University R & D Session

KAIST Activities

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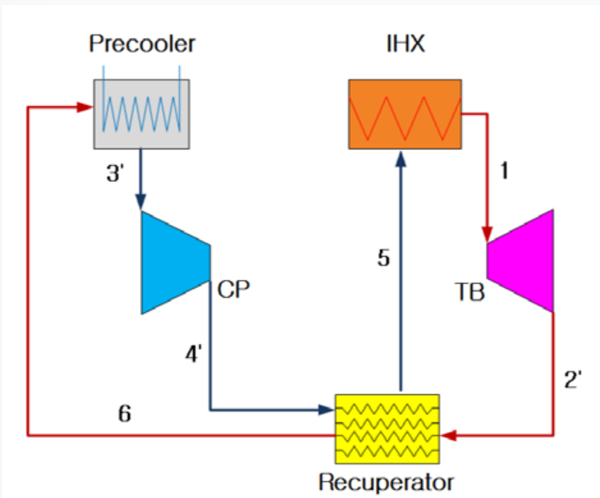
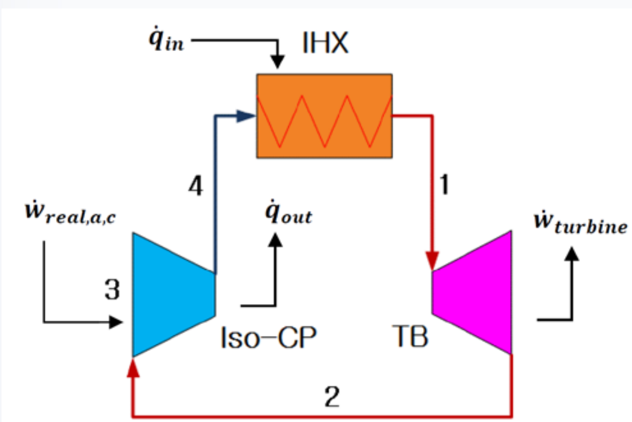
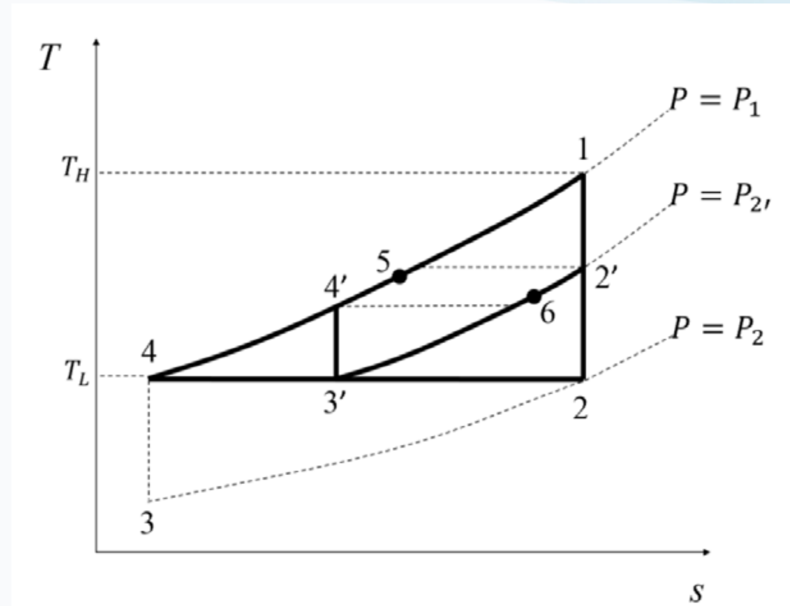
Issues Studied in KAIST

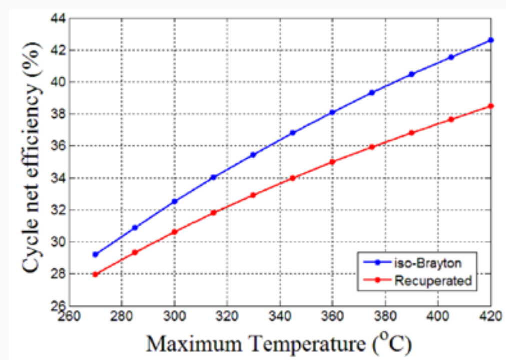
- Larger power system requires higher specific power
- Advanced turbomachinery and heat exchanger design and analysis methodologies
- New type of components or systems
- Transient analysis (Startup, Shutdown, Incidents…)
- Specific Technical Issues to Specific Heat Source
- Critical Flow and Phase Change
- Materials

