REFERENCES


QUESTIONS AND PROBLEMS

1. Problem available (at instructor’s discretion) in WileyPLUS.
2. Tutoring problem available (at instructor’s discretion) in WileyPLUS.
3. Multi-Part problem available (at instructor’s discretion) in WileyPLUS.

Concepts of Stress and Strain

7.1 Using mechanics-of-materials principles (i.e., equations of mechanical equilibrium applied to a free-body diagram), derive Equations 7.4a and 7.4b.
7.2 (a) Equations 7.4a and 7.4b are expressions for normal (σ) and shear (τ) stresses, respectively, as a function of the applied tensile stress (ε) and the inclination angle of the plane on which these stresses are taken (θ of Figure 7.4). Make a plot showing the orientation parameters of these expressions (i.e., cos θ and sin θ vs ∇) versus θ.
(b) From this plot, at what angle of inclination is the normal stress a maximum?
(c) What inclination angle is the shear stress a maximum?

Stress–Strain Behavior

7.3 A specimen of aluminum having a rectangular cross section 10 mm × 12.7 mm (0.4 in. × 0.5 in.) is pulled in tension with 35,500 N (8,000 lbs) force, producing only elastic deformation. Calculate the resulting strain.

7.4 A cylindrical specimen of a titanium alloy having an elastic modulus of 107 GPa (15.5 × 10^5 psi) and an original diameter of 3.8 mm (0.15 in.) will experience only elastic deformation when a tensile load of 2000 N (450 lbs) is applied. Compute the maximum elongation of the specimen before deformation if the maximum elongation is 0.42 mm (0.0165 in.).

7.5 A steel bar 100 mm (4.0 in.) long and having a square cross section 20 mm (0.8 in.) on an edge is pulled in tension with a load of 80,000 N (20,000 lbs) and experiences an elongation of 0.008 mm (0.0003 in.) along the 20 mm (0.8 in.) long axis of the specimen. Assuming that the deformation is entirely elastic, calculate the elastic modulus of the steel.

7.6 Consider a cylindrical titanium wire 1.0 mm (0.040 in.) in diameter and 2.5 × 10^5 mm (0.0001 in.) long. Calculate its elongation when a load of 500 N (112 lbs) is applied. Assume that the deformation is totally elastic.

7.7 For a bronze alloy, the stress at which plastic deformation begins is 275 MPa (40,000 psi), and the modulus of elasticity is 115 GPa (16.7 × 10^5 psi).
(a) What is the maximum load that may be applied to a specimen with a cross-sectional area of 325 mm^2 (0.5 in.) without plastic deformation?
(b) If the original specimen length is 115 mm (4.5 in.), what is the maximum length to which it may be stretched without causing plastic deformation?

7.8 A cylindrical rod of copper (E = 110 GPa, 16 × 10^5 psi) having a yield strength of 240 MPa (35,000 psi) is to be subjected to a load of 6600 N (1500 lbs). If the length of the rod is 380 mm (15.0 in.), what must be the diameter of the rod to allow an elongation of 0.50 mm (0.020 in.)?

7.9 Compute the elastic modulus for the following metal alloys, whose stress–strain behaviors may be observed in the Tensile Tests module of Virtual Materials Science and Engineering (VAMES): (a) stainless steel, (b) tempered steel, (c) titanium, (d) aluminum, and (e) copper. How do these values compare with those presented in Table 7.1 for the same metals?

7.10 Consider a cylindrical specimen of a steel alloy (Figure 7.33) 10.0 mm (0.39 in.) in diameter and 75 mm (3.0 in.) long that is pulled in tension. Determine its elongation when a load of 20,000 N (4400 lbs) is applied.

7.11 Figure 7.34 shows, for a gray cast iron, the tensile engineering stress–strain curve in the elastic region.

Determine (a) the tangent modulus at 10.3 MPa (1500 psi) and (b) the secant modulus taken to 6.9 MPa (1000 psi).

