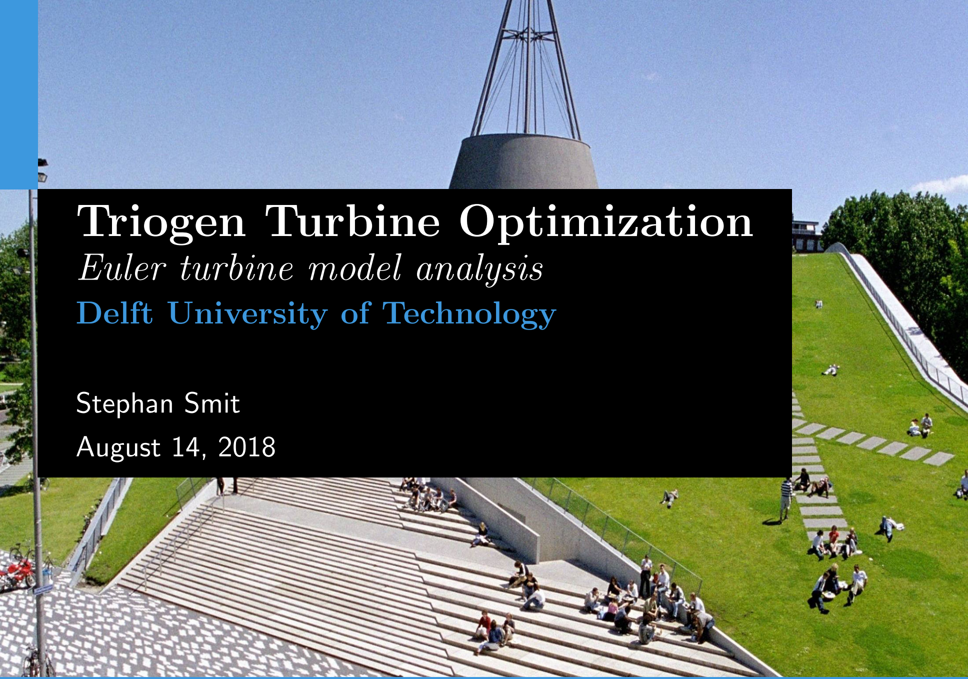

Triogen Turbine Optimization

Euler turbine model analysis

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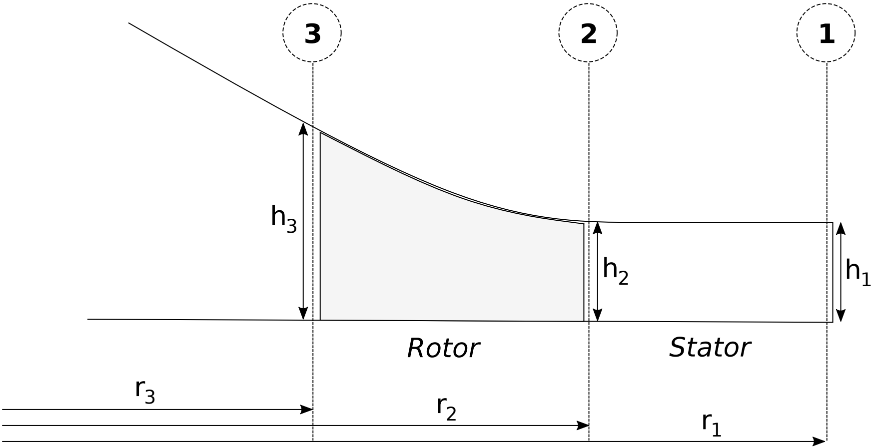
Euler Turbine model

- 0-D model for Centripetal Radial Turbine
- Solves for each position in the turbine:
  - Total thermodynamic conditions (TC)
  - Static thermodynamic conditions (SC)
  - Velocity triangle (VT)
- Three main modelling assumptions:
  - Mass conservation at all turbine states
  - Conservation of total enthalpy between stator inlet and outlet
  - Conservation of rothalpy between rotor inlet and outlet
- Properties of Toluene included using Coolprop
- Written in Python (including parallized solution domain solving)

