ENES 220 – Mechanics of Materials
Spring 2003

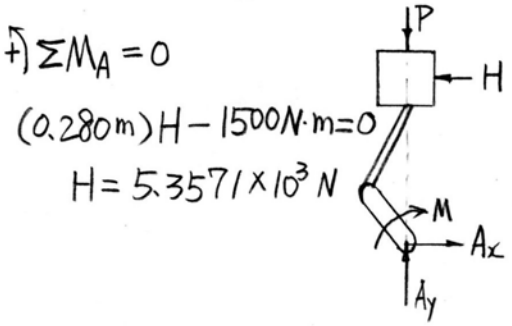
Solutions to Homework #1

Problem 1.13

$M = 1500\ N\cdot m$, $P = ?$ $\sigma_{BC} = ?$

[Solution]

Use piston, rod, and crank together as free body. Add wall reaction H and bearing reactions A_x and A_y



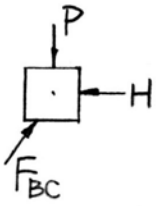
$+\circlearrowleft \Sigma M_A = 0$

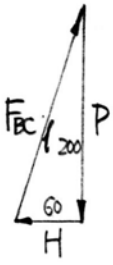
$(0.280\ m)H - 1500\ N\cdot m = 0$

$H = 5.3571 \times 10^3\ N$

Use piston alone as free body. Note that rod is a two-force member; hence, the direction of force F_{BC} is known. Draw the force triangle and solve for P and F_{BC} by proportions

$$l = \sqrt{200^2 + 60^2} = 208.81\ mm$$





(a) $\dfrac{P}{H} = \dfrac{200}{60}$

$\therefore P = \dfrac{200}{60} \times 5.3571 \times 10^3\ N = 17.86 \times 10^3\ N = \boxed{17.86\ kN}$

(b) $\dfrac{F_{BC}}{H} = \dfrac{208.81}{60}$

$\therefore F_{BC} = \dfrac{208.81}{60} \times 5.3571 \times 10^3\ N = 18.644 \times 10^3\ N = 18.644\ kN$

Rod BC is a compression member

$\therefore \sigma_{BC} = -\dfrac{F_{BC}}{A} = -\dfrac{18.644 \times 10^3\ N}{450 \times 10^{-6}\ m^2} = -41.43 \times 10^6\ N/m^2 = \boxed{-41.43\ MPa}$

Problem 1.15

$\tau = 800\ kPa, \quad L = ?$

[Solution]

There are four separate areas of glue. Each area must transmit half of the 24 kN load. Therefore,

$F = 12\ kN = 12 \times 10^3\ N$

Shearing stress in glue $\tau = 800\ kPa = 800 \times 10^3\ Pa$

$$\tau = \frac{F}{A} \quad \therefore A = \frac{F}{\tau} = \frac{12 \times 10^3\ N}{800 \times 10^3\ Pa} = 15 \times 10^{-3}\ m^2$$

Let ℓ = length of glue area and w = width = 100 mm = 0.1 m

$$A = \ell w \quad \therefore \ell = \frac{A}{w} = \frac{15 \times 10^{-3}}{0.1}\ m = 150 \times 10^{-3}\ m = 150\ mm$$

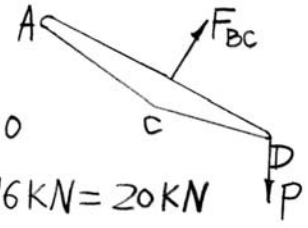
$$L = 2\ell + gap = 2 \cdot 150\ mm + 8\ mm = \boxed{308\ mm}$$

Problem 1.37

$\sigma_u = 480\ MPa, \quad P = 16\ kN, \quad F.S. = ?$

[Solution]

Use member ACD as a free body and note that member BC is a two-force member.



$+\circlearrowleft M_A = 0$

$$(480\ mm)F_{BC} - (600\ mm)P = 0$$

$$\therefore F_{BC} = \frac{600}{480}P = \frac{600}{480} \times 16\ kN = 20\ kN$$

$$\therefore \sigma_{BC} = \frac{F_{BC}}{A} = \frac{20 \times 10^3\ N}{(6\ mm)(25\ mm)} = 133.33\ N/mm^2 = 133.33\ MPa$$

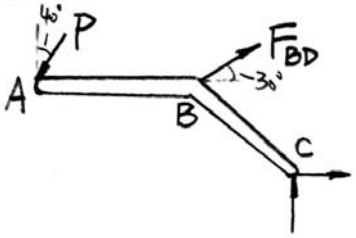
Factor of safety for BC. $F.S. = \dfrac{\sigma_u}{\sigma_{BC}} = \dfrac{480\ MPa}{133.33\ MPa} = \boxed{3.60}$

Problem 1.40

$F_u = 25$ kips, $F.S. = 3.2$, $P = ?$

[Solution]

Use member ABC as a free body and note that member BD is a two-force member



$+\circlearrowleft \sum M_C = 0$

$$(P\cos 40^\circ)(30\text{ in}) + (P\sin 40^\circ)(15\text{ in}) - (F_{BD}\cos 30^\circ)(15\text{ in}) - (F_{BD}\sin 30^\circ)(12\text{ in}) = 0$$

$$\Rightarrow P = \frac{15\cos 30^\circ + 12\sin 30^\circ}{30\cos 30^\circ + 15\sin 30^\circ} F_{BD} = 0.58216\, F_{BD}$$

Allowable load for member BD is

$$F_{BD} = \frac{F_u}{F.S.} = \frac{25 \text{ kips}}{3.2} = 7.8125 \text{ kips}$$

$\therefore$ Allowable load $P = (0.58216)(7.8125 \text{ kips}) = \boxed{4.55 \text{ kips}}$