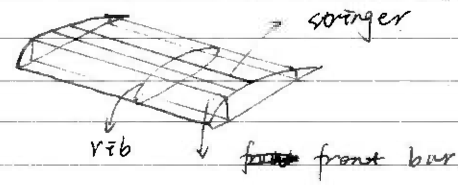
AE 3001 Aircraft Structure I

Semester 1 2008 - 2009

1. (a)



① front bar and rear bar. They are the final load carrier of the wing

② skin. The main purpose of skin is for good aerodynamic performance. But they are ~~st~~ still integrated to carry load

③ stringer. It prevents skin buckling.

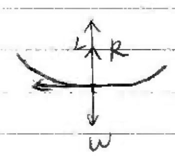
④ rib. It increases wing stiffness.

(b) ① flap. high lift device which increases lift through increase effective angle of attack.

② slot. high lift device which increase lift through increase wing area and delay flow ceperation

③ spoiler high drag devices which helps in ~~bo~~ landing

(c)



$$L - w = \frac{mv^2}{R} = \frac{wv^2}{gR}$$

$$n = \frac{L}{w}$$

$$\Rightarrow n - 1 = \frac{v^2}{gR}$$

Date No.

$$R = \frac{V^2}{g(n-1)}$$

$$R_{min} = \frac{V^2}{g(n_{max}-1)} = \frac{400^2}{g(9\times1.5-1)} = 1304.8\ (m)$$

(d) $L = \frac{1}{2}\rho_\infty U_\infty^2 S C_L$

$$\Delta L = \frac{1}{2}\rho_\infty U_\infty^2 S \frac{dC_L}{d\alpha}\cdot\Delta\alpha$$

due to the downwash

$$\Delta\alpha = -\frac{u}{U_\infty} = -0.06$$

$$\therefore \Delta L = \frac{1}{2}\times\rho\cancel{1.225}\times150^2\times \cancel{5}S\times5\times(-0.06) = -3375\rho S$$

$$\Sigma F = L_{new} - W = ma$$

$$a = \frac{L_{new}-W}{m} = \frac{(L_{steady}-\Delta L)-W}{m}$$

$$W = L_{steady} = \frac{1}{2}\rho U_\infty^2 S C_L = 2025\rho S$$

$$\Rightarrow a = -16.35\ (kg/s^2)$$

2 (e)

During steady level flight

the angle of attack is α.

$$\Sigma F_x = T\cos\alpha - D = ma_x = 0$$

Date No

$$L = \frac{1}{2}\rho_\infty U_\infty^2 S C_L \Rightarrow C_L = 0.295$$

$$C_D = 0.02 + 0.04 C_L^2 = 0.02348$$

$$D = \frac{1}{2}\rho_\infty U_\infty^2 S C_D = 28716 \text{ (N)}$$

$$M_0 = \frac{1}{2}\rho_\infty U_\infty^2 S \bar{c}\, C_{m_0} = -158990 \text{ (Nm)}$$

$$\Sigma M_{cg} = L \cdot (0.5) + M_0 - D \times 0.4 - P \times 8.5 = 0$$

$$\therefore P = 1195.3$$

$$\therefore \text{ Lift } L = 361273.7 \text{ (N)}$$

$$P = 1195.3 \text{ (N)}$$

(iii) $\Sigma F_x = T - D = 0 \Rightarrow T = D = \frac{1}{2}\rho_\infty U_\infty^2 S (0.02 + 0.04 C_L^2)$ ....

$\Sigma F_y = L + P = nW \Rightarrow L = nW - P$ .... ②

$\Sigma M_{cg} = L(0.5) + T(0.4) + M_0 - D \times (0.4) - P\, 8.5 = 0$ ...... ③

$M_0 = \frac{1}{2}\rho_\infty U_\infty^2 S \bar{c}\, C_{m_0} = -3.97 U_\infty^2$ ...... ④

Date No.

$\Sigma F_y = L + P + T\sin\alpha - W = 0$

$\Sigma M_{cg} = L\cos\alpha \cdot (0.5) + L\sin\alpha (0.4) + T \cdot a_4 + M_0$

$- D\cos\alpha (0.4) + D\sin\alpha (0.5) - P\cos\alpha (8.5) = 0$

If α is considered as small angle.

