

# Wake Modelling using the Prescribed Wake Method

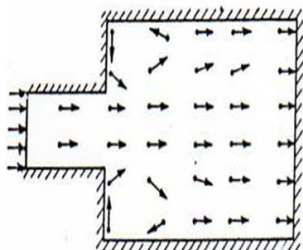
Cibin Joseph

September 5, 2018

# Wake/Fluid Modelling

## Eulerian-based

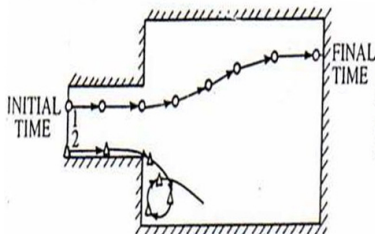
- ▶ Conventional CFD



(b) EULERIAN APPROACH  
(STUDY AT FIXED STATIONS IN SPACE)

## Lagrangian-based

- ▶ Vortex filament method
  - ▶ Prescribed wake
  - ▶ Free wake
- ▶ Vortex particle method
- ▶ Lattice-Boltzmann CFD



(a) LAGRANGIAN APPROACH  
(STUDY OF EACH PARTICLE WITH TIME)

# Observations

## Wake In Hover

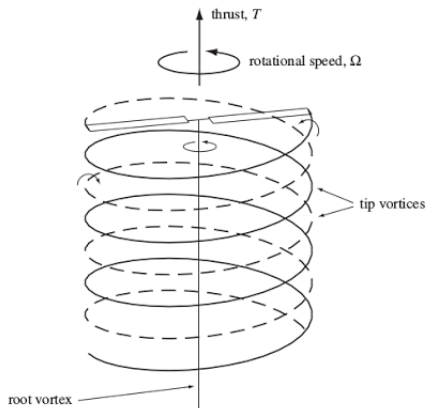


Figure 3.12. Rotor vortex wake in vertical flight.

Source: W. Johnson, Rotorcraft Aeromechanics

# Landgrebe wake model for Hover

$$\bar{r}_{tip} = A + (1 - A)\exp(-\Lambda\psi_w) \quad (1)$$

$$\bar{z}_{tip} = k_1\psi_w \quad 0 \leq \psi_w \leq 2\pi/N_b \quad (2)$$

$$= k_1\frac{2\pi}{N_b} + k_2(\psi_w - \frac{2\pi}{N_b}) \quad \psi_w \geq 2\pi/N_b \quad (3)$$

Parameters:

$$A=0.78, \Lambda = 0.145 + 27C_T$$

$$k_1 = -0.25(C_T + 0.001\theta_{tw}^\circ)$$

$$k_2 = -(1.41 + 0.001\theta_{tw}^\circ)\sqrt{C_T/2}$$

## Beddoes generalised wake model

$$\lambda_i = \lambda_o(1 + E\bar{x} - E|\bar{y}^3|) \quad (4)$$

$$\bar{x}_{tip} = r_v \cos \psi_v + \mu \psi_w \quad (5)$$

$$\bar{y}_{tip} = r_v \sin \psi_v \quad (6)$$

$$\bar{z}_{tip} = -\mu \tan \alpha \psi_w + \int_0^{\psi_w} \lambda_i d\psi \quad (7)$$

Note that,  $\psi_v = \psi_b - \psi_w$

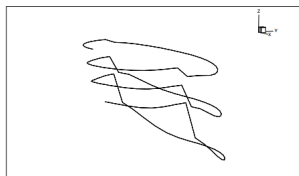
3 cases when evaluating integral term:

$$\text{if } \bar{x}_{tip} < -r_v \cos \psi_v \Rightarrow -2\lambda_o(1 + E \cos \psi_v + 0.5\mu - E|\bar{y}_{tip}^3|)\psi_w$$

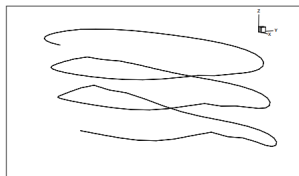
$$\text{if } \cos \psi_v > 0 \Rightarrow -2\lambda_o(1 - E|\bar{y}_{tip}^3|)\psi_w$$

$$\text{else} \Rightarrow -2\lambda_o \bar{x}_{tip} \frac{1 - E|\bar{y}_{tip}^3|}{\mu}$$

# Murakami's correction



(a) Without correction



(b) With correction

Figure 9: Tip vortex trajectory at  $\mu = 0.012$

Source: G. Reboul. A parametrized BVI noise prediction code. Greener Aviation 2014, Belgium