Problems

2.1 A steel rod of varying cross-section is loaded as shown in Fig. 2.17. Determine where the maximum stress occurs.

2.2 It is required to make a large concrete foundation block which, when supporting a comprehensive load together with its self-weight, will have the same compressive stress at all cross-sections. Determine a suitable profile.

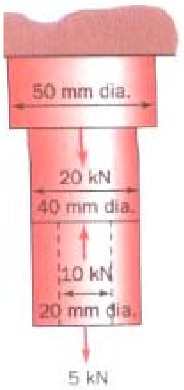
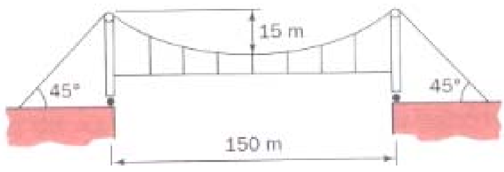


Fig. 2.17

2.3 The two parabolic cables of a suspension bridge are subjected to a horizontal uniformly-distributed load of 80 kN/m as shown in Fig. 2.18. Calculate the required area of the cables at each end if their maximum permissible stress is 200 MN/m^2. What is the compressive load in the vertical columns?

2.4 A suspension footbridge spanning a ravine is constructed with twin cables and carries a horizontal uniformly-distributed loading of 2 kN/m of span, which is 300 m. The lowest point of the cables is 50 m below one cliff support, which is 10 m below the higher cliff support. Determine a suitable cross-sectional area for each cable using a safety factor of 2 and a tensile stress of 300 MN/m^2.

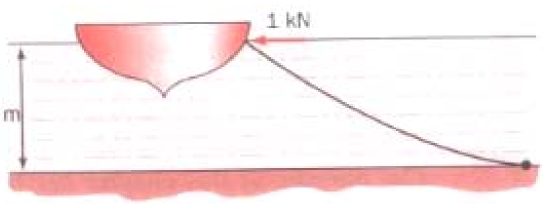
Fig. 2.18



2.5 A cable is freely suspended from two points which are at the same horizontal level. If the cable is subjected to a uniformly-distributed loading of w per unit length (self-weight, snow, birds), derive an expression for the maximum tension in the cable.

2.6 A small boat is anchored as shown in Fig. 2.19. When the tide causes a horizontal force of 1 kN on the boat the steel rope is tangential at the anchor point. If the rope diameter is 20 mm calculate (*a*) the distance between the boat and the anchor point, and (*b*) the maximum stress in the rope. The density of the steel is 7800 kg/m^3 and the density of the water is 1000 kg/m^3.

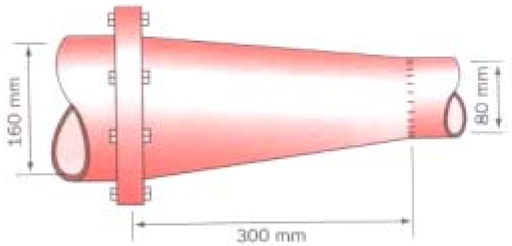
Fig. 2.19



2.7 A chemical reaction process is carried out in a thin-walled steel cylinder of internal diameter 400 mm with closed ends rotated about a longitudinal axis at a speed of 5000 rev/min. Whilst it is rotating, it is subjected to an internal pressure of 4 MN/m^2. If the maximum allowable tensile stress in any direction in the material is 175 MN/m^2, calculate a suitable shell thickness. Density of steel = 7.83 Mg/m^3.

2.8 The pineline reducer shown in Fig. 2.20 has a uniform wall thickness of 3 mm. If the pipeline carries a fluid at a pressure of 0.7 Mg/m^3, calculate the axial and hoop stresses in the reducer at a point halfway along its length. Assuming that the coupling at the large end of the reducer takes all the axial thrust, calculate the stress in each of the six 10 mm diameter retaining bolts.

