Module-4

Lecture-18

Maneuvering Flight: Introduction, Steady Coordinated turn.

Turning Flight

Longitudunal control and Maneuverability

- Generally both trim and static stability are defined only for an equilibrium flight condition. We need to understand how a pilot uses control surfaces to accelerate from one equilibrium to another.

"Lift is the primary force to provide these accelerations."

- Angle of attack governs the magnitude of lift; the elevator controls the angle of attack.
- The ailerons are used to control the direction of lift vector as the rudder is generally used only to coordinate the maneuver and eliminate the side slip.
- Coordinated turn $\Rightarrow$ Turning Without Sideslip
- Turning can be done by two ways:
  - Using aileron through bank
  - Using rudder
- For large turn rate: aileron is used. The airplane is banked using aileron and component of lift is used to make a turn.
- Rudder can also be used for turn rate of smaller magnitudes.

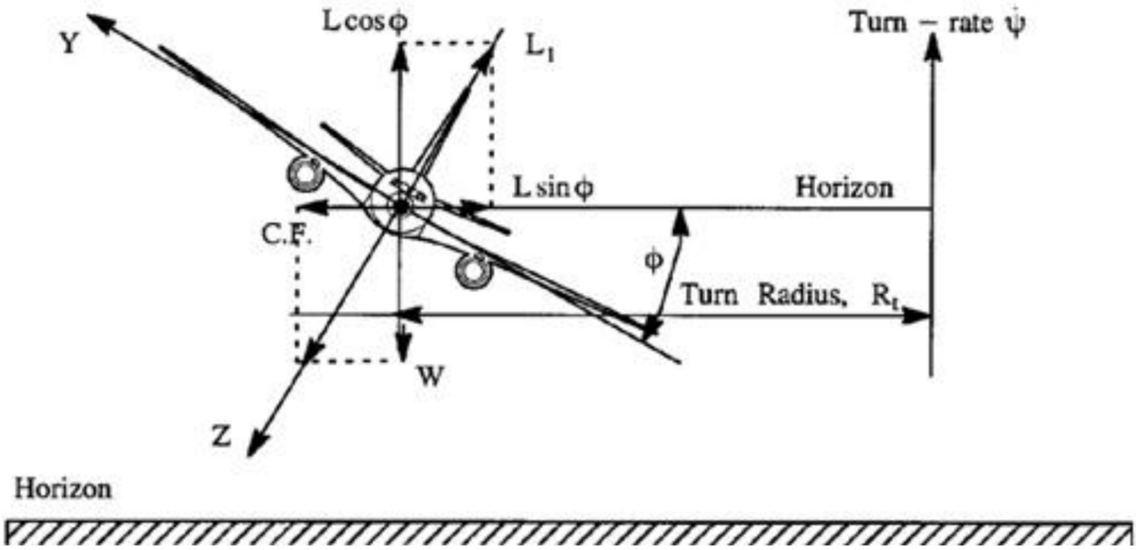

Figure 1: Figure representing forces acting on aircraft during turning flight

Steady coordinated turn

- The aircraft needs to be kept such that it does not loose altitude and at the same time no side slip, i.e.
- One component of lift should balance the weight.
- Other component should provide enough force to generate centripetal acceleration.
- By resolving lift to satisfy above requirements, we need to fly such that

$$L\cos\phi = W = mg$$

  and

$$L\sin\phi = \frac{mV^2}{R}$$

- Combining these two equations, we have

$$\tan\phi = \frac{V^2}{Rg} \Rightarrow R = \frac{V^2}{g\tan\phi}$$

  Pitch rate due to $\dot{\psi}$ (yaw rate), when the aircraft is turning using component of lift (bank angle is ϕ)

$$q = \dot{\psi}\sin\phi$$

  and

$$V = R\dot{\psi} \Rightarrow \dot{\psi} = \frac{V}{R}$$

- Therefore, the pitch rate can also be expressed as

$$q = \dot{\psi} \sin\phi = \frac{V}{R} \sin\phi$$

Since,

$$R = \frac{V^2}{g \tan\phi}$$

Therefore,

$$q = \frac{g}{V} \sin\phi \tan\phi$$

- Load factor,

$$n = \frac{lift}{weight} = \frac{L}{mg} = \frac{L}{L\cos\phi} = \frac{1}{\cos\phi}$$

$$n = \frac{1}{\cos\phi}$$

Now,

$$\cos\phi = \frac{1}{n}$$

$$\sin\phi = \frac{\sqrt{n^2 - 1}}{n}$$

$$\tan\phi = \sqrt{n^2 - 1}$$

$$q = \frac{g}{V} \sin\phi \tan\phi$$

$$= \left(\frac{g}{V}\right) \frac{\sqrt{n^2 - 1}}{n} \times \sqrt{n^2 - 1}$$

$$= \left(\frac{g}{V}\right) \left(\frac{n^2 - 1}{n}\right)$$

$$q = \left(n - \frac{1}{n}\right) \frac{g}{V}$$