Turbomachinery Panel

CSP Research and Development Virtual Workshop

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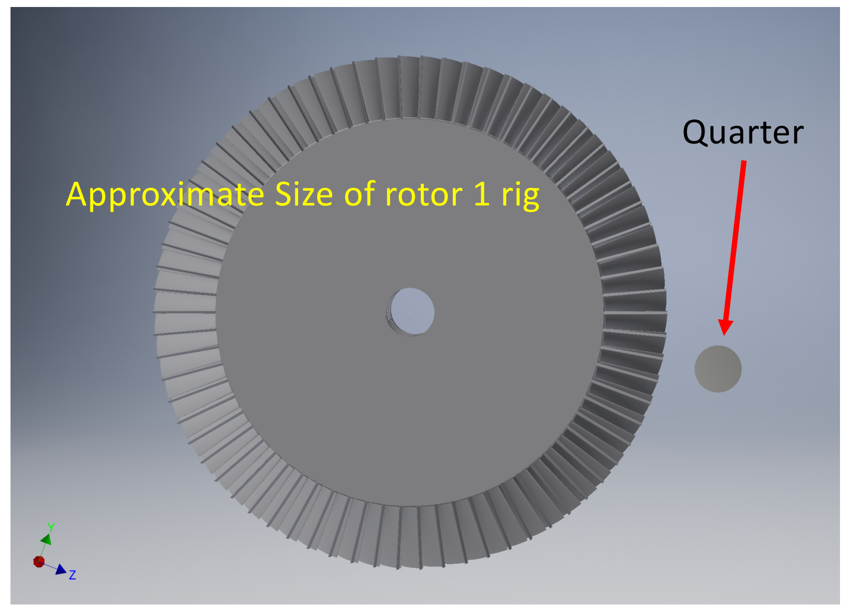
Introduction

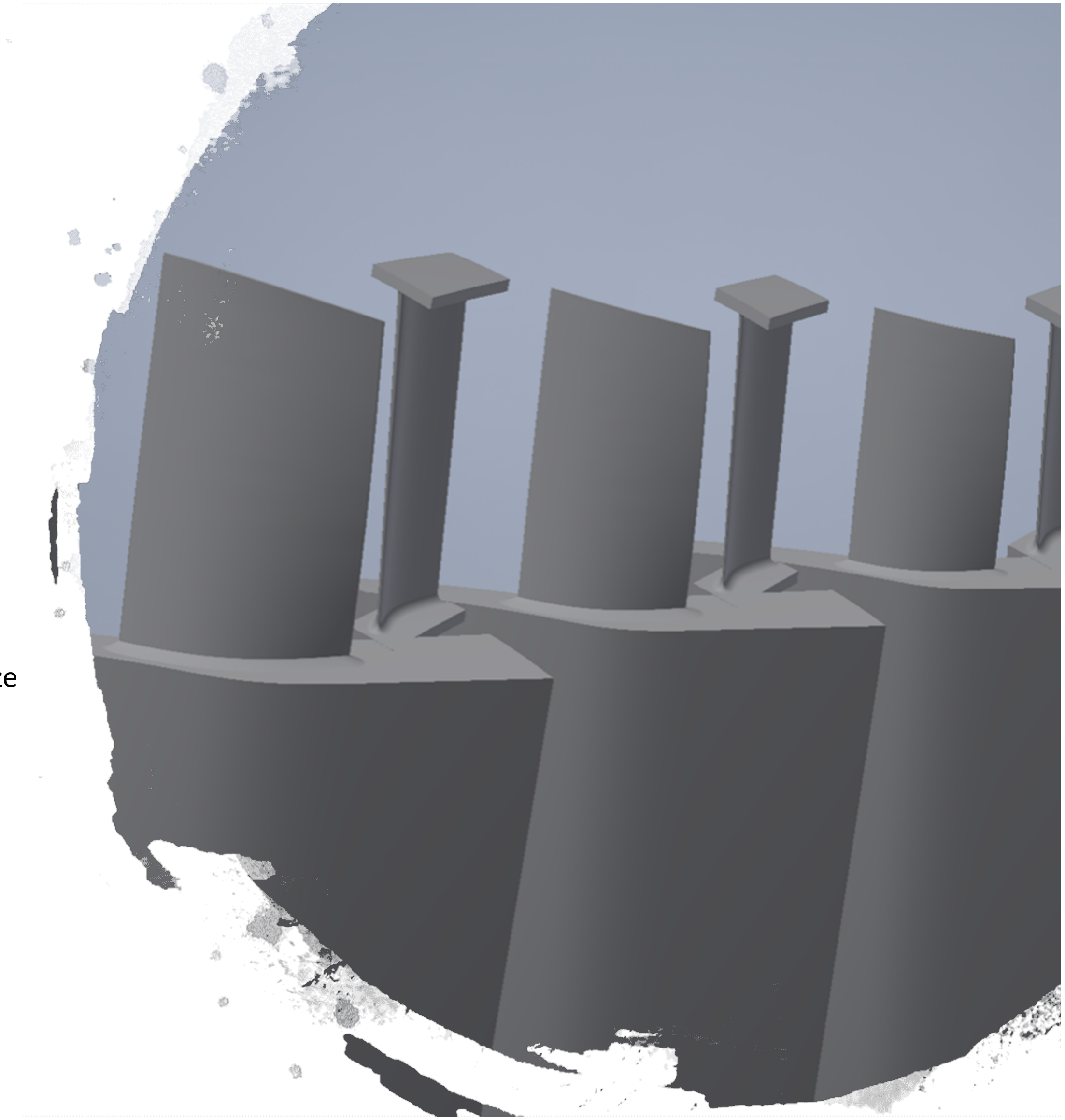
- UC is part of an Echogen team with Notre Dame to design an axial compressor for Energy Storage Application
- Full Scale Preliminary Design
- Roughly half scale design to be tested at Notre Dame as single stage, two stage, and 3 stages



