INDIAN INSTITUTE OF TECHNOLOGY HYDERABAD

Department of Mechanical and Aerospace Engineering

Take Home - 2

Time: Take Home	**ME1050: Basics of Mech Engg - I (2021-22)**
Date: 22-12-21	**Instructor: Dr. M. Ramji**

1. A hollow circular post ABC (see Fig. 1) supports a load P_1 = 7.5 kN acting at the top. A second load P_2 is uniformly distributed around the cap plate at B. The diameters and the thickness of the upper and the lower parts of the post are d_{AB} = 32 mm, t_{AB} = 12 mm, d_{BC} = 57 mm, and t_{BC} = 9 mm, respectively.

i) Calculate the normal stress σ_{AB} in the upper part of the post.

ii) If it is desired that the lower part of the post have the same compressive stress as the upper part, what should be the magnitude of the load P_2?

iii) If P_1 remains at 7.5 kN and P_2 is now set at 10 kN, what new thickness of BC will result in the same compressive stress in both parts?

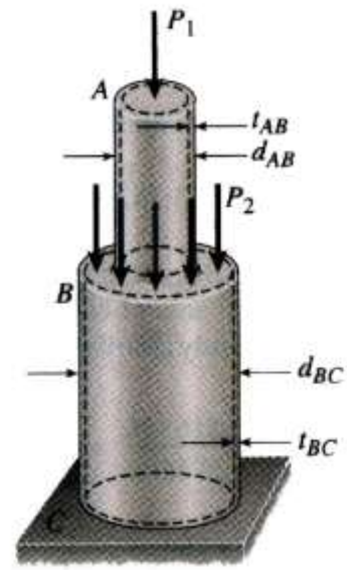


Fig. 1 Circular Post ABC

Soln: σ_{AB} = 9.95 MPa; P_2 = 6 kN ;

2. A round bar ACB of length 2L (see Fig. 2) rotates about an axis through the midpoint C with constant angular speed per second). The material of the bar has weight density .

(a) Derive a formula for the tensile stress σ_x in the bar as a function of the distance x from the midpoint C.

(b) What is the maximum tensile stress σ_{max}?

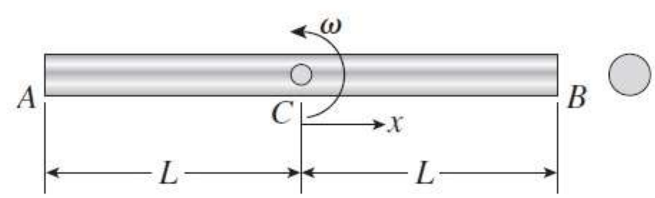


Fig 2 Round bar

Soln: $\sigma_x = \gamma\omega^2(L^2-x^2)/2g$; $\sigma_{max} = \gamma\omega^2L^2/2g$

3. A pressurized circular cylinder has a sealed cover plate fastened with steel bolts (see Fig. 3). The pressure p of the gas in the cylinder is 1900 kPa, the inside diameter D of the cylinder is 250 mm, and the diameter d_B of the bolts is 12 mm. If the allowable tensile stress in the bolts is 70 MPa, find the number of bolts needed to fasten the cover.

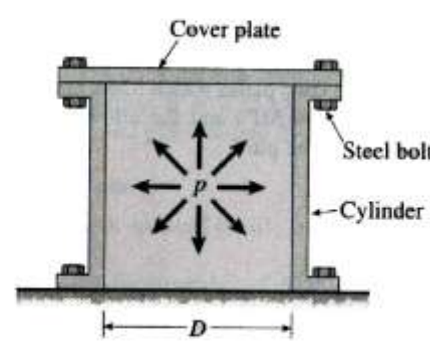


Fig 3 Pressurized Cylinder

Soln: No of bolts = 12

4. A ship's spar is attached at the base of a mast by a pin connection (see Fig. 4). The spar is a steel tube of outer diameter d_2 = 80 mm and inner diameter d_1 = 70 mm. The steel pin has diameter d = 25 mm, and the two plates connecting the spar to the pin have thickness t = 12 mm.
The allowable stresses are as follows: compressive stress in the spar, 70 MPa; shear stress in the pin, 45 MPa; and bearing stress between the pin and the connecting plates, 110 MPa. Determine the allowable compressive force P_{allow} in the spar.