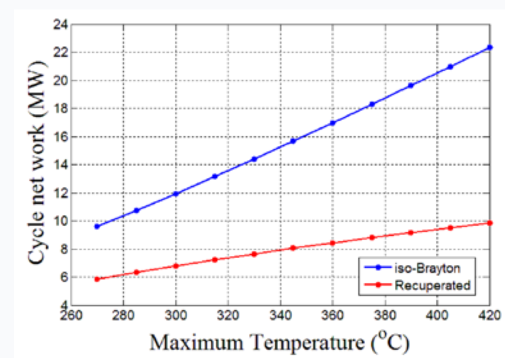
Increasing Specific Power









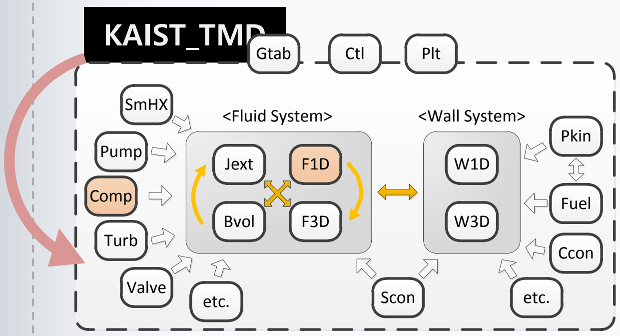


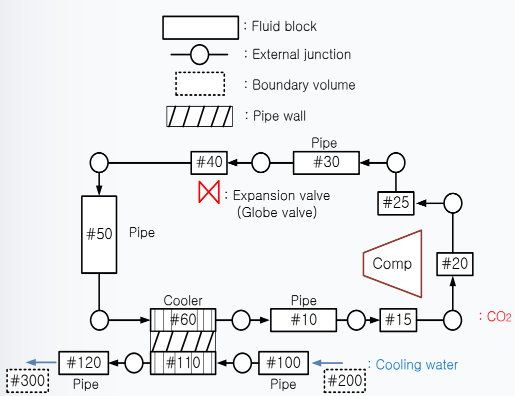
Calculated values	Recuperated	iso-Brayton
Heat (MW)	49.8	49.8
Effectiveness (%)	95.7	90
Volume (m^3)	3.34	1.17
UA (MW/K)	1.99	0.48
CO_2 mass flow rate (kg/s)	194.75	86.07

Turbomachinery Design & Analysis

Transient analysis

- ✓ Turbomachinery performance maps support transient analysis for abnormal system operation scenarios



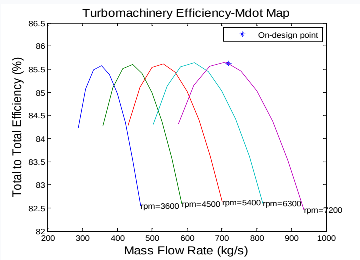


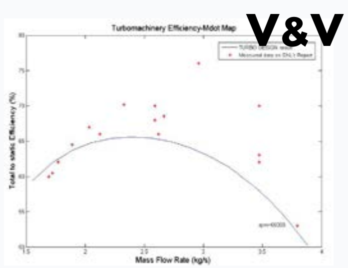
KAIST_TMD - 1D Meanline Analysis -

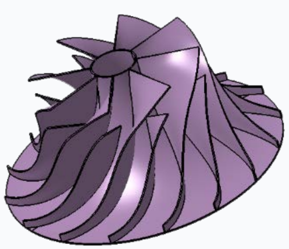
$$\dot{m} = \rho(T_s, P_s)AV$$

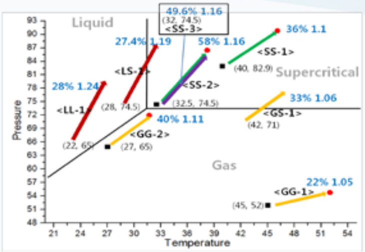
$$h_0 = h_s + \frac{V^2}{2}$$

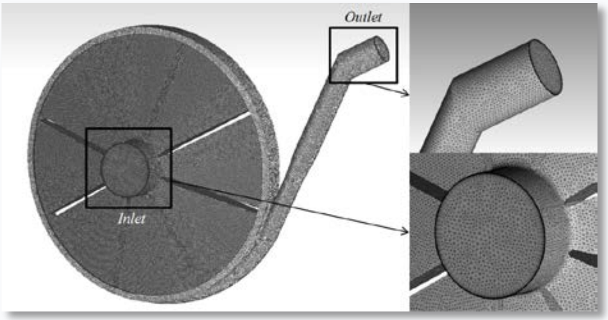
$$P_s(h_s, s) \qquad T_s(h_s, s)$$





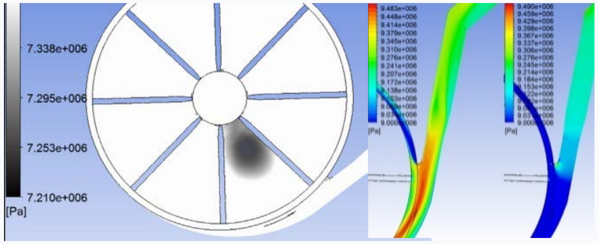






3D CFD analysis

- ✓ Internal flow analysis can be supported by 3D CFD analysis
- ✓ Complementary assistance platform can be constructed from 3D model information generation



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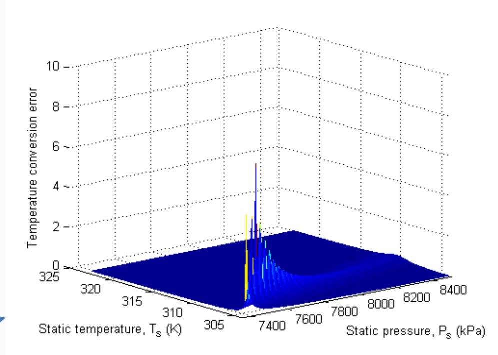
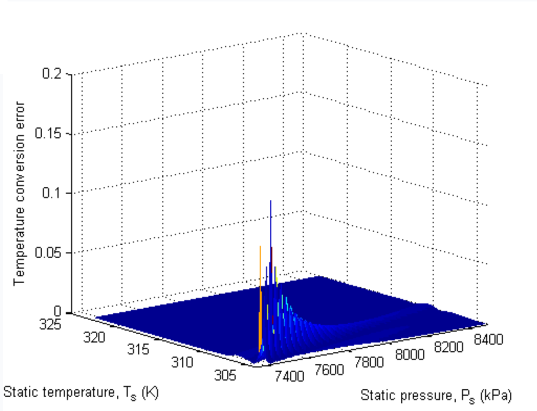
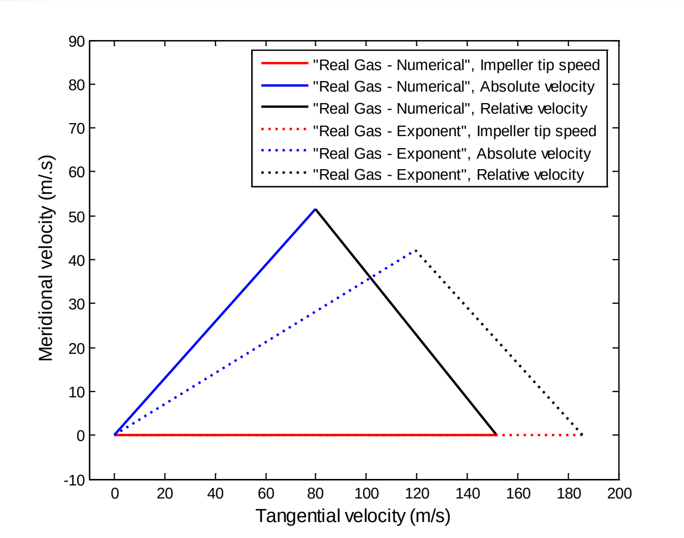
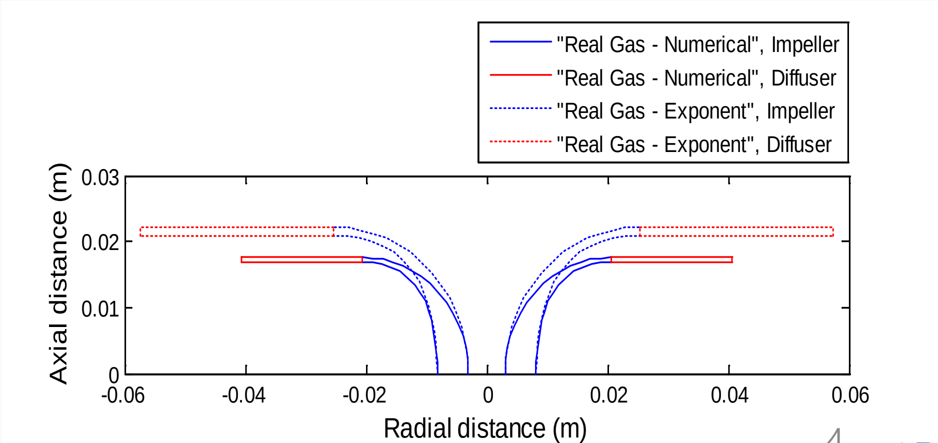
Turbomachinery Design Issues