$\sin\alpha = 0. \quad \cos\alpha = 1$

$\Sigma F_x = T - D = 0$

$\Sigma F_y = L + P - W = 0$

$\Sigma M_{cg} = L \cdot (0.5) + T \cdot (0.4) + M_0 - D \times (0.4) - P \times 8.5 = 0$

(ii) $\Sigma F_y = L + P = nW$

since $L >> P \quad \therefore L = nW = \frac{1}{2}\rho_\infty U_\infty^2 S C_L$

$\Rightarrow C_L = 0.2196$

$C_D = 0.02 + 0.04 C_L^2 = 0.0235$

$\therefore D = \frac{1}{2}\rho_\infty U_\infty^2 S C_D = 28740.5 \,(N)$

$M_0 = \frac{1}{2}\rho_\infty U_\infty^2 S \bar{c}\, C_{M_0} = -158990 \,(Nm)$

$\Sigma M_{cg} = L(0.5) + M_0 - D \times (0.4) - P \times 8.5 = 0$

$P = 1266.3 \,(N)$

Interation :

$\Sigma F_y = L + P = nW \Rightarrow L = nW - P = 361273.7 \,(N)$

UNIVERSITY

Date No.

From ① ② ③ ④

$$(nW - P) \times 0.5 - 3.87 U_\infty^2 - 8.5P = 0$$

$$P = 8055n - 0.44 U_\infty^2$$

the bending moment about cg is

$$M_b = n M_{steady} - 8.5P$$

$$M_{CG-steady} = M_{steady} - 8.5P = 300\,000$$

$$P_{steady} = 8055 \times 1 - 0.44 \times 250^2 = -19445 \ (N)$$

$$\therefore M_{steady} = 280563.5 \ (Nm)$$

$$\therefore M_b = 280563.5n - 8.5 \times (8055n - 0.44 U_\infty^2)$$

$$= 212096.5n + 3.74 U_\infty^2$$

check the corner point

At point C

$n_C = 4 \quad V_C = 250$

$$M_{b-C} = 1082136 \ (Nm)$$

At point D_1

$n_{D_1} = 2.5 \quad V_{D_1} = 300$

$$M_{b-D_1} = 866841.25 \ (Nm)$$

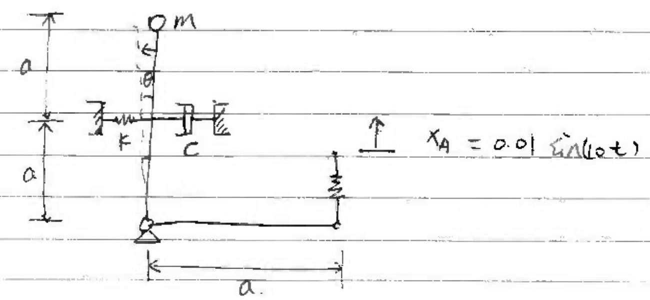
$\therefore$ the maximum bending moment is at point C

$$M_{b-max} = 1082136 \ (Nm)$$

NANYANG TECHNOLOGICAL UNIVERSITY

Date No.

3 (i)



$$\Sigma M = mg \cdot \theta \cdot (2a) - k \cdot \theta a \cdot a - c\dot{\theta} a \cdot a - k(a\theta - x_A) \cdot a = I\ddot{\theta}$$

$$I = m(2a)^2 = 0.64$$

$$\therefore \quad 0.64\ddot{\theta} + 0.16\dot{\theta} + 30.55\theta = 0.48 \sin(10t)$$

(ii) $$\omega_n = \sqrt{\frac{k_e}{m_e}} = \sqrt{\frac{30.55}{0.64}} = 6.9 \ (rad/s)$$

$$\zeta = \frac{c}{2\sqrt{mk}} = \frac{0.16}{2\sqrt{0.64 \times 30.55}} = 0.018$$

(iii) $$Q = \frac{1}{2\zeta} = \frac{1}{2 \times 0.018} = 27.78$$

$$M = \frac{1}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}} = \frac{Q}{\sqrt{2}} = \frac{1}{2\sqrt{2}\zeta} \Rightarrow$$

$$r_1 = \sqrt{1 - 2\zeta^2 - 2\zeta \cdot \sqrt{1+\zeta^2}} = 0.9815$$

$$r_2 = \sqrt{1 - 2\zeta^2 + 2\zeta\sqrt{1+\zeta^2}} = 1.018$$

$$\therefore \Delta\omega = (r_2 - r_1)\omega_n = 0.252 \ (rad/s)$$

(iv) For Equation of motion

$$0.64\ddot{\theta} + 0.16\dot{\theta} + 30.55\theta = 0.48 \sin(10t)$$

NANYANG TECHNOLOGICAL UNIVERSITY

Date No.

