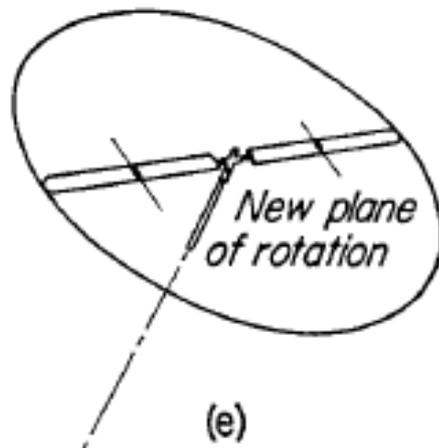
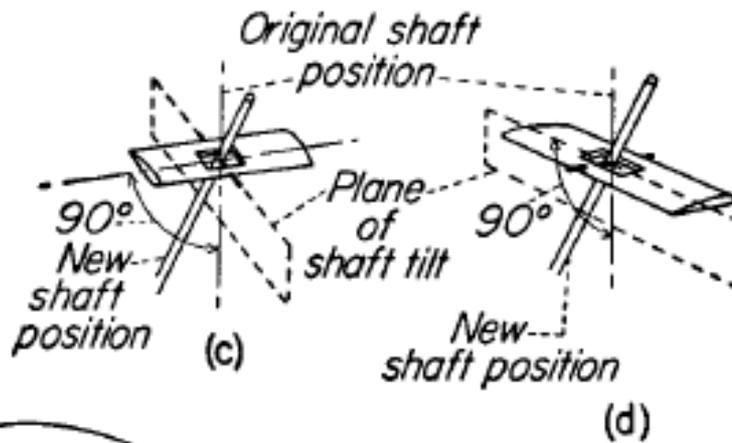
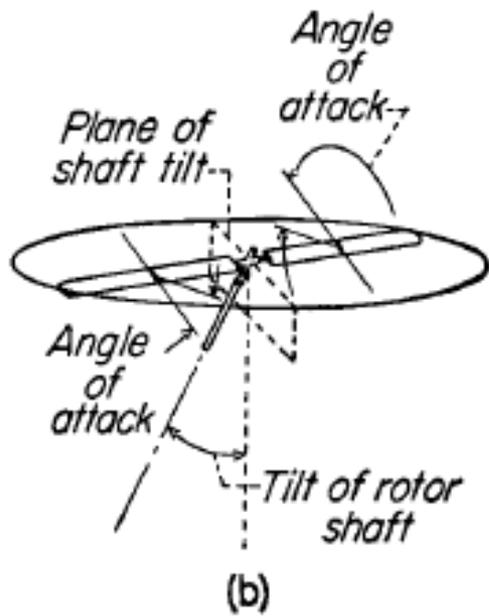
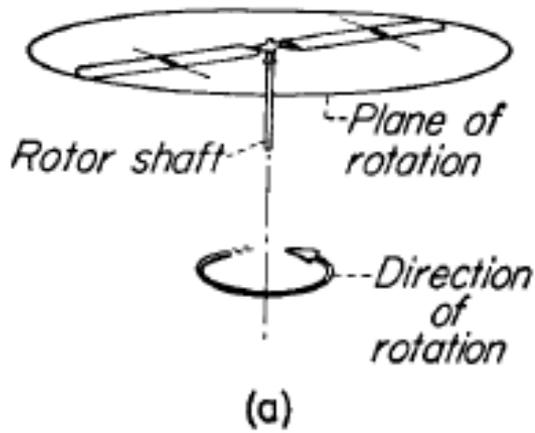


