CBCS SCHEME

USN 18ME34

Third Semester B.E. Degree Examination, Dec.2019/Jan.2020
Material Science

Time: 3 hrs. Max. Marks: 100

Note: ***Answer any FIVE full questions, choosing ONE full question from each module.***

Module-1

1 a. Define APF. Calculate the APF for BCC Unit cell. (07 Marks)
b. Explain edge dislocation and screw dislocation. (08 Marks)
c. State and explain Fick's 1st law of diffusion. (05 Marks)

OR

2 a. Define Stiffness , Yield strength , Toughness and Ultimate tensile strength. (08 Marks)
b. Explain Plastic deformation by Slip and twinning. (06 Marks)
c. Explain strain hardening and solid state hardening process of strengthening of metals. (06 Marks)

Module-2

3 a. Draw and explain the S – N curve. (04 Marks)
b. Derive and expression for stress relaxation. (04 Marks)
c. Draw the Iron carbon diagram indicating the phase temperatures. Explain the different phases in Iron carbon diagram. (12 Marks)

OR

4 a. State and explain Hume Rothery Rules. (06 Marks)
b. Explain the effect of any 4 alloying elements in steel. (06 Marks)
c. Two metals A & B are alloyed in the proportion of 60% A and 40% B. The melting temperature of A & B are 650°C and 450°C. When they are alloyed together they do not form any compound or intermediate phase, but form an Eutetic of composition 40% A and 60% B which solidifies at 300°C. The maximum and minimum solid solubilities of B in A and A in B are 10% at 300°C and remains constant till 0°C. Assume solidus , liquidus and solves lines to be straight.
i) Draw the equilibrium diagram and label all the fields.
ii) The temperature at which solidification start and complete.
iii) Percentage of Eutectic at room temperature. (08 Marks)

Module-3

5 a. Define Heat treatment and give its classification. (06 Marks)
b. Explain how a TTT diagram is drawn. (08 Marks)
c. Explain Austempering and Martempering. (06 Marks)

OR

6 a. Draw the TTT diagram for Eutectoid steel and explain it. (07 Marks)
b. With neat sketch, explain induction hardening process. (05 Marks)
c. Explain the composition , properties and uses of Gray Cast Iron, White Cast Iron and SG Iron and Malleable Iron. (08 Marks)

Module-4

7 a. Define Composite. Give its classification. (06 Marks)
b. Explain metal matrix composites and ceramic matrix composites. (06 Marks)
c. List the advantages, disadvantages and applications of composite materials. (08 Marks)

OR

8 a. Derive an expression for Young's modulus for ISO stress and ISO strain condition. (12 Marks)
b. With neat sketch, explain Pultrusion process. (08 Marks)

Module-5

9 a. Define Ceramic. Explain the types of ceramics. (05 Marks)
b. Differentiate between Thermoplastic and Thermosetting plastics. (05 Marks)
c. With neat sketch, explain Processing of plastic by Injection Moulding method. (10 Marks)

OR

10 a. Explain the different Non – destructive testing methods used for accessing residual life (10 Marks)
b. Define Smart Material. Explain the types of smart materials. (10 Marks)

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Solved Question Paper

Sem: III

Sub: Material Science (18ME3

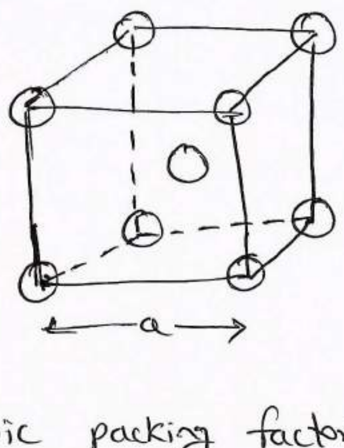
Examination: Dec2019/Jan2020

Module- I

Q1. a. Atomic Packing Factor: It is the ratio of volume of atoms per unit cell to total volume occupied by the unit cell.

$$APF = \frac{\text{Volume of atom / unit cell}}{\text{Total volume occupied by the unit cell}}$$

Calculation of APF for BCC unit cell:



$$\text{Atomic packing factor} = \frac{\text{Volume of atoms in unit cell}}{\text{Volume of unit cell}}$$

$$= \frac{\text{Volume of 1 centre atom} + 8 \times \frac{1}{8} \text{ volume of 1 atom}}{a^3}$$

