\[ Q_d = \frac{\Delta T}{R_d} \quad R_d = \frac{1}{h_0} + \frac{2h_0}{k_3} + \frac{1}{h_i} \quad \text{(for unit area)} \]

\[ Q_s = \frac{\Delta T}{R_s} \quad R_s = \frac{1}{h_0} + \frac{L_d}{k_3} + \frac{1}{h_i} \quad \text{same } \Delta T = T_i - T_o \]

Reduction in heat transfer:
\[ \frac{Q_s - Q_d}{Q_s} = \frac{\frac{1}{R_s} - \frac{1}{R_d}}{\frac{1}{R_s}} \equiv \Delta \]

\[ \Delta = 1 - \frac{1}{h_0} + \frac{L_d/k_3 + L_a/k_3 + 1/h_i}{1/h_0 + 2h_0/k_3 + L_d/k_3 + 1/h_i} \]

\[ L_d = 0.005 \text{ m} \quad L_a = 0.004 \text{ m} \]

Find \( \Delta = 0.564 \)

So heat transfer is reduced by 56.4\% due to significantly higher resistance of air film.
Cooled turbine blade no TBC

\[ T_{w,0} \rightarrow T_{w,i} \rightarrow T_{w,0} \]

1) TBC inside

\[ \Delta T_{TBC} = \frac{1}{T_{w,0}} + \frac{L_{TBC}}{K_{TBC} T_{w,0}} + \frac{L_I}{K_I} + \frac{1}{T_{w,0}} = R_{tot} T_{w,0} \]

\[ T_{w,0} = T_{w,0} - \frac{T_{w,0} - T_{w,1}}{R_{tot}} \]

\[ R_{tot} = 0.00373 \text{ K/m}^2 \]

\[ T_{w,0} = 1183 \text{ K} \]

2) Fourier: \( q = -k \frac{dT}{dn} \)

\[ T_{w,0} \rightarrow T_{w,i} \rightarrow T_{w,0} \]

3) Newtonian: \( q = n (T_{w,0} - T_{w,i}) \)

4) Highest temp in blade: \( T_{w,0} \)

\[ \dot{Q} = \frac{T_{w,0} - T_{w,i}}{R_{tot} n} \]

\[ T_{w,0} = T_{w,0} - \frac{T_{w,0} - T_{w,1}}{R_{tot}} \cdot \frac{1}{R_{tot}} \]

blades will melt!

5) Summary again

High resistance in TBC and thin sanding again yields significant temperature drop.
Concept: Reynolds analogy, convective heat transfer

Re-analogy: \( S_t = \frac{cf}{2} \), \( D = \frac{1}{2} \frac{cfA}{\rho_\infty C_p} \)

\[
S_t = \frac{h}{\rho_\infty C_p} \quad \text{so} \quad \frac{h}{\rho_\infty C_p} = \frac{D}{A \rho_\infty C_p} \quad \Rightarrow \quad h = \frac{D \rho_\infty}{A \rho_\infty C_p}
\]

\( h = 66.9 \, \text{W/m}^2\text{K} \)

Newton's law of cooling: \( \dot{Q} = A h (T_w - T_\infty) = \dot{Q}_{el} \)

\( \text{find} \dot{Q}_{el} = 2,043 \, \text{W} \) of electrical power required to maintain surface temperature