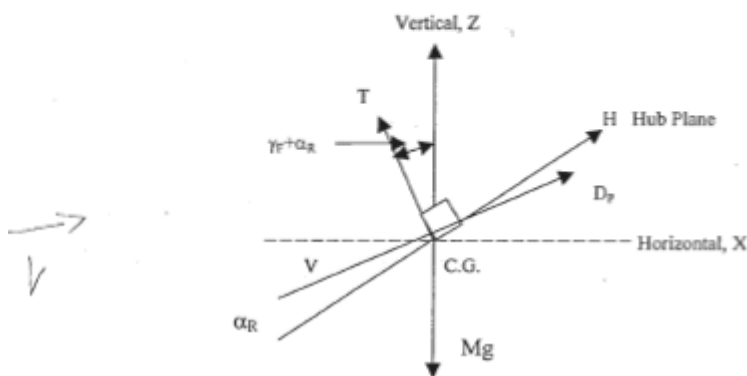


헬리콥터 동역학 과제물 4번

제출기한: 6월 8일 (금)

1.

Consider the trim condition of a helicopter flying in steady level flight with a fixed velocity V as shown below. The mass of the helicopter is M .



Geometry for trim calculation.

$$\frac{V \cos \alpha}{\Omega R}$$

Assume that the helicopter's CG, hub and blade hinges all coincide. The rotor consists of four centrally hinged articulated blades that have uniform mass distribution. Assume that each blade has only flapping degree of freedom and neglect reversed flow, stall and compressibility.

The trim or equilibrium condition for this helicopter implies the following relations.

$\sum F_x = 0$ force equilibrium in the x-direction

$$-T \sin \alpha_R + H \cos \alpha_R + D_p = 0 \quad (1)$$

$\sum F_z = 0$, force equilibrium in the vertical, or z-direction

$$T \cos \alpha_R = Mg \quad \rightarrow \quad C_{T_{MR}} = \frac{T}{\rho (\pi R^2) (\Omega R)^2} \quad (2)$$

Time averaged moment equilibrium:

$$(M_{pe})_z = 0 \quad C_w = M_j \quad (3)$$

$$(M_{ra})_z = 0 \quad C_{w_{ra}} = \frac{M_j}{\rho (\pi R^2) (\Omega R)^2} \quad (4)$$

Equation (3) above represents pitch equilibrium about the CG (point 0) about the y-axis (perpendicular to the xz-plane), and Eq. (4) represents roll equilibrium about the x-axis. These four equations combined with

$$\lambda = \mu \tan \alpha_R + \frac{C_T}{2\sqrt{\mu^2 + \lambda^2}} \quad (5)$$

are sufficient for determining the trim state of the helicopter, when one assumes that

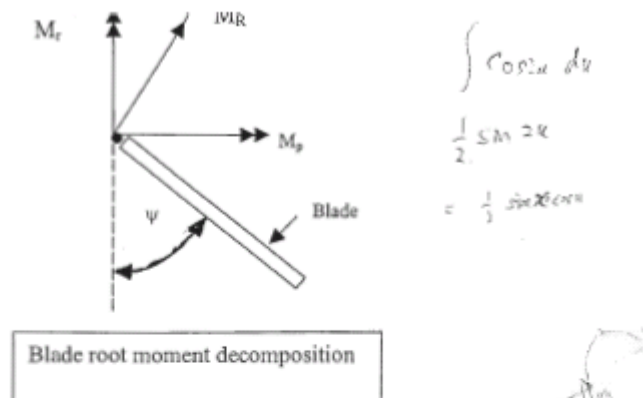
$$D_p = \frac{1}{2} \rho V^2 f \quad (6)$$

$$f \approx 0.01 \pi R^2 \quad (7)$$

Furthermore, assume that the flapping degree of freedom is restrained by a flapping spring having a spring constant equal to k_β , and the magnitude of this spring constant is such that it produces a fundamental rotating flap frequency of

$$\frac{\omega_\beta}{\Omega} = 1.1 \Rightarrow \quad \text{e.g. } 1.1 \cdot 10 \cdot 16 = 176 \text{ rad/s}$$

Note that the effect of the flapping hinge is to introduce a resultant moment component M_R in the rotating reference frame as indicated below



where $\psi = \Omega t$.