(Gurunath Mevundi)

$$= \frac{2 \times \text{Volume of 1 atom (Spherical Shape)}}{a^3}$$

$$= 2 \times \frac{4}{3}\pi R^3 \times \frac{1}{\left(\frac{4R}{\sqrt{3}}\right)^3} \qquad \because a = \frac{4R}{\sqrt{3}}$$

$$= \frac{8}{3} \times \frac{\pi \, 3\sqrt{3}}{4^3}$$

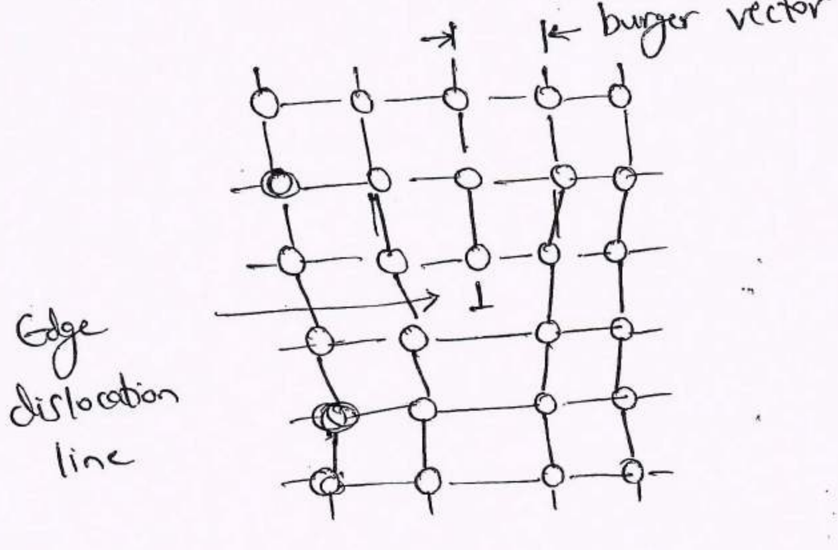
$$= 0.68 \text{ or } 68\%.$$

Q1.b. Linear defects :

Dislocation is a one-dimensional defect around which some of the atoms are misaligned.

Edge dislocation: An extra portion of plane of atoms or half plane, the edge of which terminates within the crystal.

It is a linear defect that centers around the line that is defined along the end of the extra half plane of atoms.

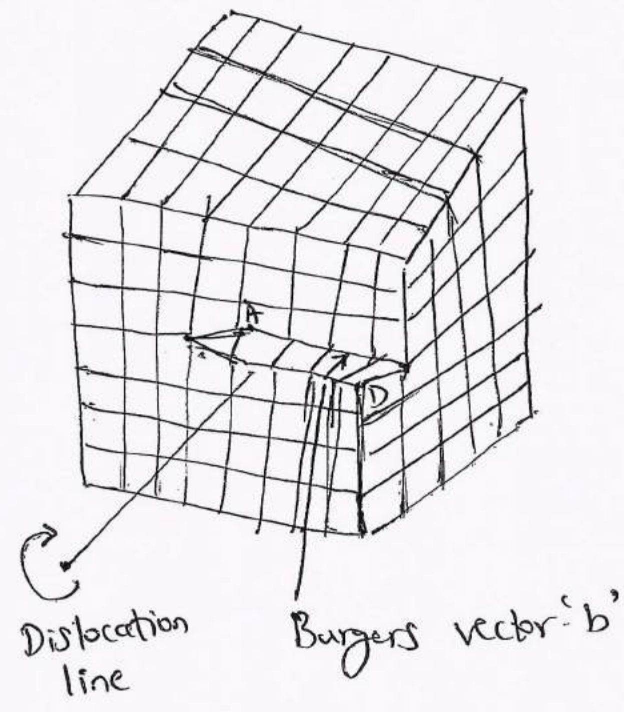


Edge dislocation is represented by the symbol ⊥.

Screw dislocation:

- Screw dislocation is formed by a shear stress that is applied to produce the distortion as shown in the figure below.

- Upper front region of the crystal is shifted one atomic distance to the right relative to the bottom portion.



Magnitude & direction of lattice distortion is expressed in terms of Berger's vector denoted as 'b'.

- It is characterised by spiral or helical path that is traced around the dislocation line by the atomic planes of atoms

- Some times there can be combination of dislocations

ex - edge dislocation + screw dislocation.

Q 1 C. Fick's 1st law of diffusion:

Fick's 1st law of diffusion states that "for diffusion to occur between 2 points there exists concentration gradient and the rate of diffusion is proportional to concentration gradient."

-or-

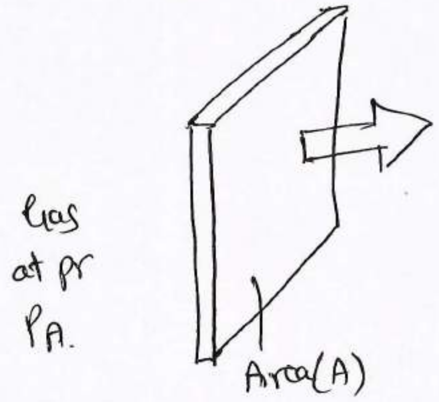
"Flux or flow of atoms in the system is proportional to concentration gradient and related through expression, $J = -D . \frac{dc}{dx}$ "

where J = flux or flow of atoms (rate of diffusion)

D = Proportionality constant called diffusivity

$\frac{dc}{dx}$ = Concentration gradient

According to this, there is no change in concentration of Solute atoms at the planes for the system with time.



