Chapter 2

1. Fill in the blanks (5 pts.)

(1) The maximum engineering stress is called the **Ultimate Tensile strength**.

(2) The modulus of elasticity is essentially a measure of the **Stiffness** of the material.

(3) The speed at which a specimen elongates is called **Strain rate**.

(4) At room temperature, with the same true stress 7075-O Aluminum will have **higher** (higher/lower) strain than 410 stainless steel.

(5) The extent of plastic deformation a material undergoes before fracture is called **Ductility**.

2. Short Answer (10 pts.)

(1). Describe the difference between elastic and plastic behavior (5 pts.)

**Answer:**

Elastic behavior describes the reversible deformation of the material. The material returns to its original shape if the load is removed. Plastic behavior describes the permanent deformation of the material.

(2) What is the effect of temperature on the tensile test? What properties in tension are affected by temperature? (5 pts.)

**Answer:**

Increasing the temperature generally increase the ductility, toughness and the yield stress but decrease the modulus of elasticity. Temperature also affects the strain-hardening exponent of most metals.
3. Below is a plot from a tensile test result. What is the Young’s modulus of this material? What are the plastic range, and the strength? Is it stiffer than aluminum? (10 pts.)

Answer:

Young’s modulus is about 300 Ksi. (Note: This question mainly test whether the student know to the definition of the Young’s modulus.)

Plastic range: See the plot.

The strength is about 1.5 Ksi.

It is not stiffer than aluminum.

4. Quantitative Problems (75 points)

(1) A paper clip is made of wire 0.7 mm in diameter. If the original material from which the wire is made a rod 25 mm in diameter, calculate the longitudinal (along length) engineering and true strains that the wire has undergone during processing. (20 points)

Solution:
Because of volume constancy:

\[
\frac{l_f}{l_o} = \frac{A_o}{A_f} = \left(\frac{d_o}{d_f}\right)^2 = \left(\frac{25}{0.7}\right)^2 = 1275.5
\]

Engineering strain

\[
e = \frac{l_f - l_o}{l_o} = \frac{l_f}{l_o} - 1 = 1275.5 - 1 = 1274.5
\]

True strain

\[
e = \ln\left(\frac{l_f}{l_o}\right) = \ln(1275.5) = 7.151
\]

(2) A 200-mm-long strip of metal is stretched in two steps, first to 300 mm and then to 400 mm. Show that the total true strain is the sum of the true strains in each step; in other words, the true strains are additive. Show that, in the case of engineering strains, the strains cannot be added to obtain the total strain. (15 points)

Solution:

For true strain is obvious

\[
\epsilon_1 + \epsilon_2 = \ln\left(\frac{l_1}{l_o}\right) + \ln\left(\frac{l_2}{l_1}\right) = \ln\left(\frac{l_1}{l_o}\right)\left(\frac{l_2}{l_1}\right) = \ln\left(\frac{l_2}{l_o}\right) = \epsilon_{\text{total}}
\]

which satisfies all numbers. Therefore true strain is additive.

For engineering strain

\[
e_1 + e_2 = \frac{l_1 - l_o}{l_o} + \frac{l_2 - l_1}{l_1} = \frac{300 - 200}{200} + \frac{400 - 300}{300} = 0.833 \neq 1
\]

\[
e = \frac{400 - 200}{200} = \frac{l_2 - l_o}{l_o} = e_{\text{total}}
\]

Engineering strain is not additive.

(3) A cable is made of two strands of different materials, A and B, and cross sections as follows:
For material A, K=60,000 psi, n=0.5, A_o=0.6 in^2.
For material B, K=30,000 psi, n=0.5, A_o=0.3 in^2.
Calculate the maximum tensile force that this cable can withstand prior to necking. (20 points)
Solution:

Necking occurs when $\varepsilon = n = 0.5$. At this point, the true stresses for A and B at necking point are:

$$\sigma_A = 60,000\varepsilon^{0.5} = 424,260 \text{ psi}$$
$$\sigma_A = 30,000\varepsilon^{0.5} = 212,130 \text{ psi}$$

The true areas at necking are:

$$A_A = 0.6 \exp(-0.5) = 0.3639$$
$$A_B = 0.3 \exp(-0.5) = 0.182$$

Thus the total load that the cable can support is

$$P_{total} = (424,260)(0.3639) + (212,130)(0.182) = 193000 \text{ lb}$$

(4) On the basis of the information given in Fig. 2.6 in the text, calculate the ultimate tensile strength (engineering) of 304 stainless steel. (20 points)

Solution:

From Fig. 2.6, the true stress at necking for 304 stainless steel is found to be about 130,000 psi, while the true strain is about 0.45. We also know that the ratio of the original to the necked areas of the specimen is given by

$$\ln\left(\frac{A_o}{A_{neck}}\right) = 0.45$$

Or

$$\frac{A_o}{A_{neck}} = \exp(-0.45) = 0.6376$$

Thus the engineering stress is calculated as

$$S = (130,000)(0.6376) = 82,890 \text{ Psi}$$

Or 571.7 MPa.