كلية الهندسة الميكانيكية والكهربائية — امتحانات الفصل الثاني للعام الدراسي 2022-2023 — الدرجة:80

قسم هندسة المعادن — سلم تصحيح مادة: ديناميك الآلات والاهتزازات — المدة: ساعتان

السؤال الأول: (18 درجة)

1- عزم العطالة الكتلي المرجع على الحد القائد:

$$J(\varphi_2) = J_2\acute{\varphi}_2^2 + J_3\acute{\varphi}_3^2 + J_6\acute{\varphi}_6^2 + m_{34}r^2\acute{\varphi}_3^2 + (m_{45}+m_5)\acute{x}_5^2$$

$$\grave{\varphi}_2 = \frac{d\varphi_2}{d\varphi_2} = 1 \quad , \quad r_2\varphi_2 = r_3\varphi_3 \Rightarrow \varphi_3 = \frac{r_2}{r_3}\varphi_2 \Rightarrow \grave{\varphi}_3 = \frac{r_2}{r_3} = \frac{0.15}{0.6} = \frac{1}{4} = 0.25$$

$$r_3\varphi_3 = -r_6\varphi_6 \Rightarrow \varphi_6 = -\frac{r_3}{r_6}\varphi_3 = -\frac{r_3}{r_6}\frac{r_2}{r_3}\varphi_2 \Rightarrow \grave{\varphi}_6 = -\frac{r_2}{r_6} = -\frac{0.15}{0.3} = -\frac{1}{2}$$

$$X_5 \cong L + r\cdot cos\,\varphi_3 = L + r\cdot cos\frac{r_2}{r_3}\varphi_2 \Rightarrow \acute{X}_5 = -r\cdot\frac{r_2}{r_3}\sin\frac{r_2}{r_3}\varphi_2 \Rightarrow \acute{X}_5 = -0.3(0.25)\sin\frac{\varphi_2}{4}$$

$$\acute{X}_5 = -\mathbf{0.075}\sin\frac{\varphi_2}{4} \quad (6)$$

$$m_{34} + m_{45} = m_4 = 8\,,\ m_{34}l = m_{45}(L-l) \Rightarrow m_{34}(0.3) = m_{45}(1.2-0.3) \Rightarrow m_{34} = 3m_{45}$$

$$\boldsymbol{m_{45} = 2\ kg\ ,\ m_{34} = 6\ kg} \quad (4)$$

$$J(\varphi_2) = 0.12 + 0.6(0.25)^2 + 0.4\left(-\frac{1}{2}\right)^2 + 6(0.3)^2(0.25)^2 + (2+10)\left(-0.075\sin\frac{\varphi_2}{4}\right)^2$$

$$J(\varphi_2) = \mathbf{0.29125} + \mathbf{0.0675}\sin^2\left(\frac{\varphi_2}{4}\right)$$

$$J(\varphi_2) = 0.29125 + 0.0675\left(\frac{1-\cos\left(\frac{\varphi_2}{2}\right)}{2}\right) \Rightarrow J(\varphi_2) = \mathbf{0.325} - \mathbf{0.03375}\cos\left(\frac{\varphi_2}{2}\right) \quad (6)$$

$$J(\varphi_2) = J_m \mp \Delta J \Rightarrow \delta = \frac{\Delta J}{J_m} = \frac{0.03375}{0.325} = \mathbf{0.10385} \quad (2)$$

السؤال الثاني: (22 درجة)

1- حساب عزم مقاومة العمل المرجع على الحد القائد:

$$Q = \sum_{i=2}^{n}\left[F_{Xi}\cdot\acute{X}_i + F_{Yi}\cdot\acute{Y}_i + M_i\cdot\acute{\varphi}_i\right]$$

$$M_5^{(5)} = \begin{cases} 0 & 0 \le \varphi_5 \le \pi \\ -2700\ [N\cdot m] & \pi \le \varphi_5 \le \frac{3\pi}{2} \\ -1350\ [N\cdot m] & \frac{3\pi}{2} \le \varphi_5 \le 2\pi \end{cases}$$