Fig. 2.20

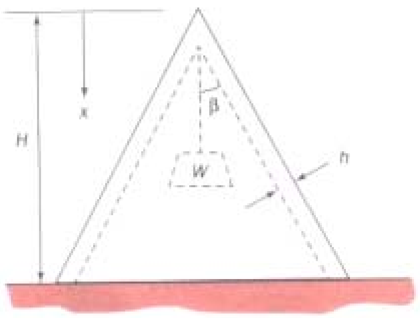


2.9 A thin spherical steel vessel is made up of two hemispherical portions bolted together at flanges. The inner diameter of the sphere is 300 mm and the wall thickness of 6 mm. Assuming that the vessel is a homogeneous sphere, what is the maximum working pressure for an allowable tensile stress in the shell of 150 MN/m^2?

If twenty bolts of 16 mm diameter are used to hold the flanges together, what is the tensile stress in the bolts when the sphere is under full pressure?

2.10 A thin wall conical shell supports a weight W as shown in Fig. 2.21. Derive an expression for the stress in the wall of the cone.

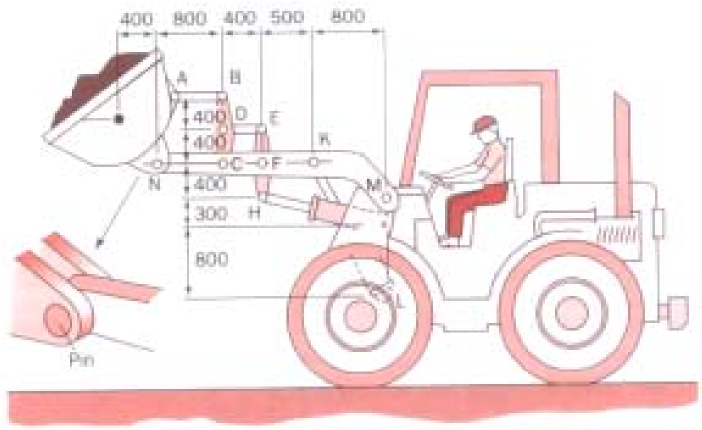
Fig. 2.21



2.11 A conical storage tank has a wall thickness of 20 mm and an apex angle of 60°. If the vessel is filled with water to a depth of 3 m, calculate the maximum meridional and circumferential stresses. The water loading is 9.81 kN/m^3.

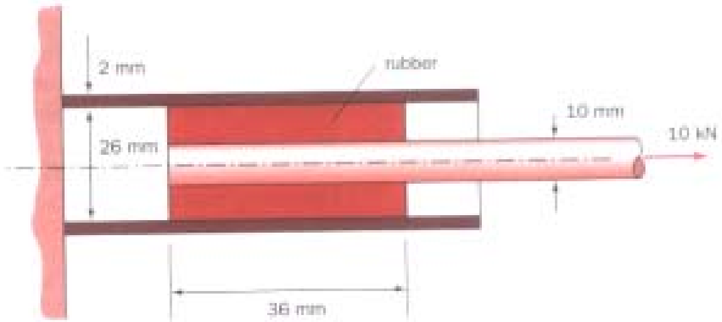
2.12 In the mechanical digger shown in Fig. 2.22 the combined weight of the bucket and its contents is 1000 kg and the centre of gravity is at G. For the position shown in which the arm NKM is horizontal, calculate the shear stress in the pins at N and M. The inset sketch shows the joint arrangement in each case, and the pin diameters at N and M are 10 mm and 15 mm respectively.

Fig. 2.22



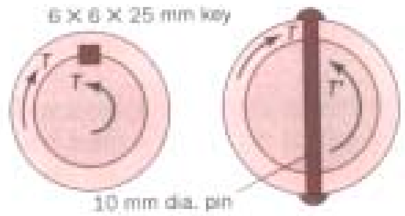
2.13 A solid circular rod of 10 mm diameter is coupled to a metal tube using a bonded rubber cylinder as shown in Fig. 2.23. If an axial pull of 10 kN is applied to the rod, calculate (*a*), the shear stress between the rod and the rubber, (*b*) the shear stress between the rubber and the metal tube, and (*c*) the axial stress in the tube.