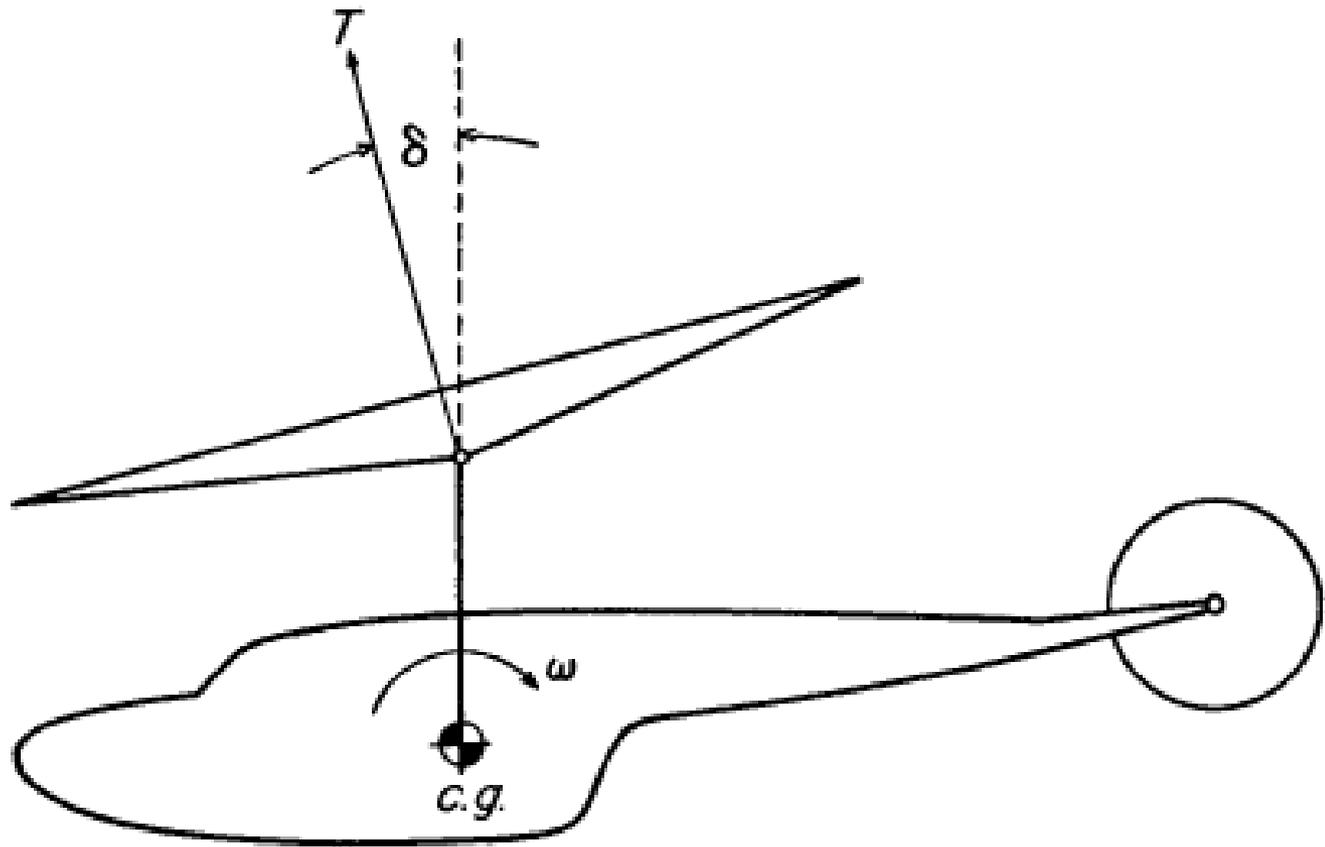


STABILITY



Damping in Pitch or Roll

- There is a delay between the rapid shaft tilt and realignment of rotor with the shaft
- If continued, tip path plane will continue to lag behind
- When the helo is tilted, ω produces moment about the CG.
- Due to the presence of offset hinges, additional moment is caused by the tilt.
- The moments attributable to the tilting velocity are known as Damping in Roll or Pitch depending upon the axis responsible for it.



ω Angular velocity of helicopter in rad/sec (Pitching or Rolling)

δ Angular displacement of rotor cone due to Angular velocity in rad/sec

- Amount of rotor tilt is inversely proportional to the rotor speed and blade mass factor

