367K HW1

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9/6/2024

① A smooth golf ball experiences a profile drag as the air flow around the ball separates at the back of the and creates a wake or a large low-pressure turbulent region.
Dimples on the golf ball reduces this profile drag by increasing the distance to the separation of flow relative to that of the smooth ball.
The dimples create turbulances on the surface of the ball, which causes the skin friction drag to increase.
This turbulence and skin friction allow boundary layer to stick further down the golf ball, push back where the separation of flow occurs, and decrease the wake region.

* So, the magnitude of the profile drag decreases when dimples are introduced.
  Although the skin fiction is also increased by the dimples, the decrease in the wake area is much greater that golf ball experiences less overall profile drag

* Also, the magnitude of the induced drag is increased as the lift is increased with the introduction of dimples.
  With dimples, the golf ball spins on its axis faster than a smooth ball, creating a greater pressure gradient.
  This greater gradient generates more lift, which also generates a greater induced drag. However, again, the magnitude of reduction of the profile drag from dimples is greater than the increase in the induced drag. This results in overall reduction in drag and golf ball goes faster than a smooth ball.

The ball spins
Turn the flow of air surrounding it downward. (induced drag)

747-400 $2.5cm = 50 ft$

(2) a) Platform area

$$S = \frac{b}{2} C_r (1+\lambda)$$

$b = 213$ ft $C_r = 48$ ft

$C_t = 14$ ft $\lambda = \frac{C_t}{C_r} = 0.291\overline{6}$

$$S = \frac{213}{2}(48)\left(1+\frac{14}{48}\right) = 6603 \text{ ft}^2$$

b) Aspect Ratio

$$AR = \frac{b^2}{S} = \frac{213^2}{6603} = 6.87$$

c) Leading edge wing swing

$$\Lambda_{LE} = \arctan\left(\tan(\Lambda_{\frac{c}{4}}) + \frac{4p(1-\lambda)}{AR(1+\lambda)}\right)$$

$$\Lambda_{\frac{c}{4}} \approx 37°$$

$$\Lambda_{LE} = \arctan\left(\tan(37°) + \frac{4\left(\frac{1}{4}\right)\left(1-\frac{14}{48}\right)}{6.87\left(1+\frac{14}{48}\right)}\right)$$

$$= \arctan(0.75 + 0.079)$$

$$= 39.81°$$

d) Trailing edge sweep

$$\Lambda_{TE} = \arctan\left(\tan(\Lambda_{\frac{1}{4}}) - \frac{4(1-p)(1-\lambda)}{AR(1+\lambda)}\right)$$

$$= \arctan\left(\tan(37^\circ) - \frac{4(1-0.25)(1-\frac{14}{48})}{6.87(1+\frac{14}{48})}\right)$$

$$= 27.21^\circ$$

e) mean aerodynamic chord

what does it mean?

$$\bar{c} = \frac{2}{3} c_r \left(\frac{\lambda^2+\lambda+1}{\lambda+1}\right) = 34.11'$$

f) Lateral location of the aerodynamic center

$$y_{ac} = \frac{b}{6} \cdot \frac{1+2\lambda}{1+\lambda} = \frac{213}{6} \cdot \frac{1+2(\frac{14}{48})}{1+\frac{14}{48}}$$

$$= 43.52'$$

g) Longitudinal location

$$x_{ac} = p \cdot \bar{c} + \tan(\Lambda_{LE}) \cdot y_{ac}$$

$$= \frac{1}{4} \cdot 34.11 + \tan(39.81^\circ) \cdot 43.52$$

$$= 44.80'$$

The wing sweep of 747-400 is greater than that of 737-900 because 747 is designed to travel at a different speed than 737.

The greater the wing sweep the faster an airplane can travel because the free flow of air approaches the wing at a greater angle. This angled flow reduces the speed of air above the wing and delays the speed of onset of shockwaves that causes drag.

