CHAPTER 4 TENSILE TESTING

EXERCISE 28, Page 67

1. What is a tensile test? Make a sketch of a typical load/extension graph for a mild steel specimen to the point of fracture and mark on the sketch the following: (a) the limit of proportionality, (b) the elastic limit, (c) the yield point.

See pages 64 and 65 of the textbook

2. In a tensile test on a zinc specimen of gauge length 100 mm and diameter 15 mm, a load of 100 kN produced an extension of 0.666 mm. Determine (a) the stress induced, (b) the strain, (c) Young's modulus of elasticity.

(a) **Stress**, $\sigma = \dfrac{\text{force F}}{\text{area A}} = \dfrac{100\times10^3}{\pi\left(\dfrac{15\times10^{-3}}{2}\right)^2} = 566\times10^6$ = **566 MPa**

(b) **Stain**, $\varepsilon = \dfrac{\text{extension x}}{\text{length L}} = \dfrac{0.666}{100}$ = **0.00666**

(c) **Young's modulus of elasticity**, E = $\dfrac{\text{stress}\,\sigma}{\text{strain}\,\varepsilon} = \dfrac{566\times10^6\ \text{Pa}}{0.00666} = 85\times10^9$ = **85 GPa**

3. The results of a tensile test are: Diameter of specimen 20 mm, gauge length 50 mm, load at limit of proportionality 80 kN, extension at limit of proportionality 0.075 mm, maximum load 100 kN, and final length at point of fracture 60 mm.

Determine (a) Young's modulus of elasticity, (b) the ultimate tensile strength, (c) the stress at the limit of proportionality, (d) the percentage elongation.

(a) Young's modulus of elasticity is given by: E = $\dfrac{\text{stress}}{\text{strain}} = \dfrac{\frac{F}{A}}{\frac{x}{L}} = \dfrac{FL}{Ax}$

where the load at the limit of proportionality, F = 80 kN = 80000 N,

L = gauge length = 50 mm = 0.050 m,

A = cross-sectional area = $\dfrac{\pi d^2}{4} = \dfrac{\pi (0.020)^2}{4}$ = 0.00031416 m^2, and

x = extension = 0.075 mm = 0.000075 m.

Hence, Young's modulus of elasticity E = $\dfrac{FL}{Ax} = \dfrac{(80000)(0.050)}{(0.00031416)(0.000075)}$

$= 169.8 \times 10^9$ Pa = **169.8 GPa**

(b) Ultimate tensile strength = $\dfrac{\text{maximum load}}{\text{original cross-sectional area}} = \dfrac{100000}{0.00031416}$

$= 318.3 \times 10^6$ Pa = **318.3 MPa**

(c) Stress at limit of proportionality = $\dfrac{\text{load at limit of proportionality}}{\text{cross-sectional area}}$

$= \dfrac{80000}{0.00031416} = 254.6 \times 10^6$ Pa = **254.6 MPa**

(d) Percentage elongation = $\dfrac{\text{increase in length}}{\text{original length}} \times 100 = \dfrac{(60-50)\text{ mm}}{50\text{ mm}} \times 100$ = **20%**