Conversion method	Equations
Definition based	$h_o = h_s + \frac{v^2}{2}$
Ideal gas based	$\frac{p_o}{p_s} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma - 1}}$ $\frac{T_o}{T_s} = 1 + \frac{\gamma - 1}{2} M^2$
Real gas isentropic exponent based	$\frac{p_o}{p_s} = \left(1 + \frac{n_s - 1}{2} M^2\right)^{\frac{1}{n_s - 1}}$ $\frac{T_o}{T_s} = \left(1 + \frac{n_s - 1}{2} M^2\right)^{\frac{m_s n_s}{n_s - 1}}$

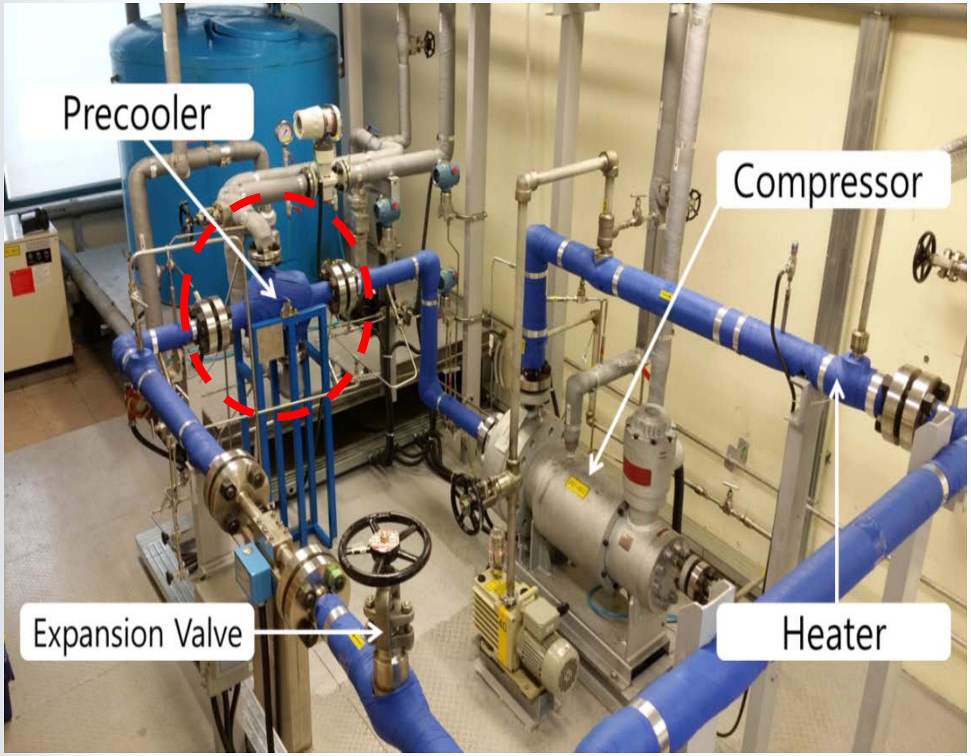


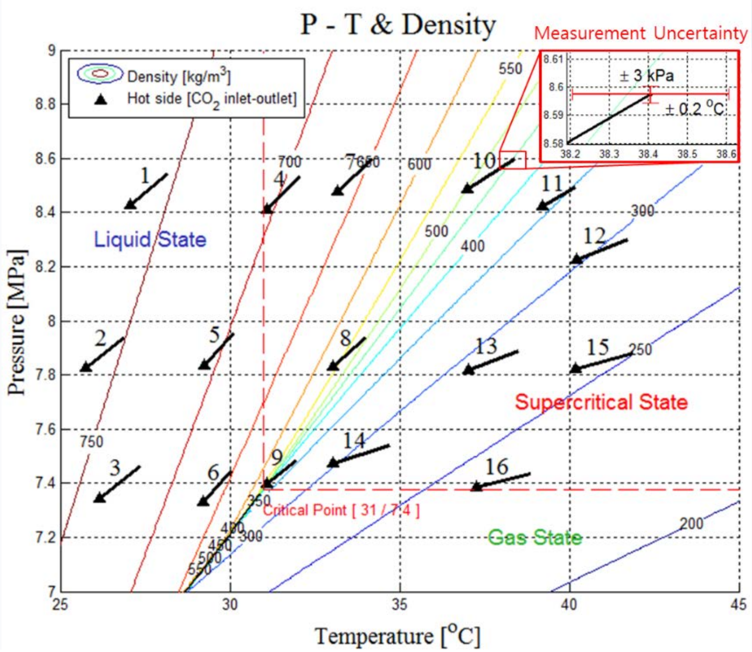