$P_A > P_B$

$$\text{Concentration gradient} = \frac{dc}{dx} = \frac{C_A - C_B}{X_A - X_B}$$

Q2. a. Definitions:

Stiffness: Stiffness is the material's resistance to elastic deformation. Stiffness describes the opposition offered by the material for elastic deformation.

Yield Strength: Yield strength is the strength value (or point on stress strain curve) at which significant plastic deformation starts. For some materials, it is taken as strength value corresponding to 0.2 % plastic strain.

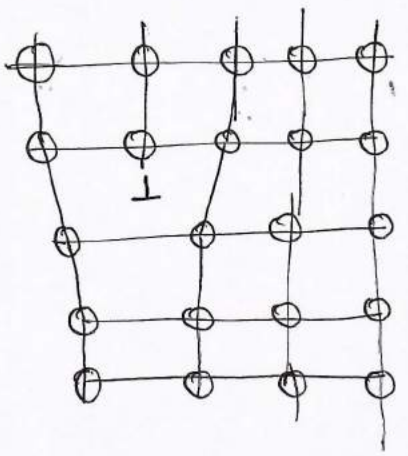
Toughness: Toughness is defined as the measure of the ability of a material to absorb energy during plastic deformation upto fracture.

Ultimate tensile strength: Ultimate tensile strength is the maximum strength reached in the engineering-stress-strain curve. It is maximum stress value developed in the specimen (material).

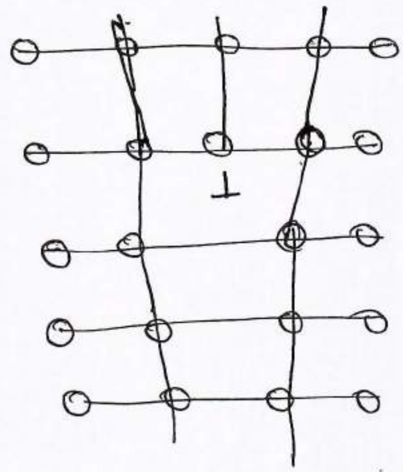
Grn.

Q2. b.

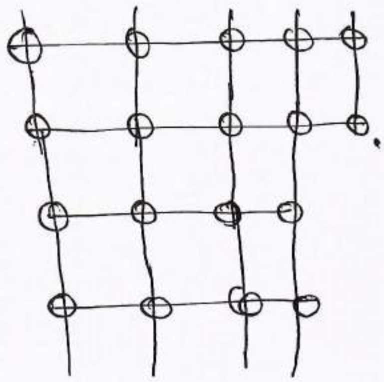
Plastic deformation by slip:



(a)



(b)



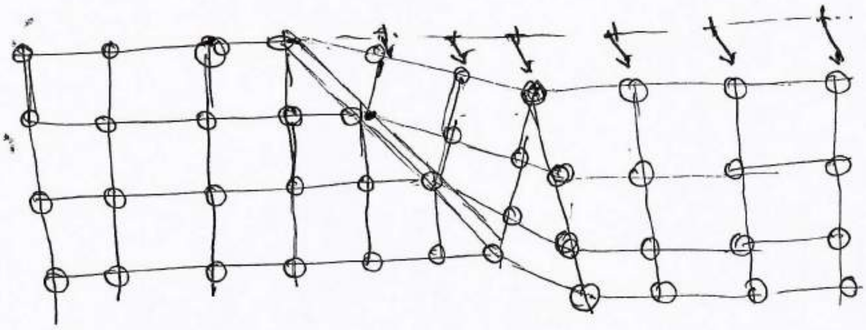
(C)

This involves motion of large number of dislocations.

- An edge dislocation moves in response to a shear stress applied in a direction perpendicular to line. It causes shift of atomic bonds to next plane (fig b)

- Dislocation moves across the crystal.

Plastic deformation by twinning:



- In this type of deformation, a part of the atomic lattice is deformed so that it forms a mirror image of the undeformed lattice next to it.
- The plane about which undeformed and deformed parts of metal lattice are found is called twinning plane.
- In twinning, the atoms move distances proportional to their distances from the twinning plane.

Q2. c.

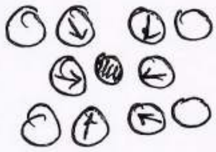
Strengthening mechanisms are used to increase the Strength of metals & alloys by some actions.

i) <u>Strain hardening:</u> It is the phenomenon whereby a ductile metal becomes harder and stronger as it is plastically deformed. It is also called as work hardening or cold working. As the metal is deformed, or when it undergoes cold working, the dislocation density in metal increases. [They are positioned closer]. This results in hinderance to dislocation movements. Thus imposed stress necessary to deform a metal increases with increasing cold work.

