Assignment questions. MT30001 Materials Engineering 27 August 2019

Submission instruction:

Send the scanned copy or the soft copy (Word file) of your answers as attachment with the email only to the following email address:

mt30001.SKK@gmail.com

Your email subject must contain your "roll number" followed by "Assignment 1"

Do not send to my office email. It won't be considered if you send to my office email id.

Submission deadline: by 04 September 2019.

1. Frenkel defect belongs to which of the following classes?
   a) point, b) linear, c) 2-dimensional, d) volume

2. Edge dislocation and screw dislocation are linear crystalline defect.
   True or false

3. The solubility of solute in a solvent in a solid solution is governed by Hume Rothery rules. The solubility is more if:
   a) radii of solute are much smaller than that of solvent
   b) solute of a solvent have a similar crystal structure
   c) solute has low valence
   d) all of the mentioned

4. Write down the Bravais lattice and also the number of formula units in one unit cells of ZnS (Zinc blende)

5. Show how a typical stress-strain curve indicating various tensile properties of i) a ductile, and ii) a strain hardened material

6. Differentiate between climb and cross slip, explaining why those are not observed in all dislocations.

7. Write the Hall Petch relation explain its terms.

8. What is slip system? why the deformation in FCC metals is greater than bcc metals although bcc having more number of slip system?

9. Which of the following isn't a strengthening mechanism for a multiphase material?
   a) Precipitation strengthening, b) dispersion strengthening, c) Solid solution strengthening, d) martensite strengthening

10. Which of the following is not improved by grain size reduction?
    a) Hardness, b) toughness, c) elasticity, d) strength

11. Most unsymmetrical Bravais lattice is:
    a) Monoclinic, b) triclinic, c) rhombohedral d) hexagonal

12. Convert [2 -1 -1 1] from sour index system to three index system.
    a) [2 1 0], b) [3 0 1], c) [-1 -1 1], d) [-1 2 1]

13. Which of the following strain field are present for screw dislocation?
    a) tensile, b) compressive, c) shear

14. A eutectoid steel is slowly cooled from a temperature of 750°C to a temperature just below 727°C. Calculate the percentage of Ferrite and Cementite.
    a) 88.3% and 11.7%
    b) 70% and 30 %
    c) 85.4% and 14.6%
    d) 20% and 20%

15. A single crystal of Zinc (Zn) is oriented for tensile stress such that the slip plane normal makes an angle of 60° with the tensile axis. Three possible slip directions lie in this plane and make angles of 30°, 48° and 78° with respect to the applied tensile load. Crystal structure of Zn is HCP and its lattice parameters are a=0.267 nm and c=0.495 nm.
    a. What is the size of the Burgers vector in Zn?
    b. Of the three slip directions described in the problem, which is the most likely to produce slip?
    c. If plastic deformation begins at a stress of 2.5 MPa, determine the critical resolved shear stress for Zn.

16. What is the ratio of the interplanar spacing of the planes denoted by the first two peaks of a XRD profile of a FCC crystal? What is the ratio of the same for a BCC crystal?

Calculate the fraction of atom sites that are vacant for lead at its melting point of 327 °C . Assume and energy for vacancy formation of 0.55 eV/atom

Melting point of lead: 327 °C = 600 K

The fraction of vacancy at any temperature is given by:

$$\frac{N_v}{N} = exp\left(-\frac{Q_v}{kT}\right)$$

Q_v = free energy for vacancy formation, 0.55 eV/atom

k = Boltzmann's constant = 8.62×10^{-5} eV/atom.K

Therefore,

$$\frac{N_v}{N} = exp\left(-\frac{0.55}{8.62 \times 10^{-5} \times 600}\right) = 2.41 \times 10^{-5}$$

Why is interstitial diffusion normally more rapid than vacancy diffusion

Interstitial diffusion is normally more rapid than vacancy diffusion, because

1. Interstitial atoms, being smaller, are more mobile
2. The probability of finding an empty adjacent interstitial site is greater than for a substitutional vacancy adjacent to a host atom

Why are metals with HCP structure more brittle than BCC or FCC metals?

HCP metals are more brittle than BCC and FCC metals because the number of slip systems available in HCP metals are far less than BCC and FCC metals

FCC: 12 slip systems

BCC: 48 slip systems

HCP: only 3 slip systems

An undeformed specimen of some alloy has an average grain diameter of 0.040 mm. You are asked to reduce its average grain diameter to 0.010 mm. Is this possible? If so, explain the procedures you would use and name the processes involved.

Yes, it is possible. In order to do this, plastically deform the material at room temperature (i.e., cold work it), and then anneal at an elevated temperature in order to allow recrystallization and some grain growth to occur until the average grain diameter is 0.010 mm.

