Introduction to Aerospace

Tutorial 5

b 1. The static stability of a system investigates

   (a) the balance of forces acting on a system;
   (b) the instantaneous reaction of a system to a perturbation away from its equilibrium;
   (c) the time it would take for a system to converge/diverge from its equilibrium;
   (d) how easy it is to perturb a system away from its equilibrium.

bd 2. Which of the following statements is/are true?

   (a) The aerodynamic centre is at the quarter mean aerodynamic chord of lifting surfaces;
   (b) The aerodynamic centre is the point through which any pressure forces generated by a change in angle of attack will act;
   (c) The aerodynamic centre location is a function of the lifting surface design only;
   (d) The aerodynamic centre is the point about which the derivative dC_M/d_α is zero.

a 3. The component of the aircraft required for static pitch stability is the

   (a) wing $\qquad \frac{\partial C_M}{\partial \alpha} < 0$
   (b) vertical tail
   (c) horizontal tail
   (d) undercarriage

C 4. The neutral point represents

   (a) the foremost centre of gravity location for which the aircraft will be stable;
   (b) the centre of pressure of an aircraft;
   (c) the aerodynamic centre of an aircraft;
   (d) the static margin of the aircraft.

d 5. For an aircraft to be longitudinally statically stable and trimmable

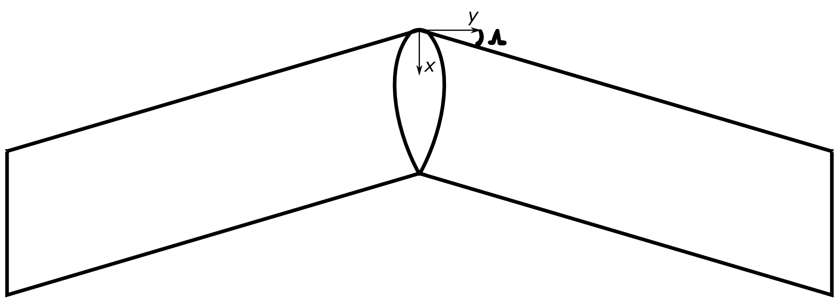
   (a) $K_n > 0$ and $C_{M_0} = 0$;
   (b) $dC_M/dC_L > 0$ and $C_{M_0} < 0$
   (c) $K_n = 0$ and $C_{M_0} = 0$;
   (d) $K_n > 0$ and $C_{M_0} > 0$. $C_M = 0 = C_{M0} - K_n C_L$

6. Which of the following would affect 1) an aircraft's longitudinal stability and 2) it's trim? Indicate your answer by marking **S** and/or **T** next to each question respectively.

   T (a) Changing the horizontal tailplane setting angle. $\Delta i_H \rightarrow \Delta C_{LH}$
   T (b) Adjusting the throttle of a jet powered aircraft. ΔT
   S, T (c) Adjusting the throttle of a propeller powered aircraft. ΔT, $\Delta \alpha_W$
   T (d) Deflecting the elevator. $D \uparrow$
   T (e) Changing the wing setting angle. $\Delta i_W \rightarrow \Delta C_{LW}$
   S, T (f) Deploying a set of extendible high lift devices (e.g. Fowler flaps or Slats). $\Delta \alpha_W \rightarrow \Delta C_L$
   (S), T (g) Consuming fuel during flight; $W \downarrow$, affect on S depends on wheater $\bar{x}_{CG}$ moves
   S, T (h) Changing the wing sweep angle (as done in an F-14 Tomcat or Panavia Tornado). $\Delta \alpha \rightarrow \Delta C_L$
   S, T (i) Going from subsonic to supersonic flight speeds. $\Delta \alpha$, ΔC_L
   T (j) Changing flight speed while remaining subsonic. ΔD
   None (k) Changing altitude while maintaining the same equivalent airspeed.

Foam Glider Design Exercise

Consider the tailless foam glider shown in the figure below.



It consists of a hollow fuselage, containing all avionics, mounted on an aft-swept, constant chord wing, of aspect ratio $A\!\!\!R$ and span b. The wing is made of solid foam, of density ρ_f, and the centroid of the airfoil section used is known to be at 40% of the local chord. The cross sectional area for a *unit* chord airfoil of this type is 0.1. The fuselage has a known weight W_f and a component centre of gravity $x_{CG_f}c$ aft of the leading edge at the wing root.