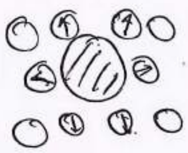
ii) <u>Solid state hardening:</u> (Solid solution hardening)

In this process, metals are alloyed with impurity atoms that go into either substitutional or interstitial solid solution. The impurity atoms that go into solid solution impose lattice strains on the surrounding host atoms.

Lattice strain field interactions b/w dislocations and impurity atoms result & consequently dislocation movement restricted.



a) Smaller impurity atom induces tensile strains on host atoms



b) Larger impurity atom added induces compressive strains on host atoms.

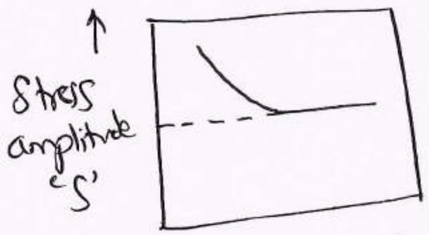
[illegible]

Module-2

Q3. a. S-N curve is used to determine fatigue life of the components. The component (specimen) is subjected to required type of fatigue loading and data are plotted as stress 'S' vs the logarithm of the number 'N' of cycles to failure for each of the specimens.

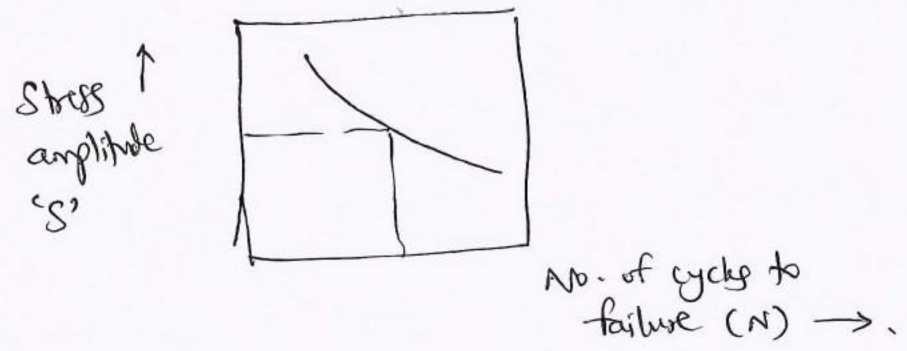
The values of 'S' are normally taken as stress amplitudes (σ_a), sometimes σ_{max} & σ_{min} values can also be used.

i) fatigue limit S-N curve.



For some Fe & Ti alloys, S-N curve becomes horizontal @ higher N value or there is limiting stress level called fatigue limit (endurance limit) below which fatigue failure will not occur.

ii) No. of cycles for fatigue failure.



Most non ferrous alloys (Al, Cu, Mg) do not have fatigue limit. S-N curve continues its downward trend @ increasingly greater N values. Here it is defined as fatigue strength – stress level @ which failure will occur for some specified No. of cycles.