7.12 As noted in Section 3.19, for single crystals of some substances, the physical properties are anisotropic; that is, they depend on crystallographic direction. One such property is the modulus of elasticity. For cubic single crystals, the modulus of elasticity in a general [uvw] direction, Euvw, is described by the relationship:

\[ E_{uvw} = \frac{E_{000}}{3 \left( 1 - \nu_{000} \right)} \]

where E_{000} and E_{uvw} are the moduli of elasticity in the [000] and [uvw] directions, respectively, and u, v, and w are the cosines of the angles between [000] and the respective [001], [100], and [011] directions. Verify that the E_{000} values for aluminum, copper, and iron in Table 3.7 are correct.

7.13 In Section 2.6 it was noted that the net bonding energy E_{00} between two isolated positive and negative ions is a function of interionic distance r as follows:

\[ E_{00} = a + \frac{B}{r} + \frac{C}{r^2} \]  

where A, B, and C are constants for the particular ion pair. Equation 7.30 is also valid for the bonding energy between adjacent ions in solid materials. The modulus of elasticity E is proportional to
the slope of the interionic force-separation curve at the equilibrium interionic separation, that is,

\[ E \propto \frac{dF}{dr} \]

Derive an expression for the dependence of the modulus of elasticity on these \( A, B, \) and \( n \) parameters (for the two-ion system), using the following procedure:

1. Establish a relationship for the force \( F \) as a function of \( r \), realizing that

\[ F = \frac{dE}{dr} \]

2. Now take the derivative \( dF/dr \).

3. Develop an expression for \( r_0 \), the equilibrium separation. Because \( r_0 \) corresponds to the value of \( r \) at the minimum of the \( E_0 versus r \) curve (Figure 2.6b), take the derivative \( dE/dr \), set it equal to zero, and solve for \( r_0 \), which corresponds to \( r_0 \).

4. Finally, substitute this expression for \( r_0 \) into the relationship obtained by taking \( dF/dr \).

7.14 Using the solution to Problem 7.13, rank the magnitudes of the moduli of elasticity for the following hypothetical X, Y, and Z materials from the greatest to the least. (a, b, and n parameters (Equation 7.30) for these materials are shown in the following table; they yield \( E_{\text{D}} \) in units of electron volts and \( r \) in nanometers):

<table>
<thead>
<tr>
<th>Material</th>
<th>( A )</th>
<th>( B )</th>
<th>( n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>2.5</td>
<td>2.0 \times 10^{-3}</td>
<td>8</td>
</tr>
<tr>
<td>Y</td>
<td>2.3</td>
<td>8.0 \times 10^{-4}</td>
<td>10.5</td>
</tr>
<tr>
<td>Z</td>
<td>3.0</td>
<td>1.5 \times 10^{-3}</td>
<td>9</td>
</tr>
</tbody>
</table>

7.15 A cylindrical specimen of aluminum having a diameter of 1.5 mm (0.075 in) and length of 200 mm (8.0 in) is deformed elastically in tension with a force of 48,800 N (11,000 lb). Using the data in Table 7.5, determine the following:

(a) The amount by which this specimen will elongate, in the direction of the applied stress.

(b) The change in diameter of the specimen. Will the diameter increase or decrease?

7.16 A cylindrical bar of steel 10 mm (0.4 in.) in diameter to be subjected to an elastic stress and strain by application of a force along the bar axis. Using the data in Table 7.5, determine the force that will produce an elastic reduction of 1.2 \( \times 10^{-4} \) in. in the diameter.

7.17 A cylindrical specimen of an alloy 8 mm (0.31 in.) in diameter is stressed elastically in tension. A force of 15,700 N (3530 lb) produces a reduction in specimen diameter of 5 \( \times 10^{-4} \) mm (2.0 \times 10^{-5} in.). Compute Poisson's ratio for this material if its modulus of elasticity is 140 GPa (203 \times 10^{9} \text{ Pa}).