$$\frac{\delta}{\omega} = \frac{16}{\gamma \Omega}$$

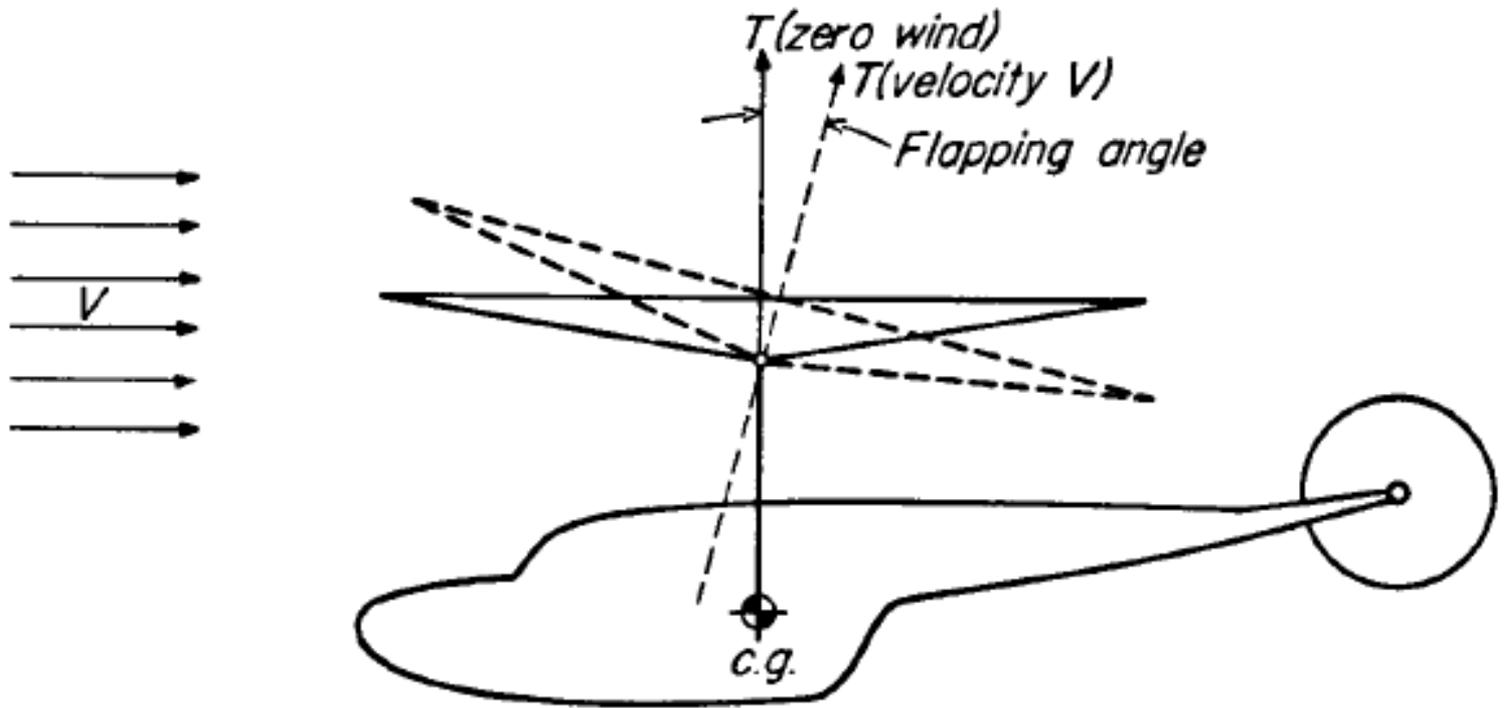
Control sensitivity

- Maximum rate of roll or pitch achieved by a unit displacement of controls is generally termed as control sensitivity.

$$\text{Control sensitivity} \left\{ \begin{array}{l} = \frac{\text{control power}}{\text{rotor damping}} \\ = \frac{\text{control moment}}{\text{stick displacement}} \frac{\text{damping moment}}{\text{angular velocity}} \\ = \frac{\text{angular velocity}}{\text{stick displacement}} \end{array} \right.$$

Rotor Static stability with speed

- Rotor subjected to translational velocity
- The effect is to tilt the tip path plane
- This tilt is due to blade flapping
- Tilting further increases the velocity of the advancing blades
- It produces a moment about CG
- This moment will nose up with increasing speed and vice versa
- This variation of moment due to change in translational velocity is a means of stability with speed



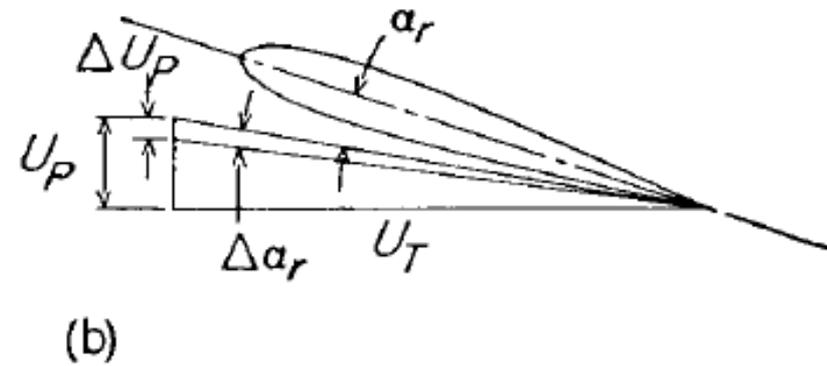
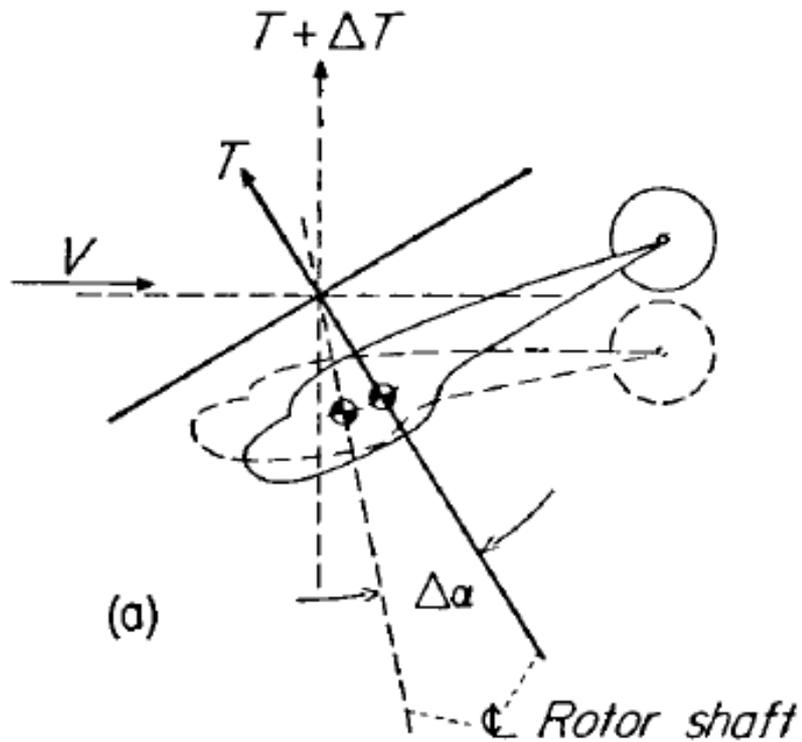
M_V or $\Delta M / \Delta V$

M_V Is positive for helicopters

Rotor stability with AOA

- Change in attitude of hovering helicopter
- Equal tilt of rotor plane with the result that no rotor moment or change in thrust occurs
- A hovering helicopter has neutral stability with attitude change
- In forward flight, a change in longitudinal attitude will produce a rotor moment and a thrust change
- This is due to change in AoA at constant velocity due to flapping.
- The change in relative velocities and Angle of Attack due to change in fuselage angle.