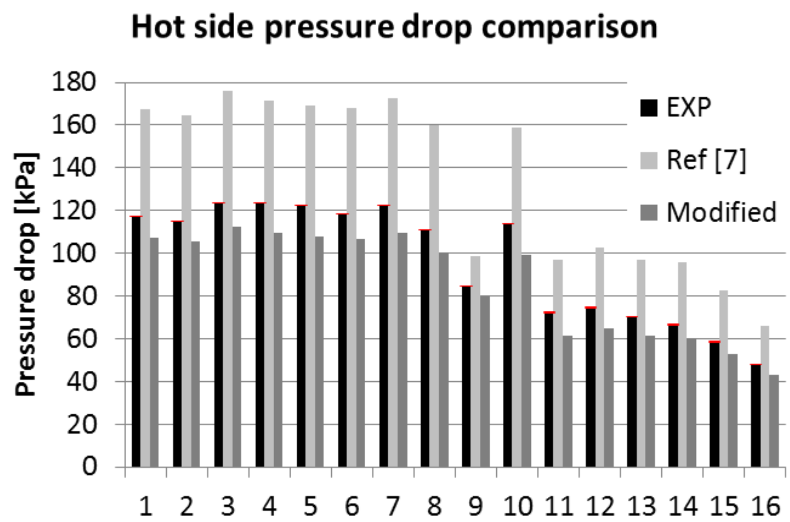


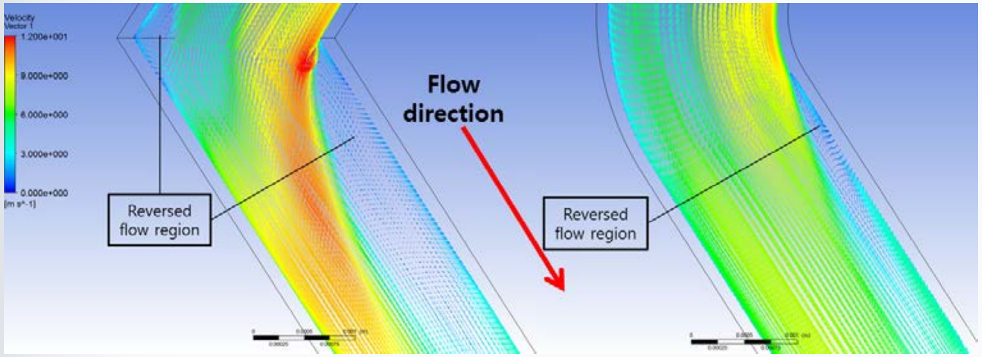


Heat Exchanger Design & Analysis







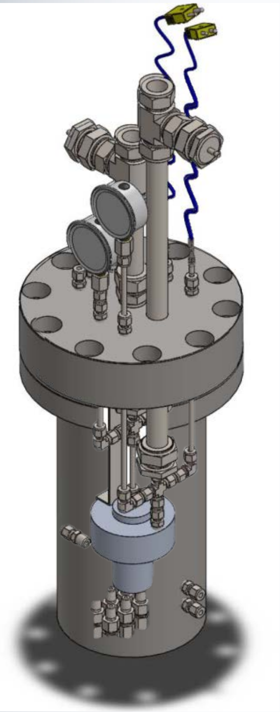


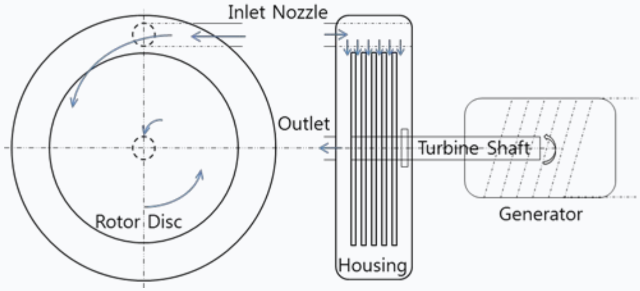
New Component

KAIST – SCO_2PE

Tesla turbine

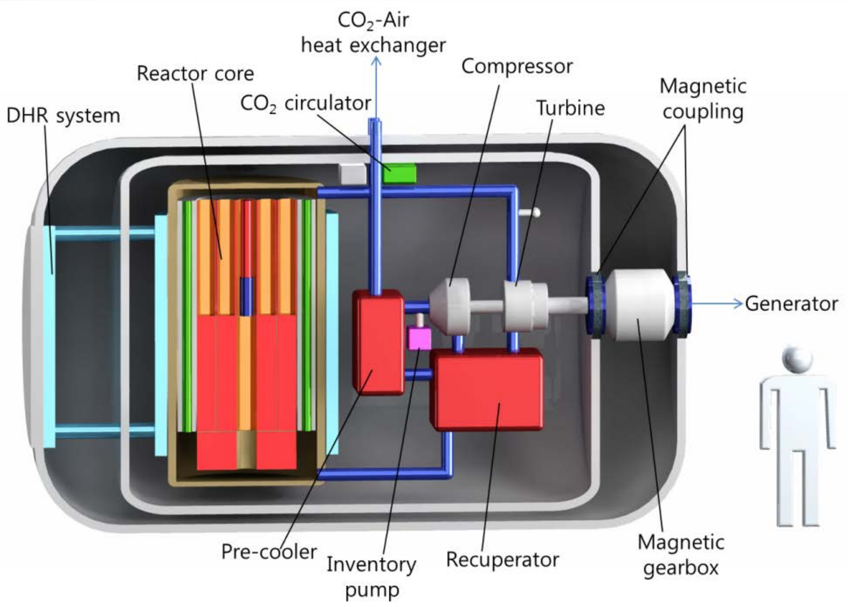
- A **Tesla turbine** will be tested in S-CO_2 power cycle expander operating conditions.
- The external pressure vessel allows to test in high pressure (>7.4 MPa)