7.18 A cylindrical specimen of a hypothetical metal alloy is stressed in compression. If its original and final diameters are 20.025 and 20.020 mm, respectively, and its final length is 74.96 mm, compute its original length if the deformation is totally elastic. The elastic and shear moduli for this alloy are 105 and 39.7 GPa, respectively.

7.18 Consider a cylindrical specimen of some hypothetical metal alloy that has a diameter of 8.0 mm (0.31 in.) and Poisson's ratio of 0.30. A tensile force of 1000 N (225 lb) produces an elastic reduction in diameter of 9 \( \times 10^{-4} \) in. (1.10 \times 10^{-5} m). Compute the modulus of elasticity for this alloy, given that Poisson's ratio is 0.30.

7.20 A brass alloy is known to have a yield strength of 275 MPa (40,000 psi), a tensile strength of 380 MPa (55,000 psi), and an elastic modulus of 100 GPa (15 \times 10^{9} \text{ Pa}). A cylindrical specimen of this alloy 12.7 mm (0.50 in.) in diameter and 250 mm (10.0 in.) long is stressed in tension and found to elongate 7.5 mm (0.30 in.). On the basis of the information given, is it possible to compute the magnitude of the load that is necessary to produce this change in length? If so, calculate the load. If not, explain why.

7.21 A cylindrical metal specimen 12.7 mm (0.5 in.) in diameter and 250 mm (10 in.) long is to be subjected to a tensile stress of 28 MPa (4000 psi) at this stress level the resulting deformation will be totally elastic.

(a) If the elongation must be less than 0.009 mm (0.00035 in.), which of the metals in Table 7.5 are suitable candidates? Why.

(b) If, in addition, the maximum permissible diameter decrease is 1.2 \( \times 10^{-4} \) mm (4.7 \times 10^{-6} in.) when the tensile stress of 38 MPa is applied, which of the metals that satisfy the criterion in (a) are suitable candidates? Why.

7.22 Consider a brass alloy for which the stress-strain behavior is shown in Figure 7.12. A cylindrical specimen of this material 6 mm (0.24 in.) in diameter and 50 mm (2.0 in.) long is pulled in tension with a force of 5000 N (1125 lb). If it is known that this alloy has a Poisson's ratio of 0.30, what will be the strain when the stress-strain behavior shown in Figure 7.13 is found to have a cross-sectional diameter of 15 mm (0.6 in.).

(a) Will the specimen experience elastic and/or plastic deformation? Why.

(b) If the original specimen length is 250 mm (10 in.), how much will it increase in length when this load is applied?

7.23 A cylindrical rod 100 mm long and having a diameter of 10.0 mm to be deformed elastically in tension of 27.5 GPa (4000 psi). How much will it increase in length when this strain is applied?

7.28 A bar of a steel alloy that exhibits the stress-strain behavior shown in Figure 7.33 is subjected to a tensile load; the specimen is 300 mm (12 in.) long and has a square cross section of 4.5 mm (0.175 in.) on a side.

(a) Compute the magnitude of the load necessary to produce an elongation of 0.045 mm (0.0018 in.).

(b) What will be the deformation after the load has been released?

7.29 A cylindrical specimen of aluminum having a diameter of 0.505 in. (12.8 mm) and a gauge length of 2.000 in. (50.800 mm) is pulled in tension. Use the load-elongation characteristics shown in the following table to complete parts (a) through (f).

(a) Plot the data as engineering stress versus engineering strain.

(b) Compute the modulus of elasticity.

(c) Determine the yield strength at a strain offset of 0.002.

(d) Determine the tensile strength of this alloy.

(e) What is the approximate ductility, in percent elongation?

(f) Compute the modulus of resilience.