What is the magnitude of the maximum stress that exists at the tip of an internal crack having a radius of curvature of 2.5 × 10^{-4} mm and a crack length of 2.5 × 10^{-2} mm when a tensile stress of 170 MPa is applied?

The maximum stress at the tip of an internal crack of length a and radius of curvature ρ is

$$\sigma_m = 2\sigma\sqrt{\frac{a}{\rho}}$$

Using the parameters mentioned in the problem, the maximum stress at the tip of the internal crack:

$$\sigma_m = 2 \times 170 \times \sqrt{\frac{0.025}{0.00025}} = 2404\ MPa$$

Mention two non-destructive testing methods used to detect the internal flaws in a material

1) Ultrasonic testing
2) X-ray imaging

A fatigue test was conducted in which the mean stress was 50 MPa and the stress amplitude was 225 MPa.

(a) Compute the maximum and minimum stress levels.

(b) Compute the stress ratio.

$Mean\ stress = \frac{\sigma_{max}+\sigma_{min}}{2}$ = 50 MPa Stress amplitude $= \frac{\sigma_{max}-\sigma_{min}}{2}$ = 225 MPa

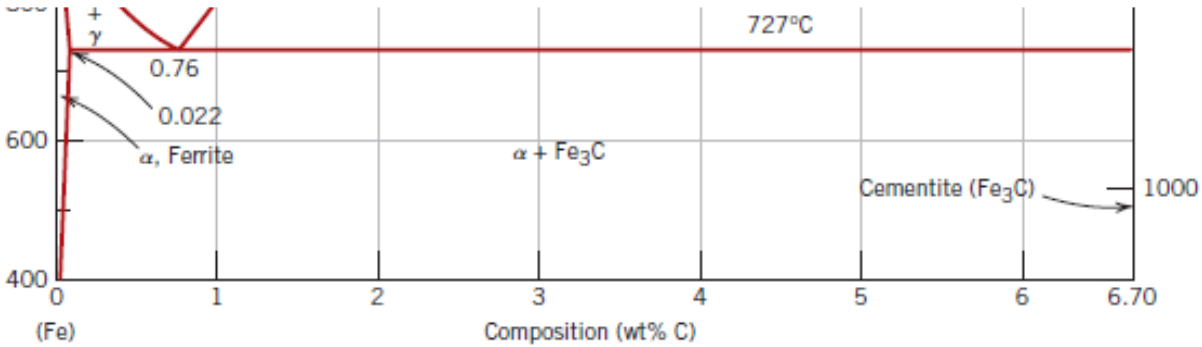
Solving, σ_{max} = 275 MPa and σ_{min} = -175 Mpa

$Stress\ ratio = \frac{\sigma_{min}}{\sigma_{max}} = \frac{-175}{275}$ = -0.64

Cite one undesirable consequence of coring

One undesirable consequence of a cored structure is that, upon heating, the grain boundary regions will melt first and at a temperature below the equilibrium phase boundary from the phase diagram; this melting results in a loss in mechanical integrity of the alloy.

Compute the mass fractions of α ferrite and cementite in pearlite at room temperature



Lever rule needs to be used.

Lever rule expression for ferrite fraction calculation

$$W_\alpha = \frac{C_{Fe_3C} - C_0}{C_{Fe_3C} - C_\alpha} = \frac{6.70 - 0.76}{6.70 - 0.022} = 0.89$$

Hence, mass fraction cementite = 1.00 – 0.89 = 0.11

In a hypoeutectoid steel, both eutectoid and proeutectoid ferrite exist. Explain the difference between them.

For a hypoeutectoid steel, the proeutectoid ferrite is a microconstituent that formed above the eutectoid temperature. The eutectoid ferrite is one of the constituents of pearlite that formed at a temperature below the eutectoid.

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
Mid-Autumn Semester 2019 - 20

Subject Name: MATERIALS ENGINEERING (Sub. No. MT30001)

Date of Examination: 16/09/2019 Session: AN Duration: 2 Hrs. Full Marks: 30

Subject No.: MT30001 **Subject: MATERIALS ENGINEERING**

Department: Metallurgical and Materials Engineering

No specific chart, graph paper, log-book etc is required.
Instructions: Answer ALL the questions. Total number of questions: 5. Total number of pages: 2. Where necessary, use schematic diagrams to illustrate your answer.

