Introduction to Aerospace

Tutorial 1

Check You Knowledge

b 1. Based on the ISA model, the variation of temperature, pressure and density is given as a function of

   (a) true height above the ground
   (b) geopotential height above mean sea level;
   (c) true height above mean sea level;
   (d) geopotential height above the ground.

e 2. During a steady climb, your aircraft's static port becomes blocked. As a result:

   (a) the airspeed is unaffected / the altimeter is unaffected;
   (b) the airspeed over-reads / the altimeter over-reads;
   (c) the airspeed under-reads / the altimeter over-reads;
   (d) the airspeed over-reads / the altimeter under-reads;
   (e) the airspeed under-reads /the altimeter under-reads.

P_s read > P_s real

$\frac{1}{2}\rho V^2 = P_t - P_s$

$h \propto \left(\frac{P_s}{P_0}\right)^{-\frac{R\lambda_0}{g_0}}$

d 3. During a steady climb, your aircraft's pitot tube becomes blocked. As a result:

   (a) the airspeed is unaffected / the altimeter unaffected;
   (b) the airspeed over-reads / the altimeter over-reads;
   (c) the airspeed under-reads / the altimeter under-reads;
   (d) the airspeed over-reads / the altimeter is unaffected;
   (e) the airspeed under-reads / the altimeter is unaffected;

P_t read > P_t real

$\frac{1}{2}\rho V^2 = P_t - P_s$

h not related to P_t

b 4. An aircraft with a lift curve slope of 4.5 rad^{-1}, a zero-lift angle of attack of $-2°$ and $C_{L_{max}} = 1.6$ is approaching the runway to land at an approach speed $V_{at} = 1.3V_s$ and maximum landing weight. If the runway is at sea level and standard conditions apply, what is the aircraft's angle of attack α during the approach.

   (a) $\alpha = 18.37°$;
   (b) $\alpha = 10.05°$;
   (c) $\alpha = -1.64°$;
   (d) $\alpha = -1.79°$;
   (e) insufficient information provided.

$$V_s^2 = \frac{2W}{\rho_0 S C_{Lmax}} \quad \therefore C_{Lmax} \propto \frac{1}{V_s^2}$$

$$C_L = a(\alpha - \alpha_0) = \frac{C_{L\,max}}{1.3^2}$$

$$\therefore \alpha = \frac{C_L}{a} + \alpha_0 \text{ (in rad)}$$

c 5. How would the angle of attack of the aircraft in question 4 change if the aircraft was landing at Denver International Airport in summertime, where $h \approx 5,500$ ft and ambient temperatures are of the order of 30° C.

(a) The AoA required would be greater;
(b) The AoA required would be lower;
(c) The AoA required would be the same.

~~C_L only varies by the change of α~~

Aircraft still lands at $V_{at} = 1.3V_s$, C_L is constant

a 6. The landing distance required by an aircraft can be considered to be proportional to the aircraft's stall speed squared. How would landing at Denver International affect the aircraft's landing distance relative to that at sea level ISA conditions?

(a) The distance required would be greater;
(b) The distance required would be lower;
(c) The distance required would be the same.

$P < P_s \quad T > T_s \quad \rho = \frac{P}{RT} \ll \rho_s$

$V_s^2 = \frac{2W}{\rho_0 S C_{Lmax}} \gg (V_s)_s^2 \propto S$

Extra: Does Q5 provide sufficient information for you to calculate the exact percentage effect that ambient conditions would have on the landing distance? Yes

c 7. How would the angle of attack of the aircraft in question 4 change during the approach if the aircraft weighed less than the maximum landing weight?

(a) The AoA required would be greater;
(b) The AoA required would be lower;
(c) The AoA required would be the same.

C_L still $= \frac{C_{Lmax}}{1.3^2}$ ~~only varies by the change of α~~

a 8. An aircraft is initially flying at a constant altitude of 10,000 ft and a true airspeed of 200 kn. If the aircraft climbs to a new constant altitude of 20,000 ft and maintains the same true airspeed and weight, how would the angle of attack required for level flight be affected?

(a) The AoA required would be greater;
(b) The AoA required would be lower;
(c) The AoA required would be the same.
(d) insufficient information provided.

$L = \frac{1}{2}\rho V^2 S C_L = W$

$\sim \quad \downarrow \sim \sim \uparrow$

$\alpha \propto C_L \uparrow$

b 9. Consider the aircraft in question 8. How would the change in altitude affect the balance of drag forces acting on the aircraft?