1. Show that the weight of the wing W_W is given by
$$W_W = 0.1\rho_f bc^2 = 0.1\rho_f\sqrt{S_{ref}^3/A\!\!\!R}$$
where $A\!\!\!R = b^2/S_{ref}$ and that the wing's centre of gravity will be
$$x_{CG_W} = \frac{b}{4}\tan\Lambda + 0.4c$$
aft of the root leading edge, where Λ is the wing leading edge sweep angle.

2. Show that the wing sweep required to achieve a static margin K_n for the aircraft is
$$\tan\Lambda = \frac{(4K_n - 1)(W_f + W_W) + 4x_{CG_f}W_f - 1.6W_W}{W_f\ A\!\!\!R}.$$
You may assume that the mean aerodynamic chord of this wing is located at $y = b/4$.

3. If the aircraft is expected to fly at a density ρ and airspeed V_∞, what is the requirement for trim to be achieved? How might that requirement be met?

1. $W_w = \rho_f V = \rho_f (0.1c) c b = 0.1 \rho_f b c^2$

∵ $AR = \frac{b}{c} = \frac{b^2}{S_{ref}}$ ∴ $c = \frac{S_{ref}}{b} = \frac{b}{AR} = \frac{\sqrt{S_{ref} \cdot AR}}{AR} = \sqrt{\frac{S_{ref}}{AR}}$

∴ $W_w = 0.1 \rho_f b c^2 = 0.1 \rho_f \sqrt{S_{ref} AR} \frac{S_{ref}}{AR} = 0.1 \rho_f \sqrt{\frac{S_{ref}^3}{AR}}$

∴ $x_{CGw} = \int_0^{\frac{b}{2}} (y \tan\Lambda + 0.4c) A \, dy \Big/ \int_0^{\frac{b}{2}} A \, dy$

$= (\frac{b^2}{8} \tan\Lambda + 0.2cb) A \Big/ \frac{b}{2} A = \frac{b}{4} \tan\Lambda + 0.4c$

2. $K_n = \bar{x}_{np} - \bar{x}_{CG}$

For $\bar{x}_{CG}$, $\bar{x}_{CG} = \frac{\bar{x}_{CGw} W_w + \bar{x}_{CGf} W_f}{W_f + W_w} = \frac{(\frac{b}{4c} \tan\Lambda + 0.4) W_w + x_{CGf} W_f}{W_w + W_f} = \frac{(\frac{1}{4} AR \tan\Lambda + 0.4) W_w + x_{CGf} W_f}{W_w + W_f}$

For $\bar{x}_{np}$, $x_{np} = \frac{b}{4} \tan\Lambda + \frac{c}{4}$ ∴ $\bar{x}_{np} = \frac{1}{4} AR \tan\Lambda + \frac{1}{4}$

∴ $K_n = \frac{1}{4} AR \tan\Lambda + \frac{1}{4} - \frac{(\frac{1}{4} AR \tan\Lambda + 0.4) W_w + x_{CGf} W_f}{W_w + W_f}$

∴ $K_n = \frac{1}{4} AR (1 - \frac{W_w}{W_w + W_f}) \tan\Lambda + \frac{1}{4} - \frac{0.4 W_w + x_{CGf} W_f}{W_w + W_f}$

∴ $AR (1 - \frac{W_w}{W_w + W_f}) \tan\Lambda = 4K_n - 1 + \frac{0.4 W_w + x_{CGf} W_f}{W_w + W_f}$

∴ $\tan\Lambda = \frac{(4K_n - 1)(W_f + W_w) + 4 x_{CGf} W_w - 1.6 W_w}{W_f AR}$

3. When trim achieved. $\Sigma F = 0$, $\Sigma M = 0$, $L = W$

∴ $C_M = 0$

∵ $C_M = C_{M0} - K_n C_L$

∴ $C_{M0} = K_n C_L = [\frac{1}{4} AR \tan\Lambda + \frac{1}{4} - \frac{(\frac{1}{4} AR \tan\Lambda + 0.4) W_w + x_{CGf} W_f}{W_w + W_f}] (\frac{W}{\frac{1}{2} \rho V_\infty^2 S_{ref}})$

Could be meet by $C_{M0} > 0$

1) Using reflexed airfoil

2) Using twist

3) Mount elevators near the tip