Improvement of transient analysis of S-CO_2 cooled micro modular reactor using DNN based turbomachinery off-design model

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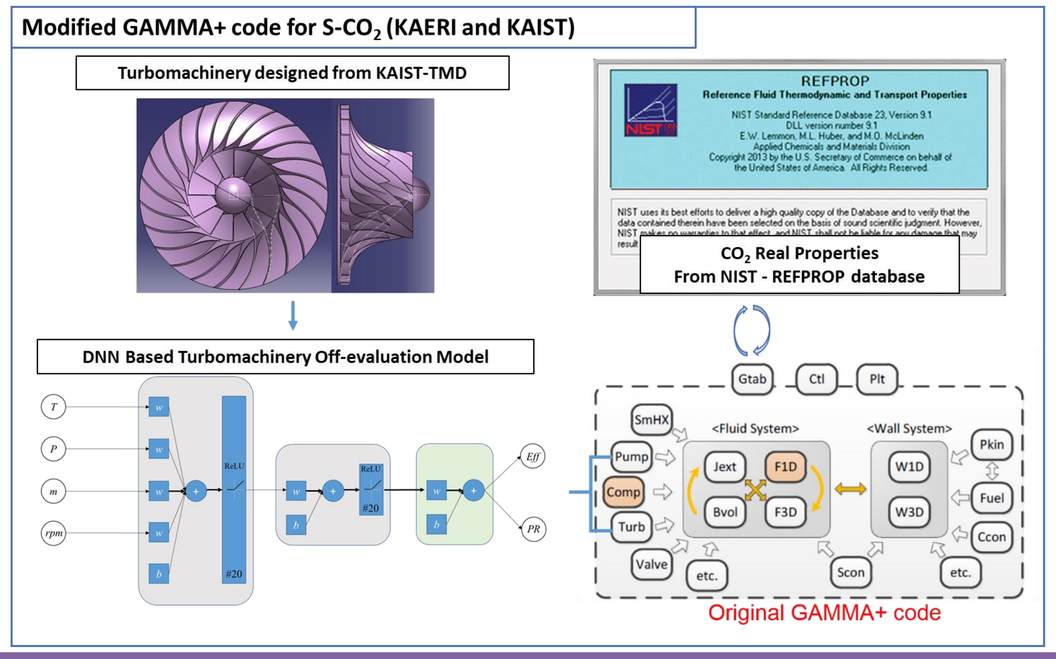
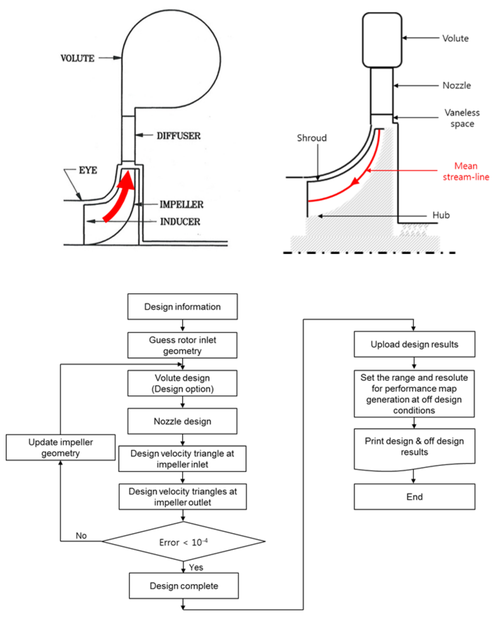
Research objectives

Development of pre-trained DNN model through the KAIST-TMD simulation data for transient simulation of nuclear system transient



S-CO_2 turbomachinery off-design data generation (KAIST-TMD)

