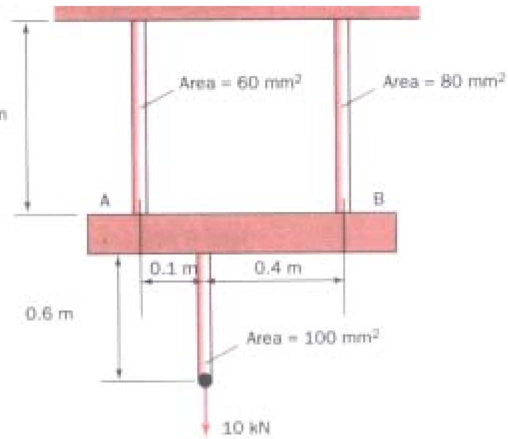
Problems

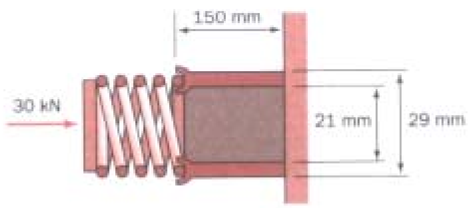
4.1 A composite shaft consists of a brass bar 50 mm in diameter and 200 mm long, to each end of which are concentrically friction-welded steel rods of 20 mm diameter and 100 mm length. During a tensile test to check the welds on the composite bar, at a particular stage the overall extension is measured as 0.15 mm. What are the axial stresses in the two parts of the bar? $E_{brass} = 120\,GN/m^2$, $E_{steel} = 208\,GN/m^2$.

4.2 A rigid bar AB is supported by 2 cables and subjected to a 10 kN force as shown in Fig. 4.10. Calculate the vertical displacement at the point of force application. $E_s = 200\,GN/m^2$.



4.3 A spring-loaded buffer stop is illustrated in Fig. 4.11. The spring which has a stiffness of 6 kN/mm, is located on the end of a steel tube of inner and outer diameters 21 mm and 29 mm respectively and 150 mm length. Determine accurately the total axial displacement of the system under a load of 30 kN. What would be the simple approximate solution? $E = 207\,GN/m^2$.

Fig. 4.11



4.4 (*a*) Create a spreadsheet to calculate the extension due to a load F of a number of bars in series, given the modulus E, cross sectional area A and length L of each bar. Calculate also the stress in each bar.

(*b*) Use the spreadsheet to find the extension of the bars in Problem 4.1 under a unit load. Use trial and error (or the spreadsheet 'Solve-for' facilities) to find the load to cause a total extension of 0.15×10^{-3} m.

(*c*) Use the spreadsheet to solve Problem 4.3 by replacing a bar stiffness EA/L with the spring stiffness.

4.5 The spring shown in Fig. 4.12 has an unstretched length of 200 mm and a stiffness of 500 kN/m. If it is compressed to 150 mm, placed over the aluminium bar AB and then released, calculate the forces which will be exerted on each of the two side walls. Before the spring is released there is a gap of 0.15 mm between the end B and the right hand wall. $E_{al} = 70\,\text{GN/m}^2$.

4.6 The steel bolt shown in Fig. 4.13 has a thread pitch of 1.6 mm. If the nut is initially tightened up by hand so as to cause no stress in the copper spacing tube calculate the axial stresses in the copper and the

Fig. 4.12

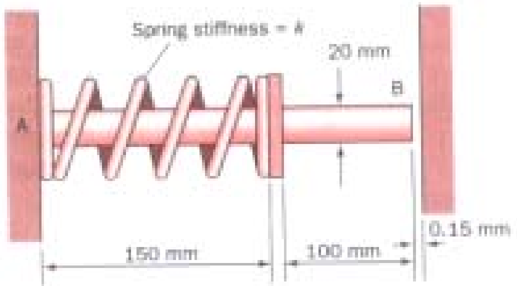
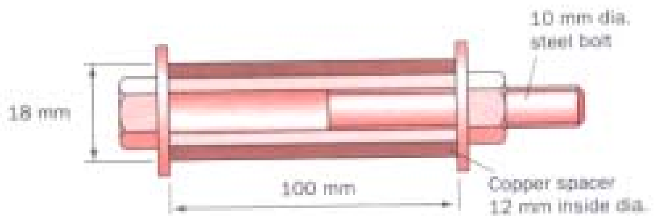


Fig. 4.13



bolt if a spanner is then used to turn the nut through 90°. $E_c = 100\,GN/m^2$, $E_s = 208\,GN/m^2$.

4.7 Figure 4.14 shows a series of bars of modulus E_i, cross-sectional area A_i, length L_i which are loaded in parallel by a force F.

The bars are slightly mismatched in length so that each bar has to be stretched by an amount d_o to match its neighbours.

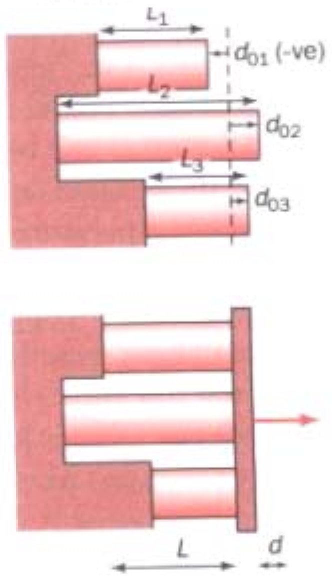
(a) Derive an expression for how the force in a given bar depends on d and d_{oi}.

(b) By summing up forces on all bars, determine how the final deflection d depends on the applied total force F.