Model schematic



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Euler Turbine model inputs

- Radial position and height at each state — $h_n,\ r_n$ for $n = 1, 2, 3$
- Total conditions at inlet stator and the direction and magnitude of the velocity — $P_{01},\ T_{01},\ ||\bar{c}_1||,\ \alpha_1$
- Absolute velocity angle at inlet rotor — α_2
- Static pressure at the outlet of the rotor — P_3
- Degree of reaction — R
- Speed of rotation — ω

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Recap important equations

- Massflow: $\dot{m} = \rho A c_r$
- Total Enthalpy: $h_0 = h + \frac{||\overline{c}||^2}{2}$
- Rothalpy: $I = h + \frac{||\overline{w}||^2}{2} - \frac{||\overline{U}||^2}{2}$
- Degree of reaction: $R = \frac{h_2 - h_3}{h_1 - h_3}$
- Velocity triangles: $\overline{c} = \overline{w} + \overline{U}$
- Angular velocity: $\overline{U} = [U_r, U_\theta]^T = [0, \omega r]^T$
- Specific work $w = U_{\theta-2} c_{\theta-2} - U_{\theta-3} c_{\theta-3}$

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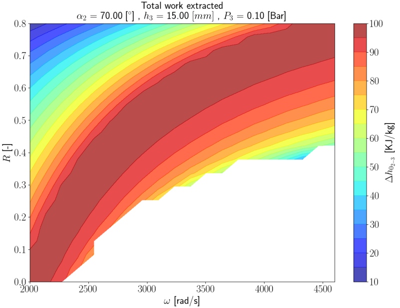
Model solving procedure

1. Calculate U_2 and U_3 using ω, r_2, and r_3
2. Calculate $TC|_1$, $SC|_1$ and $VT|_1$, using P_{01}, T_{01}, $||\overline{c}_1||$ and α_1
3. Calculate m_1 with A_1, $SC|_1$ and $VT|_1$

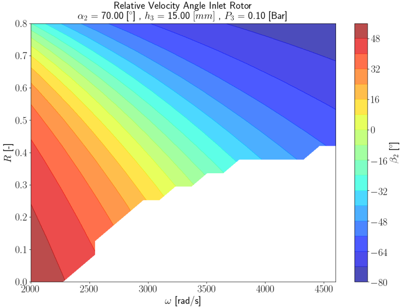
4. Assuming $s_3 = s_1$, calculate $SC|_3$ using P_3
5. Assuming $s_2 = s_1$, calculate $SC|_2$ by means of R and $SC|_3$
6. Assuming $TC|_1 = TC|_2$, calculate $||\overline{c}_2||$ using $SC|_2$
7. Given α_2, calculate $VT|_2$
8. Given $VT|_2$ find h_2 such that $\dot{m}_2 = \dot{m}_1$

9. Given $I_2 = I_3$, $SC|_2$ and $SC|_3$ calculate $\overline{w}_3$
10. Given the $\dot{m}_3 = \dot{m}_2$ and the SC_3 calculate c_{r-3}
11. Using c_{r-3} and $\overline{w}_3$ calculate the $VT|_3$
12. Calculate h_{03} using the Eulerian work formula and $VT|_2$ and $VT|_3$
13. Calculate $TC|_3$ with h_{03} and s_3