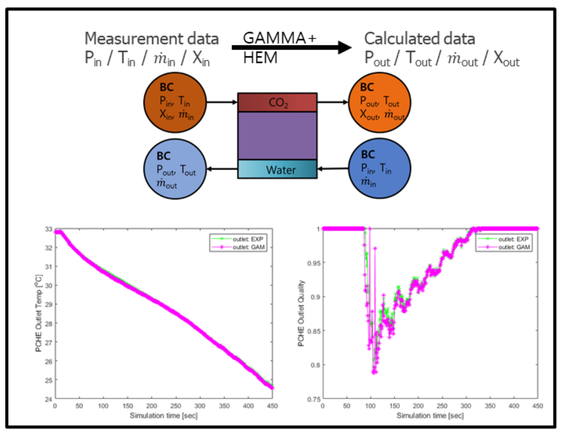
	Loss Classification	Loss Models
Radial Compressor	Incidence	Conrad
	Blade loading	Coppage
	Skin friction	Jasen
	Mixing	Johnston and Dean
	Clearance	Jansen
	Disk friction	Ali
	Leakage	Aungier
	Recirculation	Oh
Radial Turbine	Incidence	Wasserbauer and Glassman
	Rotor passage	CETI
	Trailing edge	Ghosh
	tip clearance	Jansen
	Disk friction	Daily and Nece



Transient simulation platform (GAMMA+)

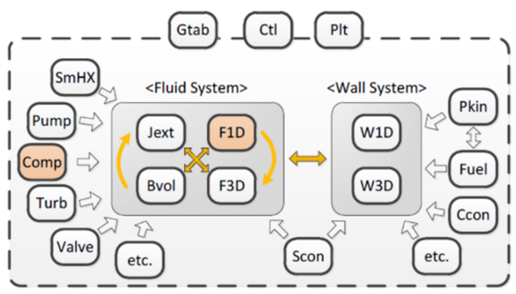
GAMMA+ (KAERI)

- To model dynamics of a gas-cooled system, dependent variables are linearized to solve governing equations
- It was used in the analysis of the S-CO_2 system in conjunction with NIST-REFPROP.



Experiment validation of GAMMA+ by SCO2PE facility

(KAIST, Oh., 2019)



Code Structure of GAMMA+

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial z}(\rho V) = \sum_s R_{s,w}$$

$$\frac{\partial}{\partial t}(\rho H) + \frac{\partial}{\partial z}(\rho H V) = \frac{\partial P}{\partial t} + V\frac{\partial P}{\partial z} + \frac{\partial q''}{\partial z} + \sum_s h_s R_s + q'''_W$$

$$\frac{\partial}{\partial t}(\rho V) + \frac{\partial}{\partial z}(\rho V V) = -\frac{\partial P}{\partial z} - \rho g - \rho\left(\frac{f'}{d} + K\right)V^2$$

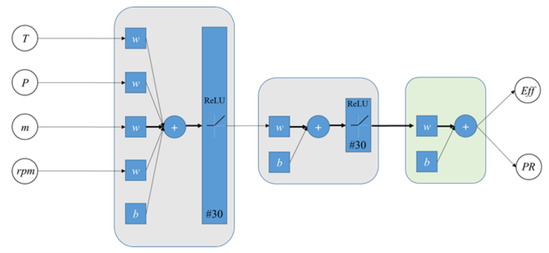
$$\frac{\partial \omega}{\partial t} = \frac{\sum_i W_i \cdot \varepsilon_{gen} - W_{grid}}{\sum_i I_i \cdot \omega}$$

Governing Equation of GAMMA+

Training DNN based S-CO_2 turbomachinery off-design model

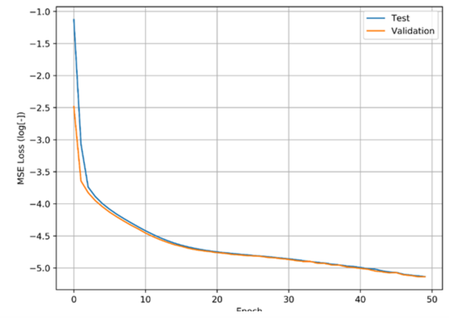
DNN based model

- A method was developed to accurately predict the performance of S-CO_2 turbomachinery by using the 1D mean-line turbomachinery performance module pre-trained by DNN.