(3)

assume α and θ are equal

$\oplus\uparrow +$

$$x = \frac{1}{2}\rho V^2 S \qquad y = \frac{1}{2}\rho V^2 S_H$$

$$\cancel{xC_{LW_0}} + \cancel{xC_{LW_\alpha}\alpha} + \cancel{yC_{LH_0}} + \cancel{yC_{LH_\alpha}\alpha} + \cancel{yC_{LH_\delta}\delta} - W = 0$$

$$(xC_{LW_0} + yC_{LH_0}) + (xC_{LW_\alpha}\alpha + yC_{LH_\alpha}\alpha) + (yC_{LH_\delta}\delta) - W = 0$$

$$[\cancel{xC_{LW_0}} + \cancel{xC_{LW_\alpha}\alpha}]a - [\cancel{yC_{LH_0}} + \cancel{yC_{LH_\alpha}\alpha} + yC_{LH_\delta}\delta]b + M_0 = 0$$

$$(xC_{LW_0}a - yC_{LH_0}b) + (xC_{LW_\alpha}\alpha a - yC_{LH_\alpha}\alpha b) - yC_{LH_\delta}\delta b + M_0 =$$

$$\begin{bmatrix} xC_{LW_0} + yC_{LH_0} \\ xC_{LW_0}a - yC_{LH_0}b \end{bmatrix} + \begin{bmatrix} xC_{LW_\alpha} + yC_{LH_\alpha} & yC_{LH_\delta} \\ xC_{LW_\alpha}a - yC_{LH_\alpha}b & -yC_{LH_\delta}b \end{bmatrix} \begin{bmatrix} \alpha \\ \delta \end{bmatrix}$$

$$+ \begin{bmatrix} -W \\ M_0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} \alpha \text{ or } \theta_0 \\ \delta_0 \end{bmatrix} = \begin{bmatrix} xC_{LW_\alpha} + yC_{LH_\alpha} & yC_{LH_\delta} \\ xC_{LW_\alpha}a - yC_{LH_\alpha}b & -yC_{LH_\delta}b \end{bmatrix}^{-1} \left(\begin{bmatrix} W \\ -M_0 \end{bmatrix} - \begin{bmatrix} xC_{LW_0} + yC_{LH_0} \\ xC_{LW_0}a - yC_{LH_0}b \end{bmatrix} \right)$$

$$\boxed{\begin{bmatrix} \theta_0 \\ \delta_0 \end{bmatrix} = \begin{bmatrix} k_1 + k_2 & k_\delta \\ ak_1 - bk_2 & -bk_\delta \end{bmatrix}^{-1} \left(\begin{bmatrix} W \\ -M_0 \end{bmatrix} - \begin{bmatrix} F_{1_0} + F_{2_0} \\ aF_{1_0} - bF_{2_0} \end{bmatrix} \right)}$$

where $k_1 = xC_{LW_\alpha}$, $k_2 = yC_{LH_\alpha}$, $k_\delta = yC_{LH_\delta}$,
$F_{1_0} = xC_{LW_0}$ and $F_{2_0} = yC_{LH_0}$

④ From ③

$$\begin{bmatrix} F_{1_0} + F_{2_0} \\ aF_{1_0} - bF_{2_0} \end{bmatrix} + \begin{bmatrix} k_1+k_2 & k_\delta \\ ak_1 - bk_2 & -bk_\delta \end{bmatrix}\begin{bmatrix} \theta \\ \delta \end{bmatrix} + \begin{bmatrix} -W \\ M_0 \end{bmatrix} = \begin{bmatrix} m\ddot{h} \\ I\ddot{\theta} \end{bmatrix}$$

Consider perturbation and given

$$\begin{bmatrix} \theta \\ \delta \end{bmatrix} = \begin{bmatrix} \theta_0 \\ \delta_0 \end{bmatrix} + \begin{bmatrix} \Delta\theta \\ \Delta\delta \end{bmatrix}$$

$$\begin{bmatrix} F_{1_0} + F_{20} \\ aF_{10} - bF_{20} \end{bmatrix} + \begin{bmatrix} k_1+k_2 & k_\delta \\ ak_1 - bk_2 & -bk_\delta \end{bmatrix}\left(\begin{bmatrix} \theta_0 \\ \delta_0 \end{bmatrix} + \begin{bmatrix} \Delta\theta \\ \Delta\delta \end{bmatrix}\right) + \begin{bmatrix} -W \\ M_0 \end{bmatrix} = \begin{bmatrix} m\ddot{h} \\ I\ddot{\theta} \end{bmatrix}$$