——— Original trim configuration
 - - - Configuration after tilt

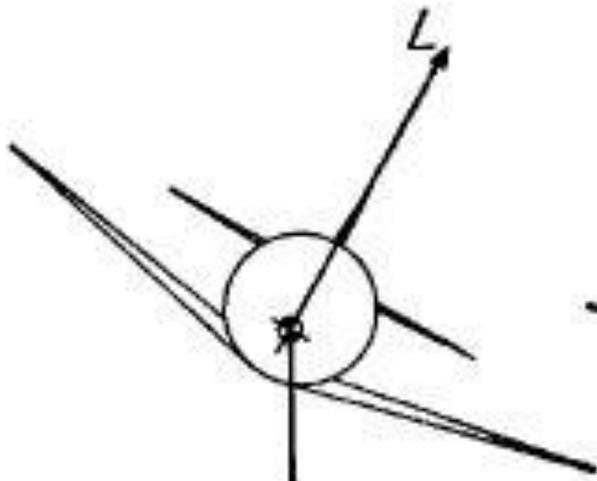


$$\Delta_{\alpha T} = \Delta U_P / \Delta U_T$$

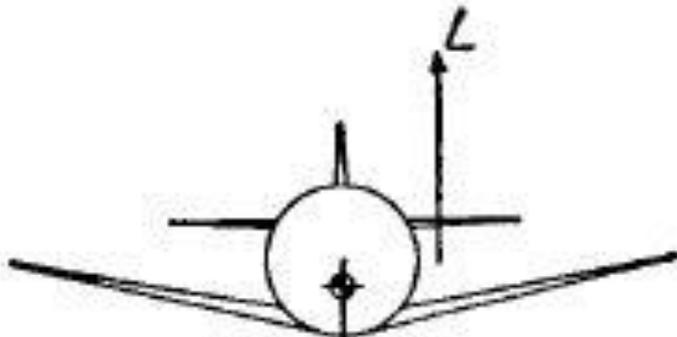
- The component of flight velocity thro the disk is constant
- Change in lift due to change in fuselage AoA is greater in advancing side
- The nose up moment has an effect on increase in magnitude of thrust rotor
- Doubling nose up change doubles nose up moment and vice versa.
- The variation of moment due to change in fuselage angle is a measure of Static stability with Angle of Attack
 - M_{α} or $\Delta M / \Delta \alpha$

STATIC STABILITY IN HOVER

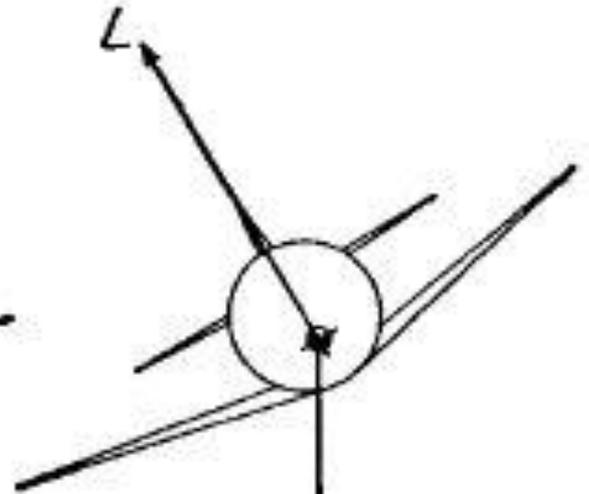
- With respect to angular displacements, the helicopter possesses neutral static stability in hover
- If it is displaced in roll or pitch and prevented from translational motion, no moments will arise to tend to restore it to its original position
- An angular displacement of a helo will result in a translational velocity due to unbalanced horizontal component of thrust force
- As a result, a moment is produced which tilts the copter , so that the horizontal thrust vector tries to reduce the trans speed & restore it to initial position



