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FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Mechanical Engineering

MEPS102:Strength of Material

Lecture 24

Topic:Beams with axial loads, Combined torsion and bending

Instructor:

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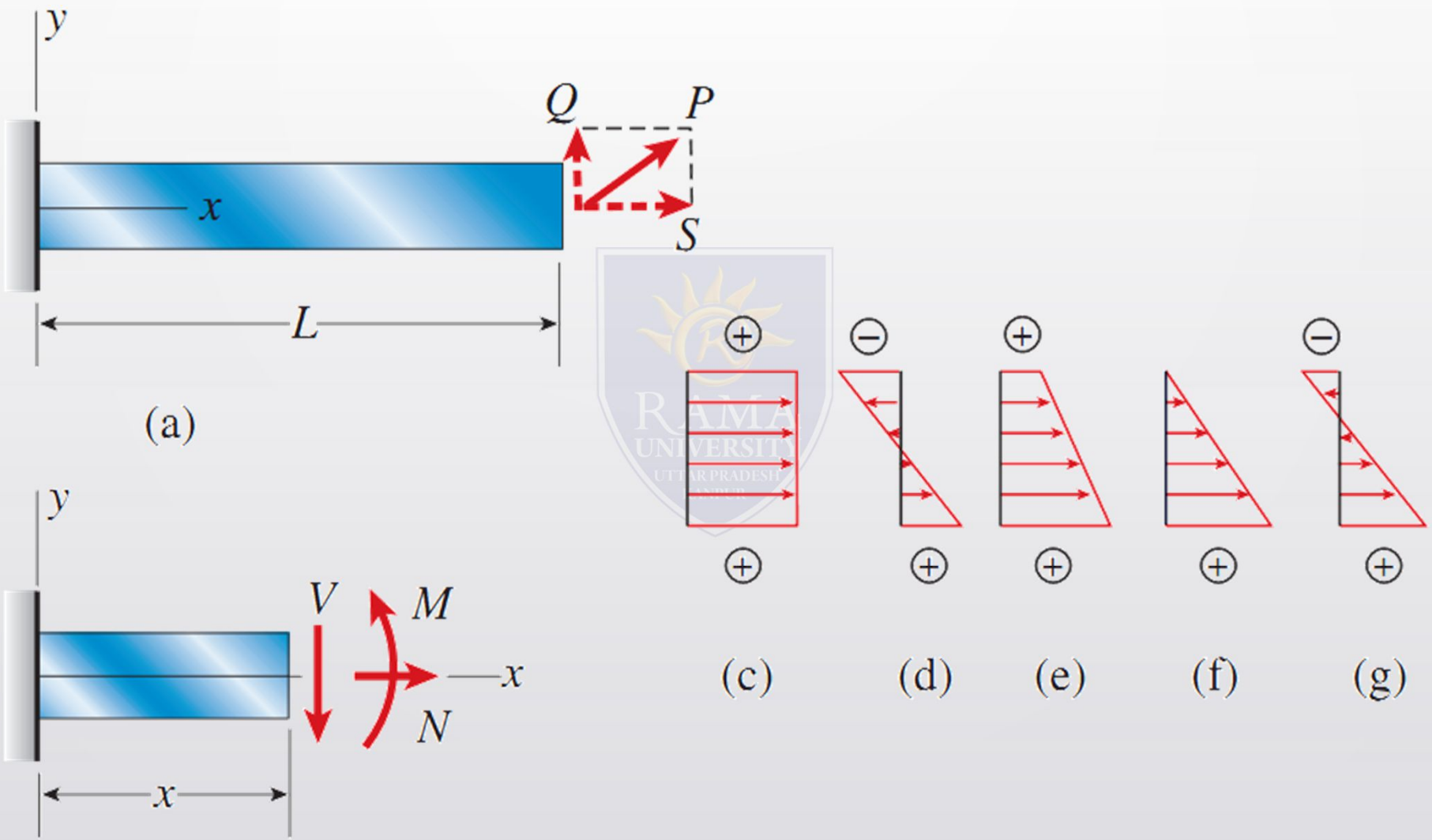
Beam with axial Load