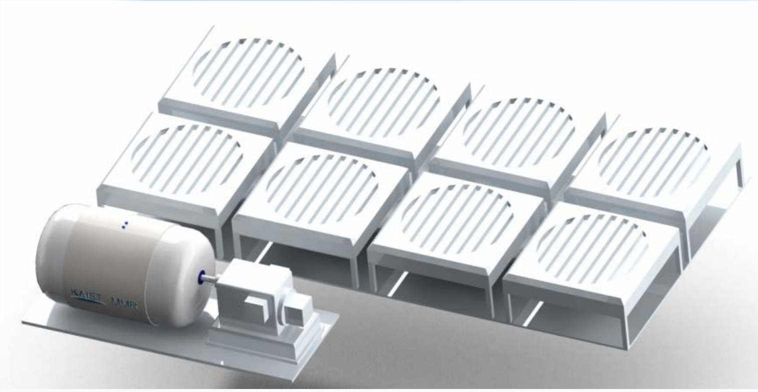


	Conventional Turbine	Tesla turbine
Characteristics	Blade	**Bladeless** disc
	Impulse & reaction force	**Friction** force
	Well experienced, optimized	**Low Pressure ratio** (S-CO_2 cycle)
	Need high quality clearance	**Manufacturing** - easy and modularized design
	No phase change allowed	**Robust** - Two phase, Sludge flow
	Maintenance Difficulties	Easy **maintenance**