(a)
 $V=0$
 $M=0$



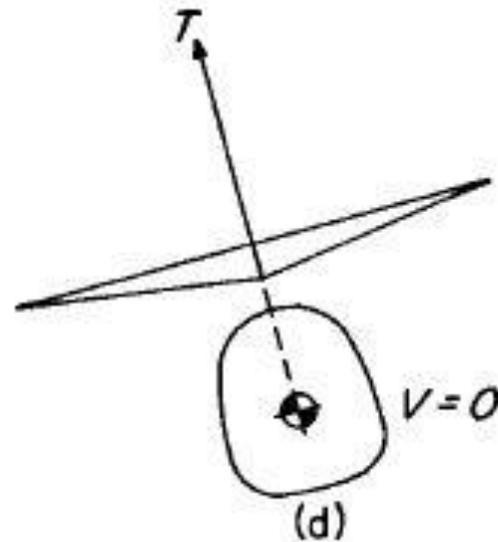
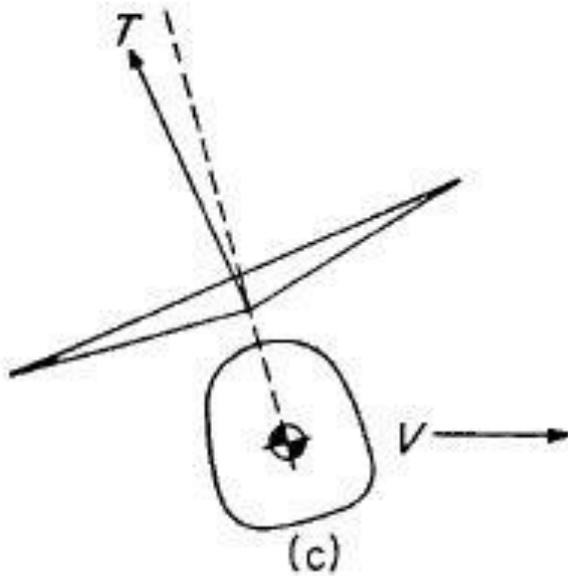
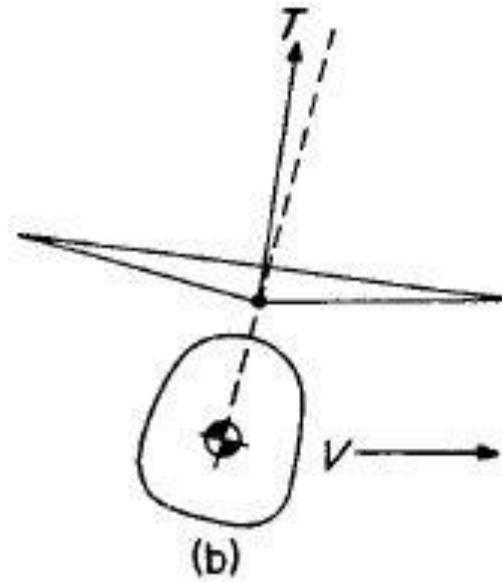
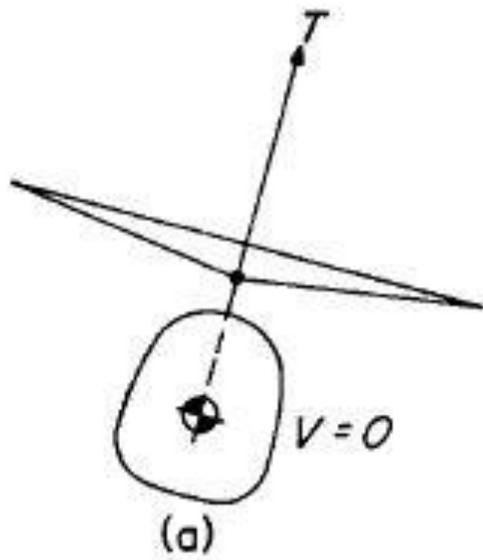
(b)
 $V = \rightarrow$
 $M = \curvearrowright$