- Structural members are often subjected to the simultaneous action of bending loads and axial Loads. This happens, for instance, in aircraft frames, columns in buildings, machinery, parts of ships, and spacecraft.
- Both the axial force N and bending moment M produce normal stresses, we need to combine those stresses to obtain the final stress distribution.
- The **axial force**(when acting alone) produces a uniform stress distribution $\boldsymbol{\sigma} = {}^{N}/_{A}$ over the entire cross section
- The **bending moment** produces a linearly varying stress $\boldsymbol{\sigma} = -\frac{My}{I}$ with compression on the upper part of the beam and tension on the lower part.
- Thus, the equation for the combined stresses is

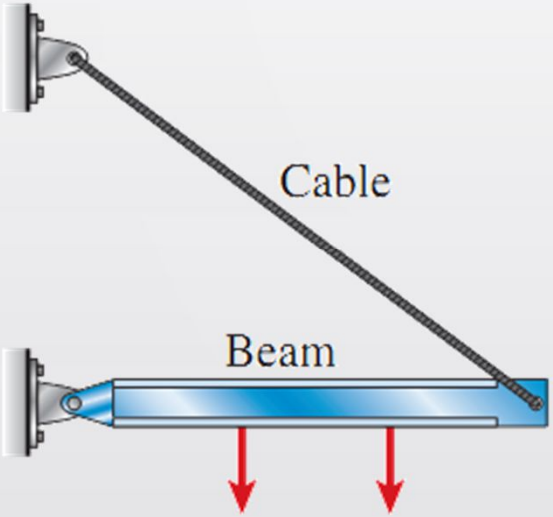
$$\boldsymbol{\sigma} = \frac{N}{A} - \frac{My}{I}$$

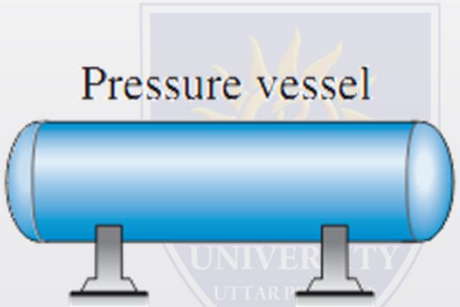
Beam with axial Load

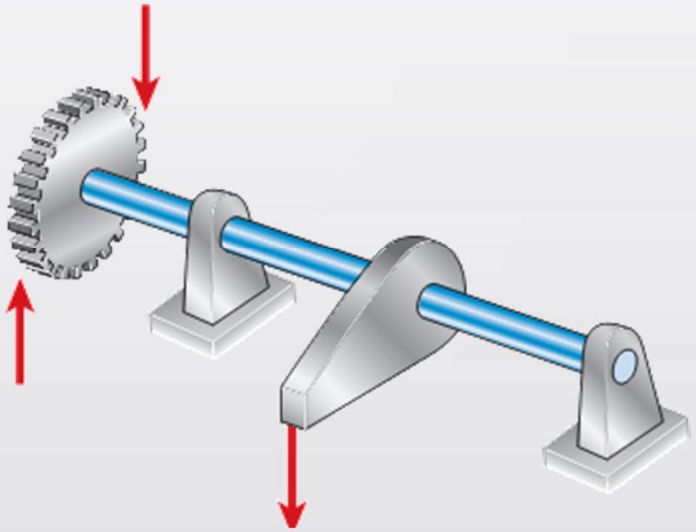


Combined Loading

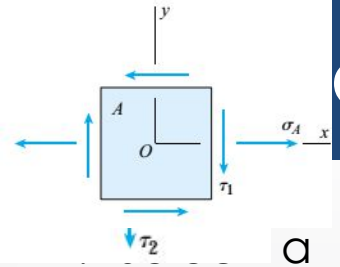
- ✓ When shaft is transmitting torque or power, it is subjected to shear stresses. At the same time the shaft is also subjected to bending moments due to gravity or inertia loads.







