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Compressor Design Method in the Supercritical CO_2 Applications

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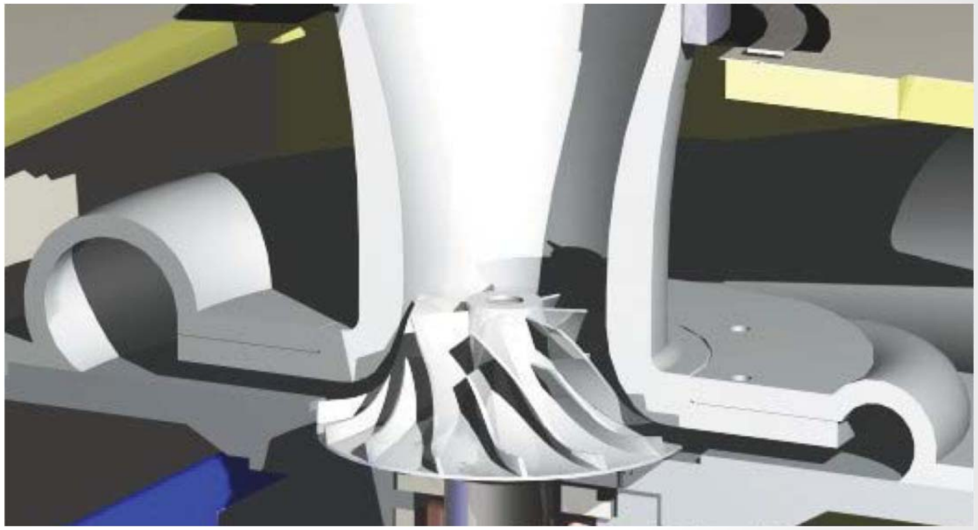
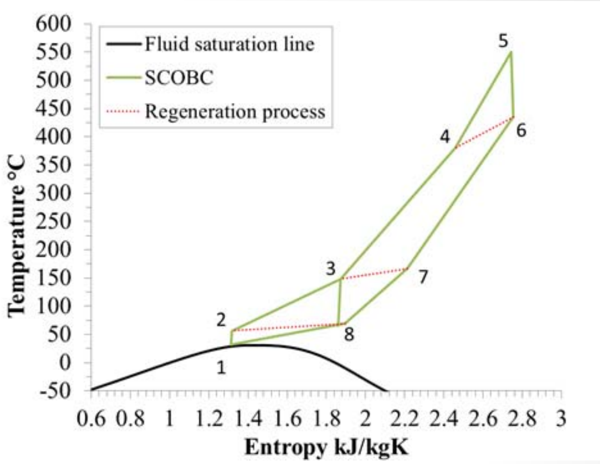
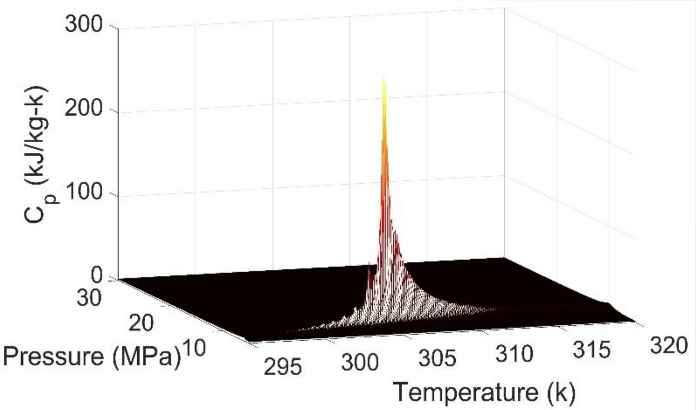