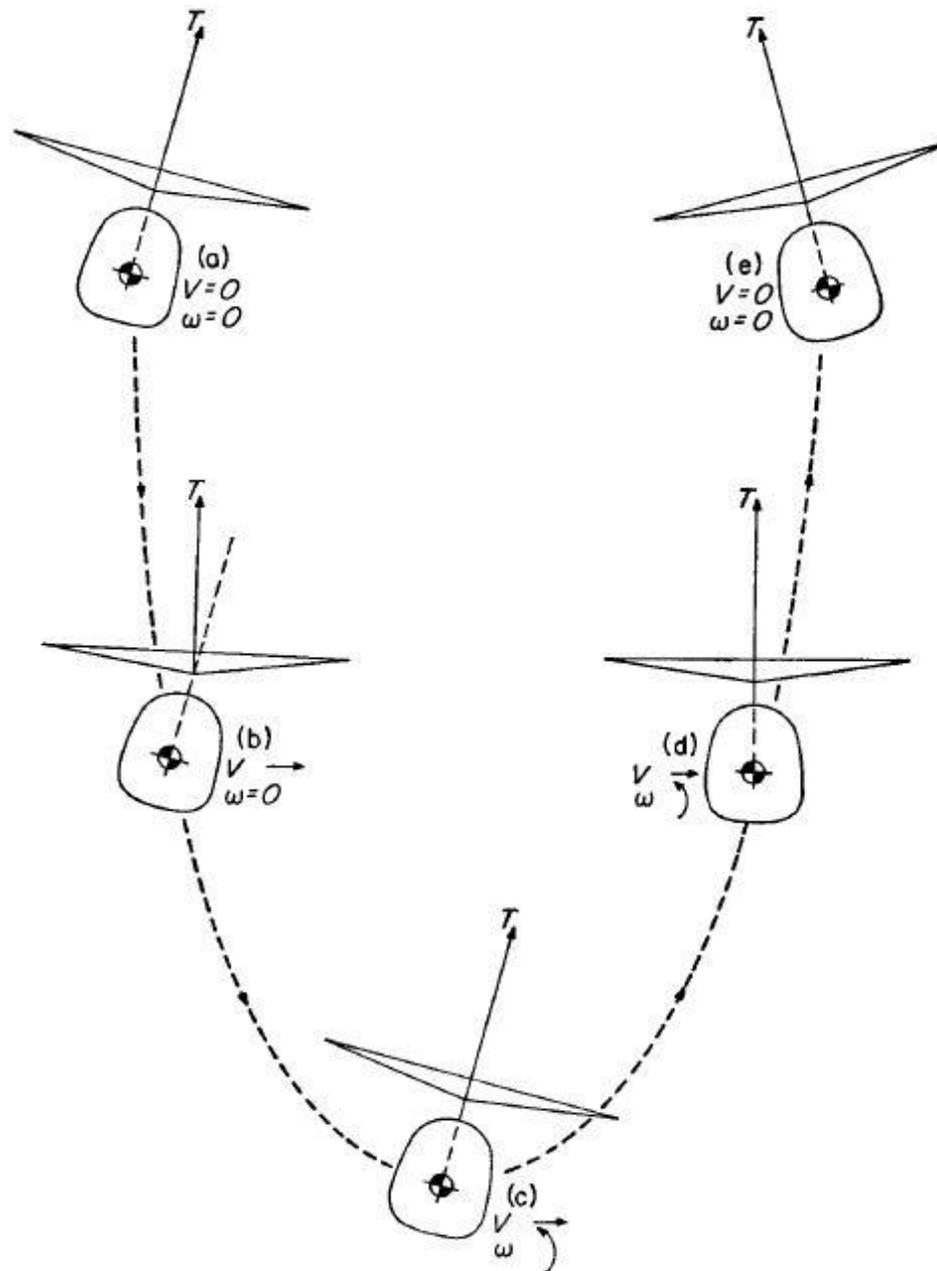
(c)
 $V=0$
 $M=0$

Dynamic stability in hover

- The motion following an initial angular displacement of a helo as well as the moments acting on it corresponds to the dynamic behavior
- If a hovering helicopter is displaced to right, the resultant force will cause the helo to move to a position where the restoring anti clockwise moment will tend to move it again to the left
- The trans velocity becomes zero and the process starts again in the opposite direction



Oscillation of a helicopter following an angular displacement in hovering (damping neglected).



Lateral oscillation of a helicopter following an angular displacement in hovering (damping included).

- The time required to move from position 1 to position 5 is one half of the oscillation
- An expression for time period of oscillation is derived as

$$P = \frac{2\pi}{\sqrt{g}} \sqrt{\frac{-M_{\omega}}{M_V}}$$

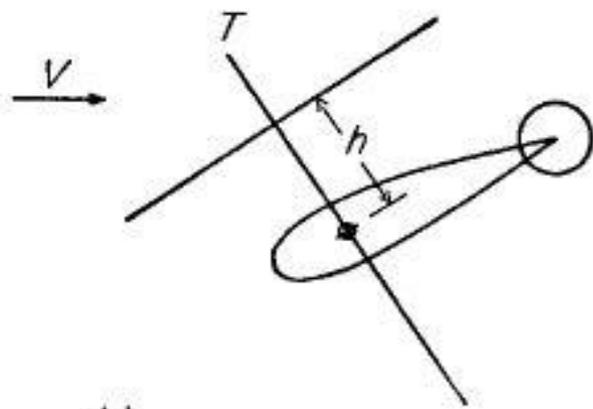
Longitudinal Static stability

- It depends upon moments produced on a helicopter by a change in speed from trim @ constant AOA and as well as moments produced by change in AOA by keeping speed constant
- Fuselage and other surfaces may also contribute to aerodynamic moments

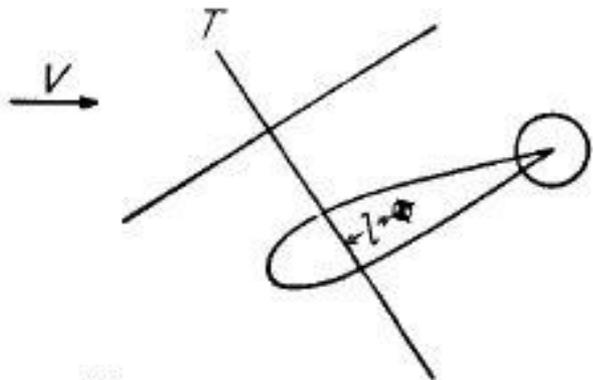
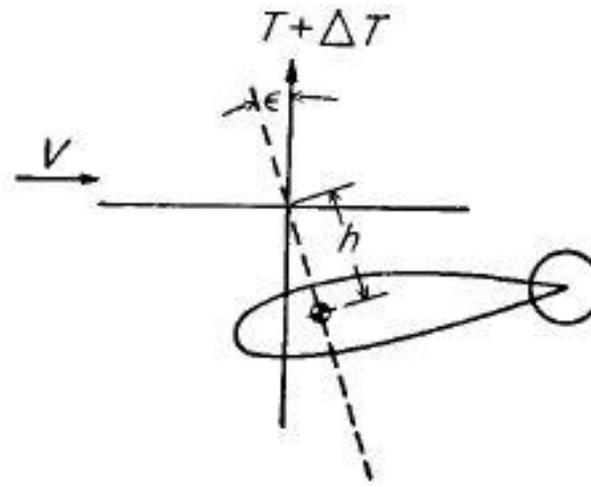
Moments are due to

