HW3

2025-1 고체역학(박성훈 교수님)

Problem 2.65, 2.101, 2.103, 2.105, 3.3, 3.11, 3.55

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Problem 2.65

In a standard tensile test, an aluminum rod of 20-mm diameter is subjected to a tension force of $P = 30\,\text{kN}$. Knowing that $\nu = 0.35$ and $E = 70\,\text{GPa}$, determine (*a*) the elongation of the rod in a 150-mm gage length, (*b*) the change in diameter of the rod.

$$A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(20\,\text{mm})^2 = 100\pi\,\text{mm}^2$$

$$\delta = \frac{PL}{EA} = \frac{(30 \times 10^3)(0.15)}{(70 \times 10^9)(100\pi \times 10^{-6})}\,\text{m} = 0.205\,\text{mm} \quad \blacktriangleleft \quad (a)$$

$$\Delta d = \varepsilon_x d = -\nu\varepsilon_y d = -\frac{\nu P d}{EA} = -\frac{(0.35)(30 \times 10^3)(0.02)}{(70 \times 10^9)(100\pi \times 10^{-6})}\,\text{m} = -9.55\,\mu\text{m} \quad \blacktriangleleft \quad (b)$$

Problem 2.101

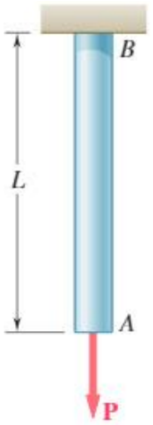

Fig. P2.101 and P2.102

The 30-mm-square bar AB has a length $L = 2.2\,\text{m}$; it is made of a mild steel that is assumed to be elastoplastic with $E = 200\,\text{GPa}$ and $\sigma_Y = 345\,\text{MPa}$. A force P is applied to the bar until end A has moved down by an amount δ_m. Determine the maximum value of the force P and the permanent set of the bar after, the force has been removed, knowing that (*a*) $\delta_m = 4.5\,\text{mm}$ (*b*) $\delta_m = 8\,\text{mm}$.

$$\delta_Y = \frac{\sigma_Y L}{E} = \frac{(345 \times 10^6)(2.2)}{200 \times 10^9}\,\text{m} = 3.795\,\text{mm}$$

In part (*a*),

$$\delta > \delta_Y \quad \Rightarrow \quad \text{(elastic situation)} \quad P_m = P_Y = \sigma_Y A = (345\,\text{MPa})(30\,\text{mm})^2 = 310.5\,\text{kN}$$

$$\delta_p = \delta_m - \delta_Y = 4.5\,\text{mm} - 3.795\,\text{mm} = 0.705\,\text{mm}$$

$$P_m = 310.5\,\text{kN}\ ;\ \delta_p = 0.705\,\text{mm} \quad \blacktriangleleft \quad (a)$$

In part (*b*),

$$\delta > \delta_Y \quad \Rightarrow \quad \text{(elastic situation)} \quad P_m = P_Y = \sigma_Y A = (345\,\text{MPa})(30\,\text{mm})^2 = 310.5\,\text{kN}$$

$$\delta_p = \delta_m - \delta_Y = 8\,\text{mm} - 3.795\,\text{mm} = 4.205\,\text{mm}$$

$$P_m = 310.5\,\text{kN}\ ;\ \delta_p = 4.205\,\text{mm} \quad \blacktriangleleft \quad (b)$$