Fig. 2.23



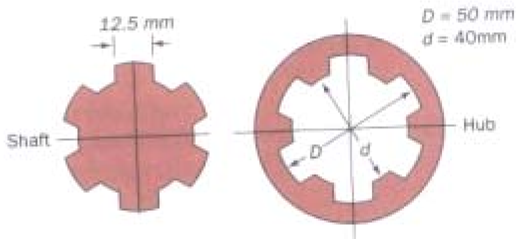
2.14 The hub of a pulley may be fastened to a 25 mm diameter shaft either by a square key or by a pin, as shown in Fig. 2.24. Determine the torque that each connection can transmit if the average shear stress in the key or pin is not to exceed 70 MN/m^2.

Fig. 2.24



2.15 A splined shaft connection as shown in Fig. 2.25 is 50 mm long and is used to permit axial movement of the shaft relative to the hub during torque transmission. In order to facilitate axial movement in the connection it is to be desgned so that the side pressure on the splines does not exceed 7 MN/m^2. Calculate the power that could be

Fig. 2.25



transmitted by the shaft at 2000 rev/min and the shear stress in the splines at this power.

2.16 Extend the spreadsheet of Example 2.1 to calculate the torque about the crankshaft due to the gas pressure.

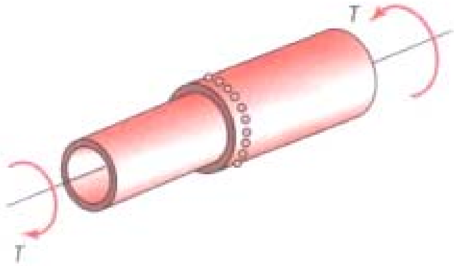
2.17 A thin-walled circular tube of 50 mm mean radius is required to transmit 300 kW at 500 rev/min. Calculate a suitable wall thickness so that the shear stress does not exceed 80 MN/m^2.

2.18 (*a*) Construct a spreadsheet in which, given the applied torque on a thin tube, its radius and wall thickness, the resulting shear stress is calculated.

(*b*) Solve Problem 2.17 by trial and error. In other words try different values of wall thickness until the stress under the applied torque is approximated 80 MN/m^2.

2.19 A torque tube consists of two sections which are riveted together, as in Fig. 2.26, by 50 rivets of 4 mm diameter pitched uniformly and the radius of the mating surface of the tubes is 100 mm. If the limiting shear stress for the rivets is 180 MN/m^2 determine the maximum torque that can be transmitted through the joint.

Fig. 2.26



2.20 (*a*) Construct a spreadsheet to solve Problem 2.19, given any values for allowable stress, number of rivets, rivet diameter and tube radius.

(*b*) If a torque of 20 kN m must be transmitted, how many rivets are needed.

Problems

3.1 Determine the overall change in length for the steel rod shown in Problem 2.1 (Fig. 2.17). The length of the upper section is 300 mm and the two lower sections are each 400 mm long. $E_s = 200\ \text{GN/m}^2$.

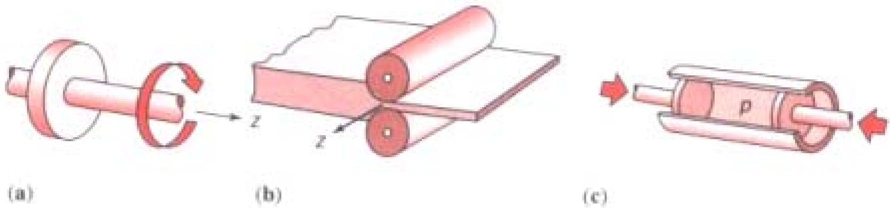
3.2 State whether the components, illustrated in Fig. 3.17 are in a state of plane stress or plane strain.

(*a*) A grinding wheel rotating at high speed.

(*b*) A plate of steel being cold-rolled.

(*c*) A long thick-walled cylinder containing a fluid pressurized by two end pistons.

