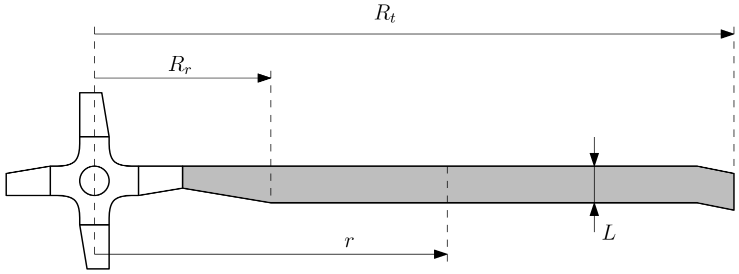
Aerodynamics **EETAC**

Q1, 16/12/2021 **Boundary Layer AD2**

Rough Estimation of the Apache AH-64 Main Rotor Friction Torque and Power

Aim: Estimate the minimum engine torque and power required to overcome friction drag of an Apache AH-64 main rotor, using a spanwise-variable speed flat plate approximation.

Consider the incompressible flow around the four-blade main rotor of an Apache AH-64 attack helicopter when hovering just above ground (sea level, air properties: temperature $T = 288.15\,\mathrm{K}$, density $\rho = 1.225\,\mathrm{kg/m^3}$, kinematic viscosity $\nu = 1.4531 \cdot 10^{-5}\,\mathrm{m^2/s}$, gas constant $R_{air} = 287.14\,\mathrm{J/(kg\,K)}$ and adiabatic index $\gamma = 1.4$). In these flight conditions the angular speed of the rotor is $\Omega = 292\,\mathrm{rpm}$. Rotor dimensions are such that each blade extends from $R_r = 2.032\,\mathrm{m}$ to $R_t = 7.3152\,\mathrm{m}$ and has a constant chord along the span of $L = 0.5334\,\mathrm{m}$.
For the sake of simplicity, neglect the contribution of both the blade grip and innermost variable-chord portion of the blades and assume that the blades can be approximated by flat plates at zero angle of attack as shown in the figure.



Neglect further any source of transverse flow such as centrifugal effects or blade tip lift-induced vortices, such that the assumption of purely streamwise flow at every blade section can be made (no spanwise flow). The boundary layers developing on the rotor blades will thus be considered incompressible and two-dimensional.

1. Calculate blade tip (and root) speed u_t (u_r), Mach number M_t (M_r) and chord-based Reynolds number Re_t (Re_r). Discuss the validity of the asumptions on incompressibility.

2. Assuming a natural turbulent transition Reynolds number $Re_T = 5 \times 10^5$, assess at which radius R_T transition starts occurring naturally along the blade-section chord.

From this point on assume further that, due to secondary flow, preturbulence levels and other factors, boundary layers on the blade are turbulent from outset, such that they can be considered turbulent along the full chord and span of the blades.

3. Express the boundary layer trailing edge momentum thickness $(\theta_{te}/L)(r)$ in terms of tip radius R_t, tip Reynolds number Re_t and distance r to blade hub.

4. Calculate the drag per unit span $D(r)$ along the blade. Express it in terms of R_t, Re_t, L and Ω.

5. Find the friction torque Γ and power P required to spin the rotor in the conditions being considered.