Computational Analysis of Seals for sCO_2 Turbomachinery and Experimental Planning

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Background

- Supercritical carbon dioxide power cycles offer high efficiencies over 50% with a compact footprint
- End seals are a particular concern [1]

Goal

Improve seal prediction techniques for sCO_2 seals through experimental validation of existing codes and CFD to maintain high cycle efficiencies

Methodology

Compare seal leakage predictions from a bulk flow code and CFD against experimental results for three seal types: smooth, labyrinth, and hole pattern

Test Matrix Development

- Reviewed existing sCO2 facilities and planned power cycles to find relevant compressor inlet conditions
- Pressure ratio of 3 planned for each test

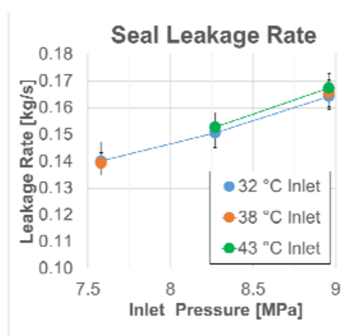
Case	Inlet Temp		Inlet Pressure		Outlet Pressure	
[#]	[C]	[F]	[MPa]	[PSIA]	[MPa]	[PSIA]
1	32.22	90	7.58	1100	2.53	366.7
2	32.22	90	8.27	1200	2.76	400
3	32.22	90	8.96	1300	2.99	433.3
4	37.78	100	7.58	1100	2.53	366.7
5	37.78	100	8.27	1200	2.76	400
6	37.78	100	8.96	1300	2.99	433.3
7	43.33	110	7.58	1100	2.53	366.7
8	43.33	110	8.27	1200	2.76	400
9	43.33	110	8.96	1300	2.99	433.3

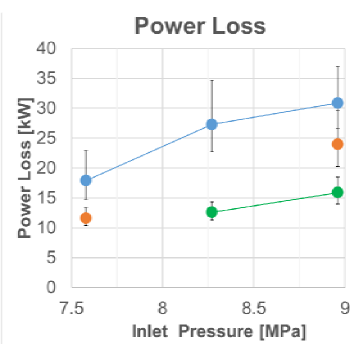
RotorLab+

- DamperSeal, a seal analysis software developed by ROMAC, uses Hirs bulk flow theory to examine the properties of smooth and hole pattern seals
- Inputs provided to the software include: shaft speed, inlet pressure and temperature, outlet pressure, gas viscosity, and compressibility factor.
- Primary outputs are leakage rate and rotor power loss

Results

- DamperSeal uses a single compressibility factor value to compute leakage and power loss
- Compressibility factor greatly changes around the critical point, thus a sensitivity study was performed by using a factor to represent the inlet, outlet and an average of the two values



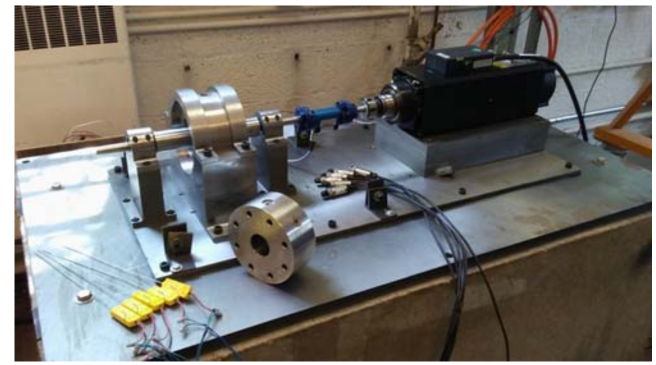


CFD

- Model being developed in ANSYS CFX using a 2 element thick annular slice
- Based on literature, a user defined fluid property table will be used with Span-Wagner as the EOS

Experimental Set-up

- Back-to-back annular seals
- Max Speed: 10,000 RPM
- Max Working Pressure: 1500 psi



	Dimension	
	[mm]	[in]
Length	50.8	2.00
Shaft Radius	25.4	1.00
Clearance	0.0254	0.001

Next Steps

- Commission test rig and add sCO_2 supply and control system
- Create CFD fluid property library using Span-Wagner EOS

References:

[1] Bidkar, R. A., Sevincer, E., Wang, J., Thatte, A. M., Mann, A., Peter, M., Musgrove, G., Allison, T., and Moore, J., (2016), "Low-Leakage Shaft-End Seals for Utility-Scale Supercritical CO_2 Turboexpanders," J. Eng. Gas Turbines Power, 139(2), p. 22503.

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