- Effect of variation of C_M with AOA
 - Fuselage has unstable variation of moment with AOA which adds to rotor AOA instability
- Effect of constant C_M during steady flight on stability with speed
 - A conventional helo has nose down C_M in steady flight.
 - If the speed of the helo is varied @ constant AOA the resulting moment variation is destabilizing. This can be counteracted by applying a nose up surface using control surfaces

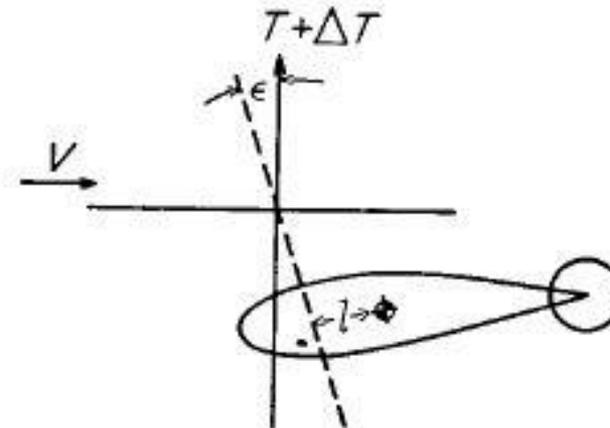
- Effect on stability with AOA of a thrust axis offset from the helo CG
- The thrust axis is offset from helo CG during steady flight in order to compensate for an aerodynamic pitching moment
- It will be offset also if the helo has offset flapping hinges and CG is not on the rotorshaft
- The offset results in the rotor contributing an additional unstable moment variation with AOA



(a)



(b)



Effect of center-of-gravity offset on pitching moment arising from fuselage angle-of-attack change.

(a) No center-of-gravity offset

(b) Center-of-gravity offset aft of thrust vector

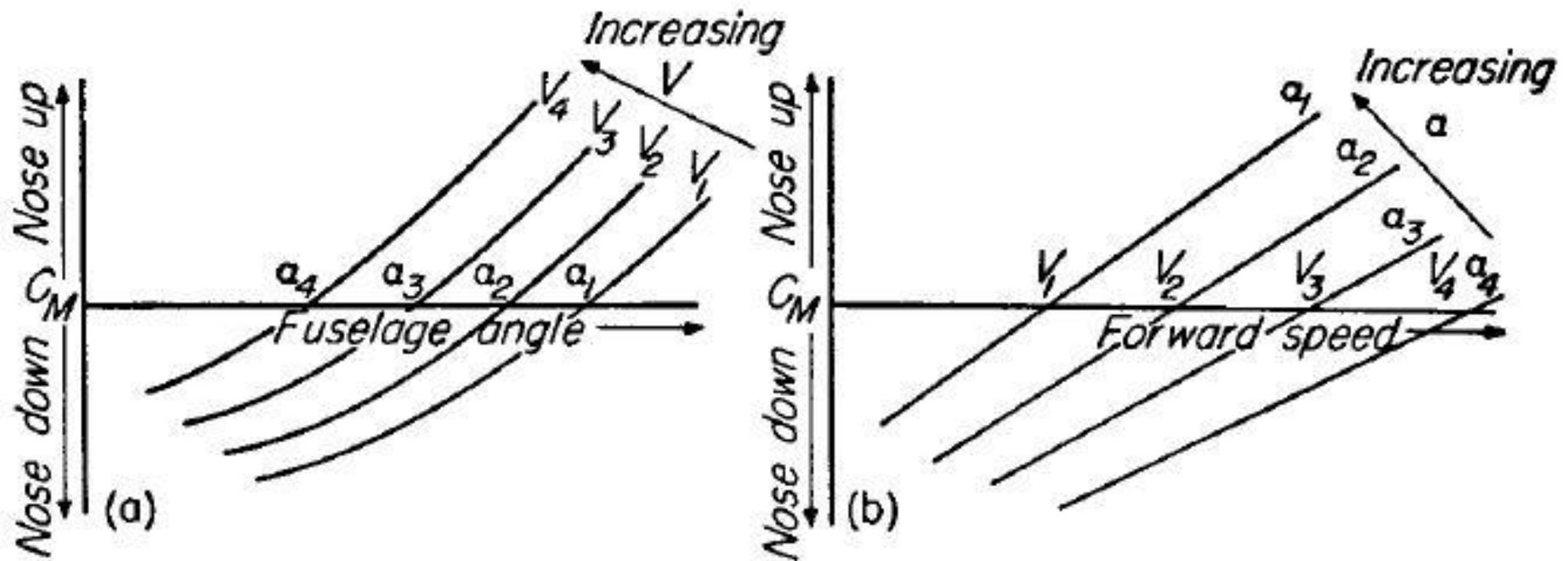


Fig. 11-16 Basic static stability curves for typical tailless helicopter.
 (a) C_m against α
 (b) C_m against V