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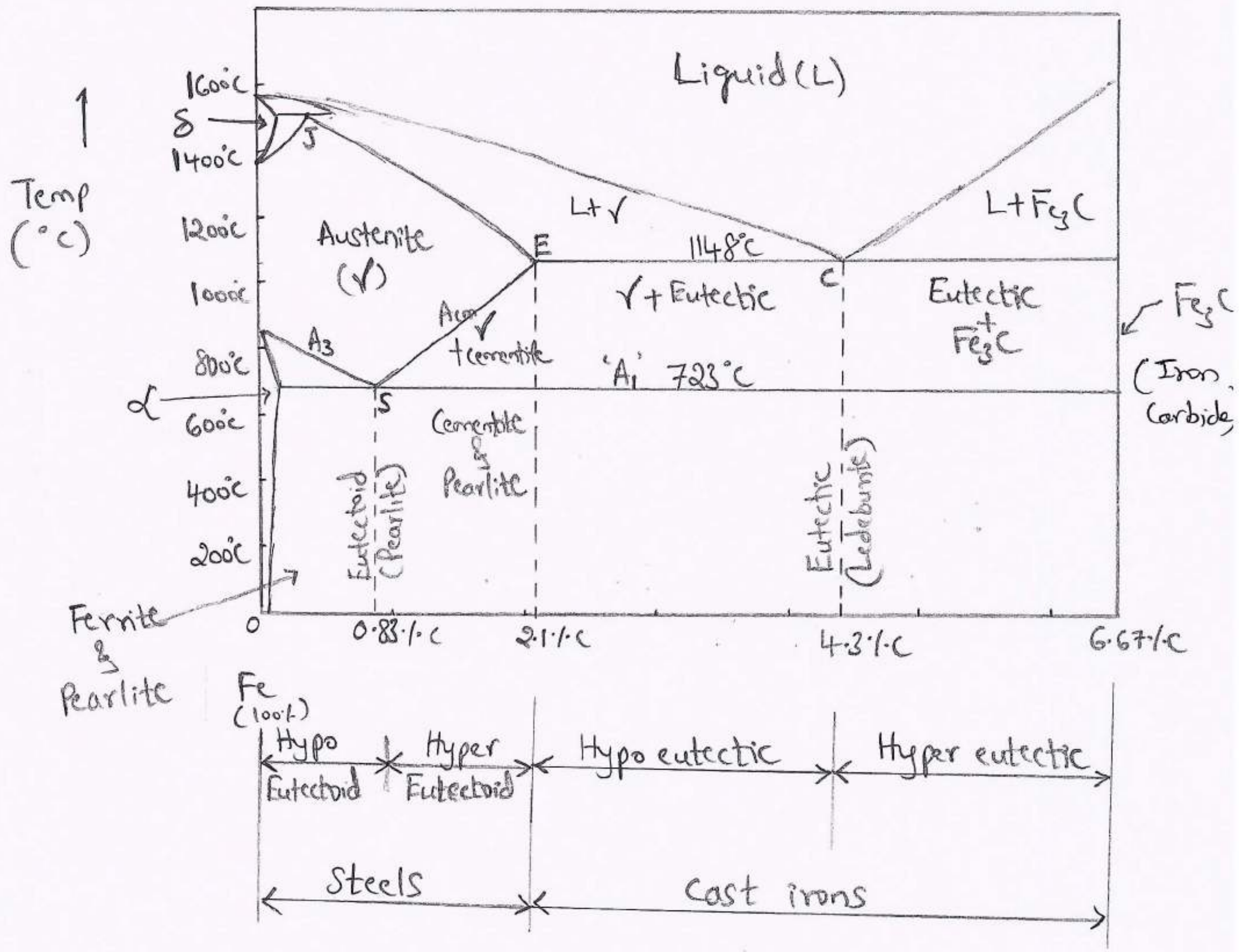
Q3. C. Iron Carbon Equilibrium Diagram:



Reactions:

1) Peritectic reaction: 1493°C @ point 'J'

$$L + \delta \rightleftharpoons \gamma \text{ (Austenite)}$$

2) Eutectic reaction: 1148°C @ point 'C'

$$L \text{ (Liquid)} \rightleftharpoons \gamma \text{ (austenite)} + Fe_3C \text{ (iron carbide)}$$

[austenite + Fe_3C = Ledeburite]

3) Eutectoid reaction : 723°C @ point 'S'

$$\gamma \text{ (austenite)} \rightleftharpoons \alpha \text{ (ferrite)} + Fe_3C$$

Different phases in iron carbide diagram:

1) Austenite (γ):
- Austenite is the solid solution of carbon and other alloying elements in gamma iron
- Max 2.1 % C
- Austenite is normally not stable at room temperature.
- Austenite is non magnetic and soft.

2) Ferrite (α):
- Ferrite is B.C.C. iron phase with very less solubility for carbon.
- Ferrite is softest structure in iron carbon phases.

3) Cementite (Fe_3C):
- Cementite or iron carbide (Fe_3C) contains 6.67 % of carbon
- It is very hard and brittle

4) Pearlite: It consists of alternate lamellae of ferrite and cementite. It is formed by austenite with eutectoid reaction (0.83 % carbon).

Gous.

5) Bainite:

- Bainite is mixture of ferrite and cementite
- Bainite is formed inbetween pearlite and martensite by austempering process.

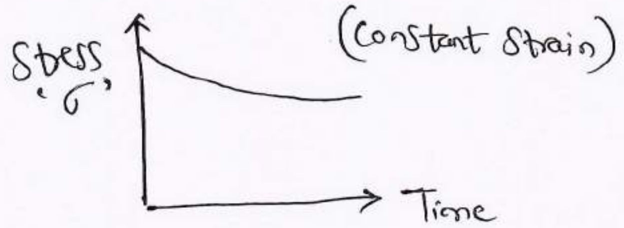
6) Martensite:

- Martensite is formed by transformation of austenite below Ms (Martensite-start) temperature by quenching process.
- It is very hard structure obtained by hardening and quenching process.

Shea.

Q3.b. Stress relaxation:

Stress relaxation is a time dependent decrease in stress under a constant strain. This characteristic behaviour is studied by applying fixed amount of deformation to a specimen and measuring the load required to maintain it as function of time. This is particularly observed and studied in polymers.



relaxation modulus, $E_r(t) = \frac{\sigma(t)}{\epsilon_0}$

[Time dependent elastic modulus] ↗

ϵ_0 = constant strain, $\sigma(t)$ = Stress necessary to maintain this strain

Gopi.

Q 4. a. Factors affecting Solid Solution (Hume Rothary Rules)

The fraction of atoms of one element that can dissolve in another can vary from a fraction of an atomic percent to 100 %. Following conditions known as Hume Rothary rules are favourable for extensive solid solubility of one element in another.