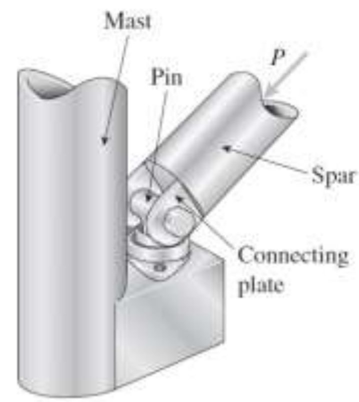


Fig 4 Spar Joint

Soln: P_{allow} = 44.2 kN.

Soln 1

Sol. A)
σAB = P / AC/S = [7.5 x 103] / [π/4 x (322 - 82)]

= 9.95 N/mm2   (MPa)

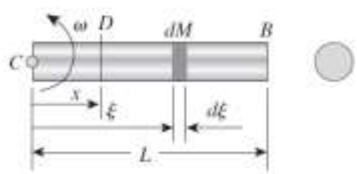
Sol. B)
σBC = (P1+ P2) / AC/S = σAB

(7.5 + P2) x 103 / [π/4 x (572 - 392)] = 9.95 N/mm2

P2 = 6 kN

Soln.2

Solution   **Rotating Bar**



ω = angular speed (rad/s)

A = cross-sectional area

γ = weight density

$\frac{\gamma}{g}$ = mass density

We wish to find the axial force F_x in the bar at Section D, distance x from the midpoint C.

The force F_x equals the inertia force of the part of the rotating bar from D to B.

Consider an element of mass dM at distance ξ from the midpoint C. The variable ξ ranges from x to L.

$$dM = \frac{\gamma}{g} A \, d\xi$$

dF = Inertia force (centrifugal force) of element of mass dM

$$dF = (dM)(\xi\omega^2) = \frac{\gamma}{g} A\omega^2 \xi d\xi$$

$$F_x = \int_D^B dF = \int_x^L \frac{\gamma}{g} A\omega^2 \xi d\xi = \frac{\gamma A \omega^2}{2g}(L^2 - x^2)$$

(a) Tensile stress in bar at distance x

$$\sigma_x = \frac{F_x}{A} = \frac{\gamma\omega^2}{2g}(L^2 - x^2) \longleftarrow$$

(b) Maximum tensile stress

$$x = 0 \quad \sigma_{max} = \frac{\gamma\omega^2 L^2}{2g} \longleftarrow$$

Soln. 3

Total Force Acting On The Cover Plate Due To Gas Pressure

$F = p$ x (π/4 x D^2)
 = 1.9 x (π/4 x 250^2)
F = 93266.032 N

Stress in one bolt, $\sigma = F$ / [N (π/4 x $d^2{}_B$)]
 = 93266.032 / [N (π/4 x 12^2)]
σ = 824.6528 / N

Now, $\sigma \leq \sigma_{allow}$

Under limiting case,

$\sigma = \sigma_{allow}$

824.6528 / N = 70

N = 11.8

Use 12 number of bolts.

Soln. 4

Solution **Pin connection for a ship's spar**

Spar: $d_2 = 80\,\text{mm}$

$d_1 = 70\,\text{mm}$

Pin: $d = 25\,\text{mm}$

Plates: $t = 12\,\text{mm}$

ALLOWABLE LOAD P BASED UPON COMPRESSION IN THE SPAR

$\sigma_c = 70\,\text{MPa}$

$$A_c = \frac{\pi}{4}(d_2^2 - d_1^2) = \frac{\pi}{4}[(80\text{ mm})^2 - (70\text{ mm})^2]$$

$$= 1178.1\text{ mm}^2$$

$$P_1 = \sigma_c A_c = (70\text{ MPa})(1178.1\text{ mm}^2) = 82.5\text{ kN}$$

ALLOWABLE LOAD P BASED UPON SHEAR IN THE PIN (DOUBLE SHEAR)

$\tau_{\text{allow}} = 45\text{ MPa}$

$$A_s = 2\left(\frac{\pi d^2}{4}\right) = \frac{\pi}{2}(25\text{ mm})^2 = 981.7\text{ mm}^2$$

$$P_2 = \tau_{\text{allow}} A_s = (45\text{ MPa})(981.7\text{ mm}^2) = 44.2\text{ kN}$$

ALLOWABLE LOAD P BASED UPON BEARING

$\sigma_b = 110\text{ MPa}$

$$A_b = 2dt = 2(25\text{ mm})(12\text{ mm}) = 600\text{ mm}^2$$

$$P_3 = \sigma_b A_b = (110\text{ MPa})(600\text{ mm}^2) = 66.0\text{ kN}$$

ALLOWABLE COMPRESSIVE LOAD IN THE SPAR

Shear in the pin governs.

$P_{\text{allow}} = 44.2\text{ kN}$ ⟵