Module-2

Lecture-10

Climb Performance - Introduction and Equations of Motion.

Climb performance

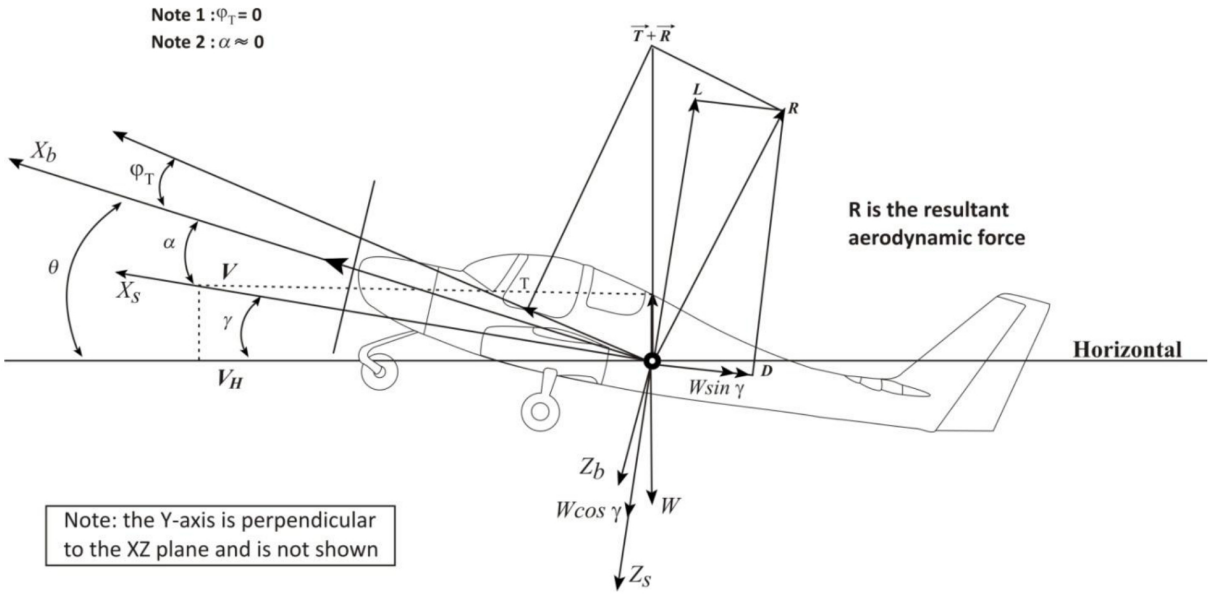

Figure 1: Forces in steady, symmetrical, straight line, climbing flight

- Consider an airplane in steady, symmetrical, straight line, climbing flight. The velocity along the flight path is V, and the flight path itself is inclined to the horizontal at angle γ(flight path angle).
- The governing equations for a steady (no acceleration) climb flight are:

$$T - D - W\sin\gamma = 0$$

$$L - W\cos\gamma = 0$$

- Re-arrange the above equations, to get:

$$VT = VD + VW\sin\gamma$$

$$\frac{VT - VD}{W} = V\sin\gamma$$

also,

$$\frac{dh}{dt} = V\sin\gamma = RC$$

where, RC - Rate of climb

- Let VT is the power available and VD is the power required for the level flight.
- For climbing flight, VD is not equal to the power required, because power is required to overcome a component of weight.