دورة العمل (عدد دورات الحد القائد التي توافق دورة واحدة للحد التنفيذي) تساوي $2\pi i = 2\pi\frac{1}{0.5} = 4\pi$ لأن $\grave{\varphi}_5 = 0.5$

$$M_5^{(2)} = M_5^{(5)}\cdot\grave{\varphi}_5 = M_5^{(5)}\cdot(0.5) = \begin{cases} 0 & 0 \le \varphi_2 \le 2\pi \\ -1350\ [N\cdot m] & 2\pi \le \varphi_2 \le 3\pi \\ -675\ [N\cdot m] & 3\pi \le \varphi_2 \le 4\pi \end{cases} \quad (6)$$

2- حساب عزم المحرك الضروري في حالة التشغيل المستقر، من مبدأ توازن العمل:

عمل كاملة (4π): عمل القوى المحركة = عمل القوى المقاومة

$$W_W = -W_M$$

$$W_M = \int_0^{4\pi} M_M d\varphi_2 = 4\pi M_M \quad [N \cdot m]$$

$$W_W = \int_0^{4\pi} M_W d\varphi_2 = \int_0^{2\pi} 0\, d\varphi_2 + \int_{2\pi}^{3\pi} (-1350)\, d\varphi_2 + \int_{3\pi}^{4\pi} (-675)\, d\varphi_2$$

$$W_W = 0 - 1350(\pi) - 675(\pi) = -2025\pi \ [N \cdot m]$$

$$4\pi M_M = 2025\pi \quad \Rightarrow \quad M_M = 506.25 \ [N \cdot m]$$

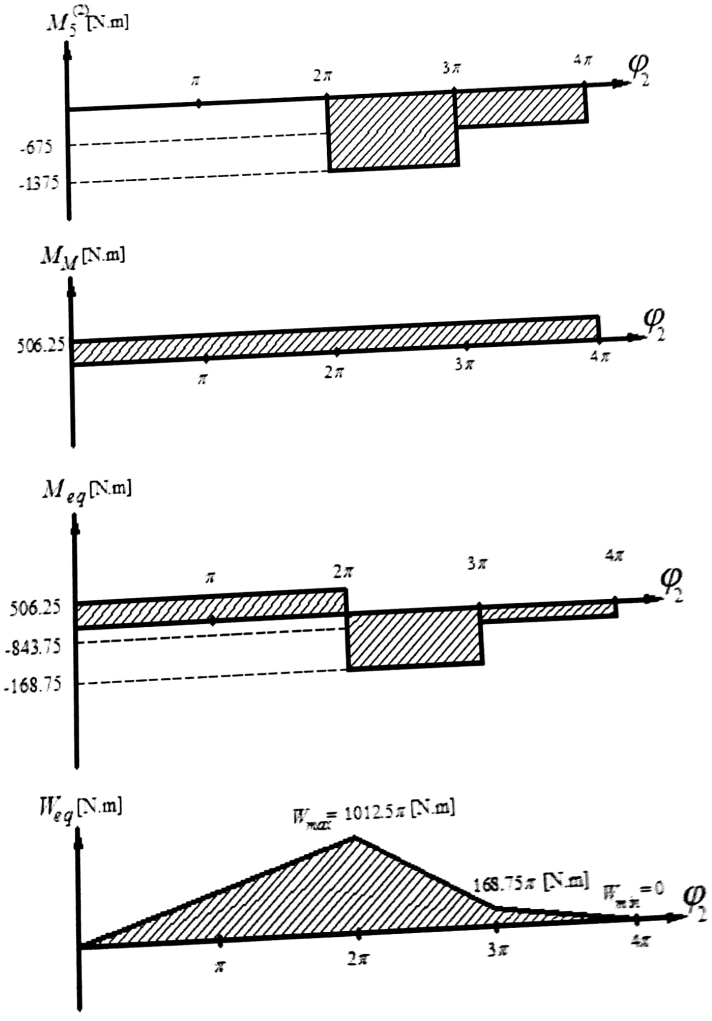
3- العزم المحصل والعمل المحصل:

$$M_{eq} = \begin{cases} 506.25 \ [N \cdot m] & 0 \le \varphi_2 \le 2\pi \\ -843.75 \ [N \cdot m] & 2\pi \le \varphi_2 \le 3\pi \\ -168.75 \ [N \cdot m] & 3\pi \le \varphi_2 \le 4\pi \end{cases}$$