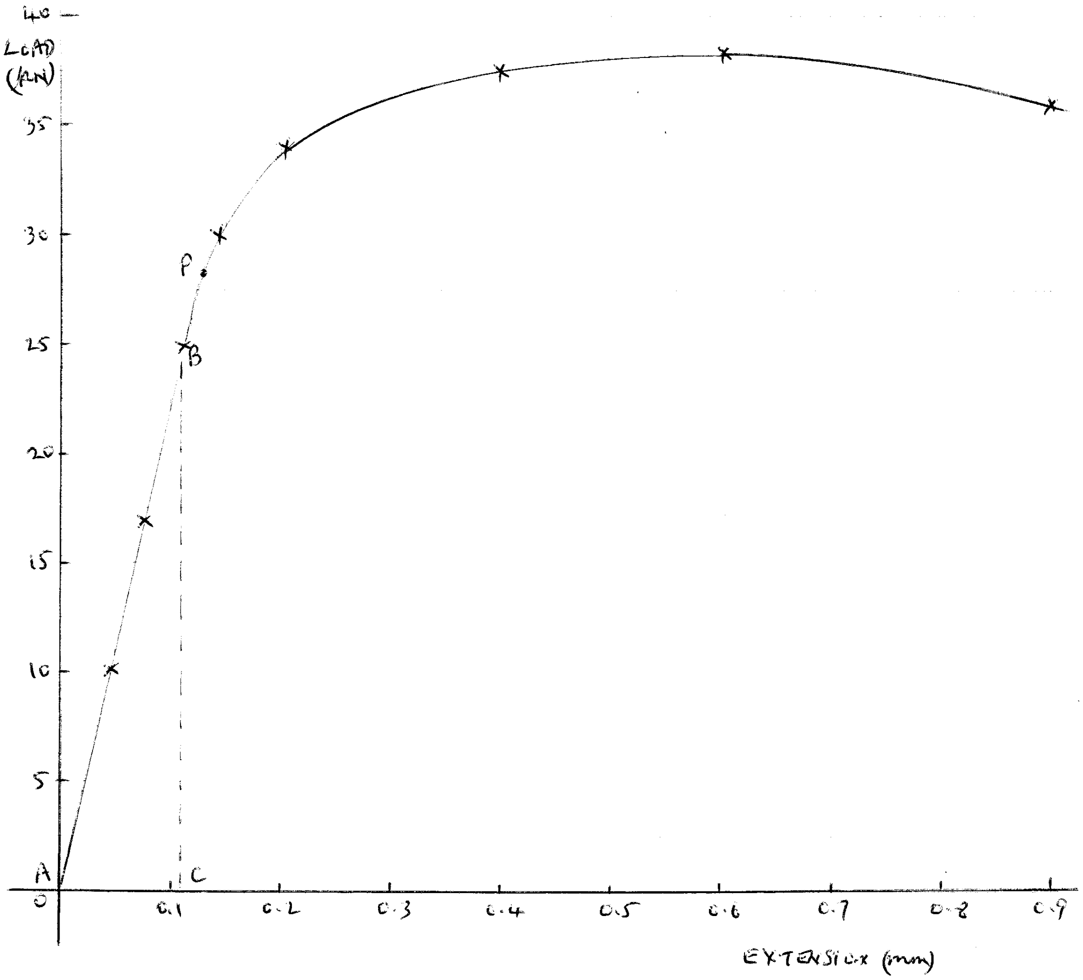
EXERCISE 29, Page 69

1. A tensile test is carried out on a specimen of mild steel of gauge length 40 mm and diameter 7.42 mm. The results are:

Load (kN)	0	10	17	25	30	34	37.5	38.5	36
Extension (mm)	0	0.05	0.08	0.11	0.14	0.20	0.40	0.60	0.90

At fracture the final length of the specimen is 40.90 mm. Plot the load/ extension graph and determine (a) the modulus of elasticity for mild steel, (b) the stress at the limit of proportionality, (c) the ultimate tensile strength, (d) the percentage elongation.

A graph of load/extension is shown below.



(a) Gradient of straight line portion of graph is given by:

$$\frac{BC}{AC} = \frac{25000\,N}{0.11\times10^{-3}\,m} = 227.27 \times 10^6\,N/m$$

Cross-sectional area, $A = \frac{\pi d^2}{4} = \frac{\pi(7.42\times10^{-3})^2}{4} = 43.24 \times 10^{-6}\,m^2$, and

gauge length, L = 40 mm = 0.040 m

Young's modulus of elasticity = (gradient of graph)$\left(\frac{L}{A}\right)$

$$= \left(227.27\times10^6\right)\left(\frac{0.040}{43.24\times10^{-6}}\right)$$

$$= 210 \times 10^9\,\text{Pa} = \mathbf{210\ GPa}$$

(b) The limit of proportionality occurs at point P on the graph, where the initial gradient of the graph starts to change. This point has a load value of 28.1 kN.

Stress at the limit of proportionality is given by:

$$\sigma = \frac{\text{force}}{\text{area}} = \frac{28.1\times10^3\,N}{43.24\times10^{-6}\,m^2} = 650 \times 10^6\,\text{Pa} = \mathbf{650\ MPa}$$

(c) Ultimate tensile strength $= \frac{\text{maximum load}}{\text{original cross-sectional area}} = \frac{38.5\times10^3\,N}{43.24\times10^{-6}\,m^2}$

$$= 890 \times10^6\,\text{Pa} = \mathbf{890\ MPa}$$

(d) Percentage elongation $= \frac{\text{extension at fracture point}}{\text{original length}}\times100 = \frac{(40.9-40)\text{mm}}{40\,\text{mm}} = \frac{0.9}{40}\times100$