Motivation and goal

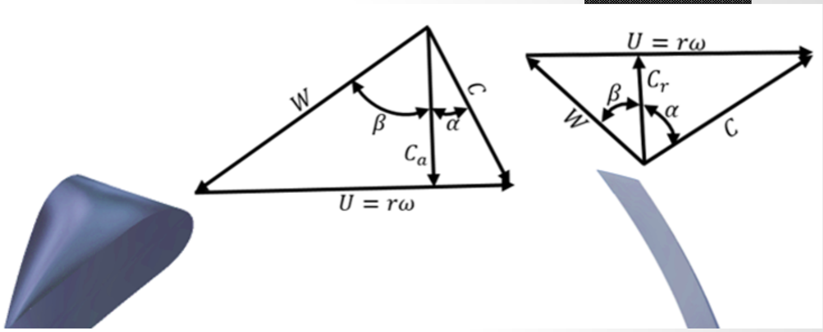
- More efficient and versatile energy conversion cycles are needed
  - $S\text{-}CO_2$ Brayton Cycle is one of the prominent candidates
- Better efficiency of the cycle is achieved when the compressor inlet is closer the critical point
- Rapidly chancing fluid properties close the critical point are playing a role in the compressor design
- Development of more accurate design methodology





Methodology

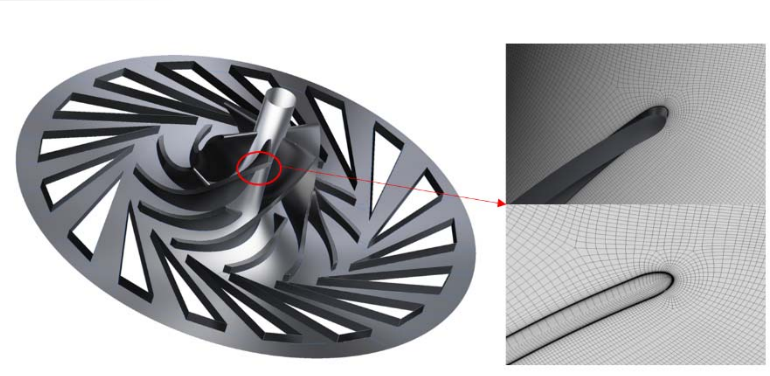
- Compressor are generally designed using meanline code with loss correlations and CFD
- Loss correlations are based on either enthalpy losses or correlations of measured data
  - Fundamentally, they are created for the ideal gas (air)



Loss model	***Reference***
Incidence loss	Conrad et al. [13]
Blade loading loss	Coppage et al. [14]
Skin friction loss	Jansen [15]
Tip clearance loss	Jansen [15]
Mixing loss	Johnston and Dean [32]
Leakage loss	Aungier [16]
Recirculation loss	Oh et al. [18]
Disc friction loss	Daily and Nece [33]

Methodology (cont.)

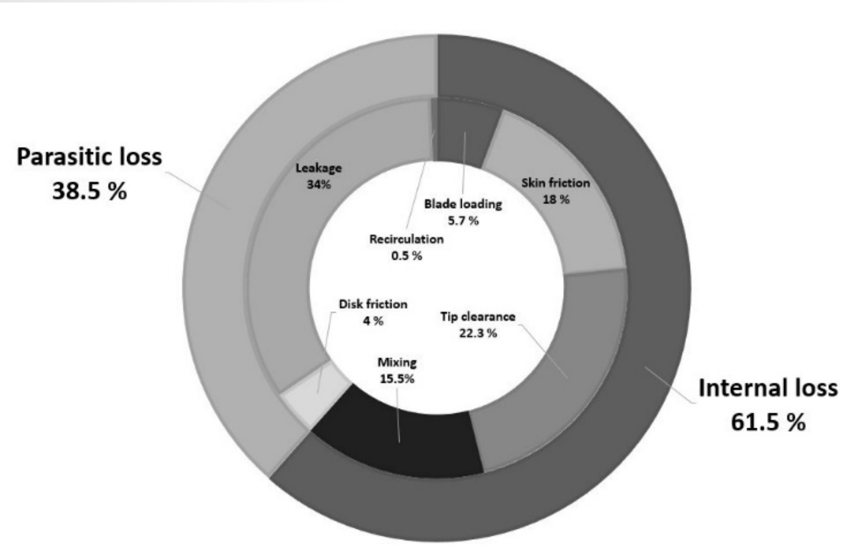
- URANS simulations using accurate real gas model
- Test case: Sandia compressor
- Several operational points were simulated