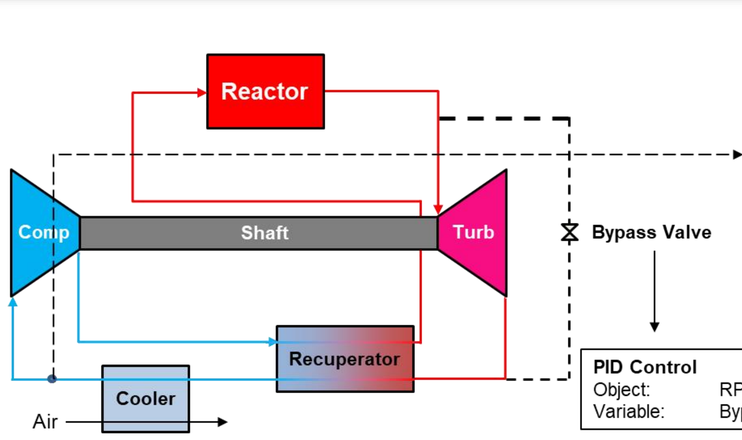


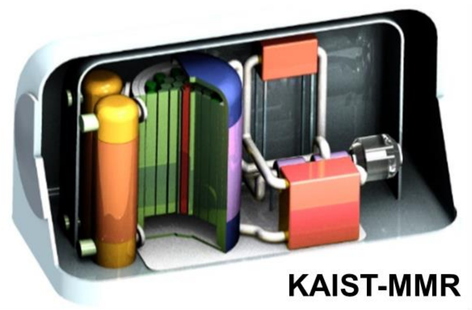
Used hyper parameters for learning KAIST-TMD

	Hyper parameter	Value	Note
Model Information	Input Size	4	$T, P, \dot{m}, rpm$
	Output Size	2	Eff, PR
	Number of hidden layer	2	
	Hidden size	30 / 30	
	Activation Function	Rectified Linear Unit (ReLU)	
	Structure	Feed Forward Net (DNN)	
Training Information	Number of Train Data	70000	
	Number of Validation Data	30000	
	Batch Size	400	
	Maximum Epoch	50	
Optimization Information	Optimizer	Adam	
	Loss Function	Mean Square Error	

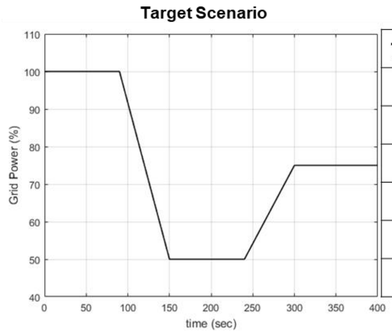


Transient scenario



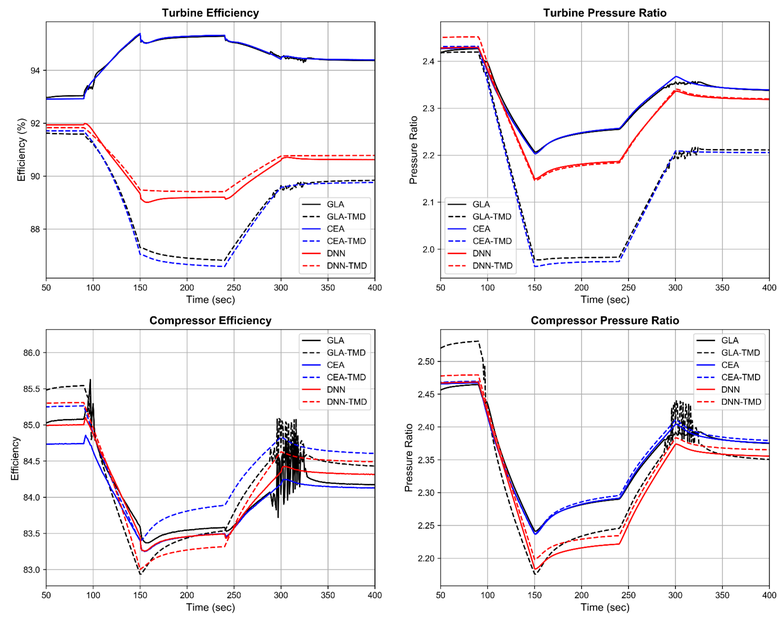


Target Scenario



Time (s)	Grid Power (MWe)
0	12
90	12
150	6
240	6
300	9
1000	9

Result and further works



- When using the same performance map method, determine how much the system dynamic response characteristics are predicted differently according to the correction method
- The accuracy of the correction method is evaluated by comparison with the 1D mean-line method
- We suggest a more accurate methodology to replace existing ethodology through machine learning

Acknowledgement

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