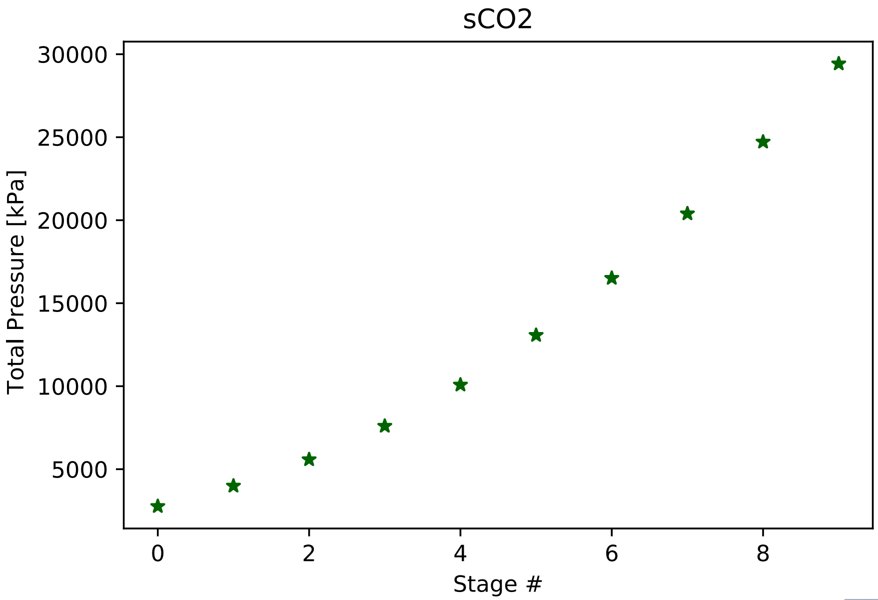
This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number DE-EE0008997

S-CO2 Compressor Design

- Use Real Properties of S-CO2 for Meanline Design
  - New python code with tables generated from Refprop
  - written by UC senior Kaden Wells
- "Fake out" Perfect Ideal Gas Meanline and Axisymmetric Code
  - Use Delta Enthalpy (not Delta TT)
  - Use Blockage to Get the Same Area
  - Create input for Blade Generator, T-Blade3 (open source)
- Optimize Sections in T-Blade3 with Mises and OpenMDAO
  - Developed by Tom Viars, Matt Ha, and Abby Scorsone
- Use Numeca Fine/Turbo with OpenMDAO and T-Blade3 to optimize the S-CO2 compressor
  - Real Gas Properties Used
  - Start with sections from Mises optimization
  - Explore lean, sweep, sections at rotor tips, leading edge & trailing edge metal angles
- Use ESP to create solid geometry (Step files)
- Use ANSYS for stress and modal analysis
- Hot-to-Cold connecting ESP and ANSYS