- wide-flange beam supported by a cable (combined bending and axial load), cylindrical pressure vessel supported as a beam, and shaft in combined torsion and bending



Combined loading : Method of Analysis

a point in the structure where the stresses and strains are to be determined. (The point is usually selected at a cross section where the stresses are large, such as at a cross section where the bending moment has its maximum value.)

2. For each load on the structure, determine the stress resultants at the cross section containing the selected point. (The possible stress resultants are an axial force, a twisting moment, a bending moment, and a shear force.)

3. Calculate the normal and shear stresses at the selected point due to each of the stress resultants. Also, if the structure is a pressure vessel, determine the stresses due to the internal pressure. (The stresses are found from the stress formulas derived previously.

4. Combine the individual stresses to obtain the resultant stresses at the selected point. In other words, obtain the stresses σx, σy, and τxy acting on a stress element at the point. (Note that in this chapter we are dealing only with elements in plane stress.)

Combined loading : Method of Analysis

5. Determine the principal stresses and maximum shear stresses at the selected point, using either the stress-transformation equations or Mohr's circle. If required, determine the stresses acting on other inclined planes.

6. Determine the strains at the point with the aid of Hooke's law for plane stress.

7. Select additional points and repeat the process. Continue until enough stress and strain information is available to satisfy the purposes of the analysis.

Question

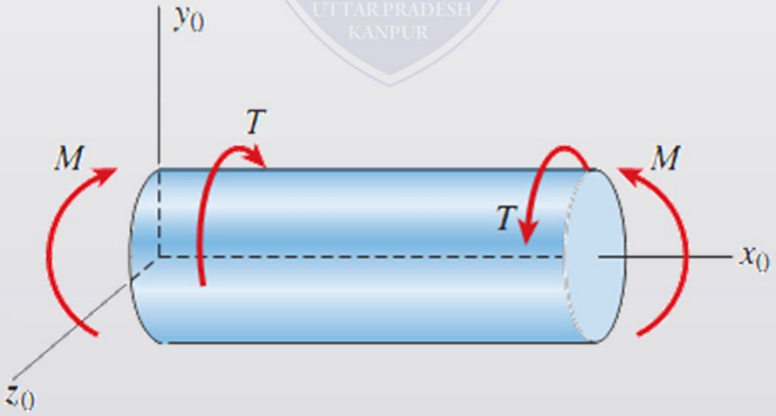
8.5-1 A cylindrical tank having diameter $d = 60$ mm is subjected to internal gas pressure $p = 4$ MPa and an external tensile load $T = 4.5$ kN (see figure).

Determine the minimum thickness t of the wall of the tank based upon an allowable shear stress of 20 MPa.

Question

8.5-5 A cylindrical pressure vessel with flat ends is subjected to a torque T and a bending moment M (see figure). The outer radius is 300 mm and the wall thickness is 25 mm. The loads are as follows: $T = 90\ \text{kN} \cdot \text{m}$, $M = 100\ \text{kN} \cdot \text{m}$, and the internal pressure $p = 6.25\ \text{MPa}$.

Determine the maximum tensile stress σ_t, maximum compressive stress σ_c, and maximum shear stress τ_{max} in the wall of the cylinder.

