on an 1D method

▣ For compressor testing, turbine impeller was temporarily removed

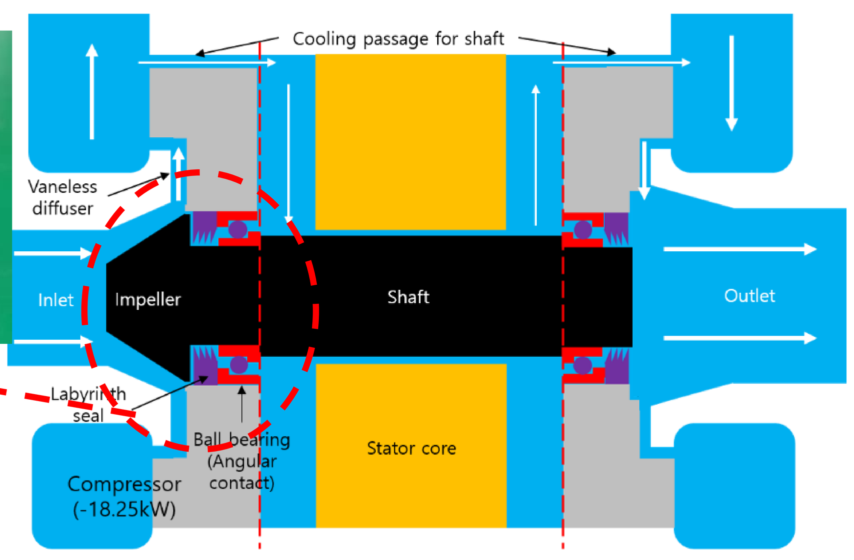
▣ As a result of testing, compressor performance map was produced, but due to small size of impeller, it is difficult to measure local flow parameter through flow passage

▲ *Bird view of experimental facility*

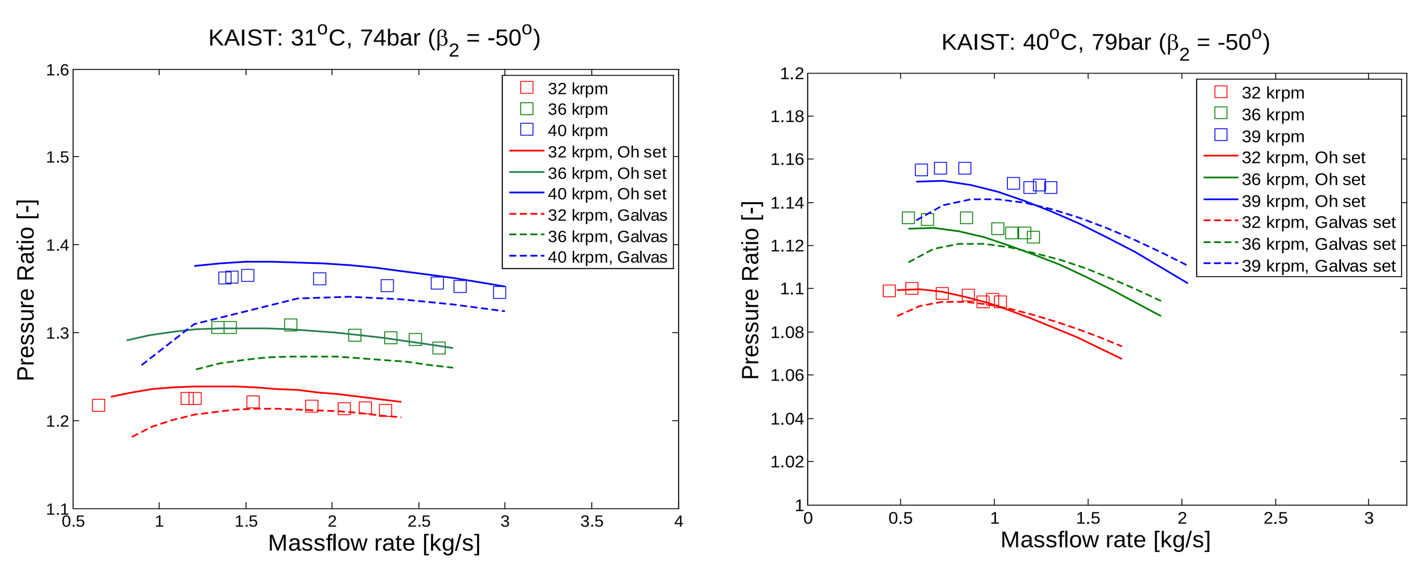
	Design condition
Specific speed	0.65
Pressure ratio	1.29
Inlet Temperature	31.4 °C
Inlet pressure	7.60 MPa
Efficiency	56 %
Mass flow rate	3 kg/s
Design speed	40,000 rpm
Impeller type	Unshrouded impeller
DN factor	1,560,000
Bearing type	Agular contact ball bearing