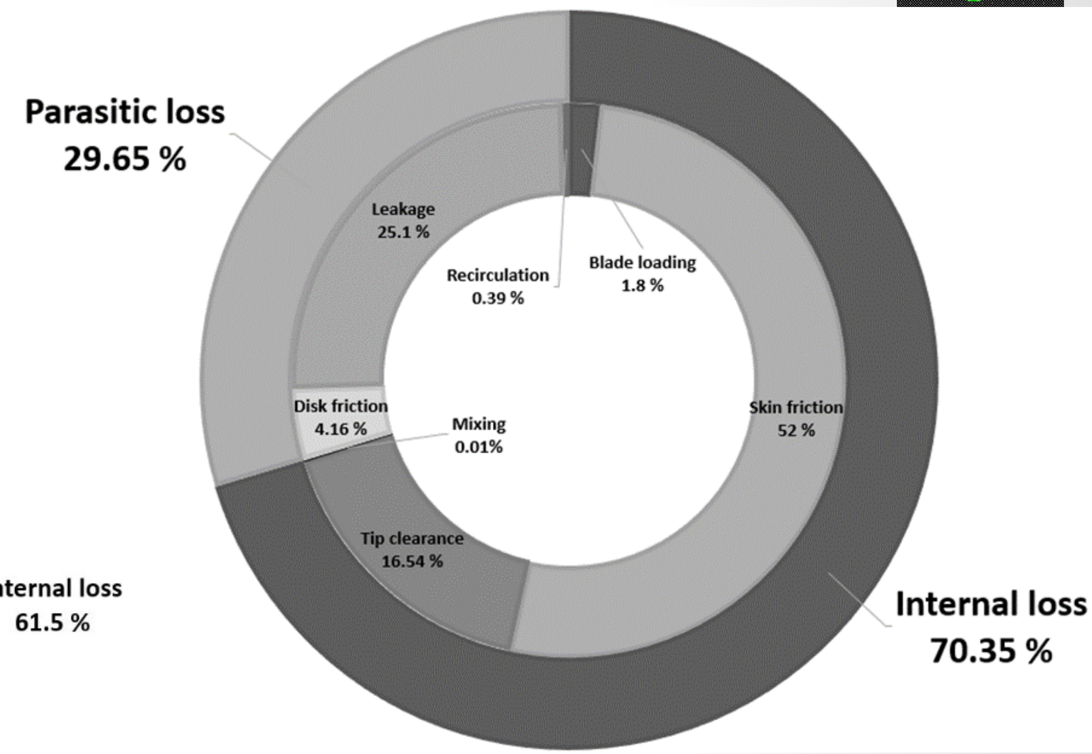


Impeller diameter ratio d_2/d_{1h}	1.993
Impeller tip diameter	37.36 (mm)
Exit blade height	1.712 (mm)
Blade tip angle (minus is backswept)	-50 (deg)
Blade thickness	0.762 (mm)
Inlet blade angle at tip	50 (deg)
Normal tip clearance (constant)	0.254 (mm)
Exit vaned diffuser angle	71.5 (deg)