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1. Q1 Total: 6

(a) A single crystal of Zinc (Zn) is oriented for tensile test such that the slip plane normal makes an angle of 60° with the tensile axis. Three possible slip directions lie in this plane and make angles of 30°, 48° and 78° with respect to the applied tensile load. Crystal structure of Zn is HCP and its lattice parameters are a=0.267 nm and c=0.495 nm.

a. What are the Miller Bravais indices of the slip plane normal and all the three slip directions? 2

b. If plastic deformation begins at a tensile stress of 25 MPa, determine the critical resolved shear stress for Zn. Show your work. 4

2. Q2 Total: 6

(a) The yield stresses σ_Y have been measured using aluminum specimens of various grain sizes (diameter d), as follows: 4

d	σ_Y
μm	MPa
11.1	235
100	225

i. Determine the coefficients σ_0 and k_Y in the Hall-Petch relation for this material.

ii. Determine the yield stress for a grain size of d=30μm.

(b) Which type of dislocation can cross slip? In general, easy cross slip in a material will cause more or less strain hardening? 1+1

3. Q3 Total: 6

(a) Convert $[2\bar{1}\bar{1}1]$ from four index Miller-Bravais system to three index Miller system. 2

Please turn over

(b) Write down all the possible slip systems (specific plane, and direction combination) in Nickel (FCC). 3

(c) Calculate the liear density (number density of atoms) of $[\bar{1}10]$ direction in a BCC crystal with lattice parameter 4 Angstrom. 1

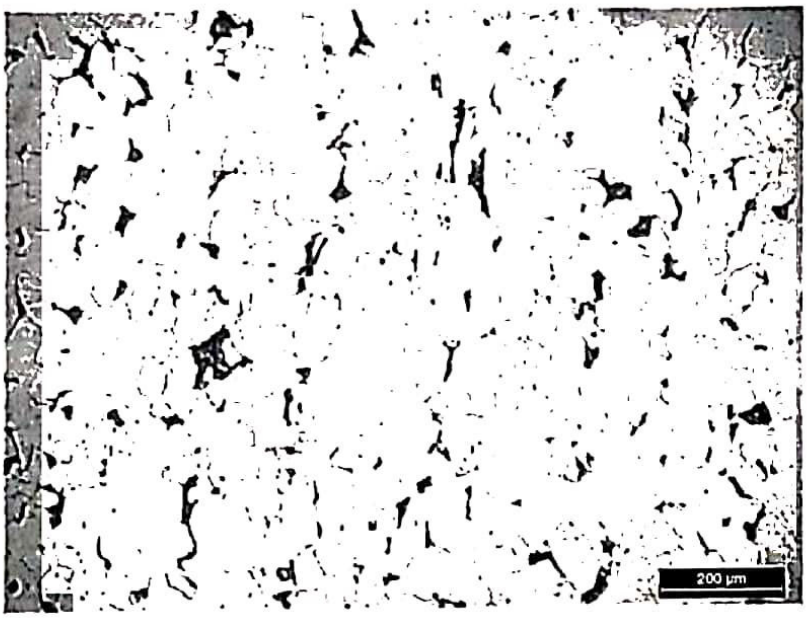
4. Q4 Total: 6

(a) Can an Iron-Carbon alloy that goes through Eutectic reaction during solidification be called as steel? 1

(b) With respect to the microstructure of a hypoeutectoid plain carbon steel given below,

i. Predict the alloy composition. State your assumption for the volume fractions of the pro-eutectoid phase. Assume that weight fraction = volume fraction. Show your work. 4

ii. What is the bright region, what is the dark region? 1



5. Q5 Total: 6

(a) Draw schematically a Time-Temperature-Transformation diagram for Austenite to Pearlite transformation for a plain carbon steel of Eutectoid composition. Show the equilibrium transformation temperature, and TTT curves for start and finish of the transformation. Explain the shape of the transformation curves with reason. 5

(b) What will be the transformation product if during quenching (cooling very fast) from the Austenitizing temperature, the cooling rate is so fast that one can avoid the nose of the above (transformation start) curve? 1

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INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
End-Autumn Semester 2019 - 20

Subject Name: MATERIALS ENGINEERING (Sub. No. MT30001)

Duration: 3 Hrs. Full Marks: 50

Subject No.: **MT30001** Subject: **MATERIALS ENGINEERING**

Department/Center/School: Metallurgical and Materials Engineering

Instructions: Answer **ALL** the questions. Total number of questions: 5. Total number of pages: 2. Answer **ALL** parts of a particular question together. Where necessary, use schematic diagrams to illustrate your answer.