▲ *Compressor impeller*



▲ *Schematic diagram of TAC*



▲ *Compressor testing results*

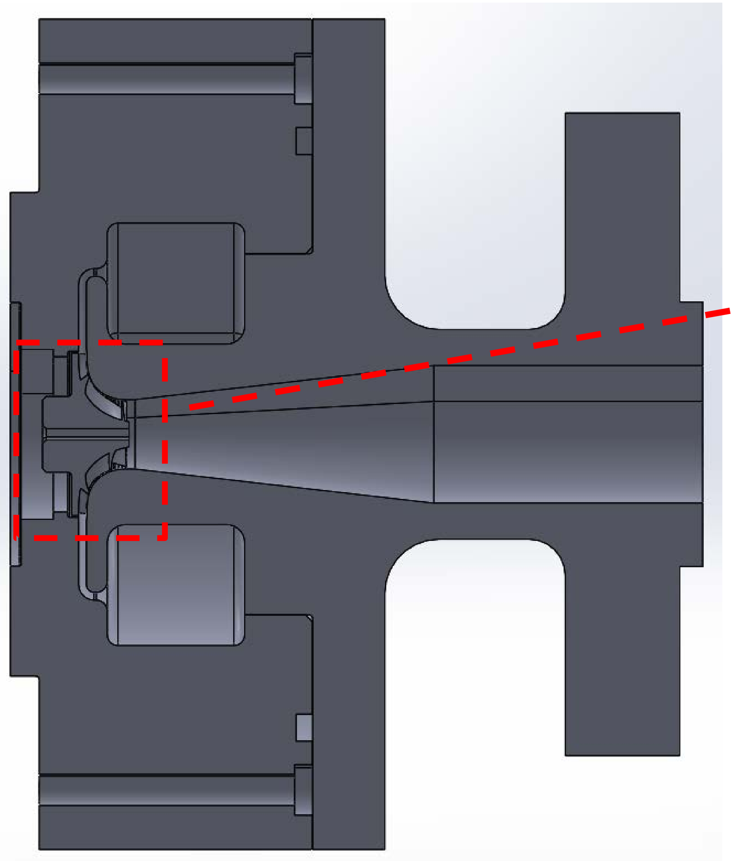
[1] Cho, Seong Kuk, et al. "Optimum loss models for performance prediction of supercritical CO2 centrifugal compressor." Applied Thermal Engineering 184 (2021): 116255.

CFD Analysis

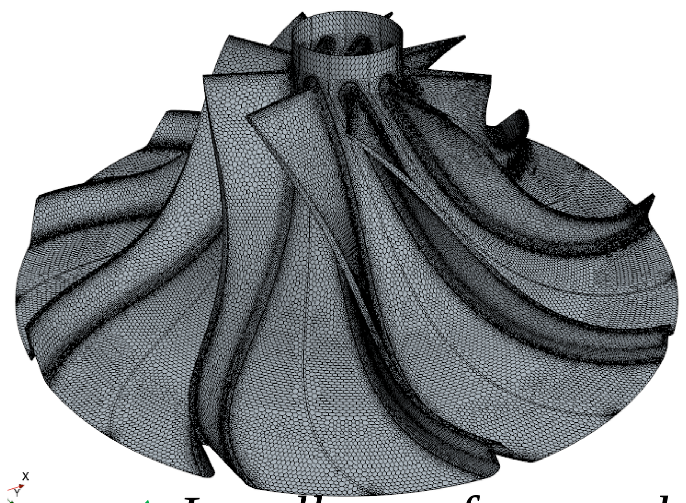
▣ Normally, a compressor consists of impeller, diffuser, and volute.. Compressor impeller mainly increase fluid velocity, and diffuser increase pressure by converting velocity effect to pressure effect. Volute is a connector between compressor and outlet pipe

▣ The target compressor is unshrouded compressor, so it has stationary casing wall and rotating impeller blade with a thin gap placed between them

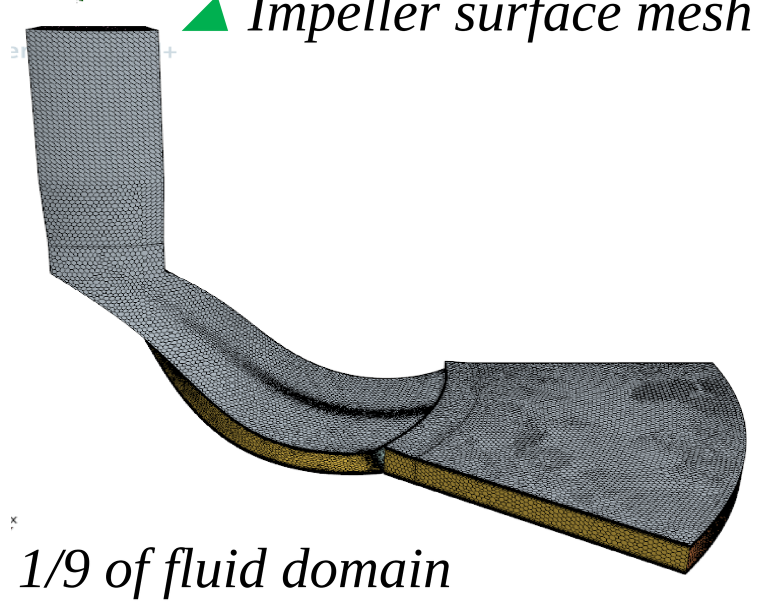
▣ Impeller and diffuser are covered for the modeling. Because of the axi-symmetric nature of the compressor, it is possible to apply periodic boundary condition