7.30 A specimen of ductile cast iron having a rectangular cross section of dimensions 4.8 mm (0.190 in.) by 15.9 mm (0.625 in.) is deformed in tension. Using the load-elongation data shown in the following table, complete parts (a) through (f).
(a) the approximate yield strength (0.002 strain offset), (b) the tensile strength, and (c) the approximate ductility, in percent elongation. How do these values compare with those for the oil-quenched and tempered 4140 and 4340 steel alloys presented in Table B.4 of Appendix B? 7.33 For the aluminum alloy whose stress-strain behavior can be observed in the Tensile Tests module of Virtual Materials Science and Engineering (VMSE), determine the following: (a) the approximate yield strength (0.002 strain offset), (b) the tensile strength, and (c) the approximate ductility, in percent elongation. When do these values increase with those for the 2024 aluminum alloy (T531 temper) presented in Table B.4 of Appendix B? 7.34 For the (plain) carbon steel alloy whose stress-strain behavior can be observed in the Tensile Tests module of Virtual Materials Science and Engineering (VMSE), determine the following: (a) the approximate yield strength, (b) the approximate tensile strength, and (c) the approximate ductility, in percent elongation. 7.35 A cylindrical metal specimen having an original diameter of 12.8 mm (0.500 in.) and gauge length of 50.80 mm (2.000 in.) is pulled to failure until fracture occurs. The diameter at the point of fracture is 6.60 mm (0.260 in.), and the fractured gauge length is 72.14 mm (2.840 in.). Calculate the ductility in terms of percent reduction in area and percent elongation. 7.36 Calculate the modulus of resilience for the materials having the stress-strain behavior shown in Figures 7.12 and 7.33. 7.37 Determine the modulus of resilience for each of the following alloys: Material Yield Strength MPa Steel alloy 550 800 Brass alloy 350 580 Aluminum alloy 250 360 Titanium alloy 800 1180 Use the modulus of elasticity values in Table 7.1. 7.38 A brass alloy to be used for a spring application must have a modulus of resilience of at least 0.75 MPa (110 psi). What must be its minimum yield strength? True Stress and Strain 7.39 Show that Equations 7.18a and 7.18b are valid when there is no volume change during deformation. 7.40 Demonstrate that Equation 7.16, the expression defining true strain, may also be represented by

\[
\varepsilon' = \ln \frac{A_f}{A_0}
\]

where the specimen volume remains constant during deformation. Which of these two expressions is more valid during necking? Why? 7.41 Using the data in Problem 7.29 and Equations 7.15, 7.16, and 7.18, generate a true stress-true strain plot for aluminum. Equation 7.18a becomes invalid past the point at which necking begins; therefore, measured diameters are given in the following table for the last four data points, which should be used in true stress computations.

<table>
<thead>
<tr>
<th>Load</th>
<th>Length</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>lb</td>
<td>mm</td>
</tr>
<tr>
<td>4,100</td>
<td>10,400</td>
<td>56.896</td>
</tr>
<tr>
<td>4,800</td>
<td>10,100</td>
<td>57.687</td>
</tr>
<tr>
<td>4,600</td>
<td>9,600</td>
<td>58.420</td>
</tr>
<tr>
<td>3,400</td>
<td>8,200</td>
<td>59.182</td>
</tr>
</tbody>
</table>

7.42 A tensile test is performed on a metal specimen, and it is found that there is a true plastic strain of 0.20 produced when a true stress of 575 MPa (83,500 psi) is applied. For the same metal, the value of K in Equation 7.19 is 860 MPa (125,000 psi). Calculate the true strain that results from the application of a true stress of 600 MPa (87,000 psi). 7.43 For some metal alloys, a true stress of 415 MPa (60,175 psi) produces a plastic true strain of 0.475. How much will this specimen of this material elongate when a true stress of 325 MPa (46,125 psi) is applied? (a) If the original length is 300 mm (11.8 in.), assume a value of 0.25 for the strain-hardening exponent n. (b) For the following true stresses, the corresponding plastic strains for a brass alloy:

<table>
<thead>
<tr>
<th>Metal</th>
<th>True Stress (psi)</th>
<th>True Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>50,000</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>60,000</td>
<td>0.20</td>
</tr>
</tbody>
</table>

7.44 Elastic Recovery after Plastic Deformation 7.45 For a brass alloy, the following engineering stresses produce the corresponding plastic engineering strains prior to necking:

<table>
<thead>
<tr>
<th>Engineering Stress (MPa)</th>
<th>Engineering Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>235</td>
<td>0.014</td>
</tr>
<tr>
<td>250</td>
<td>0.296</td>
</tr>
</tbody>
</table>

On the basis of this information, compute the engineering stress necessary to produce an engineering strain of 0.25. 7.46 Find the toughness (or energy to cause fracture) for a metal that experiences both elastic and plastic deformation. Assume Equation 7.5 for plastic deformation, that the modulus of elasticity is 172 GPa (25 x 10^6 psi), and that plastic deformation terminates at a strain of 0.3. For plastic deformation, assume that the relationship between stress and strain is described by Equation 7.19, in which the values for K and n are 600 MPa (1 x 10^6 psi) and 0.30, respectively. Furthermore, plastic deformation occurs between strain values of 0.01 and 0.75, at which point fracture occurs. 7.47 For a tensile test, it can be demonstrated that necking begins when

\[
day = \frac{\sigma_y}{\sigma_f}
\]

Using Equation 7.19, determine the value of the true strain at this onset of necking. 7.48 Taking the logarithm of both sides of Equation 7.19 yields

\[
\sigma_y = \frac{1}{\ln K} + n \ln \varepsilon_f
\]

Thus, a plot of log \( \sigma_y \) versus log \( \varepsilon_f \) in the plastic region to the point of necking should yield a straight line having a slope of \( n \) and an intercept (at log \( \sigma_y = 0 \)) of log K. Using the appropriate data tabulated in Problem 7.29, make a plot of log \( \sigma_y \) versus log \( \varepsilon_f \) and determine the values of \( n \) and K. It will be necessary to cover engineering stresses and strains to true stresses and strains using Equations 7.18a and 7.18b.

Elastic Recovery after Plastic Deformation 7.49 A cylindrical specimen of a brass alloy 7.5 mm (0.30 in.) in diameter and 50.0 mm (3.54 in.) long is pulled in tension with a force of 6000 N (1350 lb); the force is subsequently released. Use the modulus of elasticity values in Table 7.1. (a) Compute the final length of the specimen at this time. The tensile strain-stress behavior for this alloy is shown in Figure 7.12.
Chapter 7  Mechanical Properties

(b) Compute the flexural modulus of a beam that has an area moment of inertia of 10,000 cm² and a modulus of elasticity of 200 GPa. The beam is loaded with a concentrated load of 10,000 N at its center.

(c) Compute the deflection of a cantilever beam with a length of 1 meter, a width of 0.1 meter, and a thickness of 0.01 meter, subjected to a point load of 100 N at the free end. The material has a modulus of elasticity of 200 GPa and a Poisson's ratio of 0.3.

6.50 A steel alloy specimen having a rectangular cross section of dimensions 12.7 mm × 6.4 mm (0.5 in. × 0.25 in.) has the stress-strain behavior shown in Figure 7.3. The specimen is subjected to a tensile force of 30,000 N (6,800 lb). (a) Determine the elastic and plastic strain values. (b) If its original length is 460 mm (18.0 in.), what will be its final length after the load in part (a) is applied and then released?

6.51 A three-point bending test is performed on a glass fiber-reinforced composite having a rectangular cross section of height d = 2 mm (0.08 in.) and width b = 10 mm (0.4 in.); the distance between support points is 45 mm (1.8 in.). (a) Compute the flexural strength if the load at fracture is 290 N (65 lb). (b) The point of maximum deflection Ay occurs at the center of the specimen and is described by

\[ A_y = \frac{P}{4EI} \]

where E is the modulus of elasticity and I is the cross-sectional moment of inertia. Compute Ay at a load of 266 N (60 lb).

6.52 A circular specimen of MgO is loaded using a three-point bending mode. The computed minimum possible radius of the specimen without fracture, given that the applied load is 425 N (95 lb), is 21.2 mm (0.83 in.). The flexural strength is 105 MPa (15,000 psi), and the separation between load points is 50 mm (2.0 in.).