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1 a) Considering strength, toughness and Young's modulus as separate material properties, arrange ceramics, metals and polymers in ascending order for each property 3

b) For a sample very difficult to prepare metallographically, which of Brinell, Vickers and Rockwell hardness testing method should be selected? Explain briefly 2

c) Consider two different metals A and B having similar melting points but with different crystal structures – A: fcc and B: bcc. Which metal should be preferred for better creep resistance? Explain briefly 2

d) A specimen of aluminium with a Young's modulus of 70 GPa is being pulled in tension with a force of 40 kN. If the cross-section of the specimen is 12 mm × 12 mm and considering only elastic deformation, how much total elongation is expected? If the Poisson's ratio of aluminium is 0.33, calculate its shear modulus. 2+1

2 a) How should the thermal properties of a material be selected to obtain optimum resistance against thermal fatigue? 2

b) For typical metallic materials, schematically draw the creep strain rate vs. time curve. Show in the same diagram, how an increase in stress and temperature should affect the original curve. 1+1

c) How should the tensile true stress – true strain plot of a metallic material differ from that of engineering stress – engineering strain plot? Explain briefly. 2

d) A cylindrical rod 380 mm long, having a diameter of 10.0 mm, is to be subjected to a tensile load of 24.5 kN. If the rod is to experience neither plastic deformation nor an elongation of more than 0.9 mm, show which of the following metals should be selected:

Material	*Modulus of Elasticity (GPa)*	*Yield Strength (MPa)*	*Tensile Strength (MPa)*
Aluminum alloy	*70*	*255*	*420*
Brass alloy	*100*	*345*	*420*
Copper	*110*	*250*	*290*
Steel alloy	*207*	*450*	*550*

4

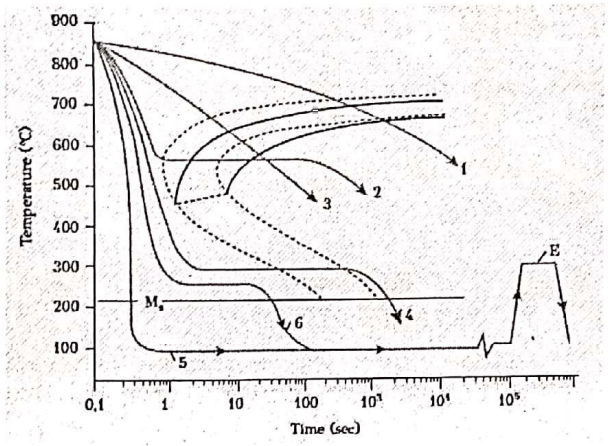
3 a) For a plain carbon steel with 0.4 wt.% C estimate the amount of i) total ferrite, ii) total cementite, iii) pearlite and iv) proeutectoid ferrite formed under equilibrium cooling. 4

b) Over the whole range of C-content (up to 2.1 wt.%) how should C-content influence the i) hardness and ii) ultimate tensile strength of steels? Explain with schematic plot 2

c) A structural component is to be fabricated from an alloy that has a plane strain fracture toughness (K_{IC}) of 77 MPa√m and yield strength of 1400 MPa. The flaw size resolution limit of an ultrasonic detector is 4.0 mm. If the design stress is one half of the yield strength and the value of Y is 1.0, determine whether or not a critical flaw for this plate is subject to detection. 3

d) Among two steels i) plain carbon steel with 0.6 wt.% C and ii) alloy steel with 0.6 wt.% C; which one should have higher retained austenite at room temperature after quenching? Give very brief justification. 1

4 a)



Identify the different heat treatment processes (cooling curves 1 - 6) in the above plot 3

b) What is intergranular attack in stainless steels? How can stabilized steels avoid the problem of sensitization? 2+1

c) Predict the microstructures expected at room temperature under the following conditions in the mentioned alloy systems:

i) Cast iron containing 3 wt.% C, 2.5 wt.% Si and cooled very slowly

ii) Cast iron containing 4.5 wt.% C, 1 wt.% Si and cooled rather fast

iii) Stainless steel containing 0.04 wt.% C, 20 wt.% Cr, 7 wt.% Ni, 2 wt.% Mo

iv) Plain carbon steel containing 1.2 wt.% C after prolonged holding at just below A_{c1} temperature 4

5 a) You are given four unnamed blocks of different metals. The blocks correspond to copper, aluminium, magnesium and nickel. Without using any equipment and just by using your sensory organs, how would you identify the blocks in a non-destructive manner? 4

b) Why is the flexural strength of a ceramic body higher than its tensile strength? 2

c) For a continuous alumina fiber reinforced aluminium metal matrix composite predict the expected Young's modulus along the fibers and transverse to the fibers. Given: fiber content = 40 vol.%, Young's modulus of alumina = 390 GPa, Young's modulus of aluminium = 70 GPa. Assume absence of porosity 4

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