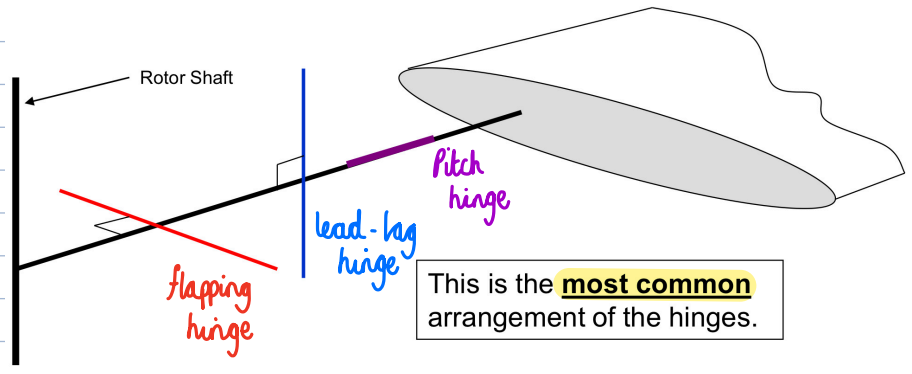
Blade Arrangements :

Teeter Hub - 2 bladed rotor, zero offset flapping hinge, no lead-lag hinge

↳ like see saw - one blade flaps up β, one down β if fully rigid

Fully Articulated Hub :

→ Offset flapping hinge for control
→ Offset lead-lag hinge to raise fundamental lead-lag frequency
→ Blade pitch hinge free from coupling effect



Mil-4 / Seaking config

↳ Could alternatively have :
Flap, pitch, lag (Gazelle / Lynx)
Pitch, lag, flap (MBB Bo-105) RARE

For Tail Rotors : prioritise simplicity

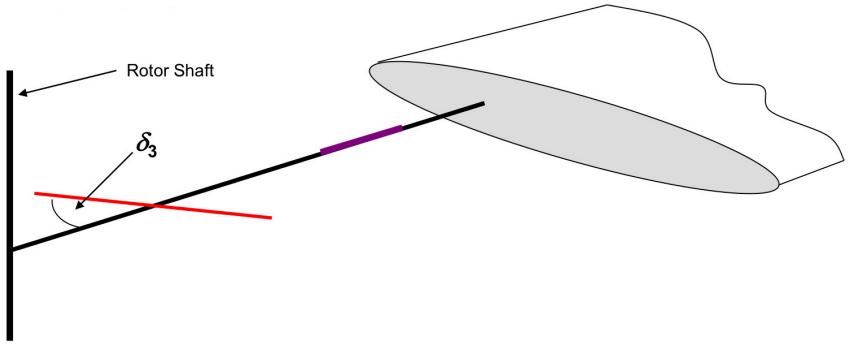
Teeter hub - 2 bladed rotor, zero offset flapping hinge, no lead-lag hinge

Tail Rotor hub (more conventional) :

→ lead lag hinge supercritical - very stiff so fundamental lag freq. > $1R_T$
→ Collective pitch control but no cyclic pitch

- Rotor still affected by lift asymmetry, so without cyclic pitch

↳ pitch-flap coupling ($\delta_3 = 45°$)

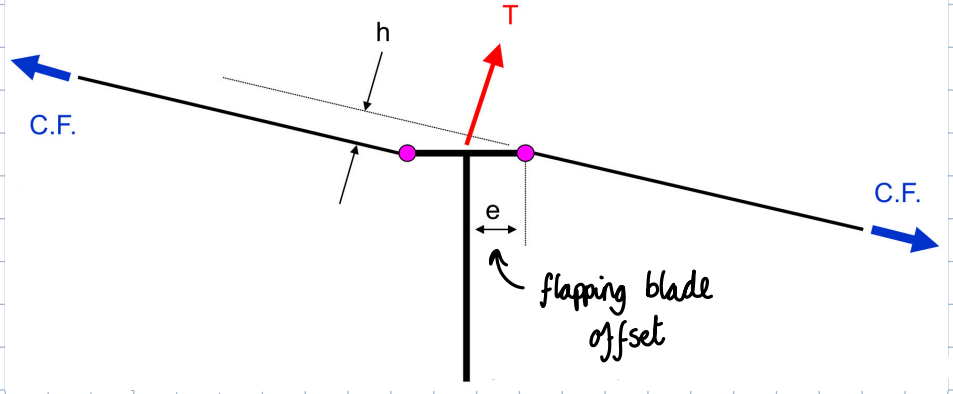


Helicopter Stability & Control :

- A rotor system with zero flapping hinge off-set (ie teeter) has no ability to impart a moment into fuselage.

