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UNIVERSIDAD POLITÉCNICA DE MADRID
Escuela Universitaria de
Ingeniería Técnica Aeronáutica

HELICOPTERS

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ROTOR AERODYNAMICS

Momentum Theory in Forward Flight

Inital thoughts:

- Forward flight is more complicated to study than vertical climb:
  - The angle between the horizontal reference and the flight speed isn´t Π/2.
  - The aerodynamical forces depend on the angular position of the blade.
  - The plane which is formed by the blade tips do not need to be perpendicular to the drive shaft.

Inital thoughts:

- There are different theories for studying rotor aerodynamics.
  - The momentum theory.
  - The blade element theory.
  - The vortex theory.

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ROTOR AERODYNAMICS

FORWARD FLIGHT

MOMENTUM THEORY.

- ✓ **Calculation of Thrust and Power.**
- ✓ **Velocity ratio.**

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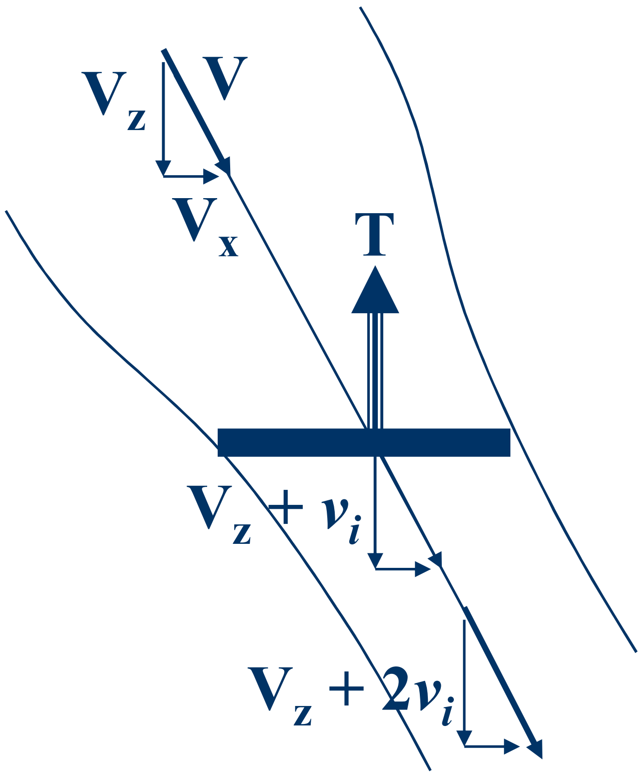
INITIAL ASSUMPTIONS

- High values of Re number flow.
- Replace the rotor with a totally porous disc of the same radius (**R**) as the rotor replaced.
- We assume the affected flow through the disc is defined by a streamtube.
- The fluid flow in the streamtube is considered to be unidimensional, steady and incompressible.
- The effects of the rotation of the slipstream and loses in the blade tips, are negleted.
- The fluid force on the rotor only has a vertical component.

CALCULATION OF THE THRUST AND POWER



- If F_x is negligible V_x is constant.
- Similarly, the induced velocity in the infinite downstream is twice the velocity in the rotor disc.

$$T = G(V_z + 2v_i - V_z) = G2v_i$$

$$G = \rho(\pi R^2)|V_1| = \rho(\pi R^2)\sqrt{V_x^2 + (V_z + v_i)^2}$$

$$T = 2\rho\left(\pi R^2\right)v_i \sqrt{V_x^2 + \left(V_Z + v_i\right)^2}$$

$$P_i = T\left(V_z + v_i\right) = 2\rho\left(\pi R^2\right)v_i\left(V_z + v_i\right)\sqrt{V_x^2 + \left(V_z + v_i\right)^2}$$

VELOCITY RATIO

$$T = 2\rho\left(\pi R^2\right) v_i \sqrt{V_x^2 + \left(V_Z + v_i\right)^2}$$

$$T = 2\rho\left(\pi R^2\right) v_{io}^2$$

$$\left(\frac{v_i}{v_{io}}\right)^2 \bullet \left[\left(\frac{V_x}{v_{io}}\right)^2 + \left(\frac{V_z + v_i}{v_{io}}\right)^2\right] = 1$$

si $V_z = 0$

$$\left(\frac{v_i}{v_{io}}\right)^2 \bullet \left[\left(\frac{V_x}{v_{io}}\right)^2 + \left(\frac{v_i}{v_{io}}\right)^2\right] = 1$$

$$\frac{P_i}{P_{io}} = \frac{V_z + v_i}{v_{io}} = \frac{v_i}{v_{io}}$$

$$\frac{v_i}{v_{io}} = \sqrt{\frac{1}{2}\left[\sqrt{4 + \left(\frac{V_x}{v_{io}}\right)^4} - \left(\frac{V_x}{v_{io}}\right)^2\right]}$$