Problem 2.103

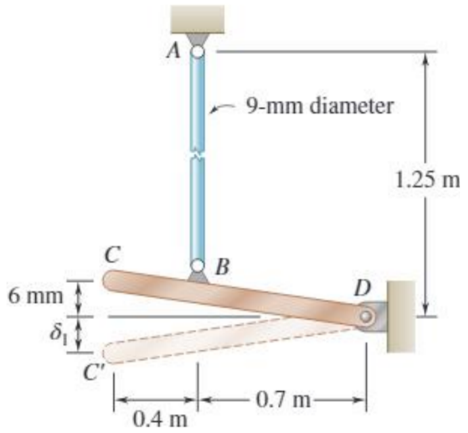

Fig. *P2.103*

Rod AB is made of a mild steel that is assumed to be elastoplastic with $E = 200\,\text{GPa}$ and $\sigma_Y = 345\,\text{MPa}$. After the rod has been attached to the rigid lever CD, it is found that end C is 6 mm too high. A vertical force Q is then applied at C until this point has moved to position C'. Determine the required magnitude of Q and the deflection δ_1 if the lever is to *snap* back to a horizontal positic sition after Q is removed.

$$\delta_p = \overline{BH} = \frac{0.7\,\text{m}}{1.1\,\text{m}}(6\,\text{mm}) = 3.81818\,\text{mm}, \qquad P = \frac{0.7\,\text{m}}{1.1\,\text{m}}Q = \frac{7}{11}Q$$

$$P_m = P_Y = \sigma_Y A = (345\,\text{MPa})\left\{\frac{\pi}{4}(9\,\text{mm})^2\right\} = 21.9480\,\text{kN}$$

$$Q_m = \frac{7}{11}P_m = 13.97\,\text{kN}$$

$$L = \overline{AB} = 1.25\,\text{m} - 3.81818\times 10^{-3}\,\text{m} = 1.246182\,\text{m}$$

$$\delta_Y = \frac{\sigma_Y L}{E} = \frac{(345\times 10^6)(1.246182)}{200\times 10^9}\,\text{m} = 2.14966\,\text{mm}$$

$$\delta_1 = \frac{11}{7}\cdot\overline{HB'} = \frac{11}{7}(\delta_m - \delta_p) = \frac{11}{7}\delta_Y = 3.38\,\text{mm}$$

$$Q_m = 13.97\,\text{kN}\ ;\ \delta_1 = 3.38\,\text{mm} \quad ◀$$

Problem 3.3

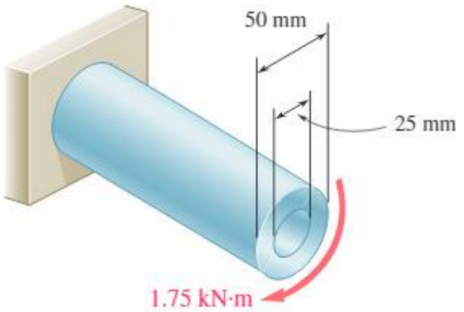

Fig. P3.3

A 1.75-kN $\cdot$ m torque is applied to the solid cylinder shown. Determine (a) the maximum shearing stress, (b) the percent of the torque carried by the inner 25-mm-diameter core.

$$J = \frac{\pi}{2}\cdot 0.025^4\,\text{m}^4 = 6.13592\times 10^{-7}\,\text{m}^4$$

$$\tau_m = \frac{Tc}{J} = \frac{(1750)(0.025)}{6.13592\times 10^{-7}}\,\text{N}\cdot\text{m} = 71.3\,\text{MPa} \quad ◀ \quad (a)$$

$$J_{\text{in}} = \frac{\pi}{2}\cdot 0.0125^4\,\text{m}^4 = \frac{1}{16}J$$

$$T = \frac{G\phi J}{L}, \quad T_{\text{in}} = \frac{G\phi J_{\text{in}}}{L} = \frac{G\phi J}{16L} = \frac{T}{16}, \quad \frac{T_{\text{in}}}{T} = \frac{1}{16} = 6.25\% \quad ◀ \quad (b)$$

Problem 3.11

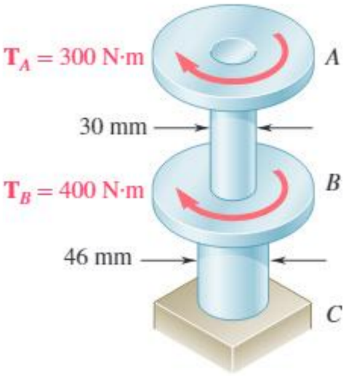

Fig. P3.11

The torques shown are exerted on pulleys A and B. Knowing that both shafts are solid, determine the maximum shearing stress in (a) shaft AB, (b) shaft BC.