From the geometry of the figure above

$$M_p = M_R(\psi) \cos \psi \quad (8)$$

$$M_r = M_R(\psi) \sin \psi \quad (9)$$

and the average values are obtained from

$$M_{p0} = \frac{1}{2\pi} \int_0^{2\pi} M_R(\psi) \cos \psi d\psi \quad (10)$$

$$M_{r0} = \frac{1}{2\pi} \int_0^{2\pi} M_R(\psi) \sin \psi d\psi \quad (11)$$

For an n_b bladed rotor it can be shown that the average pitching and rolling moment for the complete rotor is given by

$$\begin{cases} (M_{px})_R = M_{px} n_b & (12) \\ (M_{rx})_R = M_{rx} n_b & (13) \end{cases}$$

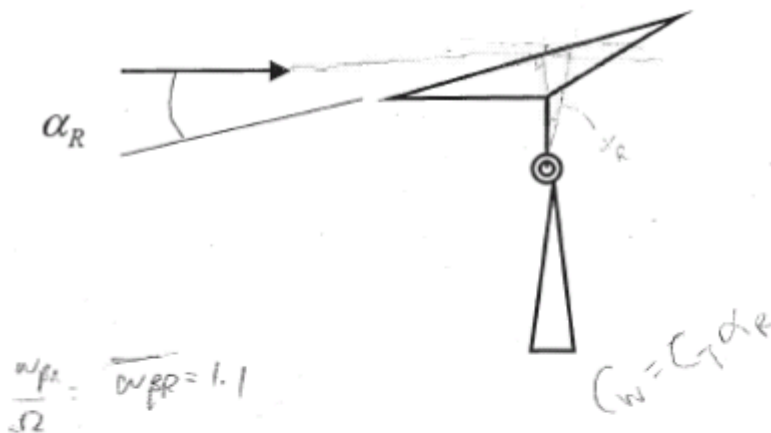
Using the material provided above, derive the following relations.

- Show that expressions (12) and (13) are true.
- Derive Equations (1)-(4) in coefficient (non-dimensional form) so that they can be combined with equation (5) to obtain the trim state of the helicopter.
- The trim state is given by

$$\theta_o, \theta_{tr}, \theta_{ic}, \alpha_R \text{ and } \lambda$$

Describe, without actually solving, how you would obtain these quantities.

2.



The rotor shown above is being tested in the wind tunnel at an advance ratio of $\mu=0.4115$ and a collective pitch setting of $\theta_o = 8.22^\circ$. The rotor is supported by a stand and has a universal joint that allows frictionless pitch and rolling motion. A shaft angle of $\alpha_R = 11.8^\circ$ is imposed on the rotor. The rotor consists of four blades that are centrally hinged and spring restrained. Assume that the blades have flapping degree of freedom only and the spring produces a rotating fundamental flap frequency of $\sigma_{fl} = 1.1$. Other data you may need can be assumed to be:

$$a = 2\pi; \quad \gamma = 12.4; \quad c = 1.5 \text{ ft}; \quad R = 20 \text{ ft}; \quad W = 5000 \text{ lbs}; \quad \Omega = 300 \text{ RPM}$$

The equilibrium conditions for the test, require that you calculate the appropriate moment trim condition, for which the pitching and rolling moments on the rotor are zero.

- Derive the equations that can serve as the basis of a trim procedure from which the values of θ_{ic} , θ_{tr} , and λ can be found; and calculate the inflow from a suitable relation.
- Try to calculate the trim state for this rotor as given by θ_{ic} , θ_{tr} , λ and $\beta(\psi)$.

If the numerical calculations become too complicated, you can "wave your hands" and describe how you would actually get these numbers.