Dynamic stability in Forward flight

- If the helo is assumed to have neutral static stability with respect to change in AOA, then the period of longitudinal oscillation in forward flight is primarily influenced by the same quantities as hovering oscillation
- Stability with respect to speed AOA and damping in pitch

- Consider a Longitudinal oscillation of a helo having neutral stability
- From trimmed condition nose down takes place due to disturbance
- It starts descending due to weight and increase in speed
- After the position 2, the increased velocity produces a backward tilt of the rotor plane and nose up moment which leads to nose up acceleration

- This nose up acceleration creates a nose up velocity and when the damping in pitch exceeds the rotor thrust, the vector tilts due to static stability with speed is neutralized
- And as the weight component increases the cycle occurs repeatedly

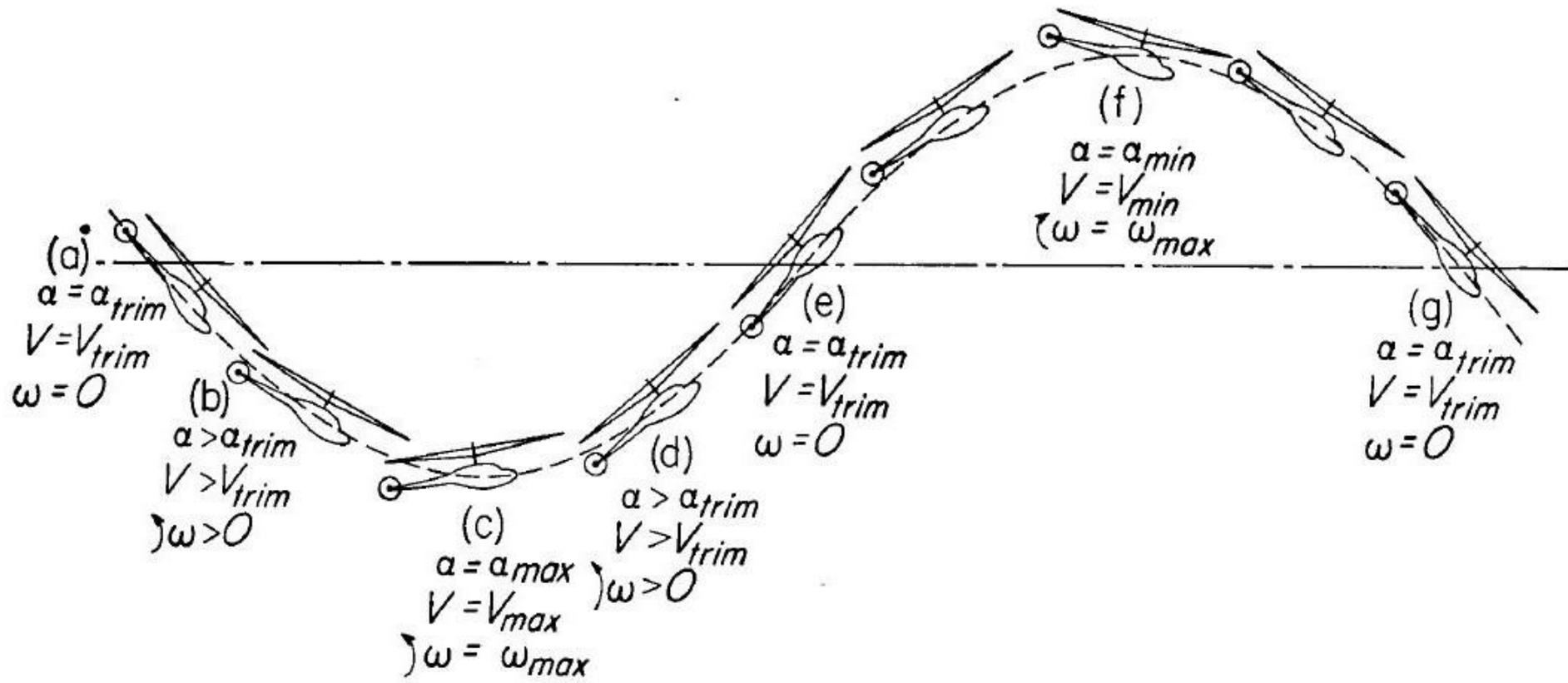


Fig. 11-20 Longitudinal oscillation of typical helicopter in forward flight.

- The Dynamic stability is also influenced by AOA, Speed and Damping in Pitch and Roll.