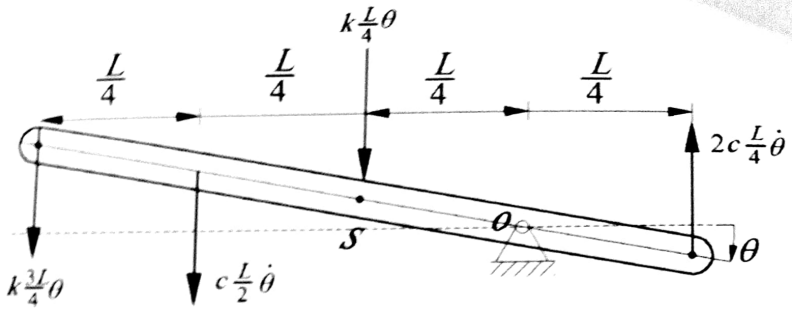
$$W_{max} = \int_0^{2\pi} M_{eq} d\varphi_2 = 506.25(2\pi) = 1012.5\,\pi = 3180.86 \ [N \cdot m]$$

$$W_{med} = \int_0^{3\pi} M_{eq} d\varphi_2 = 1012.5\,\pi - 843.75(\pi) = 168.75\pi = 530.144 \ [N \cdot m]$$

$$W_{min} = 0$$



السؤال الثالث: (16 درجة)



4

$$J_O = J_s + m\left(\frac{L}{4}\right)^2 = \frac{1}{12}mL^2 + \frac{1}{16}mL^2 = \frac{7}{48}mL^2\ [kg.m^2] \quad (2)$$

$$J_O\ddot{\theta} = -2c\frac{L}{4}\dot{\theta}\left(\frac{L}{4}\right) - c\frac{L}{2}\dot{\theta}\left(\frac{L}{2}\right) - k\frac{L}{4}\theta\left(\frac{L}{4}\right) - k\frac{3L}{4}\theta\left(\frac{3L}{4}\right) \Rightarrow$$

$$\frac{7}{48}mL^2\ddot{\theta} + c\frac{L^2}{8}\dot{\theta} + c\frac{L^2}{4}\dot{\theta} + k\frac{L^2}{16}\theta + k\frac{9L^2}{16}\theta = 0$$

$$\ddot{\theta} + \frac{18}{7}\frac{c}{m}\dot{\theta} + \frac{30}{7}\frac{k}{m}\theta = 0 \quad (8)$$

$$\omega_n = \sqrt{\frac{30}{7}\frac{k}{m}}\ \left[\frac{rad}{s}\right] \quad (2)$$

السؤال الرابع: (24 درجة)

$$m\ddot{x} = -c\dot{x} - kx + F_0\sin\omega t \Rightarrow \ddot{x} + \frac{c}{m}\dot{x} + \frac{k}{m}x = \frac{F_0}{m}\sin\omega t \quad (3)$$

$$\omega = \frac{2\pi n}{60} = \frac{2\pi(1500)}{60} = \mathbf{157.08}\ \frac{rad}{s} \quad (2)$$

$$mg = k\,\Delta \Rightarrow \omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{\Delta}} = \sqrt{\frac{9.81}{0.002}} = \mathbf{70.036}\ \frac{rad}{s} \quad (3)$$

$$\eta = \frac{\omega}{\omega_n} = \frac{157.08}{70.036} = \mathbf{2.243}\ ,\ \zeta = \mathbf{0.2}$$

$$TR = \frac{F_T}{F_0} = \sqrt{\frac{1+\left(2\zeta\frac{\omega}{\omega_n}\right)^2}{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2+\left(2\zeta\frac{\omega}{\omega_n}\right)^2}} = \sqrt{\frac{1+(2\times0.2\times2.243)^2}{[1-(2.243)^2]^2+(2\times0.2\times2.243)^2}} = \mathbf{0.3253} \quad (6)$$

$$TR = \frac{F_T}{F_0} = \frac{F_T}{2450} = 0.3253 \Rightarrow F_T = \mathbf{796.985}\ N \quad (2)$$

$$x = X\sin(\omega t - \phi) \Rightarrow mg = k\,\Delta \Rightarrow k = \frac{mg}{\Delta} = \frac{1000\times9.81}{0.002} = \mathbf{4905000}\ \frac{N}{m} \quad (2)$$

$$X = \frac{\frac{F_0}{k}}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2+\left(2\zeta\frac{\omega}{\omega_n}\right)^2}} = \frac{\frac{2450}{4905000}}{\sqrt{(1-(2.243)^2)^2+(2\times0.2\times2.243)^2}} \Rightarrow X = \mathbf{1.2095\times10^{-4}}\ m \quad (6)$$