UNIVERSITY OF Southampton
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# Aerodynamics & Flight Mechanics Research Group

## Rotor Control Power in Roll with Zero Thrust Near Hovering Flight

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# Preamble

The analysis is to consider the ability of a rotor to generate a steady roll angle. Zero thrust on the rotor is assumed. The rotor blade is modelled to have zero hinge offset but the centrifugal stiffness is modelled by adjusting the flapping frequency.

# Nomenclature

| Variable | Description |
|---|---|
| **M** | Aircraft Mass |
| **N** | Number of Blades |
| $\mathbf{b_1}$ | Lateral Disc Tilt |
| **g** | Acceleration due to Gravity |
| **I** | Blade Inertia about Flapping Hinge |
| $\mathbf{\Omega}$ | Rotor Speed |
| $\lambda_\beta$ | Shaft Torque Input from the Engine(s) |
| $k_\beta$ | Aerodynamic Torque |
| **e** | Flapping Hinge Offset (Non-Dimensional on Rotor Radius) |
| **h** | Height of Rotor Head above Aircraft CG |
| **W** | Aircraft Weight |

# Method

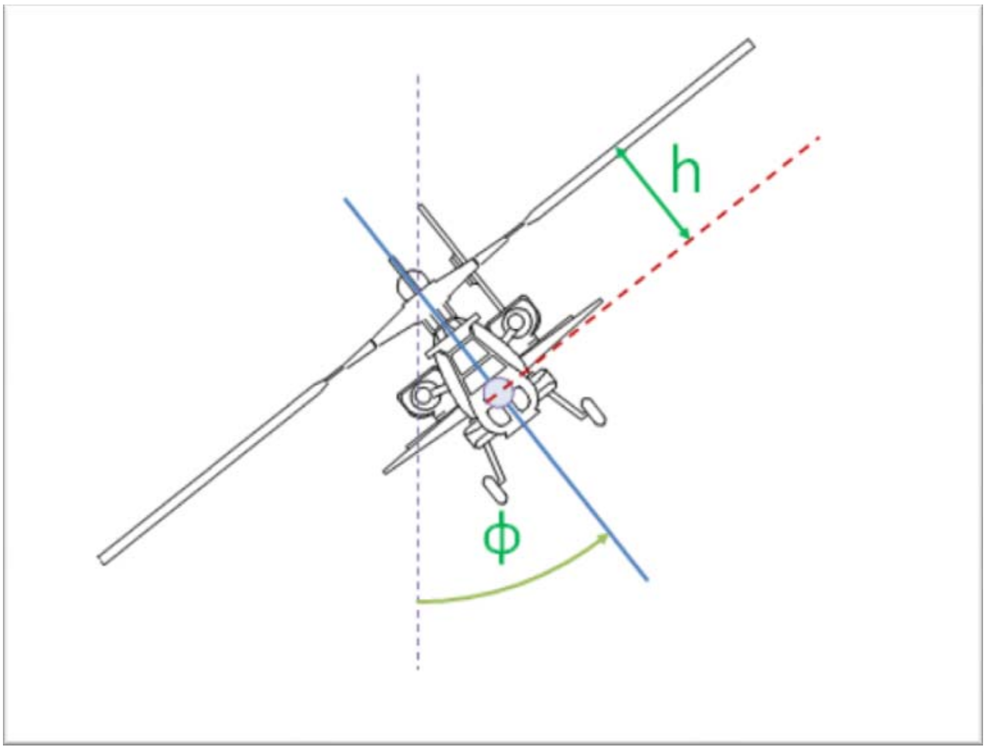


Figure 1

The equivalent flapping spring, in terms of rotor frequencies, is given by:

$$k_\beta = I\Omega^2\left(\lambda_\beta^2 - 1\right) \quad (1)$$

With a given rotor disc tilt of $b_1$, the average roll moment is given by:

$$M_{ROLL} = k_\beta \frac{N}{2} b_1 \quad (2)$$

The relationship between flapping frequency and flapping hinge offset is:

$$\lambda_\beta = \sqrt{1 + \frac{3e}{2}} \qquad (3)$$

The moment of the aircraft weight in roll is given by:

$$M_{Weight} = hW \sin\phi \qquad (4)$$

For an equilibrium condition we must have the roll moments to equate, viz:

$$M_{ROLL} = M_{Weight} \qquad (5)$$

Assembling the above results we find:

$$hW \sin\phi = \frac{N}{2} I \Omega^2 \cdot \frac{3e}{2} \cdot b_1 \qquad (6)$$

Noting that:

$$J = NI \qquad (7)$$

Whence:

$$\frac{\sin\phi}{b_1} = \frac{3}{4} e \frac{J}{hW} \Omega^2 \qquad (8)$$

From which the disc tilt required to maintain roll trim becomes:

$$b_1 = \frac{4hW}{3eJ} \cdot \frac{1}{\Omega^2} . \sin\phi \qquad (9)$$