0

$$\cancel{\begin{bmatrix} F_{1_0} + F_{20} \\ aF_{1_0} - bF_{20} \end{bmatrix}} + \begin{bmatrix} k_1+k_2 & k_\delta \\ ak_1 - bk_2 & -bk_\delta \end{bmatrix}\left(\begin{bmatrix} k_1+k_2 & k_\delta \\ ak_1 - bk_2 & -bk_\delta \end{bmatrix}^{-1}\left(\cancel{\begin{bmatrix} W \\ -M_0 \end{bmatrix}} - \cancel{\begin{bmatrix} F_{1_0} + F_{20} \\ aF_{1_0} - bF_{20} \end{bmatrix}}\right)\right)$$

$$+ \begin{bmatrix} k_1+k_2 & k_\delta \\ ak_1 - bk_2 & -bk_\delta \end{bmatrix}\begin{bmatrix} \Delta\theta \\ \Delta\delta \end{bmatrix} + \cancel{\begin{bmatrix} -W \\ M_0 \end{bmatrix}} = \begin{bmatrix} m\ddot{h} \\ I\ddot{\theta} \end{bmatrix}$$

$$\begin{bmatrix} k_1+k_2 & k_\delta \\ ak_1 - bk_2 & -bk_\delta \end{bmatrix}\begin{bmatrix} \Delta\theta \\ \Delta\delta \end{bmatrix} = \begin{bmatrix} m\ddot{h} \\ I\ddot{\theta} \end{bmatrix}$$

$$\begin{bmatrix} \ddot{h} \\ \ddot{\theta} \end{bmatrix} = \begin{bmatrix} \frac{k_1+k_2}{m} & \frac{k_\delta}{m} \\ \frac{ak_1 - bk_2}{I} & \frac{-bk_\delta}{I} \end{bmatrix}\begin{bmatrix} \Delta\theta \\ \Delta\delta \end{bmatrix}$$

$$\begin{bmatrix} \ddot{h} \\ \ddot{\theta} \end{bmatrix} = \begin{bmatrix} \frac{gC_{L\theta}}{W} & \frac{gC_{L\delta}}{W} \\ \frac{C_{M\theta}}{I} & \frac{C_{M\delta}}{I} \end{bmatrix}\begin{bmatrix} \Delta\theta \\ \Delta\delta \end{bmatrix}$$

$$\frac{\frac{1}{2}\rho V^2 S C_{LW\alpha} + \frac{1}{2}\rho V^2 S_H C_{LH\alpha}}{m} = \frac{gC_{L\theta}}{W}$$

a)

$$C_{L\theta} = \frac{W}{gm}\left(\tfrac{1}{2}\rho V^2 S C_{LW\alpha} + \tfrac{1}{2}\rho V^2 S_H C_{LH\alpha}\right)$$

$$C_{L\delta} = \frac{W}{gm}\left(\tfrac{1}{2}\rho V^2 S_H C_{LH\delta}\right)$$

$$C_{M_\theta} = a\tfrac{1}{2}\rho V^2 S C_{LW\alpha} - b\tfrac{1}{2}\rho V^2 S_H C_{LH\alpha}$$

$$C_{M_\delta} = -b\tfrac{1}{2}\rho V^2 S_H C_{LH\delta}$$

b) If $C_{LH_\delta} = C_{LH\alpha}$

$$0 > C_{M_\theta} = \frac{1}{2}\rho V^2 (a S C_{LW\alpha} - b S_H C_{LH\alpha})$$