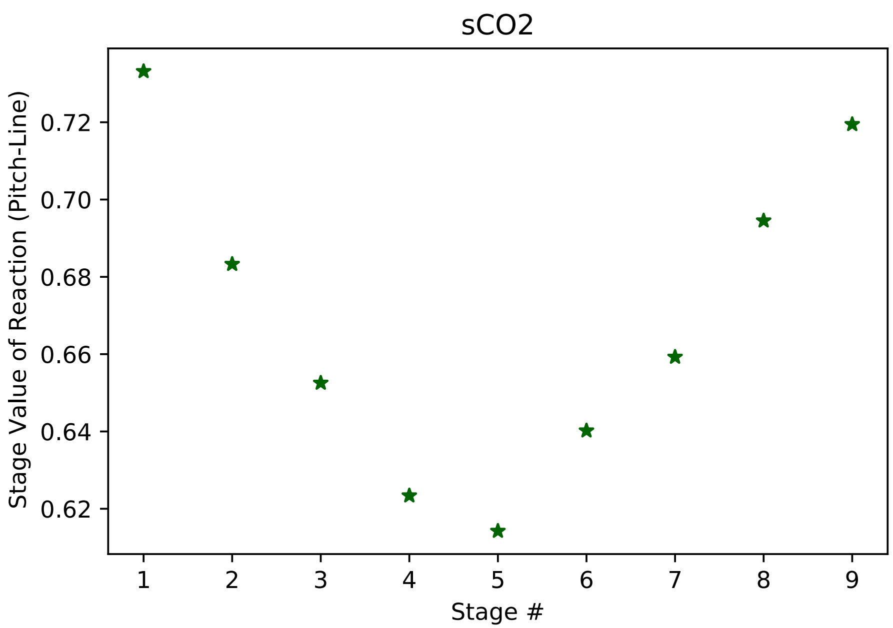
S-CO2 Meanline Code

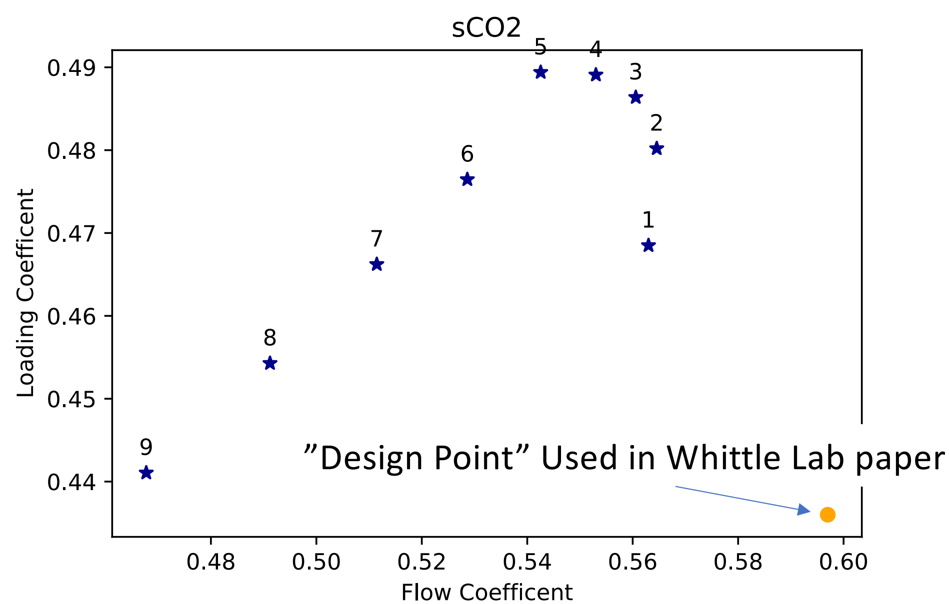


Current 100 MW design is constant hub radius and 9 stages

- Written by UC undergrad, Kaden Wells in python with some help from Jacob Beach
- Plans to be open source
- Reads property tables written by a Matlab code connected to Refprop
- Similar to UC's TC_Des written in Fortran which was an extension of compressor concepts written up in Mattingly's book on engine design
  - Loss Coefficients input, no loss model
  - Free Vortex
  - Input Enthalpy rise for each stage
- Guided by GE/NASA EEE 10 stage compressor in turning, reaction, work coefficient and flow coefficient
  - High Loading leads to fewer stages (less cost)

