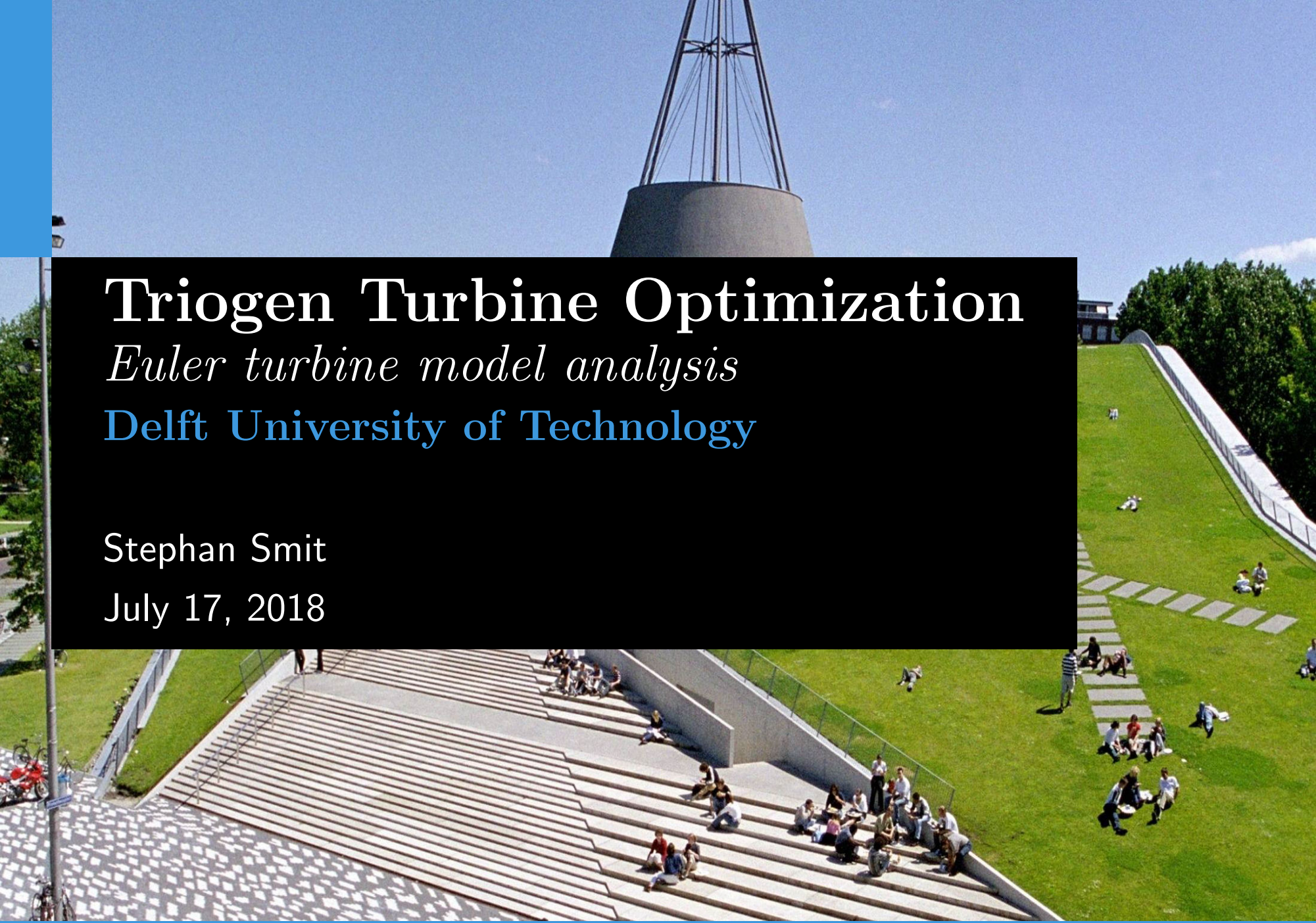

Triogen Turbine Optimization

Euler turbine model analysis

Delft University of Technology

Stephan Smit

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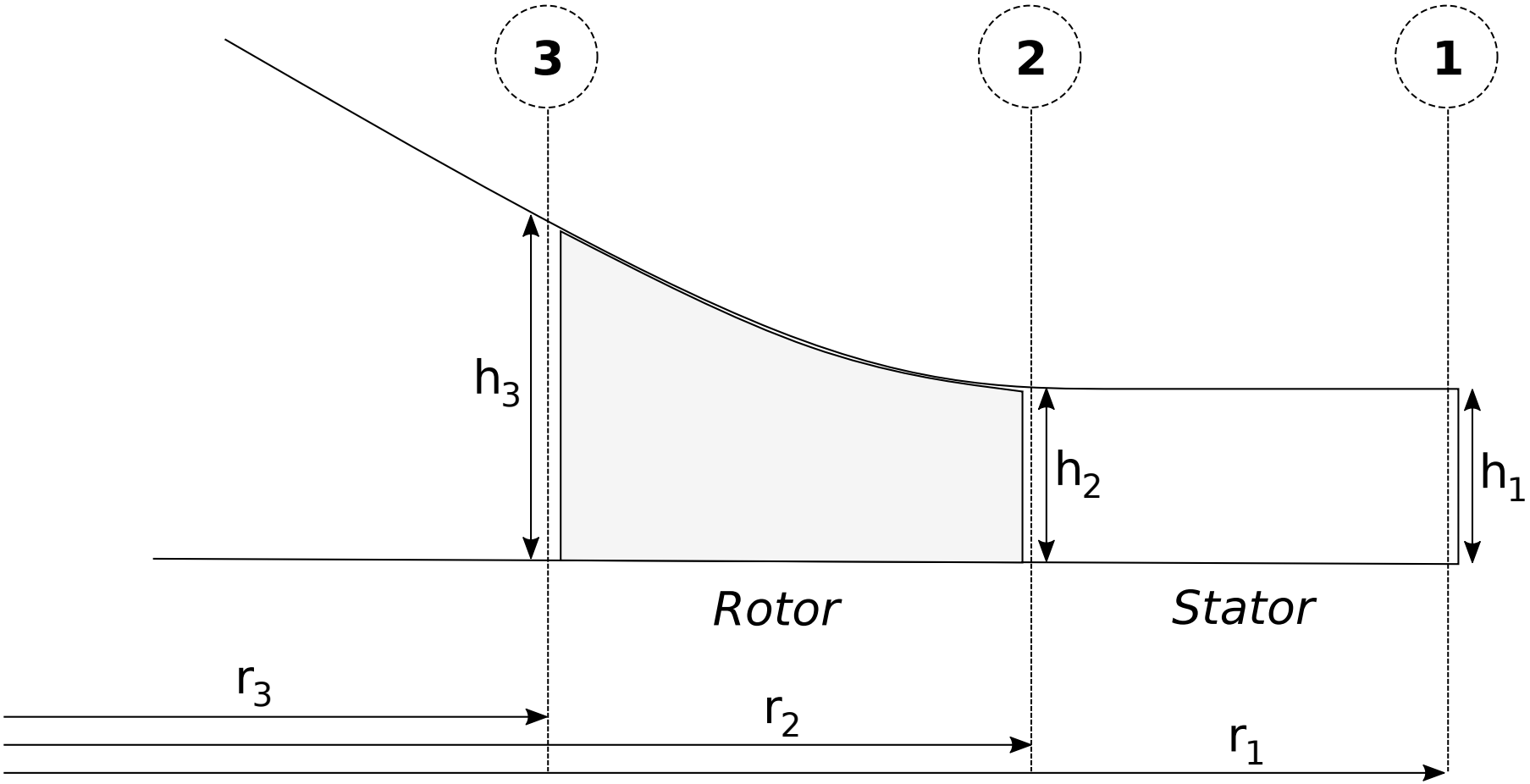
Euler Turbine model

- 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}, $||\overline{c}_1||$, 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

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: $\overline{U} = [U_r, U_\theta]^T = [0, \omega r]^T$

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_3, $SC|_1$ and $VT|_1$

4. Make guess for $||\overline{c}_2||$
5. Assuming $h_{01} = h_{02}$, $s_{01} = s_{02}$, calculate $SC|_2$ and $VT|_2$ with α_2 and $||\overline{c}_2||$
6. Calculate m_2 with $SC|_2$, $VT|_2$ and A_2
7. Go back to step 4 until $\dot{m}_1 = \dot{m}_2$

8. Calculate $SC|_3$ using R, h_2, h_1 and P_3
9. Calculate c_{r-3} with $\dot{m}_1$, A_3 and $SC|_3$
10. Assuming $I_2 = I_3$, calculate $||w_3||$ with h_3 and $\overline{U}_3$
11. Calculate $VT|_3$ at outlet rotor using $||w_3||$ and c_{r-3}
12. Calculate $TC|_3$ with $VT|_3$ and $SC|_3$