1. The diameter of the atoms of the elements must not differ by more than about 15 %.

2. The crystal structures of the 2 elements must be same.

3. There should be no appreciable difference in the electronegativities of the 2 elements so that compounds will not form.

4. The 2 elements should have same valence.

If the atomic dia differ there will be distortion of crystal lattice. Since the atomic lattice can only sustain a limited amount of contraction or expansion, there is a limit in diff in atomic diameters. (15 %) (Rul No. 1).

If the solute & solvent atoms have same crystal structure, then extensive solid solubility is favourable. (Rule no. 2)

Also if there is greater difference in electronegativity, highly electropositive element will loose electrons, & highly electronegative element will acquire electrons, & compound formation will result (∴ Rule NO.3).

If there is shortage of electrons b/w the atoms, the binding b/w them will be upset, resulting in conditions unfavourable for solid solubility (∴ Rule NO.4).

Gom

Any 4 need to be explained.

24.b. Effect of common alloying elements in steel

Alloying elements are added to improve some of the properties like; corrosion resistance, strength, hardenability, ductility, toughness, wear resistance etc. Few important are as below:

1) Carbon: Carbon content in steel affects
   - hardness
   - Tensile strength
   - machinability
   - melting point

2) Nickel
   - increases toughness & resistance to impact
   - lessens distortion in quenching
   - lowers critical temp of steel
   - Strengthens steel

3) Chromium
   - Joins with carbon to form chromium carbide thus adds to depth hardenability with improved resistance to abrasion & wear

4) Silicon
   - improves oxidation resistance
   - Strengthens low alloy steels
   - acts as deoxidiser

Molybdenum

- Promotes hardenability of steel
- makes steel fine grained
- raises tensile & creep resistance @ high temp
- corrosion resistance

Vanadium:

- Promotes fine grain in steel
- Increases hardenability
- imparts strength & toughness - heat treated steel

Tungsten

- increases hardness & red hardness
- resists heat
- promotes fine grain

Manganese:

- Contributes markedly to strength & hardness
- Counteracts brittleness from sulphur

*

Copper - increases resistance to atmospheric corrosion
acts as strengthening agent

Cobalt

- contributes to red hardness
- improves mechanical properties - tensile strength, fatigue "
- refines graphite & pearlite
- improves heat resistance

Aluminium - acts as deoxidiser
- promotes nitriding

[signature]

Q 4. c.