9 Stage, Constant Hub Reaction and Smith Chart

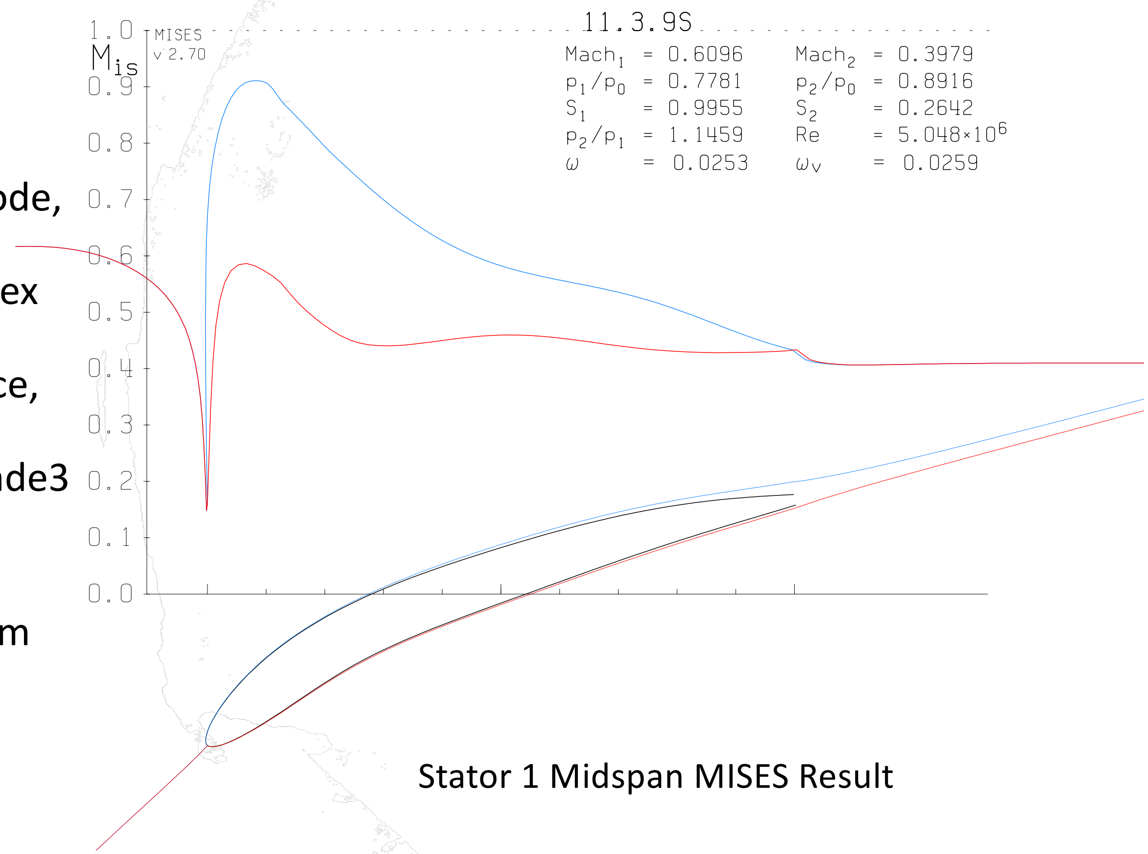




Chana, K S, Miller, R J "The Effect of Reaction on Compressor Performance," ASME GT2020-15220.

Detailed Blade Geometry

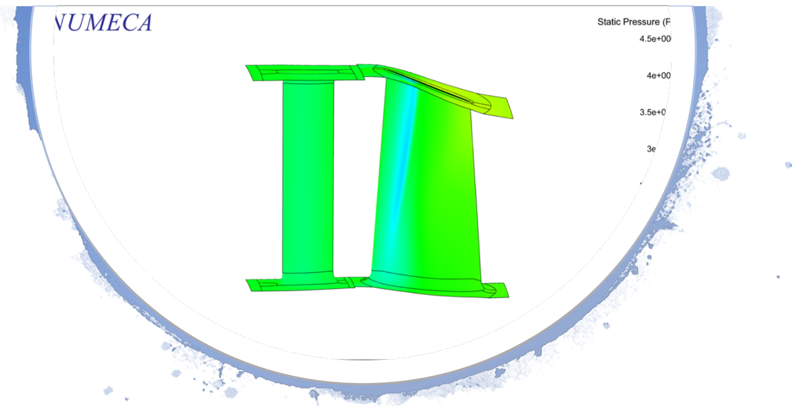
- Modified Ideal Perfect Gas Meanline Code to use Enthalpy Rise
- Used Average Gamma
- Meanline Code creates input for Axisymmetric Code, T-Axi (executable available)
  - Modified Angular Momentum from free vortex meanline code to slightly tip strong
  - Loss models for loading, tip and hub clearance, crude mixing model
  - Produces input for geometry generator, T-Blade3 (open source on github)
  - High efficiency predicted
- Optimize blade sections with Mises (available from MIT)
  - 13 variables per section
  - 5 sections per blade row
  - Optimize at design point and high incidence

