Wake Modelling using the Prescribed Wake Method

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September 5, 2018

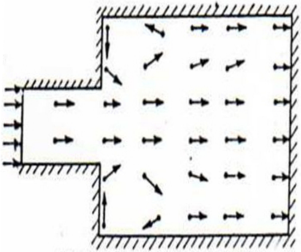
Wake/Fluid Modelling

Eulerian-based

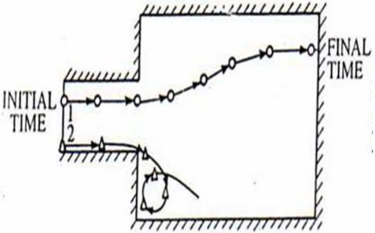
- Conventional CFD

Lagrangian-based

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



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



(a) LAGRANGIAN APPROACH
(STUDYOF EACH PARTICLE WITH TIME)

Observations

Wake In Hover

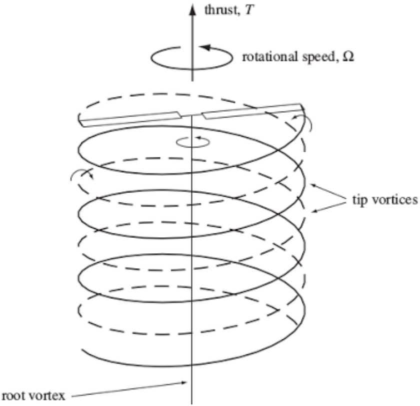


Figure 3.12. Rotor vortex wake in vertical flight.

Source: W. Johnson, Rotorcraft Aeromechanics

Landgrebe wake model for Hover

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

$$\bar{z}_{tip} = k_1\psi_w \qquad 0 \leq \psi_w \leq 2\pi/N_b \tag{2}$$

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

Parameters:

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

$$k1 = -0.25(C_T + 0.001\theta^o_{tw})$$

$$k2 = -(1.41 + 0.001\theta^o_{tw})\sqrt{C_T/2}$$

Beddoes generalised wake model

$$\lambda_i = \lambda_o(1 + E\bar{x} - E|\bar{y}^3|) \quad \text{across rotor} \tag{4}$$
$$= 2\lambda_o(1 - E|\bar{y}_{tip}^3|) \quad \text{behind rotor} \tag{5}$$

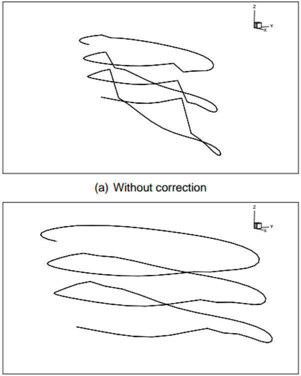
$$\bar{x}_{tip} = r_v \cos\psi_v + \mu\psi_w \tag{6}$$
$$\bar{y}_{tip} = r_v \sin\psi_v \tag{7}$$
$$\bar{z}_{tip} = -\mu \tan\alpha\psi_w + \int_0^{\psi_w} \lambda_i d\psi \tag{8}$$

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

3 cases when evaluating integral term:

$$\text{if} \quad \bar{x}_{tip} < -r_v \cos\psi_v \Rightarrow -\lambda_o(1 + E(\cos\psi_v + 0.5\mu\psi_w - |\bar{y}_{tip}^3|))\psi_w$$
$$\text{if} \quad \cos\psi_v > 0 \Rightarrow -2\lambda_o(1 - E|\bar{y}_{tip}^3|)\psi_w$$
$$\text{else} \Rightarrow -2\lambda_o\bar{x}_{tip}\frac{1 - E|\bar{y}_{tip}^3|}{\mu}$$

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