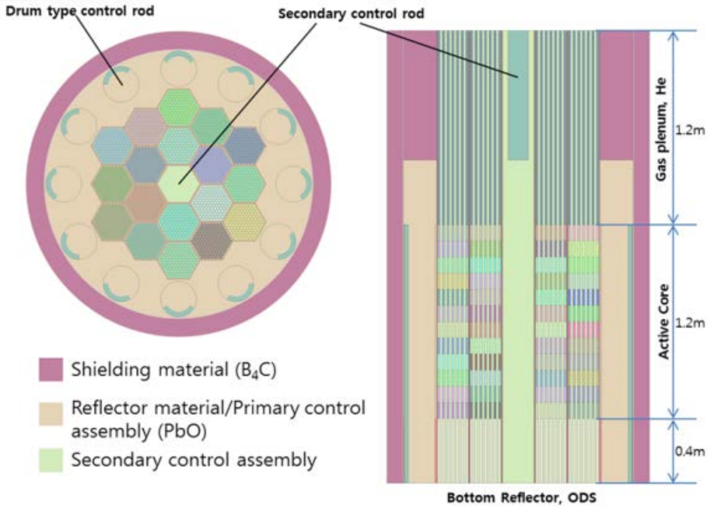
New System



<Conceptual figure of KAIST MMR>

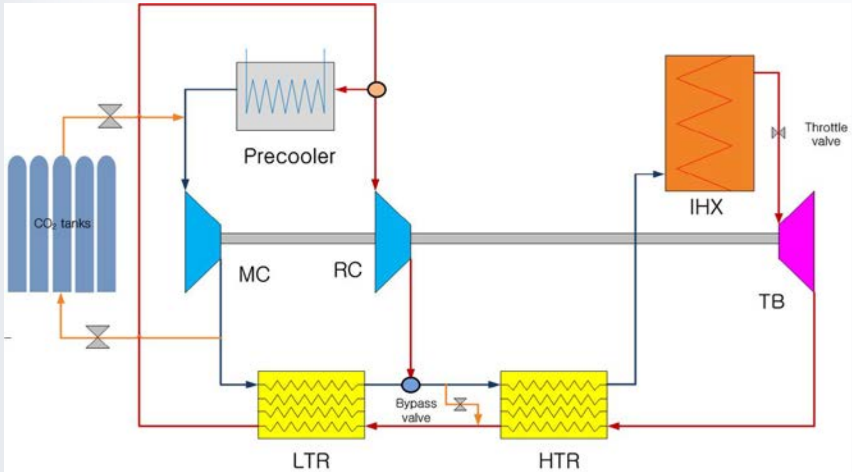


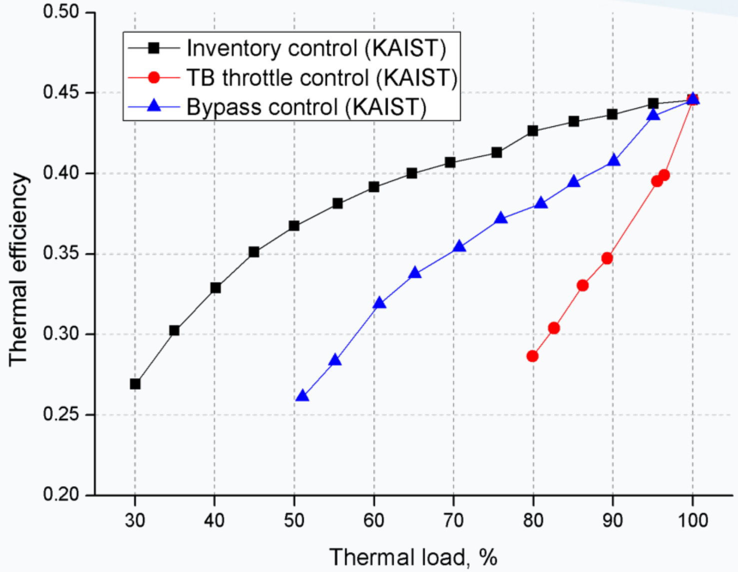
<With 8 fans and generator>

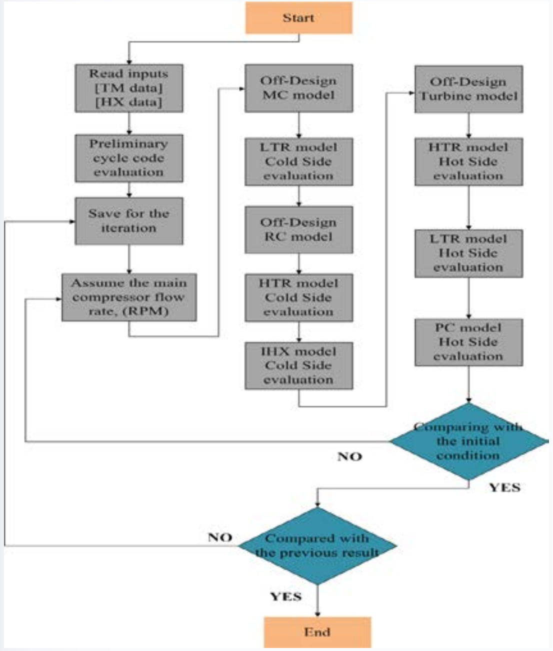


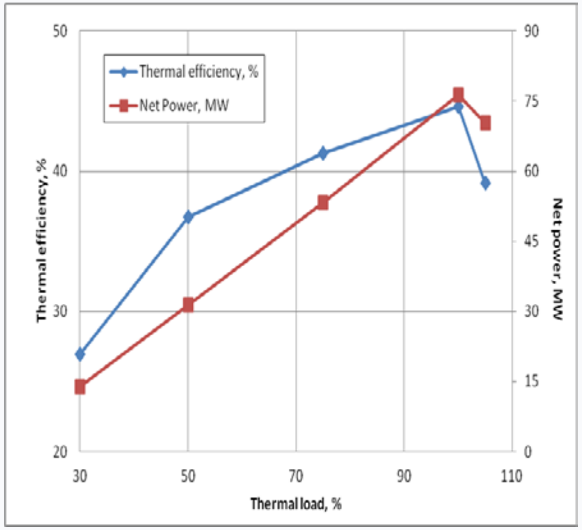
<MMR core design>

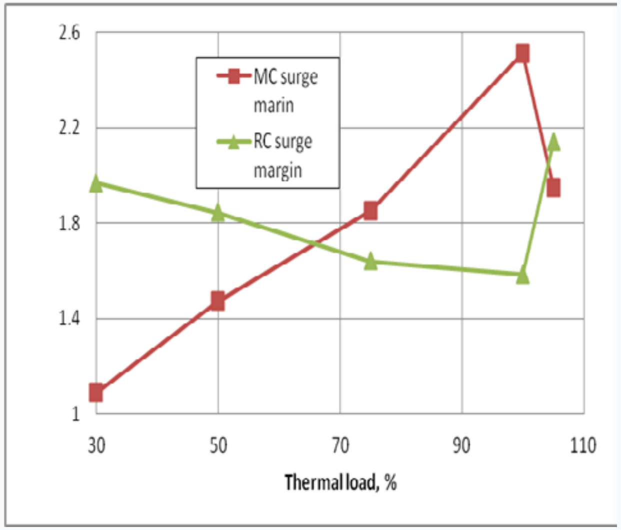
Transient Analysis for Control







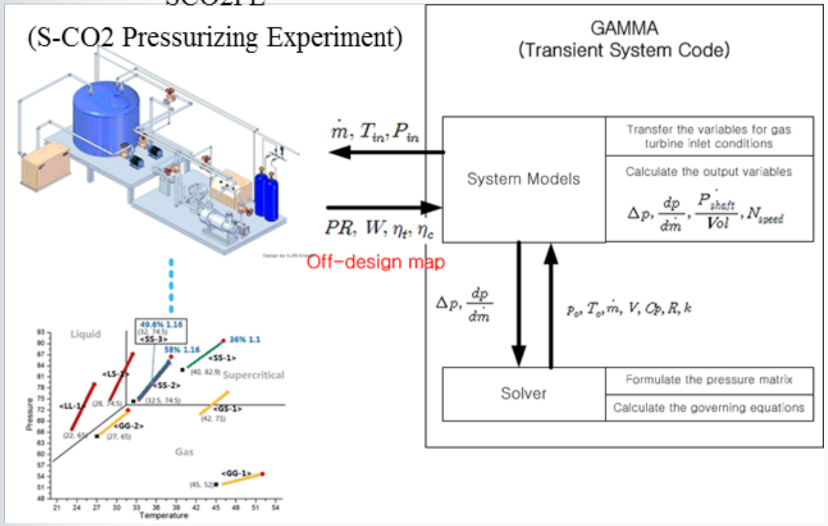




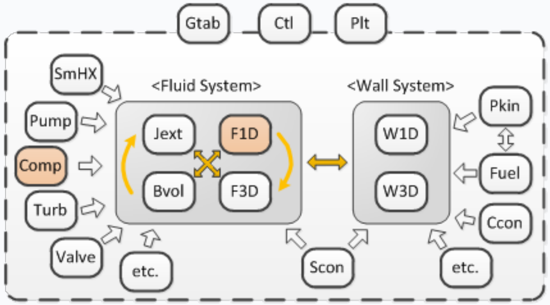
Transient Analysis for Prediction

SCO2PE

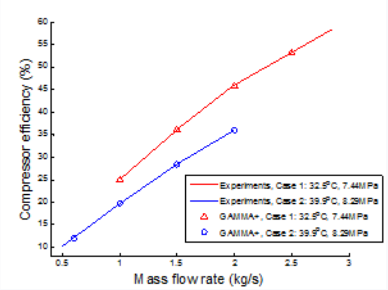
(S-CO2 Pressurizing Experiment)



