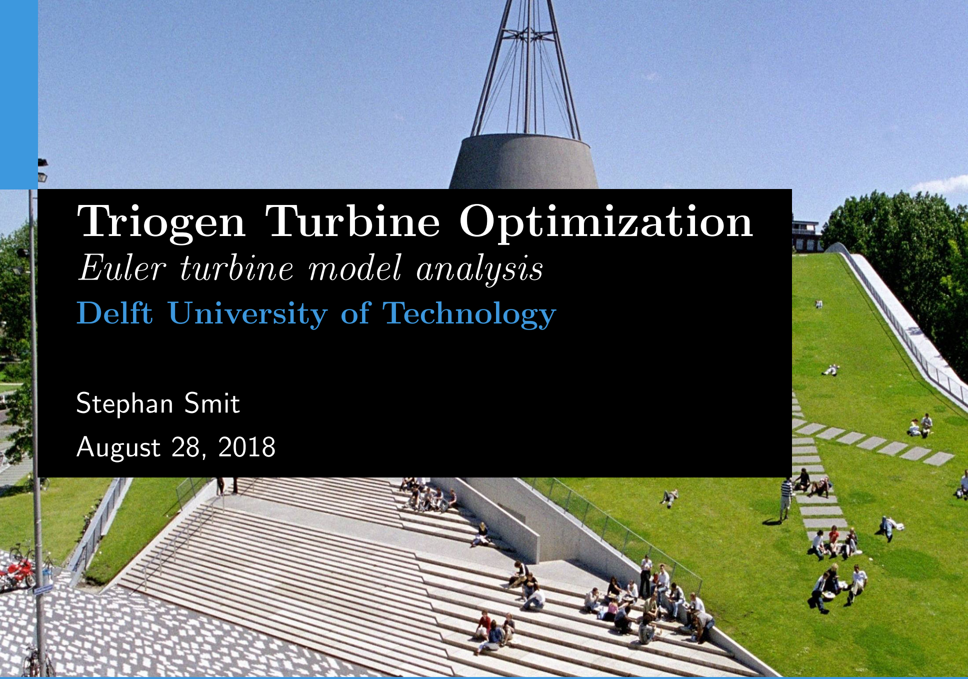

Triogen Turbine Optimization

Euler turbine model analysis

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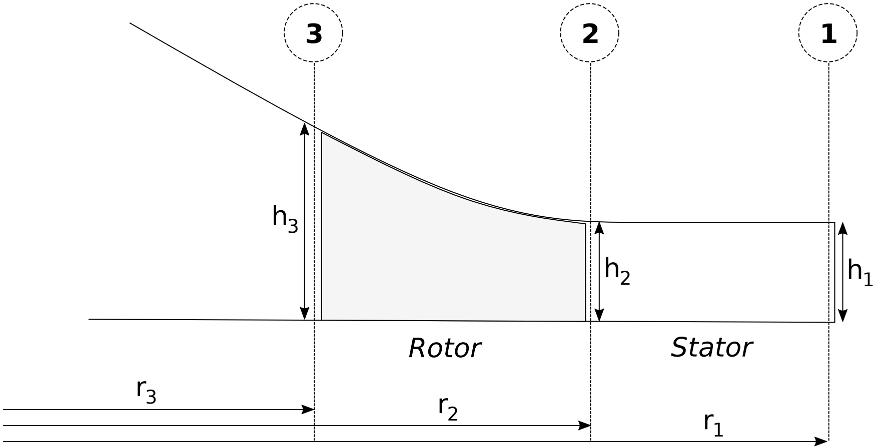
Euler Turbine model

- 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



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}, $||\bar{c}_1||$, α_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

TUDelft

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 $w = U_{\theta-2} c_{\theta-2} - U_{\theta-3} c_{\theta-3}$

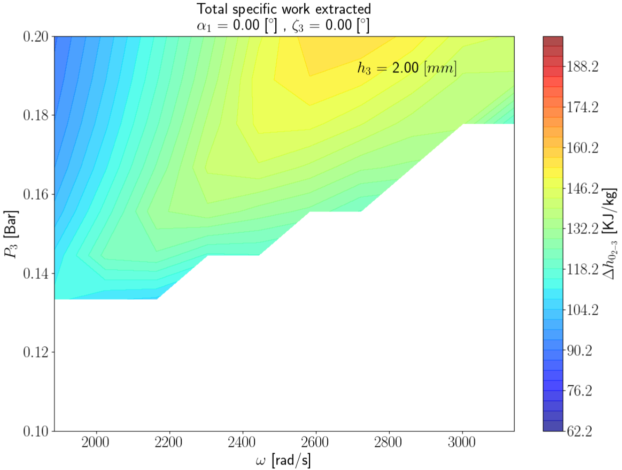
Model solving procedure

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 outlet height on extracted work



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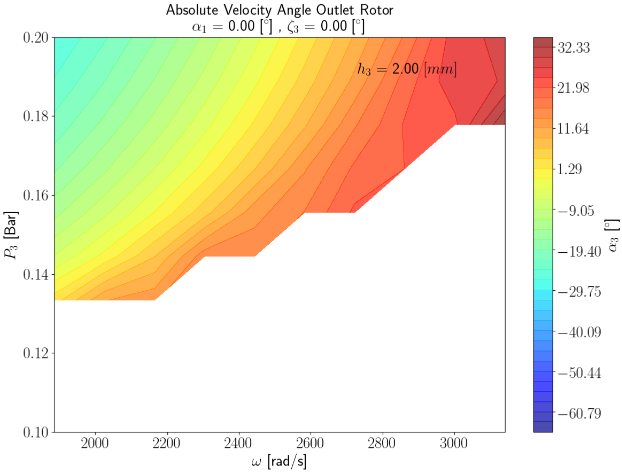
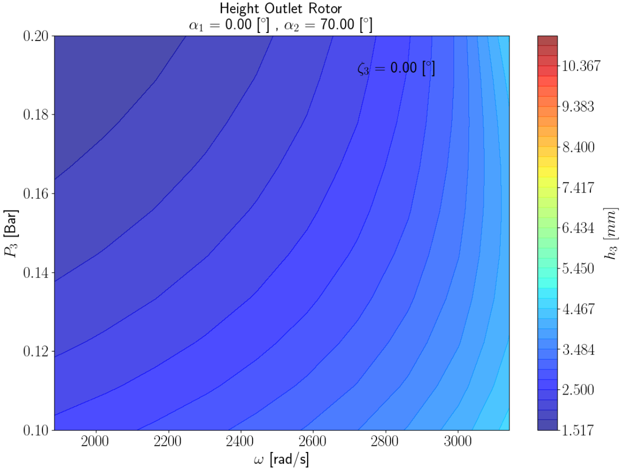
Effect of outlet height on absolute flow angle ($r\theta$-plane)



Effect of absolute flow angle (rz-plane) on extracted outlet height



Effect of absolute flow angle (rz-plane) on extracted work