$$T_{AB} = T_A = 300\,\mathrm{N \cdot m}, \quad T_{BC} = T_A + T_B = 700\,\mathrm{N \cdot m}$$

$$J_{AB} = \frac{\pi}{2} \cdot 0.015^4\,\mathrm{m}^4 = 7.95216 \times 10^{-8}\,\mathrm{m}^4$$

$$J_{BC} = \frac{\pi}{2} \cdot 0.023^4\,\mathrm{m}^4 = 4.39573 \times 10^{-7}\,\mathrm{m}^4$$

$$\tau_{m,AB} = \frac{T_{AB} c_{AB}}{J_{AB}} = \frac{(300)(0.015)}{7.95216 \times 10^{-8}}\,\mathrm{Pa} = 56.6\,\mathrm{MPa} \quad \blacktriangleleft \quad (a)$$

$$\tau_{m,BC} = \frac{T_{BC} c_{BC}}{J_{BC}} = \frac{(700)(0.023)}{4.39573 \times 10^{-7}}\,\mathrm{Pa} = 36.6\,\mathrm{MPa} \quad \blacktriangleleft \quad (b)$$

Problem 3.55

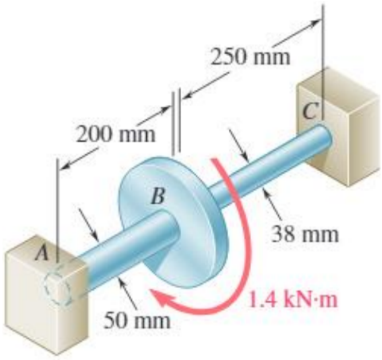

Fig. P3.55

Two solid steel shafts ($G = 77.2\,\mathrm{GPa}$) are connected to a coupling disk B and to fixed supports at A and C. For the loading shown, determine (a) the reaction at each support, (b) the maximum shearing stress in shaft AB, (c) the maximum shearing stress in shaft BC.

$$J_{AB} = \frac{\pi}{2} \cdot 0.025^4\,\mathrm{m}^4 = 6.13592 \times 10^{-7}\,\mathrm{m}^4$$

$$J_{BC} = \frac{\pi}{2} \cdot 0.019^4\,\mathrm{m}^4 = 2.04708 \times 10^{-7}\,\mathrm{m}^4$$

$$T = T_{AB} + T_{BC}, \quad T_{AB} = \frac{G\phi J_{AB}}{L_{AB}}, \quad T_{BC} = \frac{G\phi J_{BC}}{L_{BC}} \quad \Rightarrow \quad T_{AB} : T_{BC} = \frac{J_{AB}}{L_{AB}} : \frac{J_{BC}}{L_{BC}}$$

$$\left.\begin{aligned} T_{AB} &= T \cdot \frac{\frac{J_{AB}}{L_{AB}}}{\frac{J_{AB}}{L_{AB}} + \frac{J_{BC}}{L_{BC}}} = \frac{T J_{AB}}{J_{AB} + \frac{L_{AB}}{L_{BC}} \cdot J_{BC}} = 1105\,\mathrm{N \cdot m} \\ T_{BC} &= T - T_{AB} = 1400\,\mathrm{N \cdot m} - 1105.062\,\mathrm{N \cdot m} = 295\,\mathrm{N \cdot m} \end{aligned}\right\} \quad \blacktriangleleft \quad (a)$$

$$\tau_{m,AB} = \frac{T_{AB} c_{AB}}{J_{AB}} = 45.0\,\mathrm{MPa} \quad \blacktriangleleft \quad (b)$$

$$\tau_{m,BC} = \frac{T_{BC} c_{BC}}{J_{BC}} = 27.4\,\mathrm{MPa} \quad \blacktriangleleft \quad (c)$$