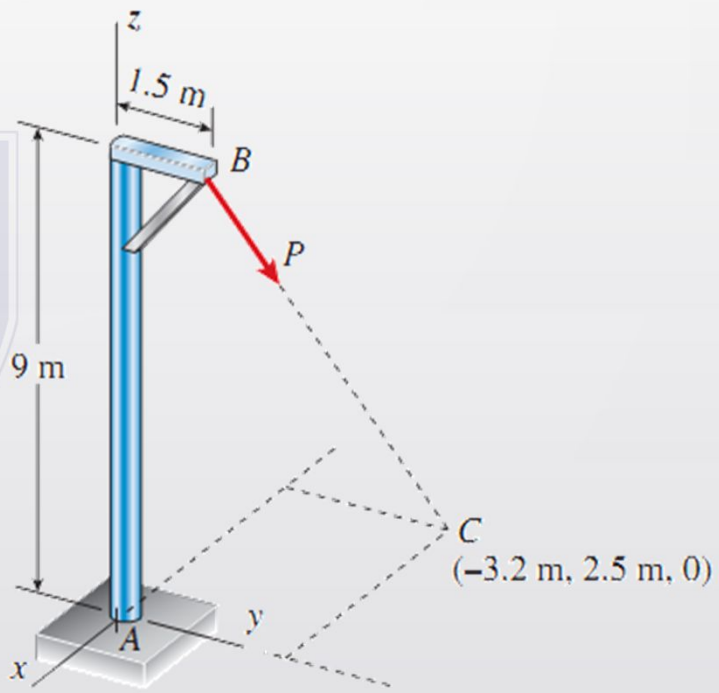


Question

8.5-10 A post having a hollow, circular cross section supports a load $P = 3.2$ kN acting at the end of an arm that is $b = 1.5$ m long (see figure). The height of the post is $L = 9$ m, and its section modulus is $S = 2.65 \times 10^5$ mm^3. Assume that the outer radius of the post is $r_2 = 123$ mm, and the inner radius is $r_1 = 117$ mm.

(a) Calculate the maximum tensile stress σ_{max} and maximum in-plane shear stress τ_{max} at point A on the outer surface of the post along the x axis due to the load P. Load P acts at B along line BC.

(b) If the maximum tensile stress and maximum inplane shear stress at point A are limited to 90 MPa and 38 MPa, respectively, what is the largest permissible value of the load P?

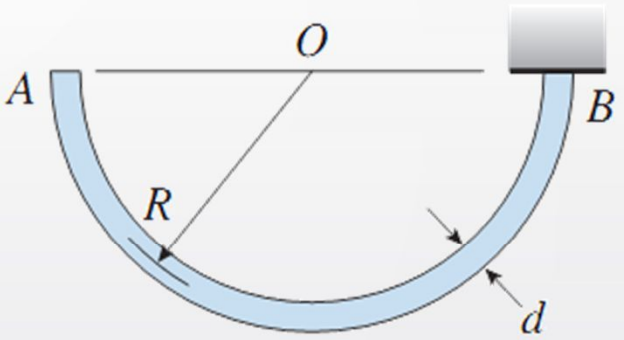


Question

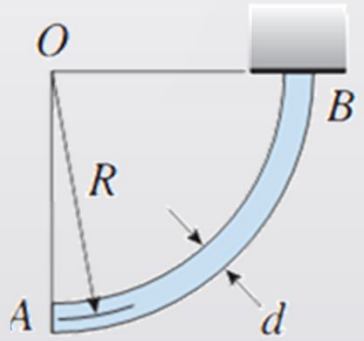
8.5-16 A semicircular bar AB lying in a horizontal plane is supported at B (see figure part a). The bar has centerline radius R and weight q per unit of length (total weight of the bar equals πqR). The cross section of the bar is circular with diameter d.

(a) Obtain formulas for the maximum tensile stress σ_t, maximum compressive stress σ_c, and maximum in-plane shear stress τ_{max} at the top of the bar at the support due to the weight of the bar.

(b) Repeat part (a) if the bar is a quarter-circular segment (see figure part b) but has the same total weight as the semicircular bar.



(a)



(b)

Question

8.5-17 An L-shaped bracket lying in a horizontal plane supports a load $P = 600$ kN (see figure). The bracket has a hollow rectangular cross section with thickness $t = 4$ mm and outer dimensions $b = 50$ mm and $h = 90$ mm. The centerline lengths of the arms are $b_1 = 500$ mm and $b_2 = 750$ mm.

Considering only the load P, calculate the maximum tensile stress σ_t, maximum compressive stress σ_c, and maximum shear stress τ_{max} at point A, which is located on the top of the bracket at the support.