Data: Metals : A & B

Alloy composition: 60% A & 40% B

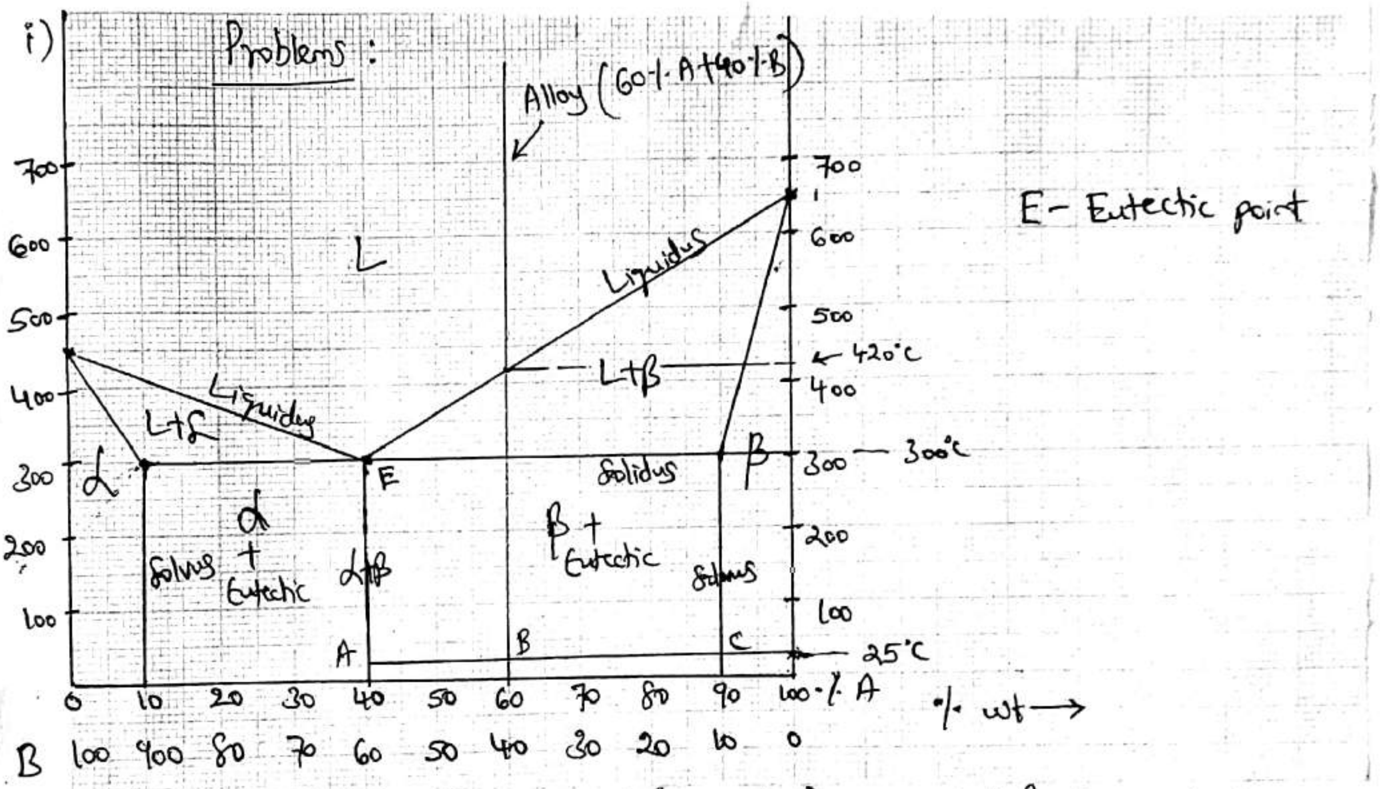
Melting temp of A : 650°C

" " " B : 450°C

Eutectic composition : 40% A & 60% B. @ 300°C

Max solubilities in each other : 10%.

i) Problems :



ii) For alloy (with 60% A & 40% B) – solidification starts at 420°C and ends @ 300°C.

iii) % of eutectic at room temp (25°C) = $\frac{AB}{AC} \times 100$

$= \frac{20}{50} \times 100 = 40\%$

Module-3

Q 5. a. **Heat treatment:** Heat treatment may be defined as an operation or combination of operations involving heating & cooling of a metal / alloy in solid state to obtain

a) desirable conditions, ex: relieved stress condition

b) desirable properties, ex: better machinability, high hardness & strength, homogeneous structure, improved ductility etc.

Classification of heat treatment process:

1. Annealing
   a) Stress relief annealing
   b) Process annealing
   c) Spheroidising "
   d) full annealing
2. Normalising

} increasing ductility & toughness

3. Hardening (by quenching)
4. Tempering

} increasing hardness & strength

5. Martempering
6. Austempering.
7. Maraging.

Gm.

5.b. <u>Construction of T.T.T.</u>

1. obtain large No. of small specimens from same bar

2. Place the samples in a molten salt bath held @ proper austenitizing temperature (complete austenite).

3. Then samples are quickly transferred to other molten salt bath held at desired reaction temperature below A1

4. Then the specimen is quenched in cold water or iced brine. (time may vary from few seconds, minutes to hours).

5. As the specimen is quenched in water, this stops isothermal reaction (or heat treatment). by causing the remaining (untransformed) austenite to change instantly to martensite

6. When a large number of specimens isothermally reacted for varying time period reaction curve is obtained.

7. When the data obtained from a series of isothermal reaction curves over the whole temp range, the result is TTT diagram for that steel.

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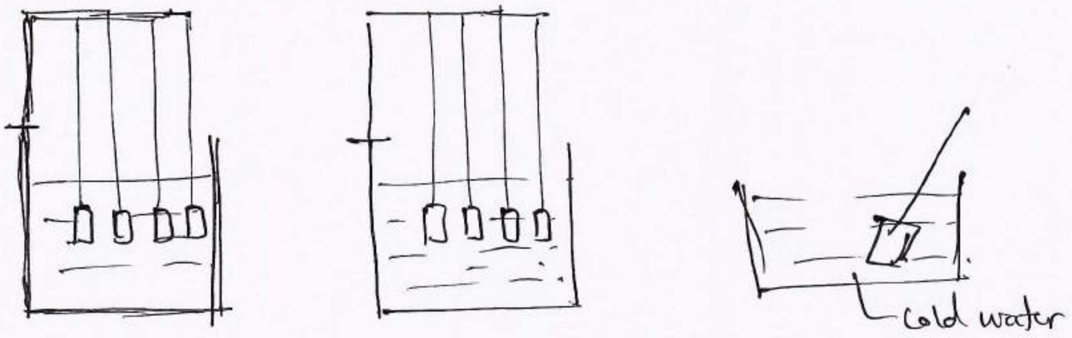
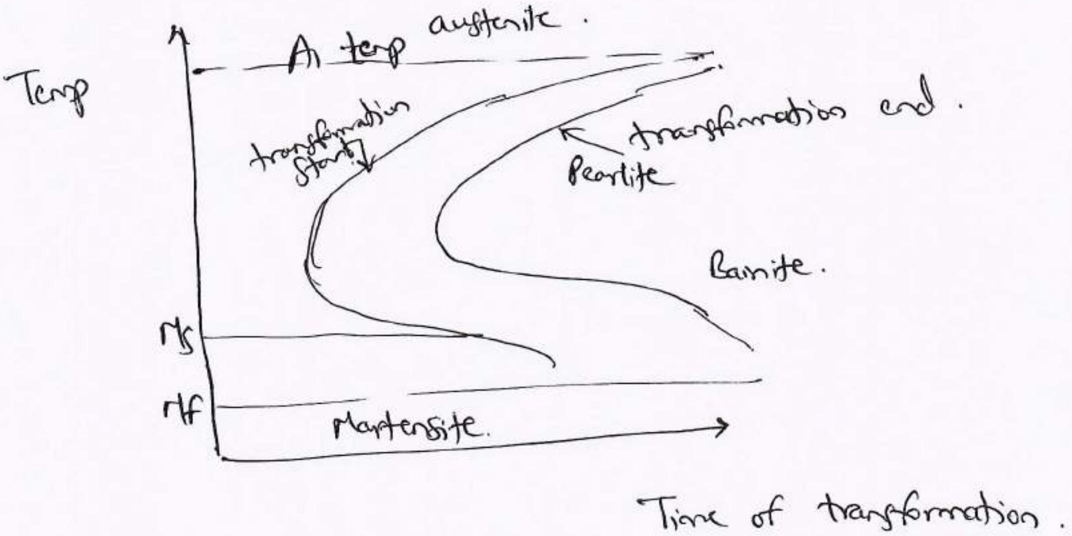


