Rotorcraft Trim Procedure (Unified from PPTs)

Inputs

$$W,\ f,\ V_\infty,\ \rho,\ c(r),\ R,\ \omega,\ \phi$$

where a is the 2D lift slope, B is the number of blades, and $\theta_{\text{tw}}(r)$ is the blade twist law.

Step-by-Step Calculations

1. Parasite Drag

$$D = \tfrac{1}{2}\rho f V_\infty^2$$

2. Rotor Thrust (Force Balance, ignoring tail/fuselage lift)

$$T = \sqrt{W^2 + D^2}$$

3. Tip-Path-Plane (TPP) Angle

$$T\cos\alpha_{\text{TPP}} = W, \qquad T\sin\alpha_{\text{TPP}} = D$$

$$\alpha_{\text{TPP}} = \tan^{-1}\left(\frac{D}{W}\right)$$

4. Rotor Disk Area

$$A = \pi R^2$$

5. Thrust Coefficient

$$C_T = \frac{T}{\rho A(\omega R)^2}$$

6. Advance Ratio

$$\mu = \frac{V_\infty \cos\alpha_{\text{TPP}}}{\omega R}$$

7. Glauert Induced Inflow Ratio

Momentum balance for forward flight:

$$C_T = 2\lambda_i\sqrt{\mu^2 + \left(\lambda_i + \frac{V_\infty}{\omega R}\sin\alpha_{\text{TPP}}\right)^2}$$

For $\mu > 0.2$ and small α_{TPP}:

$$\lambda_i \approx \frac{C_T}{2\mu}$$

8. Total Inflow Ratio

$$\lambda_G = \lambda_i + \frac{V_\infty}{\omega R} \sin \alpha_{\text{TPP}}$$

9. Radial / Azimuthal Inflow Distribution

$$\lambda(r, \phi) = \lambda_i \left[1 + \left(\frac{4}{3} \frac{\mu}{\lambda_G} \left(1.2 + \frac{\mu}{\lambda_G} \right) \right) \frac{r}{R} \cos \phi \right]$$

10. Induced Velocity

$$v(r, \phi) = \lambda(r, \phi)\, \omega R$$

Iteration Loop

11. Blade Pitch Law

$$\theta(r, \phi) = \theta_0 + \theta_{1c} \cos \phi + \theta_{1s} \sin \phi + \theta_{\text{tw}}(r)$$

12. Effective Angle of Attack

$$\alpha_{\text{eff}}(r, \phi) = \theta(r, \phi) - \frac{v(r, \phi) + V_\infty \cos \alpha_{\text{TPP}} \cos \phi}{\omega r + V_\infty \sin \phi}$$

13. Coning Angle (First Harmonic of Flapping)

$$\beta_0 \;\propto\; \frac{1}{\Omega^2 I_b} \int_0^{2\pi} \int_{r_{\text{hub}}}^{R} L'(r, \phi)\, r\, dr\, d\phi$$

14. Sectional Lift

$$L'(r, \phi) = \tfrac{1}{2} \rho U_T^2 c(r)\, a\, \alpha_{\text{eff}}(r, \phi)$$

where $U_T \approx \omega r + V_\infty \sin \phi$.

15. Instantaneous Thrust

$$dT(r, \phi) \approx L'(r, \phi)\, dr$$

$$T(\phi) = B \int_{r_{\text{hub}}}^{R} dT(r, \phi)$$

16. Mean Thrust

$$T_{\text{mean}} = \frac{1}{2\pi} \int_0^{2\pi} T(\phi)\, d\phi$$

17. Trim Conditions

$$T_{\text{mean}} = T_{\text{req}}, \quad M_x = 0, \quad M_y = 0$$

18. Update Control Angles

$$\begin{bmatrix} \theta_0 \\ \theta_{1s} \\ \theta_{1c} \end{bmatrix}^{(k+1)} = \begin{bmatrix} \theta_0 \\ \theta_{1s} \\ \theta_{1c} \end{bmatrix}^{(k)} - \gamma \begin{bmatrix} R_T \\ R_x \\ R_y \end{bmatrix}$$

with

$$R_T = T_{\text{mean}} - T_{\text{req}}, \quad R_x = M_x, \quad R_y = M_y$$

Final Outputs

At convergence:

$$\boxed{\theta_0^*,\ \theta_{1s}^*,\ \theta_{1c}^*}$$

These are the trim collective and cyclic pitch settings used for post-processing (performance, mission planner, endurance, range).