6.53 A three-point bending test was performed on an aluminum oxide specimen having a circular cross section of radius 3.5 mm (0.14 in.); the specimen fractured at a load of 950 N (215 lb) when the distance between the support points was 50 mm (2.0 in.). Another test is to be performed on a specimen of the same material, but one that has a square cross section of 12 mm (0.47 in.) length on each edge. At what load would you expect the specimen to fracture if the support point separation is 40 mm (1.6 in.)?

6.54 (a) A three-point reverse-transverse bending test is conducted on a cylindrical specimen of aluminum oxide having a reported flexural strength of 390 MPa (56,000 psi). If the specimen radius is 2.5 mm (0.10 in.) and the support point separation distance is 30 mm (1.2 in.), would you expect the specimen to fracture when a load of 620 N (140 lb) is applied? Justify your answer.

(b) Would you be 100% certain of the answer in part (a)? Why or why not?

6.55 The modulus of elasticity for beryllium oxide (BeO) having 5% vol % porosity is 410 GPa (4 x 10^10 psi).

(a) Compute the modulus of elasticity for the nonporous material.

(b) Compute the modulus of elasticity for 10% vol % porosity.

6.56 The modulus of elasticity for boron carbide (B,C) having 5% vol % porosity is 270 GPa (4 x 10^10 psi).

(a) Compute the modulus of elasticity for the nonporous material.

(b) At what volume percent porosity will the modulus of elasticity be 235 GPa (3 x 10^10 psi)?

6.57 Using the data in Table 7.2, do the following:

(a) Determine the flexural strength for nonporous MgO, assuming a value of 375 for n = 1 in Equation 7.22.

(b) Compute the volume fraction porosity at which the flexural strength for MgO is 62 MPa (9000 psi).

6.58 The flexural strength and associated volume fraction porosity for two specimens of the target ceramic material are as follows:

<table>
<thead>
<tr>
<th>P (MPa)</th>
<th>( \phi )</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>0.05</td>
</tr>
<tr>
<td>30</td>
<td>0.20</td>
</tr>
</tbody>
</table>

(a) Compute the flexural strength for a completely nonporous specimen of this material.

(b) Compute the flexural strength for a 0.1% volume fraction porosity.

6.59 From the stress-strain data for polystyrene (methyl chloride) shown in Figure 7.24, determine the modulus of elasticity and tensile strength at room temperature [20°C (68°F)].

6.60 Compute the elastic moduli for the following polymers, whose stress-strain behaviors can be observed in the Tensile Tests module of Virtual Materials Science and Engineering (VMSE), determine the following:

(a) high-density polyethylene, (b) nylon, and (c) phenol-formaldehyde (Bakelite). How do these values compare with those presented in Table 7.1 for the same polymers?

6.61 For the nylon polymer whose stress-strain behavior can be observed in the Tensile Tests module of Virtual Materials Science and Engineering (VMSE), determine the following:

(a) The yield strength.

(b) The approximate ductility, in percent elongation. How do these values compare with those for the nylon material presented in Table 7.2?

6.62 For the phenol-formaldehyde (Bakelite) polymer whose stress-strain behavior can be observed in the Tensile Tests module of Virtual Materials Science and Engineering (VMSE), determine the following:

(a) The tensile strength.

(b) The approximate ductility, in percent elongation. How do these values compare with those for the phenol-formaldehyde material presented in Table 7.2?

6.63 In your own words, briefly describe the phenomena of viscoelasticity.

6.64 For some viscoelastic polymers that are subjected to stress relaxation tests, the stress decays with time according to

\[ \sigma(t) = \sigma(0) \exp \left( -\frac{t}{\tau} \right) \]

where \( \sigma(0) \) and \( \sigma(t) \) represent the time-dependent stress (i.e., time = 0) stresses, respectively, and \( \tau \) denotes elapsed time and the relaxation time, respectively; \( \tau \) is a time-independent constant characteristic of the material. A specimen of a viscoelastic polymer whose stress relaxation obeys Equation 7.33 was suddenly pulled in tension to a fixed strain of 0.6; the stress necessary to maintain this constant strain was measured as a function of time. Determine \( \alpha(10) \) for this material if the initial stress level was 2.76 MPa (400 psi), which dropped to 1.72 MPa (250 psi) after 60 s.