The general solution is

$\theta = \theta_0 \sin(10t - \phi)$

$\left.\begin{array}{l} \theta_0 = \frac{0.48}{30.55} \cdot \frac{1}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}} \\ r = \frac{\omega}{\omega_n} = \frac{10}{6.9} = 1.45 \end{array}\right\} \Rightarrow \theta_0 = 0.014$

$\phi = \tan^{-1}\left(\frac{2\zeta r}{1-r^2}\right) = -2.71°$

$\therefore$ steady state response $\theta(t)$ is

$\theta(t) = 0.014 \cdot \sin(10t - 2.71°)$

4 (i) For m_1,

$\Sigma F = -k_1 x_1 - k_2(x_1 - x_2) = m_1 \ddot{x}_1$ ...... ①

For m_2,

$\Sigma F = F_2 - k_2(x_2 - x_1) = m_2 \ddot{x}_2$ .... ②

Let $x_1 = A_1 \sin(\omega t) \Rightarrow \ddot{x}_1 = -A_1 \omega^2 \sin(\omega t)$ ...... ③

$x_2 = A_2 \sin(\omega t) \Rightarrow \ddot{x}_2 = -A_2 \omega^2 \sin(\omega t)$ ...... ④

From ① ② ③ ④

$(m_1\omega^2 - k_1 - k_2) A_1 + k_2 A_2 = 0$

$-k_2 A_1 \sin\omega t + (k_2 A_2 - m_2 A_2 \omega^2) \sin\omega t = F_2$

natural frequency has nothing to do with F_2

$\therefore$ let $F_2 = 0$

$$\therefore \begin{bmatrix} m_1 w^2 - k_1 - k_2 & k_2 \\ -k_2 & k_2 - m_2 w^2 \end{bmatrix} \cdot \begin{bmatrix} A_1 \\ A_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

For $w = 10$ (rad/s)

$$\frac{A_1}{A_2} = \frac{1}{2} = -\frac{k_2}{(m_1 w^2 - k_1 - k_2)} = -\frac{k_2}{400 - k_1 - k_2} \quad \cdots \text{⑤}$$

For $w = 10\sqrt{3}$ (rad/s)

$$\frac{A_1}{A_2} = \frac{1}{-2} = -\frac{k_2}{m_1 w^2 - k_1 - k_2} = -\frac{k_2}{1200 - k_1 - k_2} \quad \cdots \text{⑥}$$

From ⑤ ⑥

$$k_1 = 600 \text{ (N/m)}$$

$$k_2 = 200 \text{ (N/m)}$$

(ii) For $F = 10 \sin wt$.

$$\begin{bmatrix} m_1 w^2 - k_1 - k_2 & k_2 \\ -k_2 & k_2 - m_2 w^2 \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 10 \end{bmatrix}$$

$$\Delta = \det \begin{bmatrix} m_1 w^2 - k_1 - k_2 & k_2 \\ -k_2 & k_2 - m_2 w^2 \end{bmatrix} = (4w^2 - 550) \cdot (150 - w^2) + 150^2$$

$$\Delta_1 = \det \begin{bmatrix} 0 & k_2 \\ 10 & k_2 - m_2 w^2 \end{bmatrix} = -10 k_2.$$

$$\Delta_2 = \det \begin{bmatrix} m_1 w^2 - k_1 - k_2 & 0 \\ -k_2 & 10 \end{bmatrix} = 10(4w^2 - 550)$$

NANYANG TECHNOLOGICAL UNIVERSITY

Date No

$A_2 = \frac{\Delta_2}{\Delta} = \frac{10(4w^2-550)}{(4w^2-550)(150-w^2)} = 0.$

$\therefore w = 11.726$ (rad/s)

5 (i) This is a two-degree of freedom problem.

$$\left.\begin{array}{l} \Sigma F_x = L - kx - (x+e\theta)k = m\ddot{x} \\ \Sigma M = M_0 - L\cdot a - (x+e\theta)k\cdot e = I\ddot{\theta} \end{array}\right\} \Rightarrow$$

$25\ddot{x} + 2000x + 250\theta = L$ ------ ①

$2\ddot{\theta} + 62.5\theta + 250x = M_0 - 0.15L$ ---- ②

(ii). $L(t) = 100\sin(5t)$ $M_0(t) = 25\sin(5t)$ --- ③

let $x = A_1\sin(5t)$ $\theta = A_2\sin(5t)$ ------ ④

$\ddot{x} = -25A_1\sin(5t)$ $\ddot{\theta} = -25A_2\sin(5t)$ ------ ⑤

From ① ② ③ ④ ⑤.

$A_1 = 0.0276$

$\therefore$ vertical vibration

$x(t) = 0.0276\sin(5t)$.