▲ *Compressor assembly (Solid)*



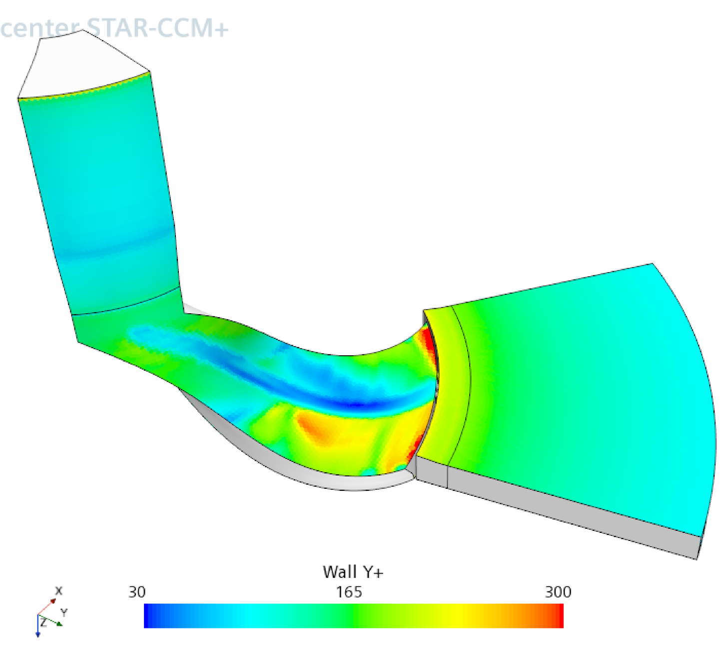
▲ *Impeller surface mesh*



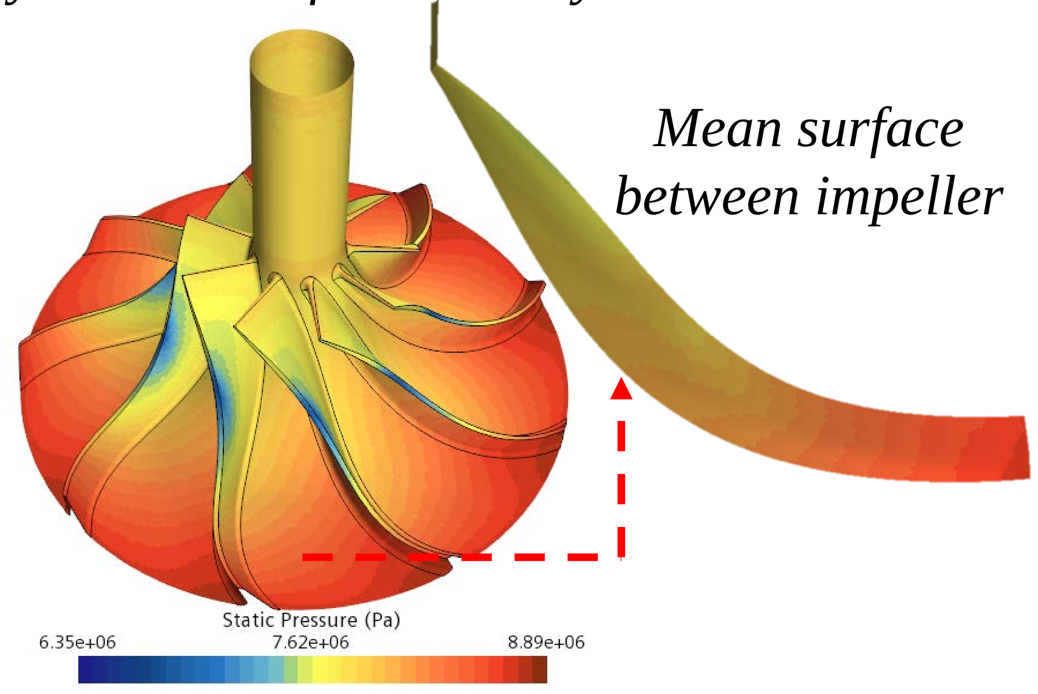
▲ *1/9 of fluid domain*

	Type	Value
Mesh	Polyhedral	4E05
Inlet BC	Total pressure	80 bar / 40 °C
Outlet BC	Static pressure	91 bar
Rotation	Moving reference frame	40,000 RPM

▲ *Summary of physical model for the analysis*



▲ *y+ value contour*



▲ *Pressure contour*

▣ For the analysis, STAR-CCM+ was used

▣ k-w SST model was employed, and other physical model applied in the model was summarized as above

▣ y+ values are between 30-300, where wall function approach is available

Future works

▣ Provided that experimental data exist, the validity of model should be confirmed with the data.. For comparison, compressor performance map data with respect to mass flow rate and rotational speed needs to be produced from CFD

▣ When global performance parameters such as pressure ratio and efficiency is comparable to the compressor testing data, local flow variable and compressor design parameters will be studied