6.65 In Figure 7.35, the logarithm of \( \alpha(t) \) versus the logarithm of time is plotted for polystyrene at a variety of temperatures. Plot \( \alpha(t) \) versus temperature and then estimate \( \alpha(T) \).

6.66 On the basis of the curves in Figure 7.26, sketch an approximate strain-time plot for the following polystyrene materials at the specified temperatures:

(a) Amorphous at 120°C

(b) Crosslinked at 150°C

6.67 (a) Crystalline at 230°C

(b) Crosslinked at 50°C

6.68 Make two schematic plots of the logarithm of relaxation modulus versus temperature for an amorphous polymer (curve C in Figure 7.29).

(a) On one of these plots demonstrate how the behavior changes with increasing molecular weight.

(b) On the other plot, indicate the changes in behavior with increasing crosslinking.

6.69 (a) A 10-mm-diameter Brinell hardness indenter produced an indentation 1.62 mm in...
diameter in a steel alloy when a load of 500 kg was used. Compute the HB of this material.

What will be the diameter of an indentation to yield a hardness of 450 HB when a 500-kg load is used?

Estimate the Brinell and Rockwell hardnesses for the following:

(a) The naval brass for which the stress-strain behavior is shown in Figure 7.12.
(b) The steel alloy for which the stress-strain behavior is shown in Figure 7.33.

Using the data represented in Figures 7.31, specify equations relating tensile strength and Brinell hardness for brass and nodular cast iron, similar to Equations 7.25a and 7.25b for steels.

Cite five factors that lead to scatter in measured material properties.

The following table gives a number of Rockwell hardness values that were measured on a single steel specimen. Compute average and standard deviation hardness values.

Design/Safety Factors

What criteria are factors of safety based on?

Determine working stresses for the two alloys that have the stress-strain behaviors shown in Figures 7.12 and 7.33.

For a cylindrical metal specimen loaded in tension to fracture, given a set of load and corresponding length data, as well as the predeformation diameter and length, generate a spreadsheet that will allow the user to plot (a) engineering stress versus engineering strain, and (b) true stress versus true strain to the point of necking.

A large tower is to be supported by a series of steel wires. It is estimated that the load on each wire will be 11,100 N (2500 lb). Determine the minimum required wire diameter, assuming a factor of safety of 2 and a yield strength of 1030 MPa (150,000 psi).

(a) Gaseous hydrogen at a constant pressure of 1.0 MPa (10 at) is to flow within the inside of a thin-walled cylindrical tube of nickel that has a radius of 0.1 m. The temperature of the tube is to be 300°C, and the pressure of hydrogen outside of the tube will be maintained at 0.01 MPa (0.1 atm). Calculate the minimum wall thickness if the diffusion flux is to be no greater than 1 × 10^{-7} mol/m^2 s. The concentration of hydrogen in the nickel, C_H (in moles hydrogen per m^2 of Ni), is a function of hydrogen pressure, P_H (in MPa), and absolute temperature, T, according to

\[ C_H = 30.8 V_{Ph} \exp \left( \frac{-12.3 \text{ kJ/mol}}{RT} \right) \]

Furthermore, the diffusion coefficient for the diffusion of H in Ni depends on temperature as

\[ D_{Ni}(m^2/s) = 4.76 \times 10^{-7} \exp \left( \frac{-39.5 \text{ kJ/mol}}{RT} \right) \]

For thin-walled cylindrical tubes that are pressurized, the circumferential stress is a function of the pressure difference across the wall (\( \Delta P \)), cylinder radius (\( r \)), and tube thickness (\( \Delta t \)) as

\[ \sigma = \frac{r \Delta P}{4 \Delta t} \]

Compute the circumferential stress to which the wall of this pressurized cylinder are exposed.