Results

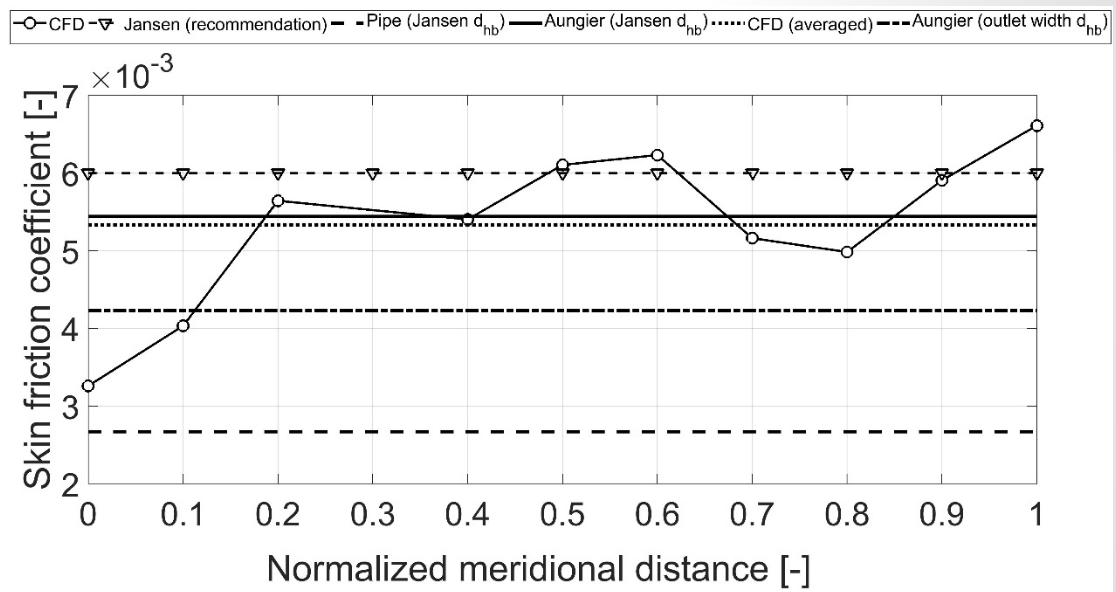
- Meanline code





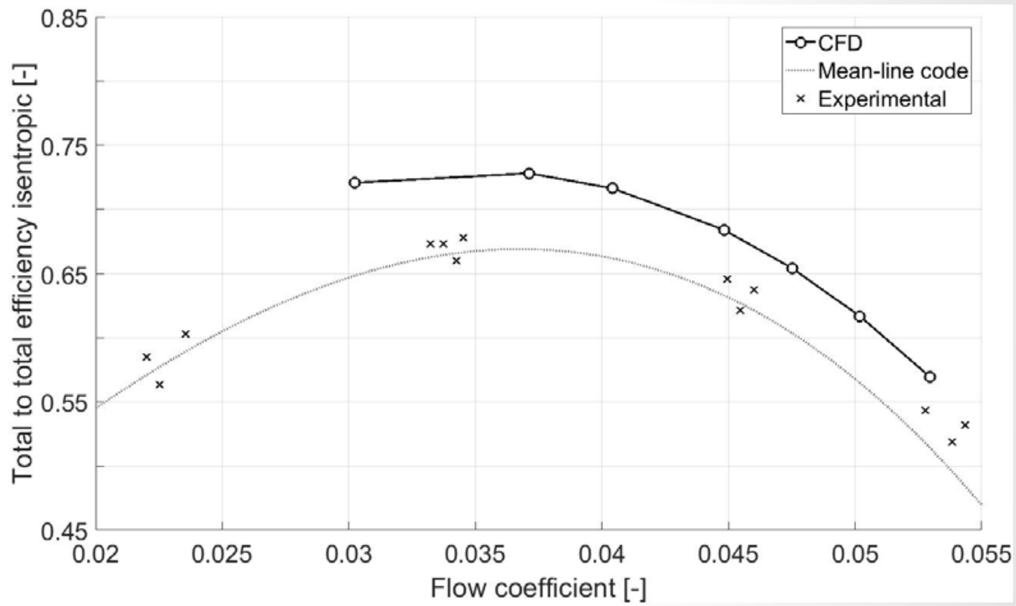
Results (cont.)

- Losses due to skin friction play significant role
- Based on CFD it is not constant over the impeller



Results (cont.)

- CFD
  - Trend is same as measurements
  - Higher efficiencies mainly due simplifications



Conclusions

- Centrifugal compressor design based on the enthalpy loss correlations were investigated
- Skin friction was found to have significant effect on the compressor performance
- A weighted averaged method proposed by Aungier by implementing the hydraulic diameter of the impeller passage by Jansen showed the best agreement with the CFD result

Future work

- Further investigate loss formation in the SCO_2 compressors
- Expand studies to the turbines
- Off-design studies of SCO_2 turbomachinery