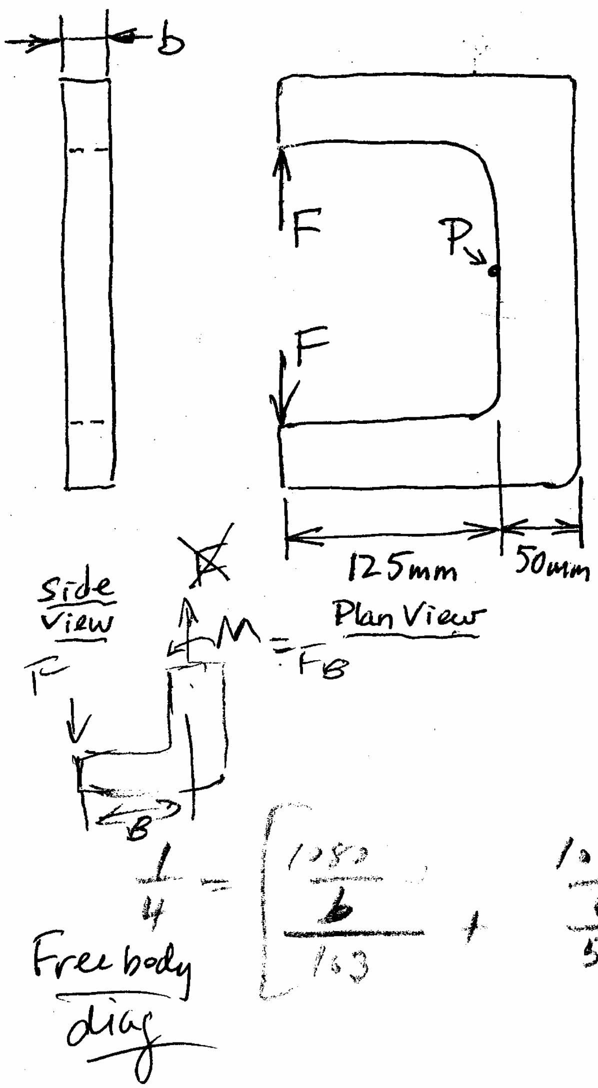
Name *MASTER*

April 7, 2003 — MAE 311 Machines and Mechanisms I — Test 2

Two 8 1/2 sheets of notes and a calculator are permitted

Time: 50 minutes

1. A C-shaped clamping device, shown below, is to be made of 50 mm wide plate and is loaded by a force, F, that fluctuates between 0 to 60 kN. What should be the thickness, b, of the clamp in order to provide a factor of 4 for an infinite life at point, P? Use a surface finish of 0.75 and a size factor of 0.87. The material (steel) has an ultimate strength of 0.5 GPa. The area moment of inertia is $bh^3/12$ where h is the width. Also, the maximum bending stress is Mc/I. (35 pts.)



$$\frac{1}{n} = \frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}}$$ (6)

$S_{ut} = 500\ MPa$ $\quad S_e' = S_{ut}/2 = 250\ MPa$

$S_e = k_a k_b k_c k_d k_e S_e' = (0.75)(0.87)(250)$

$S_e = 163\ MPa$ (10)

$F \times B$

$$\sigma_{max} = \frac{M_{max}\,c}{I} = \frac{(60{,}000\,N \times 150\,mm)(25\,mm)}{b(50\,mm)^3/12}$$ (10)

$$\sigma_{min} = \frac{M_{min}\,c}{I} = 0$$

$$\sigma_{max} = \frac{21600}{b}\ \frac{N}{mm^2} = \frac{21600}{b}\ MPa$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{10800}{b}\ MPa$$

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{10800}{b}\ MPa$$ (6)

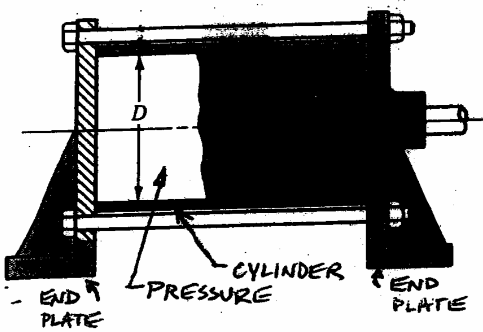
$$\frac{1}{4} = \left[\frac{\frac{1080}{b}}{163} + \frac{\frac{1080}{b}}{500}\right]$$

$b = 25.6 + 8.64$

$b = 34.2\ mm$ (3)

