Q1) The rigid beam AD is supported by a steel wire CF, a brass link BE, and a hinge at A, as shown in Figure 1. The beam is in the horizontal position before the load P is applied. The moduli of elasticity are: for steel $E_{st} = 210$ GPa; for brass, $E_{br} = 105$ GPa. The cross-sectional area are: for the steel wire, $A_{st} = 0.00015$ m$^2$; for the brass link, $A_{br} = 0.0018$ m$^2$. The dimensions indicated are the undeformed lengths before the load is applied. Find the stresses in the wire and the link.

Q2) In the figure 2 that is shown, a machine shaft of uniform cross-section having a diameter of $d = 3$ in. is subjected to the torsional loads shown. Find the maximum shear stress in the shaft.

Q3) A steel cylinder fits loosely in a copper tube, as shown in Figure 3. The length of the steel cylinder is 0.001 in. longer than the copper tube. Determine the stresses in the solid steel cylinder and in the copper tube caused by an axial force P of 55 kips applied on the rigid cap. The moduli of elasticity are: for steel, $E_{st} = 30 \times 10^3$ ksi; for Ecu = 17x10$^3$ ksi.

Q4) In the structure shown, a 8-mm diameter pin is used at A, and 12-mm-diameter pins are used at B and D. Knowing that the ultimate shearing stress is 100 MPa at all connections and that the ultimate normal stress is 250 MPa in each of the two links joining B and D, determine the allowable load P if an overall factor of safety of 3.0 is desired.

Time Left: 100 minutes
Good Luck!
Dr. M. Evren Toygar
\[ \sum M_A = 0 = F \text{ (0.5)} + T \text{ (1.0)} - 50 \times 1.5 = 0 \]

\[ 0.5F + T = 75 \]

Deformation Condition:

Since the beam is rigid:

\[ \sum \delta_c = 2 \sum \delta_{BE} \text{ or } \]

\[ \frac{T \delta_c}{A_{BR} E_{BR}} = 2 \frac{F \delta_{BE}}{A_{BR} E_{BR}} \]

\[ \frac{T \times 0.5}{(0.00015)(210 \times 10^6)} = \frac{2F \times 0.5}{(0.0018)(105 \times 10^6)} \]

\[ 25.4T = 5.29F \]

\[ F = 4.80 \quad T \]

By substituting \(2\) into \(1\) gives:

\[ 0.5 \times (4.80T) + T = 75 \]

\[ T = 22.1 \text{ kN (Tension)} \]

\[ F = 105.9 \text{ kN (Compression)} \]

\[ \sigma_{BE} = \frac{T}{A_{BR}} = \frac{22.1 \text{ kN}}{0.00015 \text{ m}^2} = 147300 \text{ kPa} = 147.3 \text{ MPa (T)} \]

\[ \sigma_{BR} = \frac{F}{A_{BR}} = \frac{105.9 \text{ kN}}{0.0018 \text{ m}^2} = 58800 \text{ kPa} = 58.8 \text{ MPa (C)} \]
(a2)

\[ \tau_{AB} = -3 \text{ kip-ft} \]
\[ \tau_{BC} = -8 \text{ kip-ft} \]
\[ \tau_{CD} = 4 \text{ kip-ft} \]

\[ |\tau_{BC}| = 8 \text{ kip-ft} = 96 \text{ kip-in} \]

Polar moment of inertia of the cross-section of the shaft is

\[ J = \frac{\pi d^4}{32} = \frac{\pi (3in)^4}{32} = 7.95 \text{ in}^4 \]

\[ \tau_{\text{max}} = \frac{\tau_C}{J} = \frac{(86 \text{ kip-in}) (1.5 \text{ in})}{7.95 \text{ in}^4} = 18.4 \text{ kip-in} \]
83) Assume: the given force \( P \) is large enough to close the gap. After gap is closed, the copper tube will also be compressed and carry part of the load.

**Setup**

**Equilibrium:**

\[ \sum F_y = P_{st} + P_{cu} - 55 = 0 \]

\[ P_{cu} = 55 - P_{st} \]  \( \text{(1)} \)

**Axial deformation in the steel:**

\[ \sigma_{st} = \sigma_{cu} + 0.004 \] or

\[ \frac{P_{st} \cdot L_{st}}{A_{st} \cdot E_{st}} = \frac{P_{cu} \cdot L_{cu}}{A_{cu} \cdot E_{cu}} + 0.004 \]  \( \text{(2)} \)

The cross-sectional area:

\[ A_{st} = \frac{1}{4} \pi d_{st}^2 = \frac{1}{4} \pi (2.5)^2 = 4.91 \text{ in}^2 \]

\[ A_{cu} = \frac{1}{4} \pi (d_{cu}^2 - d_{st}^2) = \frac{1}{4} \pi (4^2 - 2.625^2) = 7.15 \text{ in}^2 \]

**Eqn 2 becomes:**

\[ \frac{P_{st} (8,001)}{(4.91)(30,000)} = \frac{P_{cu} (8,000)}{(7.15)(12,000)} + 0.004 \]

\[ 0.543 P_{st} - 0.658 P_{cu} = 10 \]  \( \text{(3)} \)

By substituting Eq (1) into Eq (3) gives

\[ 0.543 P_{st} - 0.658 (55 - P_{st}) = 10 \]

\[ P_{st} = 38.5 \text{ kips}. \]

\[ P_{cu} = 16.5 \text{ kips}. \]

\[ \sigma_{st} = \frac{P_{st}}{A_{st}} = \frac{38.5 \text{ kips}}{4.91 \text{ in}^2} = 7.84 \text{ ksi} \]  \( \text{(C)} \)

\[ \sigma_{cu} = \frac{P_{cu}}{A_{cu}} = \frac{16.5 \text{ kips}}{7.15 \text{ in}^2} = 2.34 \text{ kips/in}^2 \]
Stokes: Use ABC as free body

Based on double shear in pin A

\[ A = \frac{\pi}{4} d^4 = \frac{\pi}{4} (0.008)^2 = 50.266 \times 10^{-6} \text{ m}^2 \]

\[ F_A = \frac{2 \sigma_u A}{F.S.} = \frac{(2)(100 \times 10^6)(50.266 \times 10^{-6})}{3.0} = 3.35 \times 10^3 \text{ N} \]

\[ P = \frac{10}{9} F_A = 3.72 \times 10^3 \text{ N} \]

Based on double shear in pins at B and D

\[ A = \frac{\pi}{4} d^2 = \frac{\pi}{4} (0.012)^2 = 113.10 \times 10^{-6} \text{ m}^2 \]

\[ F_{BD} = \frac{2 \sigma_u A}{F.S.} = \frac{(2)(100 \times 10^6)(113.10 \times 10^{-6})}{3.0} = 7.54 \times 10^3 \text{ N} \]

\[ P = \frac{10}{19} F_{BD} = 3.97 \times 10^3 \text{ N} \]

Based on compression in links BD

For the link

\[ A = (0.020)(0.008) = 160 \times 10^{-6} \text{ m}^2 \]

\[ F_{BD} = \frac{2 \sigma_u A}{F.S.} = \frac{(2)(250 \times 10^6)(160 \times 10^{-6})}{3.0} = 26.7 \times 10^2 \text{ N} \]

\[ P = \frac{10}{19} F_{BD} = 14.04 \times 10^3 \text{ N} \]

Allowable value of \( P \) is smallest \( \cdot \)

\[ P = 3.72 \times 10^3 \text{ N} \]

\[ P = 3.72 \text{ kN} \]