GAMMA+ code modification

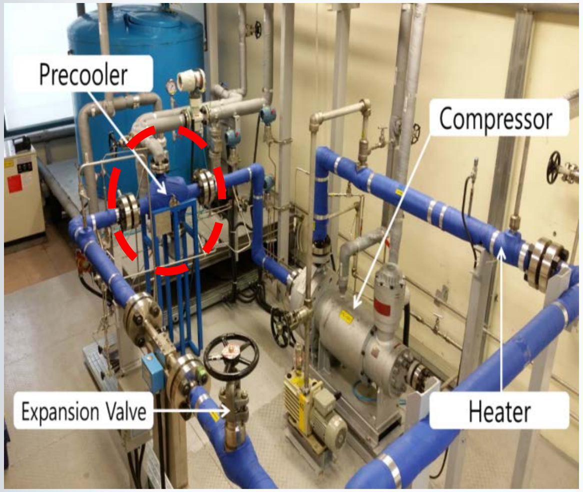


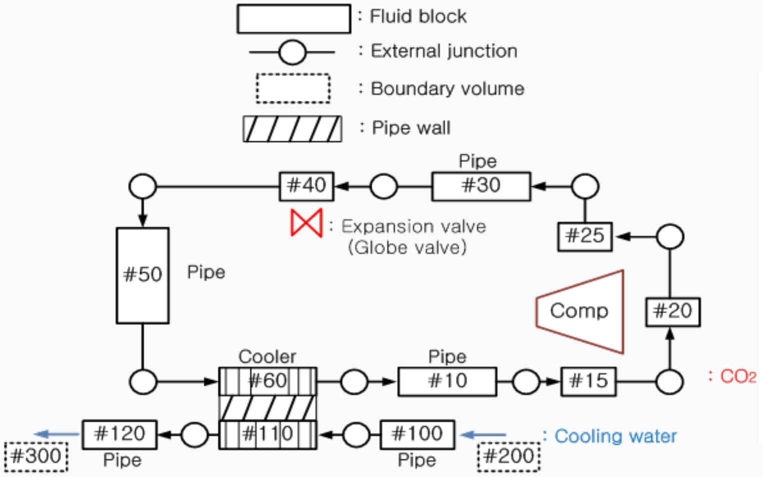
The parallel configuration of models in the GAMMA+



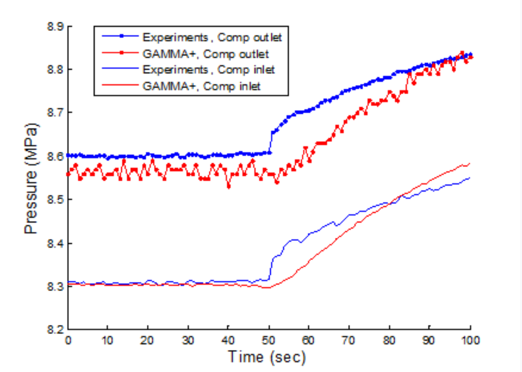
Off-design performance map of SCO2PE compressor

V&V between GAMMA+ code and SCO2PE test data





Nodalization diagram of the SCO2PE loop for GAMMA+ code



Transient pressure data comparison

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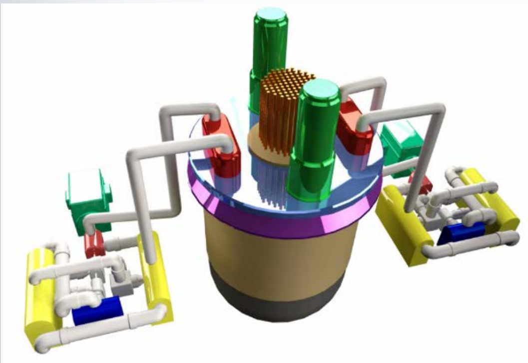
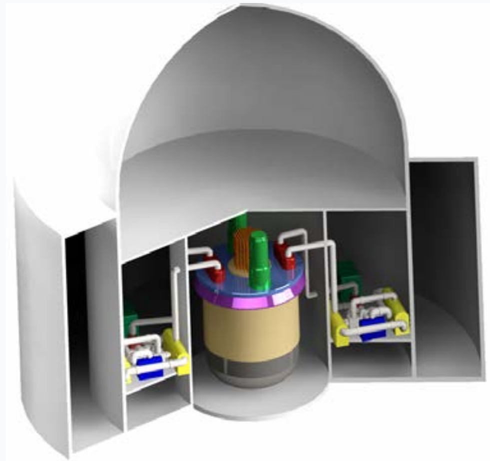
Specific Technical Issues to Sodium-cooled Fast Reactor Application





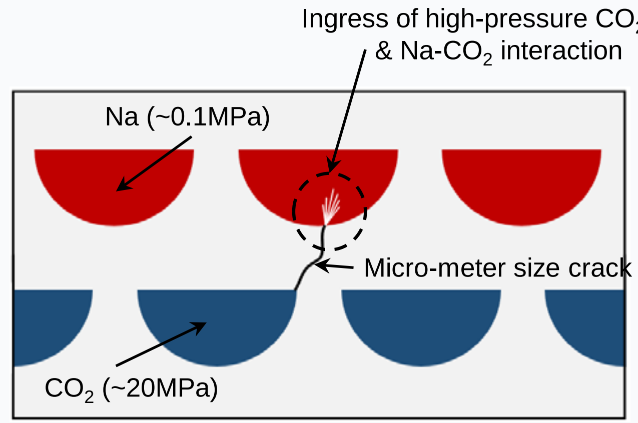
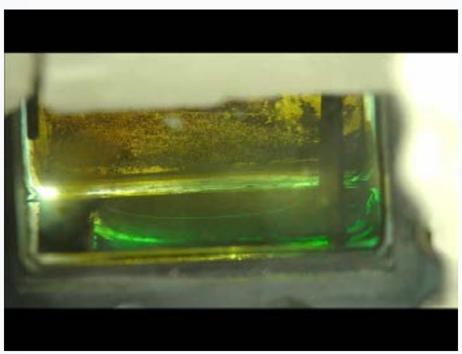
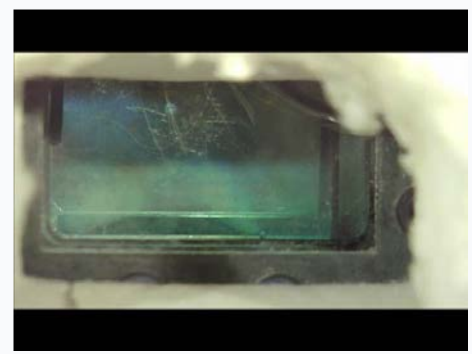


