Forming of materials

Module -1: Fundamental concepts relevant to metal forming technology

Assignment - Key

1. Distinguish between crystalline and amorphous materials.

Amorphous – absence of long range order.

2. How does elastic deformation and plastic deformation affect the lattice structure of crystals?

Elastic deformation causes temporary displacements of atoms. Plastic deformation causes permanent displacement of atoms by slipping of planes of atoms against other planes.

3. Give examples for materials that do not have crystalline structure.

Glass, amorphous silica, polyethylene.

4. Which one of the following crystal structure has fewer slip systems, so that the material having that structure is more difficult to deform at room temperature?

a) BCC, b] FCC, c] HCP

  c] HCP

5. How many effective number of atoms are there in unit cell of HCP?

2 atoms per unit cell

6. Calculate the packing factor for FCC unit cell.

PF for FCC = \( \frac{4 \times \frac{4m^3}{a^3}}{a^3} = 0.74 \), where \( a = \frac{4r}{\sqrt{2}} \)

7. State Hooke’s law.

Within elastic limit, stress is directly proportional to strain.

8. Define work hardening.

Work hardening is the increase in yield stress of a material due to prior working or straining of the material.

9. Define instability in tension.
Instability in uniaxial tensile test refers to the highly localized deformation called necking resulting in a state of triaxial stress.

10. What test is commonly used for determining the strength properties of brittle materials?

Three point bend test.

11. What method of hardness measurement is suitable for very thin sections like foils?

Microhardness test with loads in fraction of a kilogram.

12. Why higher value of m - the strain rate sensitivity parameter results in more diffuse neck in tensile loading?

With higher m value, the material gets stretched to a greater length before it fails, thereby delaying necking.

13. A certain material has a Poisson’s ratio of 0.5. What is its dilation?

Zero

14. What is the significance of slip systems?

They are responsible for plastic deformation.

15. A certain wire has a diameter of 1 mm. This wire has been made from a rod of 10 mm diameter. Calculate the longitudinal and diametral engineering and true strains undergone by the wire during its production.

Solution:

We can apply the principle of volume constancy for this case as the rod has undergone plastic deformation.

We have: \( \frac{L_f}{L_o} = \left( \frac{d_o}{d_f} \right)^2 = 10 \times 10 / 1 = 100. \)

Longitudinal Engg. Strain = \( \frac{\Delta L}{L} = \left( \frac{L_f}{L_o} \right) - 1 = 99 \)

Diametral engineering strain = \( \frac{d_f}{d_o} - 1 = -0.9 \)

Longitudinal true strain = \( \ln \left( \frac{L_f}{L_o} \right) = 4.605 \)

Diametral true strain = \( \ln \left( \frac{d_f}{d_o} \right) = -2.303 \)

Comment: Both diametral strains are negative because the material undergoes contraction in lateral direction.
16. A material has plastic stress – strain behavior represented \( \sigma = K(\varepsilon + n)^n \). \( K \) is strength coefficient. Determine the true strain at which necking of the material begins during uniaxial tensile loading. Is it possible to have such a material?

Solution:

In necking we have \( \frac{d\sigma}{d\varepsilon} = \sigma \). Please see text for proof.

Now applying this condition for this material necking begins when:

\[
K n (\varepsilon + n)^{n-1} = K (\varepsilon + n)^n
\]

That is, \( n = \varepsilon + n \).

We have seen in the text that for a normal material which obeys a plastic stress-strain relation of the form: \( \sigma = K(\varepsilon)^n \), necking begins when \( n = \varepsilon \). Therefore, it is possible to have such material.

17. A torque of 700 N-m is applied on a torsion test specimen of radius equal to 20 mm, wall thickness of 2 mm. The specimen has a gage length of 50 mm. The specimen undergoes an angular deflection of 0.2\(^\circ\). Calculate the shear stress, shear strain and shear modulus if the deformation is elastic.

Solution: Shear stress = Torque/\( 2\pi R^2 t \) = 139 MPa.

Shear strain is given by:

\[
\gamma = \frac{R \alpha}{L} = 1.4 \times 10^{-3}
\]

\[
\alpha = 0.2 \times 3.14 / 180 = 3.5 \times 10^{-3} \text{ radians}
\]

\[
\tau / \gamma = G = 99,286 \text{ MPa}
\]