Effect of DOR and Rotational Speed

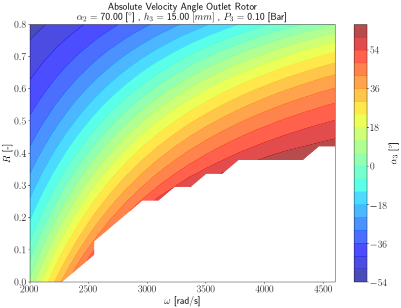


(a) Work extracted

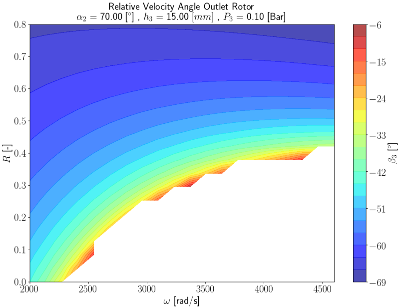


(b) Relative Flow Angle Inlet Rotor

Effect of DOR and Rotational Speed

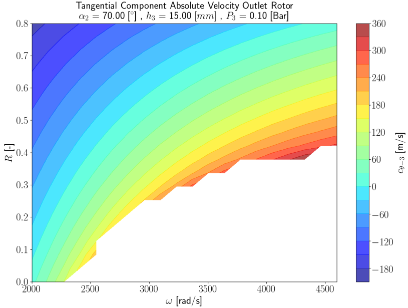


(a) Absolute Flow Angle Outlet Rotor

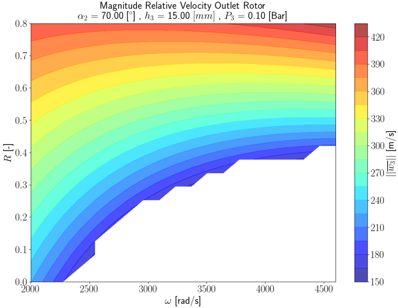


(b) Relative Flow Angle Outlet Rotor

Effect of DOR and Rotational Speed

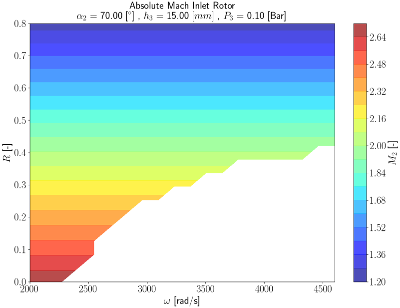


(a) Tangential Absolute Velocity Outlet Rotor

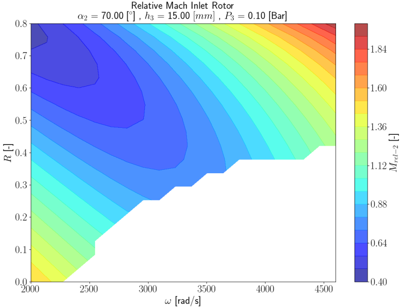


(b) Magnitude Relative Velocity Outlet Rotor

Effect of DOR and Rotational Speed

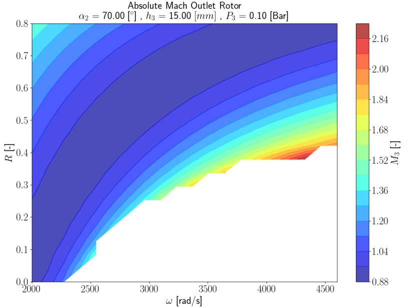


(a) Absolute Mach Inlet Rotor

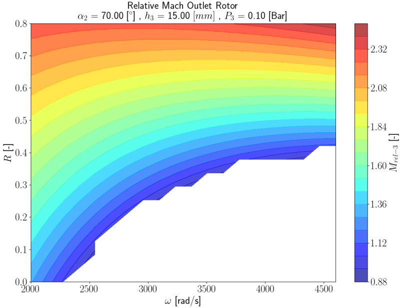


(b) Relative Mach Inlet Rotor

Effect of DOR and Rotational Speed



(a) Absolute Mach Outlet Rotor



(b) Relative Mach Outlet Rotor

Conclusion on the basis of 0-Model

- In simulations we saw that at higher rotational speed the relative outflow angle was not equal to the trailing angle (much smaller)
- 0-D model tells us that this is due to massflow conservation, the area is to small, therefor a large radial component is neccessary, reducing the angle
- Can be resolved by increasing the area at the outlet of the rotor