$$= \mathbf{2.25\%}$$

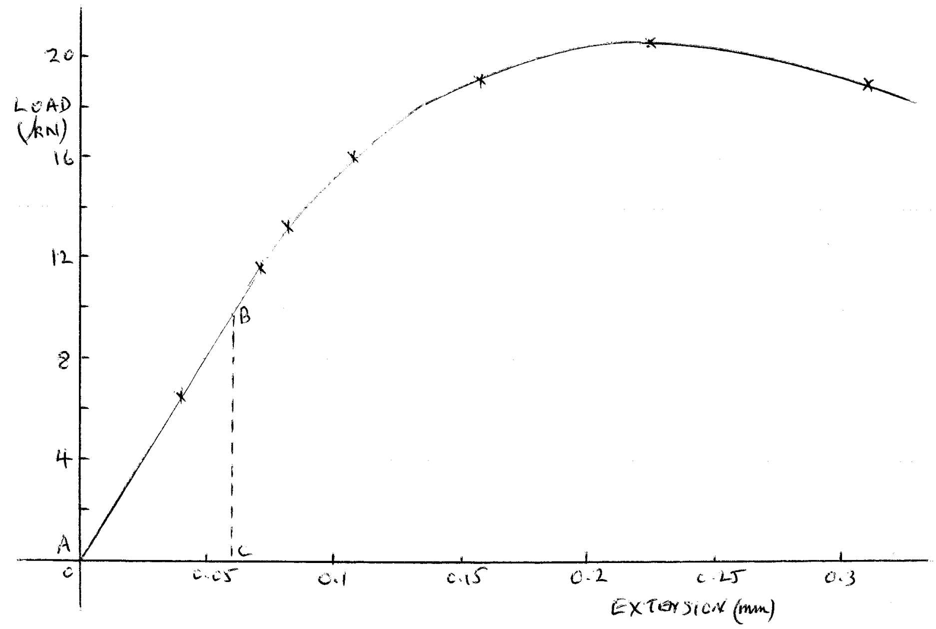
2. An aluminium alloy specimen of gauge length 75 mm and of diameter 11.28 mm was subjected to a tensile test, with these results:

Load (kN)	0	2.0	6.5	11.5	13.6	16.0	18.0	19.0	20.5	19.0
Extension (mm)	0	0.012	0.039	0.069	0.080	0.107	0.133	0.158	0.225	0.310

The specimen fractured at a load of 19.0 kN.

Determine (a) the modulus of elasticity of the alloy, (b) the percentage elongation.

A graph of load/extension is shown below.



(a) Gradient of straight line portion of graph is given by:

$$\frac{BC}{AC} = \frac{10000\,\text{N}}{0.06 \times 10^{-3}\,\text{m}} = 166.67 \times 10^{6}\,\text{N/m}$$

Gauge length, L = 75 mm = 0.075 m

Cross-sectional area, $A = \frac{\pi d^2}{4} = \frac{\pi(11.28\times10^{-3})^2}{4} = 99.933 \times 10^{-6}\,\text{m}^2$

Young's modulus of elasticity = $(\text{gradient of graph})\left(\frac{L}{A}\right)$

$$= \left(166.67\times10^{6}\right)\left(\frac{0.075}{99.933\times10^{-6}}\right)$$

$$= 125 \times 10^{9}\,\text{Pa} = \mathbf{125\ GPa}$$

(b) Percentage elongation = $\frac{\text{increase in length}}{\text{original length}}\times100 = \frac{0.31\,\text{mm}}{75\,\text{mm}}\times100$ = **0.413%**

3. An aluminium test piece 10 mm in diameter and gauge length 50 mm gave the following results when tested to destruction:

Load at yield point 4.0 kN, maximum load 6.3 kN, extension at yield point 0.036 mm, diameter at fracture 7.7 mm.

Determine (a) the yield stress, (b) Young's modulus of elasticity, (c) the ultimate tensile strength, (d) the percentage reduction in area.

(a) Force F = 4 kN = 4000 N,

cross-sectional area $A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{10\times10^{-3}}{2}\right)^2 = 78.54 \times 10^{-6}\,\text{m}^2$

Yield stress = $\frac{\text{load at yield point}}{\text{area}} = \frac{4000}{78.54\times10^{-6}}$ = **50.93 MPa**

(b) Gauge length L = 50 mm, and extension x = 0.036 mm = 0.036 mm

Hence, strain = $\frac{x}{L} = \frac{0.036}{50} = 0.00072$

Young's modulus of elasticity, E = $\frac{\text{stress}}{\text{strain}} = \frac{50.93\times10^6}{0.00072} = 70.7\times10^9$ = **70.7 GPa**

(c) **Ultimate tensile strength** = $\frac{\text{maximum load}}{\text{original cross-sectional area}} = \frac{6300\,\text{N}}{78.54\times10^{-6}\,\text{m}^2}$

$= 80.2 \times 10^6\,\text{Pa}$ = **80.2 MPa**

(d) Final cross-sectional area = $\pi r^2 = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{7.7\times10^{-3}}{2}\right)^2 = 46.57 \times 10^{-6}\,\text{m}^2$

Percentage reduction in area = $\frac{(\text{original cross-sectional area}) - (\text{final cross-sectional area})}{\text{original cross-sectional area}} \times 100$

$= \left(\frac{78.54 - 46.57}{78.54}\right)\times100 = \left(\frac{31.97}{78.54}\right)\times100$ = **40.7%**

EXERCISE 30, Page 70

Answers found from within the text of the chapter, pages 64 to 70.

EXERCISE 31, Page XX

1. (f) **2.** (d) **3.** (g) **4.** (b)