2. The hydraulic cylinder shown below is held together by four 3/8 inch diameter SAE grade 5 coarse bolts with a proof strength of 85kpsi. The tensile area is 0.078 square inches. They are tightened to a preload of 75% of the proof load. The stiffness of <u>each</u> bolts is 0.245 Mlb/in and the cylinder has a <u>total</u> stiffness of 10 Mlb/in. Will the bolts fail or will the joints separate first? Justify your answer. (Assume the end plates to be completely rigid.) (30 pts).

as pressure increases



Bolt Failure

(5) $n = \dfrac{S_p A_t - F_i}{CP}$

Separation

$n = \dfrac{F_i}{(1-c)P}$ (5)

$F_i = 0.75 S_p A_t = 4973\text{ lb}$ (4)

$c = \dfrac{k_b}{k_b + k_m} = \dfrac{0.245}{0.245 + \frac{10}{4}} = 0.09$ (5)

per bolt

Bolt Failure

$nP = \dfrac{6630 - 4973}{0.09P}$

$n = \dfrac{1848}{P}$ (3) $>$

larger n @ same P

Separation

$n = \dfrac{4973}{(1-0.09)P}$

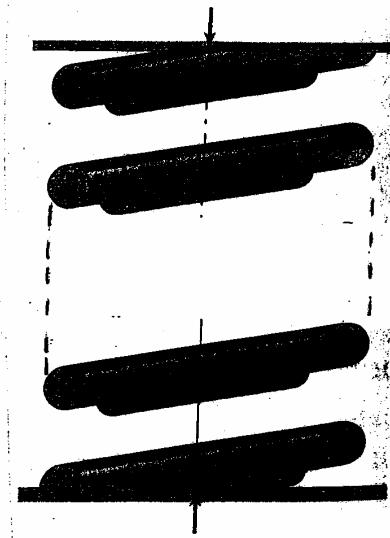
$n = \dfrac{5465}{P}$ (3)

Smaller n

∴ Separate before yield (5)

3. A nested two-spring arrangement is shown below. The outer spring has a wire diameter of 2mm and an outside diameter of 22mm. The inner spring has a 1.4mm wire diameter and a 15.4 mm outside diameter. Both springs have 16 coils and are made of steel with a shear modulus of 80 GPa. Which spring sees the higher shear stress? (Note that both springs undergo identical deflections.)(35 pts).

IF YOU ASSUME $F_o = F_i = F$ (−12)



(8)

outer → τ_o, inner → τ_i

$$\frac{\tau_o}{\tau_i} = \frac{\dfrac{K_{s_o} F_o D_o}{\pi d_o^3}}{\dfrac{K_{s_i} F_i D_i}{\pi d_i^3}}$$

$$C_o = \left(\frac{D}{d}\right)_o = \left(\frac{22-2}{2}\right) = 10 \quad \text{if} \quad D_o = 20,\ d_o = 2$$

$$C_i = \left(\frac{D}{d}\right)_i = \left(\frac{15.4-1.4}{1.4}\right) = 10 \quad \text{if} \quad D_i = 14,\ d_i = 1.4$$

(6)

$$K_s = \frac{2C+1}{2C} \quad \therefore K_{s_o} = K_{s_i}$$

(4)

$$\frac{\tau_o}{\tau_i} = \frac{F_o D_o}{d_o^3} \cdot \frac{d_i^3}{F_i D_i} \quad \text{\&} \quad F_o = k_o \delta \quad F_i = k_i \delta$$

$$\text{and} \quad \frac{F_o}{k_o} = \frac{F_i}{k_i} \quad \therefore \frac{F_o}{F_i} = \frac{k_o}{k_i}$$

$$\frac{F_o}{F_i} = \frac{d_o^4 G}{8 D_o^3 N} \Big/ \frac{d_i^4 G}{8 D_i^3 N} = \frac{d_o^4}{D_o^3} \cdot \frac{D_i^3}{d_i^4}$$

(12)

$$\therefore \frac{\tau_o}{\tau_i} = \frac{D_o}{d_o^3} \cdot \frac{d_i^3}{D_i} \cdot \frac{d_o^4}{D_o^3} \cdot \frac{D_i^3}{d_i^4}$$

$$= \frac{d_o D_i^2}{D_o^2 d_i} = \frac{2(14)^2}{(20)^2 (1.4)}$$

$$\frac{\tau_o}{\tau_i} = 0.7$$

⟶ (5) Stress on outer spring is 70% of stress on inner spring ∴ ⟶ HIGHER