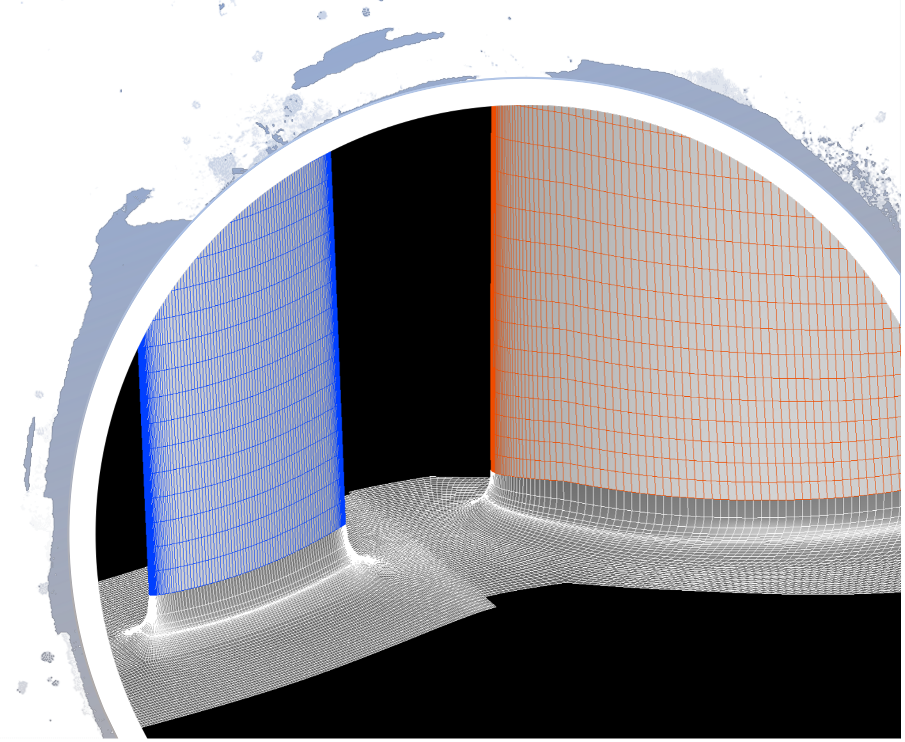


Stator 1 Midspan MISES Result

3D Optimization

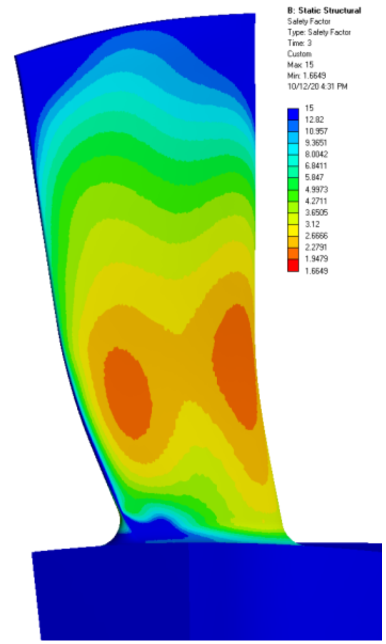
- Connect Numeca Fine/Turbo with T-Blade3 using OpenMDAO
- Optimize at Design Point and Lower exit Mach number to build in Stall Margin
- Use Appropriate Fidelity
- For First Stage, will also include second stage rotor

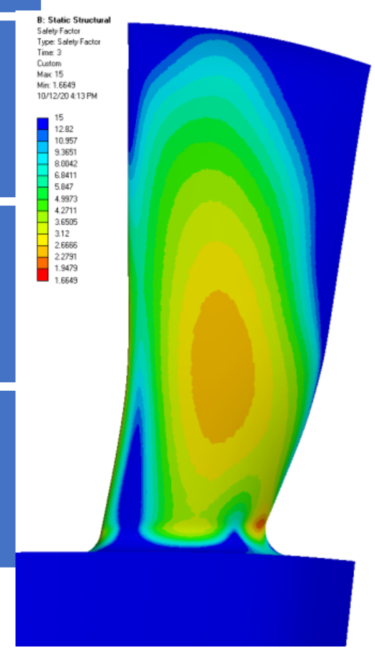




Structural Integrity

ESP	Use ESP (developed at MIT and Syracuse University) to convert sections to a solid blade
SF	Check Factor of Safety • Small changes to lean and chord
Campbell	Need to create Campbell Diagrams of all blade rows
Hot to Cold	Hot to Cold automatic





Justin Holder doing most of the structural simulations

Conclusions

- Full Scale 100MW should be efficient with 9 stages
- Base design on successful air compressors, but match non-dimensional quantities and turning
- Use of T-Blade3 as a blade geometry tool is useful in 2D and 3D
- Incorporate Structural Analysis Early in Design