(d) The room-temperature yield strength of Ni is 100 MPa (15,000 psi), and \( \sigma_y \) diminishes about 5 MPa for every 50°C rise in temperature. Would you expect the wall thickness computed in part (b) to be suitable for this Ni cylinder at 300°C? Why or why not?

If this thickness is found to be suitable, compute the minimum thickness that could be used without any deformation of the tube walls. How much would the diffusion flux increase with this reduction in thickness? On the other hand, if the thickness determined in part (e) is found to be unsuitable, then specify a minimum thickness that you would use. In this case, how much of a decrease in diffusion flux would result?

Consider the steady-state diffusion of hydrogen through the walls of a cylindrical nickel tube as described in Problem 7.12. One design calls for a diffusion flux of 5 × 10^{-4} mol/m^2 s, a tube radius of 0.125 m, and inside and outside pressures of 2.026 MPa (20 atm) and 0.0203 MPa (0.2 atm), respectively; the maximum allowable temperature is 500°C. Specify a suitable temperature and wall thickness to give this diffusion flux and yet ensure that the tube walls will not experience any permanent deformation.

It is necessary to select a ceramic material to be stressed using a three-point loading scheme (Figure 7.18). The specimen must have a circular cross section and a radius of 2.5 mm (0.10 in) and must not experience fracture or a deflection of more than 6.2 × 10^{-3} mm (2.4 × 10^{-5} in) at its center when a load of 275 N (62 lb) is applied. If the distance between support points is 45 mm (1.77 in), which of the ceramic materials in Table 7.5 are candidates? The magnitude of the center-point deflection may be computed using the equation supplied in Table 7.5.

**Questions and Problems**

A steel rod is pulled in tension with a stress that is less than the yield strength. The modulus of elasticity can be calculated as:

(A) Axial stress divided by axial strain
(B) Axial stress divided by change in length
(C) Axial stress times axial strain
(D) Axial load divided by change in length

A cylindrical specimen of brass that has a diameter of 20 mm, a tensile modulus of 110 GPa, and a Poisson's ratio of 0.35 is pulled in tension with a force of 40,000 N. If the deformation is totally elastic, what is the strain experienced by the specimen?

(A) 0.00116
(B) 0.00462
(C) 0.00239
(D) 0.01350

Figure 7.36 shows the tensile stress-strain curve for an alloy steel.

What is this alloy's tensile strength?

(A) 1400 MPa
(B) 1500 MPa
(C) 1800 MPa
(D) 50,000 MPa

What is its modulus of elasticity?

(A) 30 GPa
(B) 22.5 GPa
(C) 1,000 GPa
(D) 200 GPa

What is the yield strength?

(A) 1400 MPa
(B) 1500 MPa
(C) 1600 MPa
(D) 50,000 MPa

A specimen of steel has a rectangular cross section 20 mm wide and 40 mm high, a shear modulus of 207 GPa, and a Poisson's ratio of 0.3. If this specimen is pulled in tension with a force of 60,000 N, what is the change in width if deformation is totally elastic?

(A) Increase in width of 3.62 × 10^{-4} m
(B) Decrease in width of 7.24 × 10^{-5} m
(C) Increase in width of 7.24 × 10^{-4} m
(D) Decrease in width of 2.18 × 10^{-4} m

A cylindrical specimen of undeformed brass that has a radius of 300 mm is elastically deformed to a tensile strain of 0.001. If Poisson's ratio for this brass is 0.35, what is the change in specimen diameter?

(A) Increase by 0.028 mm
(B) Decrease by 1.05 × 10^{-4} m
(C) Decrease by 1.00 × 10^{-4} m
(D) Increase by 1.05 × 10^{-4} m

**Figure 7.36** Tensile stress-strain behavior for an alloy steel.