(a) Zero-lift drag will be reduced and lift-dependent drag will be reduced;
(b) Zero-lift drag will be reduced and lift-dependent drag will be increased;
(c) Zero-lift drag will be increased and lift-dependent drag will be reduced;
(d) Zero-lift drag will be increased and lift-dependent drag will be increased;
(e) The balance will remain the same.

d 10. Consider the aircraft in question 8. How would the change in altitude affect the total drag force acting on the aircraft?

(a) The total drag would be greater;
(b) The total drag would be lower;
(c) The total drag would be the same;
(d) insufficient information provided.

Balance of D_0 and D_i is not given

Extra: Estimate the effect that ambient conditions (30°C at a pressure altitude of 5,500 ft) would have on the ratio of landing distances required at Denver International vs an airfield at Sea-Level ISA conditions?

$$\frac{S_{G_{Denver}}}{S_{G_{SL}}} = $$ Number Check

$$\frac{S_D}{S_S} = \frac{V_D^2}{V_S^2} = \frac{\rho_S}{\rho_D} = \frac{\rho_0}{\rho_D} = \frac{1}{\sigma_D}$$

$\because$ 5500ft is in troposphere

$$\therefore \frac{\rho_D}{\rho_0} = \frac{P_D}{RT_D\rho_0} = \frac{P_0\left(1+\frac{\lambda_0 h}{T_0}\right)^{-\frac{g_0}{R\lambda_0}}}{RT_D\rho_0} = 0.77628$$

$$\therefore \frac{S_D}{S_S} = \left(\frac{\rho_D}{\rho_0}\right)^{-1} = 1.288$$

Application Exercise

An commercial jet is cruising at an angle of attack $\alpha = 0.3°$ when flying at 35,000 ft and Mach 0.75. The aircraft's lift curve slope at that Mach number is $a = 7.3$ rad^{-1} and its $\alpha_0 = -1.5°$.

The aircraft has zero-lift drag coefficient $C_{D_0} = 0.0175$, a wing $AR = 8.3$ and an Oswald efficiency $e = 0.82$. You may assume level flight conditions.

a. What is the aircraft's wing loading?

b. The aircraft is operating at a throttle setting of 80% in this cruise condition. What is the aircraft's maximum available thrust at sea level.

c. The aircraft lands at $V = 1.3V_S$. What is the throttle setting required to land at sea-level, if in the landing configuration $C_{L_{max}} = 2.8$ and deploying high-lift devices and undercarriage results in a $\Delta C_{D_0} = 0.092$.

N.B. You may assume that throttle is simply defined as the ratio of thrust generated to the maximum available thrust at any given flight condition.

a. $L = W = \frac{1}{2}\rho V^2 S C_L$ in level flight condition

$$\text{wing loading} = \frac{W}{S} = \frac{\rho V^2 C_L}{2} = \frac{\rho (MC_s)^2 a(\alpha - \alpha_0)}{2}$$

$$= \frac{0.388 \times (0.75 \times 297.6)^2 \times 7.3(\frac{0.3°\pi}{180°} - (\frac{-1.5°\pi}{180°}))}{2}$$

$$= 2216.5 \text{ (N/m}^2\text{)}$$

b. $\frac{T}{T_{max}} = 0.8 \quad \therefore T_{max} = \frac{T}{0.8} = \frac{D}{0.8}$ in level flight condition

$$S = (\frac{W}{S})^{-1} W =$$

$$\therefore T_{max} = 1.25 D = 1.25(\frac{1}{2}\rho V^2 S C_D) = 0.625 \rho V^2 S (C_{D_0} + \frac{C_L^2}{\pi AR e})$$

$$= 0.625 \rho (MC_s)^2 S (C_{D_0} + \frac{C_L^2}{\pi AR e}) =$$

$$\therefore T_{max\,s} = \frac{T_{max}}{\sigma_{35k}^{0.7}} \text{ in troposphere} =$$

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c. $V = 1.3 V_s$

$$\because \frac{C_L}{C_{Lmax}} = \frac{V_s^2}{V^2} \qquad \therefore C_L = \frac{C_{Lmax}}{1.3^2} = \frac{280}{169}$$

$$\therefore T = D = \frac{1}{2}\rho (MC_s)^2 S (C_{D_0} + \Delta C_{D_0} + \frac{C_L^2}{\pi \text{Æ} e}) =$$

$$\therefore \text{throttle setting} = \frac{T}{T_{maxs}} \times 100\% =$$