Module-3

Lecture-12

Stability and Control - Some frequently used notations, Trim - A pilot's perspective

Some frequently used notations

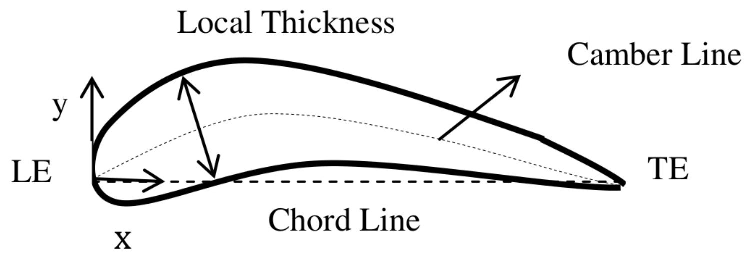

Figure 1: Schematic diagram of a cambered wing

- **Camber Line** is the locus of points midway between the upper and lower surface of an airfoil section as measured perpendicular to itself.
- **Leading Edge** (LE) is the most forward point on the camber line.
- **Trailing Edge** (TE) is the most rearward point on the camber line.
- **Chord Line** is a straight line connecting the leading edge and the trailing edge.
- **Maximum Camber** is the maximum distance between the chord line and the camber line as measured perpendicular to the chord line.
- **Local Thickness** at any point along the chord line is the distance between the upper and lower surface as measured perpendicular to the camber line.
- **Maximum Thickness** is the maximum distance between the upper and lower surfaces as measured perpendicular to the camber line.
- D: Drag parallel to V (opposite to motion)
- L: Lift perpendicular to V
- A: Axial Force parallel to chord
- N: Normal force perpendicular to chord

- M: Pitching Moment (positive nose up)

$$D, L, A, N \rightarrow C_D, C_L, C_A, C_N \rightarrow \frac{F}{\frac{1}{2}\rho V^2 S_{ref}}$$

$$m \rightarrow C_m \rightarrow \frac{M}{\frac{1}{2}\rho V^2 S_{ref} c}$$

where,

C_D, C_L, C_A, C_N are force coefficients

C_m is pitching moment coefficient.

Important Relations

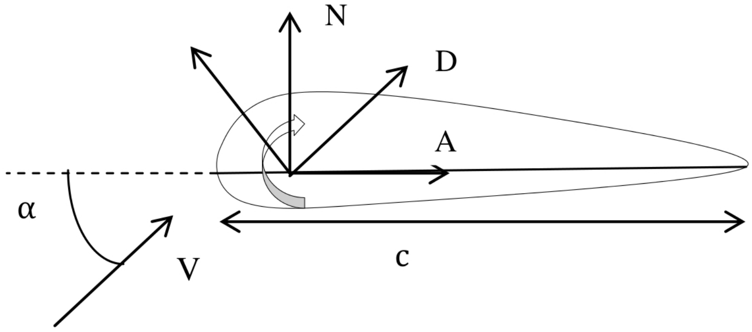

Figure 2: Axial force coefficient

- $$C_L = C_N \cos\alpha - C_A \sin\alpha$$

$$C_D = C_A \cos\alpha + C_N \sin\alpha$$

- Similarly,

$$C_N = C_L \cos\alpha + C_D \sin\alpha$$

$$C_A = C_D \cos\alpha - C_L \sin\alpha$$

- Since $C_D \ll C_L$ so, axial force coefficient C_A is often negative

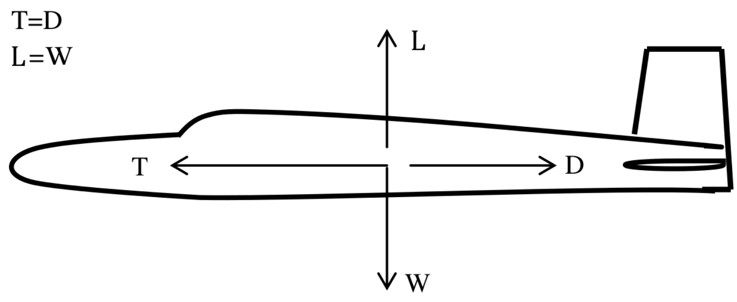

Figure 3: Schematic diagram of Static equilibrium

Trim - A pilot's perspective

- When the controls are set so that the resultant forces and the moments about the center of gravity are all zero, the aircraft is said to be in Trim, which simply means static equilibrium.
- Airplane in cruise is a typical example of an airplane in static equilibrium.

Aircraft control surfaces

Primary control surfaces are:

- **Ailerons:** To control the rolling moment
- **Elevator:** To control the pitching moment
- **Rudder:** To control the yawing moment

These control surfaces provide two functions:

1. The control surfaces must be able to maintain static trim over the entire range of airspeed and altitude for which the aircraft is able to fly. This includes being able to trim the aircraft against any asymmetric thrust force.
2. The control surfaces must provide sufficient moment necessary to maneuver the aircraft in range of speed and altitudes.

Asymmetric Thrust Force: When one or more engine fails in a multiengine configuration

Never To Forget *The ease with which a pilot is able to maintain trim is one of the most important aspects of the aircraft characteristics, known as handling quality. If the pilot cannot maintain trim with relative ease, the aircraft will be difficult or even dangerous to fly.*

The ease of maintaining static trim is related to a property of the equilibrium state - static stability.

Degree of Freedom: Rigid body: Airplane

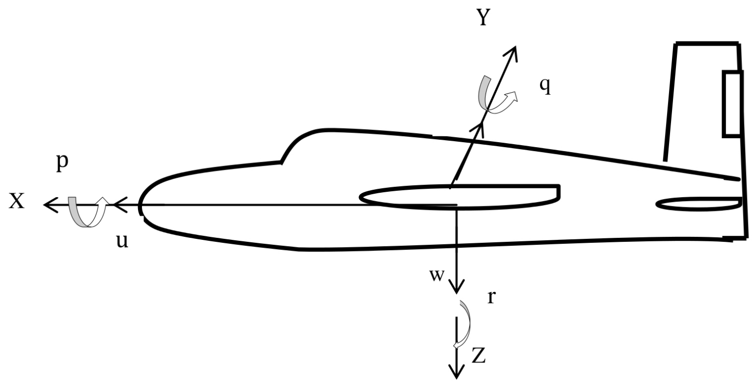

Figure 4: Degree of freedom

A rigid airplane in free flight has six degrees of freedom:

- Three translational (u, v, w)
- Three rotational (p, q, r)

Important to Understand

- For an airplane to be in fully stable trim, there can be no instability in any of the six degrees of freedom. Hence,
- Small translational disturbances in axial, normal or side slip velocity must all result in a return to the original trimmed equilibrium condition.
- Similarly, rotational disturbances in roll, pitch and yaw must all result in a return to the original equilibrium attitude.

With few exceptions, if the rotational degrees of freedom of an airplane are stable, translational stability will not be a problem.