Fig. 3.17



3.3 A 60 mm diameter mild-steel sphere has parallel flats machined on it 20 mm each side of the central axis. If a compressive load of 5 MN is applied perpendicular to the flats, calculate the decrease in length along the loading axis. The modulus of steel is $207\ \text{GN/m}^2$.

3.4 A truncated cone with a base radius, R, and a height, H, is attached to a horizontal surface by its base and truncated at height h. If the material of the truncated cone has density ρ and modulus E, show that its extension as a result of its own weight is given by

$$\delta = \rho g H^2 (H + 3h) / 6E(H + h)$$

3.5 A copper band 20 mm wide and 2 mm thick is a snug fit on a 100 mm diameter steel bar which may be assumed to be rigid. Determine the stress in the copper if its temperature is lowered by 50°C. $\alpha = 18 \times 10^{-6}/°\text{C}$, $E = 105\ \text{GN/m}^2$.

3.6 What are the shear strain and angle of twist per unit length for the tube in Problem 2.17. $G = 85\ \text{GN/m}^2$.

3.7 Express the stresses σ_x, σ_y, σ_z in terms of the three co-ordinate strains and the elastic constants. Obtain similar expressions for the cases of plane stress, $\sigma_z = 0$ and plane strain, $\varepsilon_z = 0$.

3.8 Program the formulae of eqns [3.2] and [3.3] into a spreadsheet so that, given the material properties E and ν, and the stresses on an element of material, all the strains are calculated.

3.9 For Plane Stress loading, construct a spreadsheet whereby, given the Young's modulus and Poisson's ratio

(*a*) σ_x and σ_y are entered and ε_x and ε_x are calculated.

(*b*) ε_x and ε_x are entered and σ_x and σ_y are calculated.

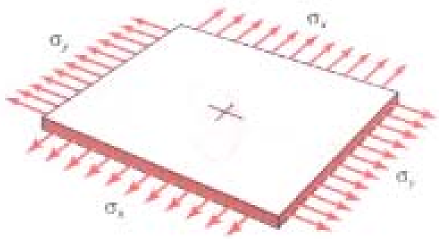
3.10 Show that the volumetric strain, e in an element subjected to triaxial stresses σ_x, σ_y and σ_z, is given by

$$e = \frac{1 - 2\nu}{E}(\sigma_x + \sigma_y + \sigma_z)$$

3.11 Determine the maximum strain and change in diameter of the cylinder in Problem 2.7 if $E = 208\ \text{GN/m}^2$ and $\nu = 0.3$.

3.12 A rectangular steel plate of uniform thickness has a strain gauge rosette bonded to one surface at the centre as shown in Fig. 3.18. It is placed in a test rig which can apply a biaxial force system along the edges of the plate. If the measured strains are +0.0005 and +0.0007 in the x- and y-directions, determine the corresponding stresses set up in the plate and the strain through the thickness. $E = 208\ \text{GN/m}^2$ and $\nu = 0.3$.

Fig. 3.18



3.13 A trapeze artist weighs 50 kg and is balanced at the centre of a 3 mm diameter wire tightrope of 20 m length. There is an initial stress of $100\ \text{MN/m}^2$ in the tightrope before the artist balances on it. Determine the strain energy stored in the wire. $E = 208\ \text{GN/m}^2$.

3.14 Determine the shear-strain energy stored in the torsion tube of Fig. 2.13. $G = 85\ \text{GN/m}^2$.

3.15 A block of material is subjected to strains ε_x, ε_y and γ_{xy}.

(*a*) Derive a spreadsheet to calculate the new position of the corners of a unit square of material in the xy plane i.e. points (0,0), (1,0), (1,1) and (0,1). Assume point (0,0) does not move.

(*b*) Normally the strains in engineering materials are very small. Add a 'strain magnification factor' which increases the displacements by a given factor.

(*c*) Link the input cells in which strains are specified to the output of the calculation of strains from stresses in Problem 3.9(*a*), so that the deformation in response to an applied stresses can be calculated.

(*d*) Create an x–y graph of the original and magnified deformed shape of the unit square. Observe how the deformed shape changes in response to different stress values.