$$VT - VD = \text{excess power}$$

so,

$$RC = \frac{\text{excess power}}{W} \tag{1}$$

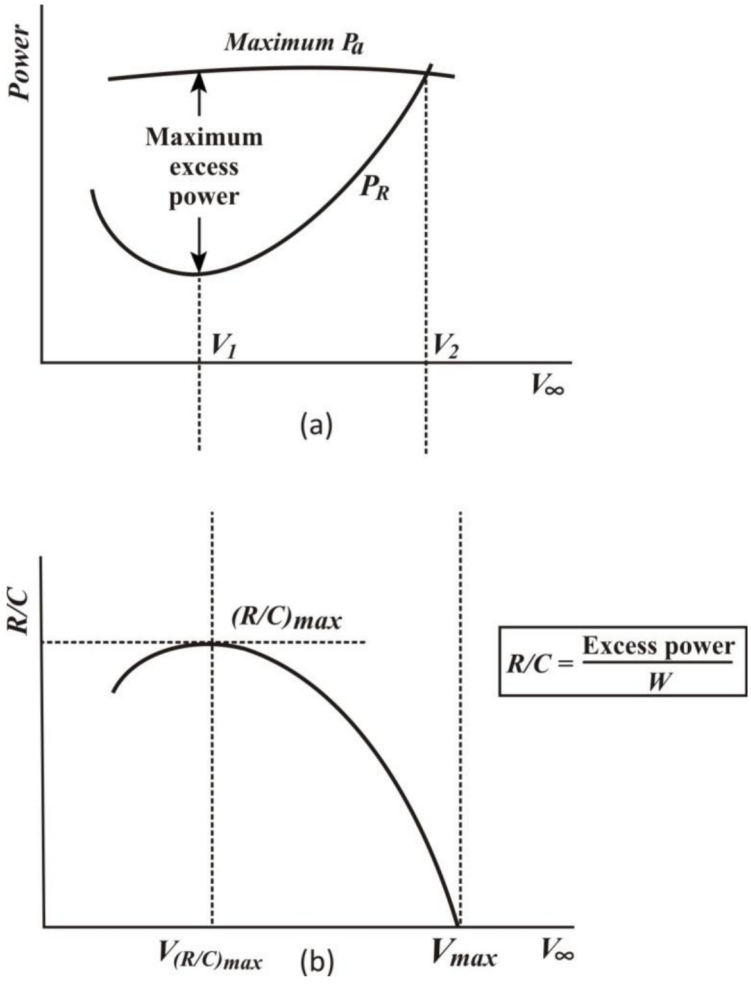

Figure 2: (a) Plot representing P_R and P_A vs Velocity (b) Determination of maximum rate of climb for a given altitude.

- Referring Figure 2(a), one could easily recognize that V_1 is the speed for maximum rate of climb (due to maximum excess power) & V_2 is the speed at which rate of climb is zero (no excess power).

- Referring Figure 2(b), one can see the variation of excess power RC with speed.
- Excess power increases to maximum and then reduce with speed (Refer Figure 2(a)). Similar is tha variation of RC with speed (Refer Figure 2(b)).

Maximum angle of climb and maximum rate of climb: Are they same?

- By plotting RC vs V one may find the max RC at corresponding altitude.
- By plotting max RC vs altitude (straight line plot), the service ceiling and absolute ceiling can be obtained easily by linear extrapolation.

What is service ceiling and absolute ceiling?

Service ceiling

Service ceiling is defined as the height at which, under standard atmospheric conditions, an aircraft is unable to climb faster than a specified rate (100 feet or 30 meters per minute).

Absolute ceiling

On the other hand, absolute ceiling is defined as is the highest altitude at which an airplane can sustain level flight, which means the altitude at which the thrust of the engines at full power is equal to the total drag at minimum drag speed. In other words it is defined as the altitude where the maximum sustained rate of climb is zero.

Velocity hodograph

- In the analysis of climb performance, it can be useful to produce a plot of the vertical velocity against the horizontal velocity for a given altitude Figure 3.
- This plot is called a velocity hodograph.
- The maximum angle of climb γ_{max} can be obtained by drawing a tangent to the above curve through the origin.
- The angle between the tangent and V_x axis gives the value of γ_{max}.
- A tangent parallel to V_x axis gives the maximum rate of climb.

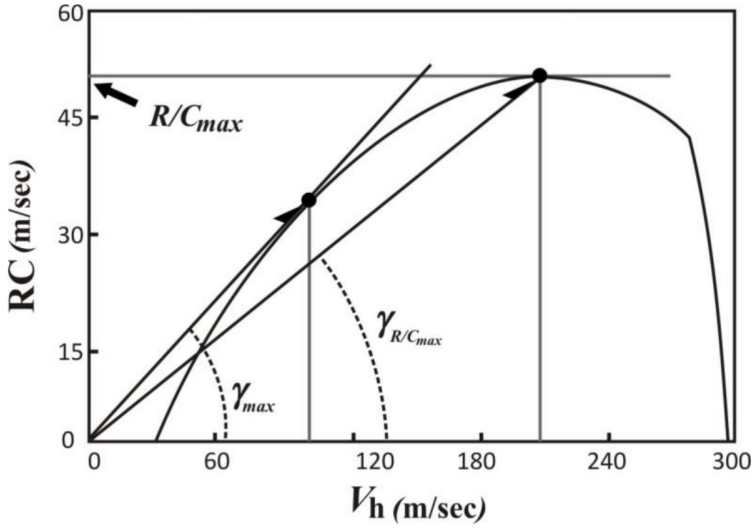

Figure 3: Velocity hodograph