Fig. Potential Na-CO_2 interaction in Printed Circuit Heat Exchanger(PCHE)



T_{Na} = 598.3 ℃

T_{Na} = 599.9 ℃
Ignition case



T_{Na} = 585 ℃
Na-air reaction

Critical Flow and Phase Change

◆CO_2 critical flow modeling process

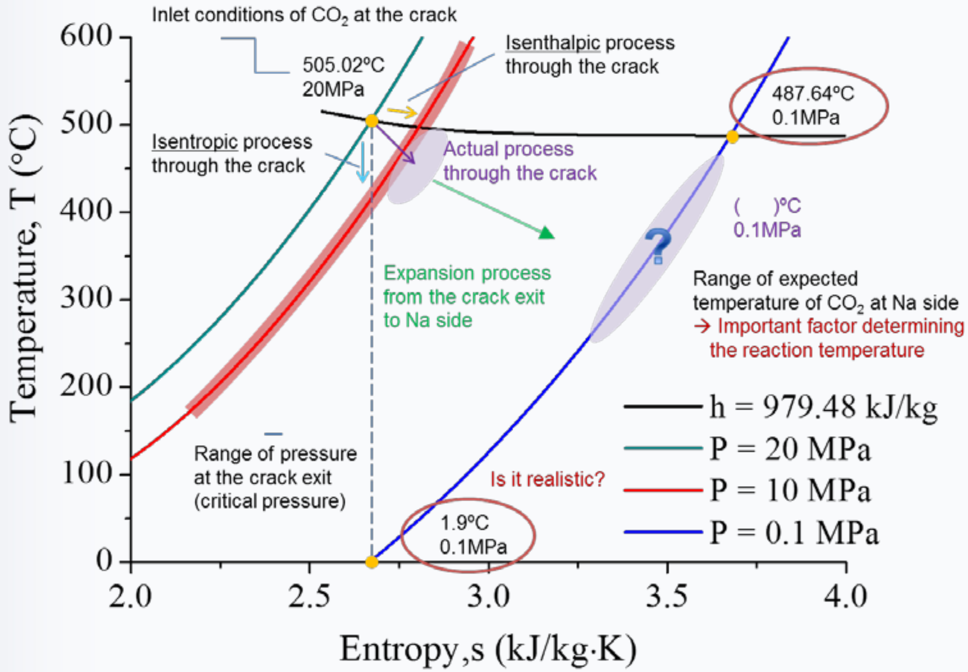
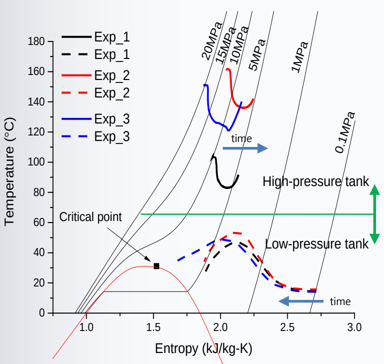
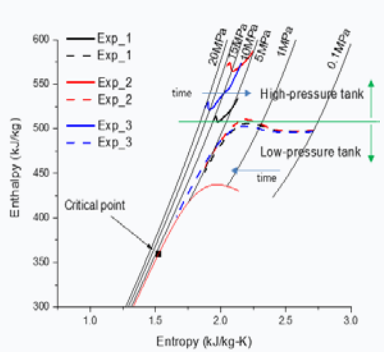
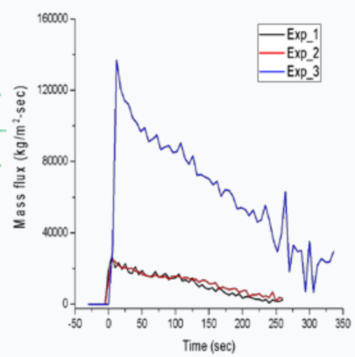


Fig. CO_2 critical speed measure instrument

◆CO_2 leak simulation results (T-s, h-s diagram, Mass flux of leaked CO_2)







		Exp_1	Exp_2	Exp_3
High Pressure Tank	P (MPa)	10.01	13.43	20.16
	T (℃)	103.3	161.5	151.2
Low Pressure Tank	P (MPa)	0.101	0.101	0.101
	T (℃)	14.5	15.6	14.1

Materials

❖ Corrosion and carburization behavior in S-CO_2 environments

- ✓ Corrosion tests in S-CO_2 environments (550-650°C, 200bar, max. 3000h)
- ✓ Evaluate the corrosion and carburization resistance in S-CO_2 environments
- ✓ Materials: Fe-base austenitic alloys, Ni-base alloys, FMS (9Cr)

❖ Long-term properties of materials after exposure to S-CO_2

- ✓ Microstructure evolution and resulting mechanical property (tensile test)
- ✓ Creep test in S-CO_2 environments (550-650°C, 200bar)

❖ Corrosion and long-term properties of diffusion-bonded PCHE materials

- ✓ Development of diffusion-bonding process for PCHE-type IHX
- ✓ Corrosion tests and mechanical property evaluation of diffusion bonded joints in S-CO_2 environments