this is when ⊕ is in btwn tail and wing

$$a S C_{LW\alpha} - b S_H C_{LH\alpha} < 0$$

$$a S C_{LW\alpha} < b S_H C_{LH\alpha}$$

$$C_{LW\alpha} < \frac{b}{a}\frac{S_H}{S} C_{LH\alpha}$$

Moment from H should be greater b/c H created negative pitch moment in this case

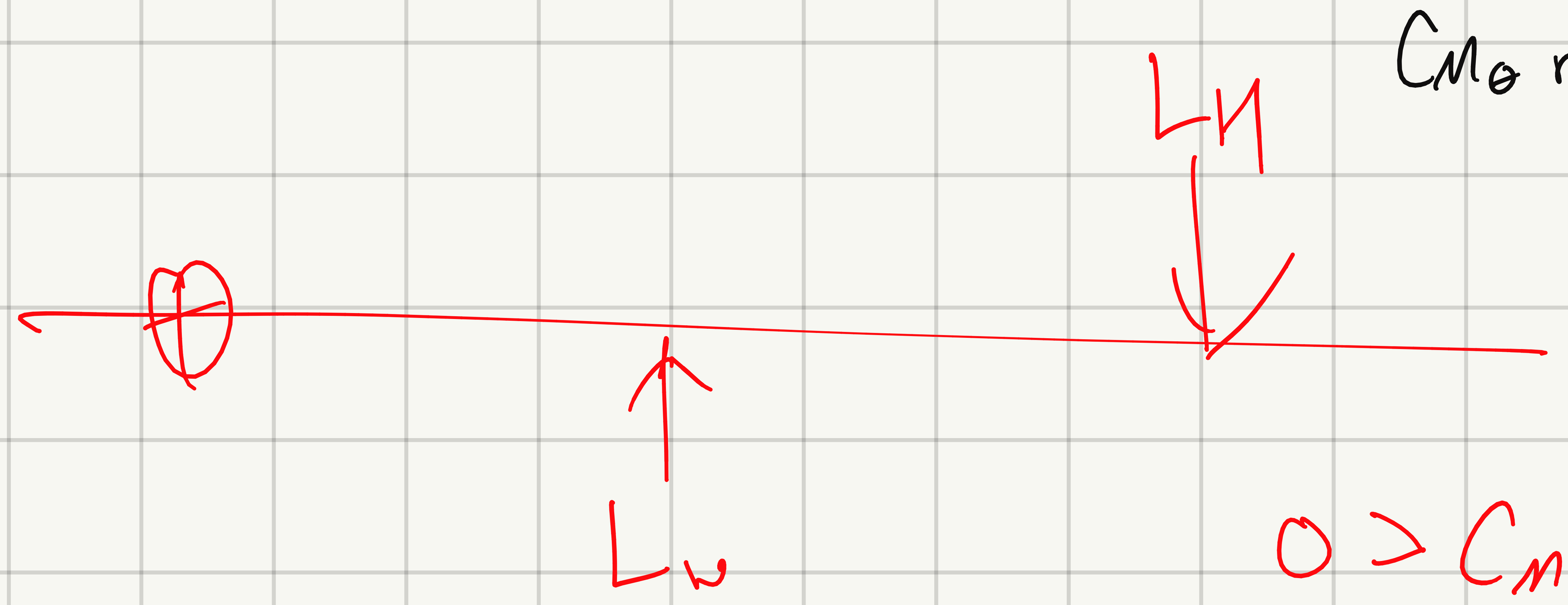
c)

LH should become negative or point downward in the same direction as W to counter act Moment occurring from LW.

d) ~~In this CG and aerodynamic center of wing and horizontal stabilizer orientation, the Moment created by the horizontal stabilizer lift due to α (angle of attack or pitch in this case) should be greater than or the wing lift due to α for C_{M_θ} to remain negative~~

C_{M_θ} means negative pitch.

these are talking about when CG is in front of the wing.



$$0 > C_{M_\theta} = \frac{1}{2}\rho V^2 (b S_H C_{LH\alpha} - a S C_{LW\alpha})$$

for $C_{M_\theta} < 0$, Moment from wing should be greater for $C_{M_\theta} < 0$ b/c wing is the one creating negative moment.

$$a S C_{LW\alpha} > b S_H C_{LH\alpha}$$

② $b = 53.13\ m$ $b_1 = 11.25 \times 2$ $b_2 = 15.315 \times 2$

$$AR(1+\lambda)$$
$$\frac{b^2}{S}(1+\lambda)$$
$$= \frac{b^{\cancel{2}}}{\frac{1}{2} C_r \cancel{(1+\lambda)} \cancel{b}} \cancel{(1+\lambda)}$$
$$= \frac{2b}{C_r}$$

$$S = \frac{1}{2}(C_r + C_m) b$$
$$= \frac{1}{2} C_r (1+\lambda) b$$

$$\tan(\Lambda_{1/4}) + \frac{4p(1-\lambda)}{\frac{2b}{C_r}}$$

$$\tan(\Lambda_{1/4}) + \frac{2pC_r(1-\lambda)}{b}$$

$$= \frac{b \tan(\Lambda_{1/4}) + 2pC_r(1-\lambda)}{b}$$

$$= \frac{\frac{b}{2}\tan(\Lambda_{1/4}) + pC_r(1-\lambda)}{\frac{b}{2}}$$

$$= \frac{11.25 \tan(35.5) + \frac{1}{4} C_r (1-\lambda)}{11.25}$$

$$= 0.7133$$