(c) Set up a spreadsheet for an assembly of 2 bars. Calculate the stress in each bar once the deflection d has been found.

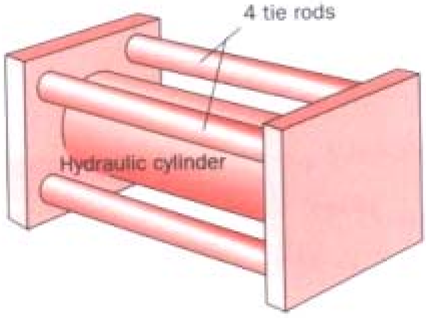
(d) Use this to solve Problem 4.6. Note that the external load is zero in this case.

Fig. 4.14



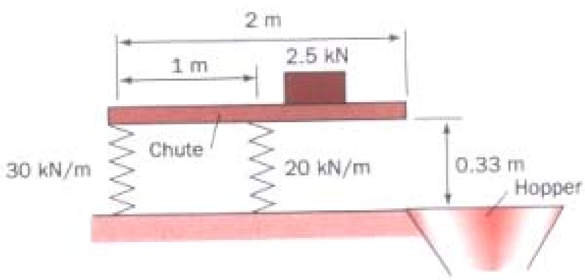
4.8 A hydraulic cylinder of 80 mm inside diameter and 4 mm wall thickness is welded to rigid end plates as shown in Fig. 4.15. The end plates are tied together by four rods of 8 mm diameter symmetrically arranged around the cylinder. Calculate the stresses in the rods and the cylinder at the cylinder design pressure of 20 MN/m^2. The cylinder and tie rods are made from steel with a Poisson's ratio value of 0.3.

Fig. 4.15



4.9 A rigid chute 2 m in length is supported horizontally, at a height of 0.33 m above a hopper, by a spring at one end of stiffness 30 kN/m and a second spring at mid-length of stiffness 20 kN/m (Fig. 4.16). Determine the position on the chute which a component of weight 2.5 kN reaches when the unsupported end of the chute just touches the edge of the hopper.

Fig. 4.16



4.10 An elastic packing piece is bolted between a rigid rectangular plate and a rigid foundation by two bolts pitched 300 mm apart and symmetrically placed on the long centre-line of the plate, which is 450 mm long. The tension in each bolt is initially 120 kN, the extension of each bolt is 0.015 mm and the compression of the packing piece is 0.6 mm. If one bolt is further tightened to a tension of 150 kN, determine the tension in the other bolt.

4.11 A bimetallic temperature-sensitive component consists of a short steel tube of outside diameter 70 mm and inside diameter 60 mm, surrounding a solid copper rod of 50 mm diameter. At 20°C the rod and cylinder have exactly the same length. If a 100 kN load is placed on top of the rod and cylinder, calculate the forces in the two materials if the whole assembly is heated to 60°C. Calculate also the temperature at which the copper would take all the force. $E_s = 208$ GN/m^2, $E_c = 104$ GN/m^2, $\alpha_s = 12 \times 10^{-6}$ per deg C, $\alpha_c = 18.5 \times 10^{-6}$ per deg C.

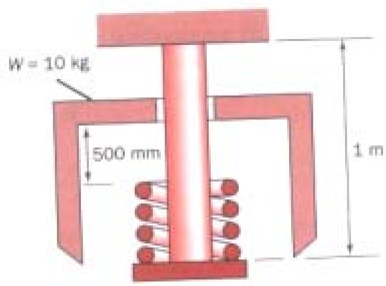
4.12 A steel tube of 150 mm internal diameter and 8 mm wall thickness in a chemical plant is lined internally with a well-fitting copper sleeve of

2 mm wall thickness. If the composite tube is initially unstressed, calculate the circumferential stresses set up, assumed to be uniform through the wall thickness, in a unit length of each part of the tube due to an increase in temperature of 100°C. Neglect any temperature effect in the axial direction. For steel $\alpha = 11 \times 10^{-6}$ per deg C, $E = 208\,GN/m^2$; for copper $\alpha = 18 \times 10^{-6}$ per deg C, $E = 104\,GN/m^2$.

4.13 For a hydraulic test a steel tube of 80 mm internal diameter, 2 mm wall thickness and 1.2 m in length is fitted with end plugs and filled with oil at a pressure of $2\,MN/m^2$. Determine the volume of oil leakage which would cause the pressure to fall to $1.5\,MN/m^2$. Bulk modulus for the oil $= 2.8\,GN/m^2$; for the steel $E = 208\,GN/m^2$, $\nu = 0.29$.

4.14 A drop-weight shearing device consists of a vertical rod with a cross-sectional area of $125\,mm^2$ which has an end collar which supports a spring of stiffness 150 kN/m, as shown in Fig. 4.17. If the shear tool of 10 kg mass is dropped through a height of 500 mm on to the spring, calculate (*a*) the initial instantaneous extension of the rod, (*b*) the maximum stress in the rod, and (*c*) the initial instantaneous compression of the spring. $E = 208\,GN/m^2$.

Fig. 4.17



4.15 A drop-hammer used for forging metal is illustrated in Fig. 4.18. If the hammer is dropped through a height of 1 m on to the workpiece, calculate the resulting compression of the workpiece. Compare the force transmitted to the foundation for the system shown with that transmitted if the workpiece were resting on the foundation before the hammer was dropped 1 m on to it. Press: Mass of hammer = 12 000 kg, mass of anvil = 5000 kg, spring stiffness = 15 MN/m. Workpiece: 30 mm dia. × 30 mm tall, modulus, $E = 208\,GN/m^2$.

Fig. 4.18