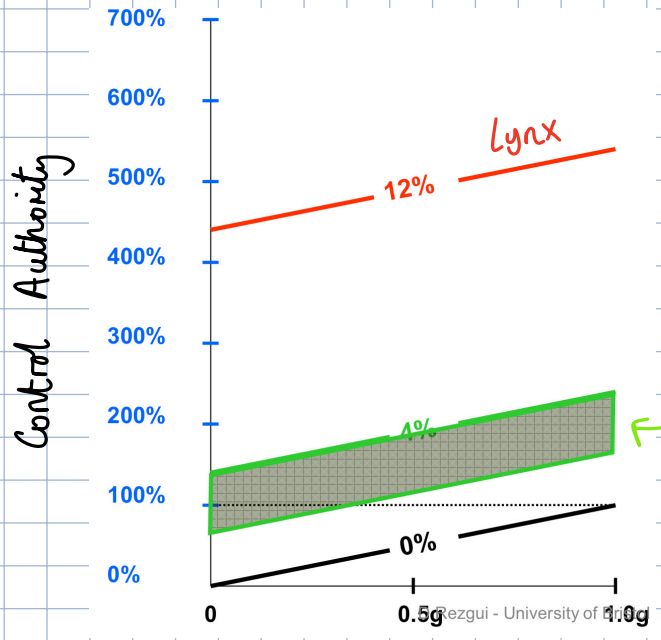
→ pitch & roll therefore achieved by orientating thrust vector relative to CG
↳ control dependent on thrust

Introducing a flapping offset has significant effect on control of helicopter.
↳ can transfer moments from rotor to fuselage and vice-versa



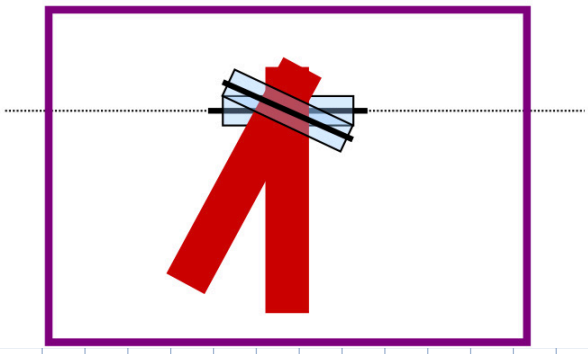
Moment induced due to C.F and displacement h

Independent of T



Pilot of Lynx unlikely to notice any effect in control power due to change in thrust

← majority of helicopters



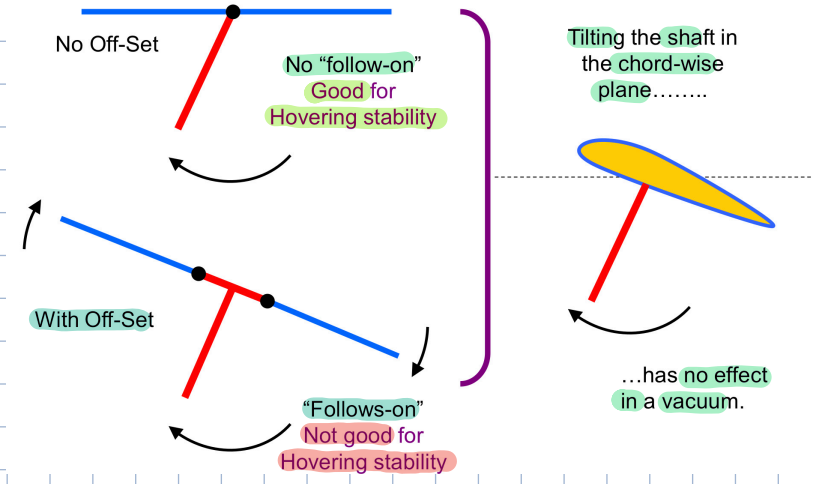
When rotor hub tilted, there is an effective cyclic pitch due to aerodynamic effects.

