Solutions to Chapter 11 Problems

S.11.2

From Eq. (1.40) Young's modulus E is equal to the slope of the stress–strain curve. Then, since stress = load/area and strain = extension/original length.

E = slope of the load–extension curve multiplied by (original length/area of cross-section).

From the results given the slope of the load–extension curve ≃ 402.6 kN/mm. Then

$$E \simeq \frac{402.6 \times 10^3 \times 250}{\left(\dfrac{\pi \times 25^2}{4}\right)} \simeq 205\,000\,\text{N/mm}^2$$

The modulus of rigidity is given by

$$G = \frac{TL}{\theta J}$$

Therefore, the slope of the torque-angle of twist (in radians) graph multiplied by (L/J) is equal to G. From the results given the slope of the torque-angle of twist graph is ≃12.38 kNm/rad. Therefore

$$G \simeq \frac{12.38 \times 10^6 \times 250}{\left(\dfrac{\pi \times 25^4}{32}\right)} \simeq 80\,700\,\text{N/mm}^2$$

Having obtained E and G the value of Poisson's ratio may be found from Section 1.15, i.e.

$$\nu = \left(\frac{E}{2G}\right) - 1 \simeq 0.27$$

Finally, the bulk modulus K may be found using Eq. (1.54)

$$K \simeq \frac{E}{3(1 - 2\nu)} \simeq 148\,500\,\text{N/mm}^2.$$

S.11.3

Suppose that the actual area of cross-section of the material is A and that the original area of cross-section is A_o. Then, since the volume of the material does not change during plastic deformation

$$AL = A_o L_o$$

where L and L_o are the actual and original lengths of the material, respectively. The strain in the material is given by

$$\varepsilon = \frac{L - L_o}{L_o} = \frac{A_o}{A} - 1 \tag{i}$$

from the above. Suppose that the material is subjected to an applied load P. The actual stress is then given by $\sigma = P/A$ while the nominal stress is given by $\sigma_{\text{nom}} = P/A_{\text{o}}$. Therefore, substituting in Eq. (i) for A/A_{o}

$$\varepsilon = \frac{\sigma}{\sigma_{\text{nom}}} - 1$$

Then

$$\sigma_{\text{nom}}(1+\varepsilon) = \sigma = C\varepsilon^n$$

or

$$\sigma_{\text{nom}} = \frac{C\varepsilon^n}{1+\varepsilon} \qquad \text{(ii)}$$

Differentiating Eq. (ii) with respect to ε and equating to zero gives

$$\frac{\mathrm{d}\sigma_{\text{nom}}}{\mathrm{d}\varepsilon} = \frac{nC(1+\varepsilon)\varepsilon^{n-1} - C\varepsilon^n}{(1+\varepsilon)^2} = 0$$

i.e.

$$n(1+\varepsilon)\varepsilon^{n-1} - \varepsilon^n = 0$$

Rearranging gives

$$\varepsilon = \frac{n}{(1-n)}.$$

S.11.4

Substituting in Eq. (11.1) from Table P.11.4

$$\frac{10^4}{5\times 10^4} + \frac{10^5}{10^6} + \frac{10^6}{24\times 10^7} + \frac{10^7}{12\times 10^7} = 0.39 < 1$$

Therefore, fatigue failure is not probable.

Solutions to Chapter 12 Problems

S.12.3

From Example 12.1 and noting that there are two rivets/pitch in double shear

$$(b-3)\times 2.5\times 465 = 2\times 2\times \frac{\pi\times 3^2}{4}\times 370$$

from which

$$b = 12\,\text{mm}$$