↳ therefore flapping

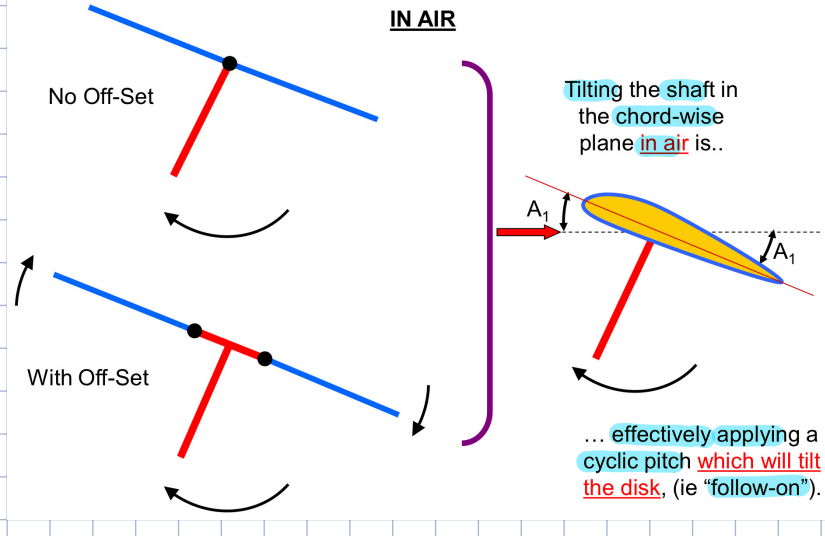
The rotor will arrange itself orthogonal to the shaft.

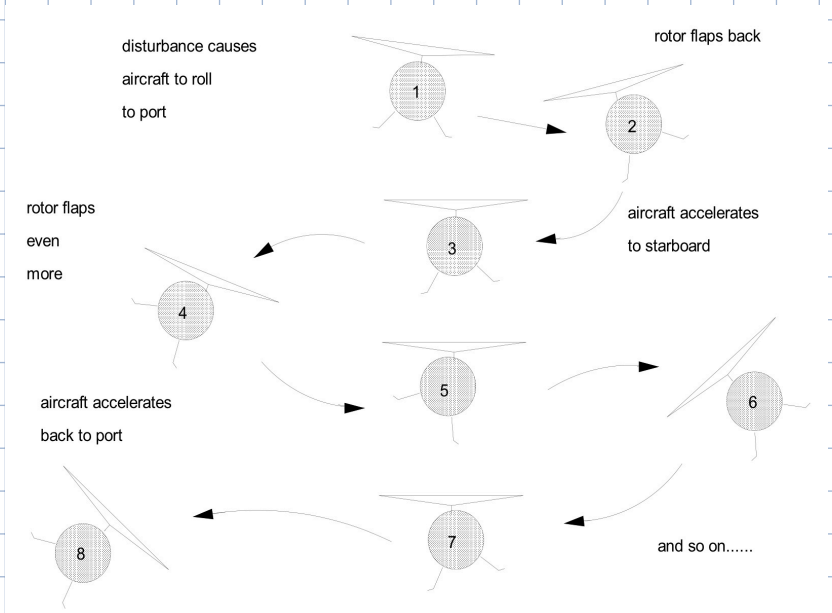
↳ follow on

In a VACUUM :



In Air :

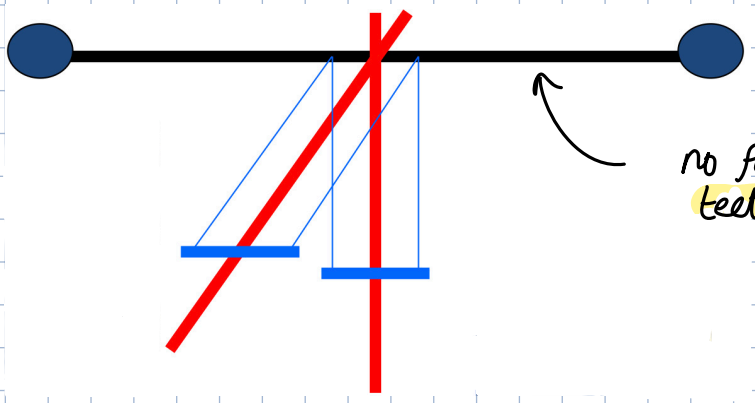




Results in unstable condition in hover.

→ need Stability System with feedback to control copter

Mechanical Feedback System : Fly-bar



no follow on teeter rotor in vacuum

↳ this creates that effective vacuum condition

↳ no aerodynamic force due to balls

Used as datum which stays in-plane if perturbed

→ swashplate connected for feedback

Other closed-loop control systems also used.