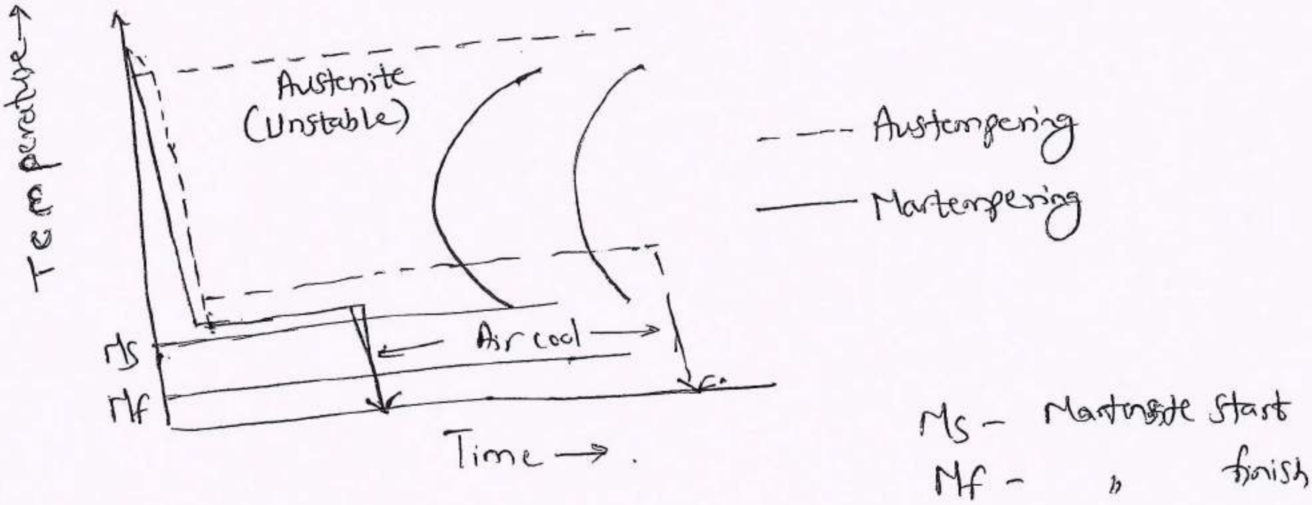
Molten salt bath (>750°C)
Austenitizing
(a)

Isothermal heat treatment
(b)

Quenching.
(c)



5.C. Martempering & Austempering.



Martempering:

In martempering, steel is

i) heated to above critical range to make it all austenite; is then

ii) quenched into a salt bath maintained at a temp above the Ms & is held at this temp along enough until the temp is uniform across the section of workpiece (i.e, from surface to core) without transformation of the austenite and

iii) Subsequently cooling the workpiece in air through the martensite range.

The result is the formation of martensite with minimum of stresses, distortion & cracking.

- The steel can be further tempered to increase ductility.
- Large sections can not be martempered ∵ time required to obtain temp uniformity exceeds the start of transformation of austenite into bainite.

Austempering:

- It is not a hardening treatment.
- Austempering is another type of interrupted quenching that forms bainite (& not martensite)
- In structure & properties, however the bainite thus formed closely resembles tempered martensite.

In general, steels treated thus are tougher & more ductile than steels of tempered martensite having equal hardness and tensile strength.

Austempering consists of:

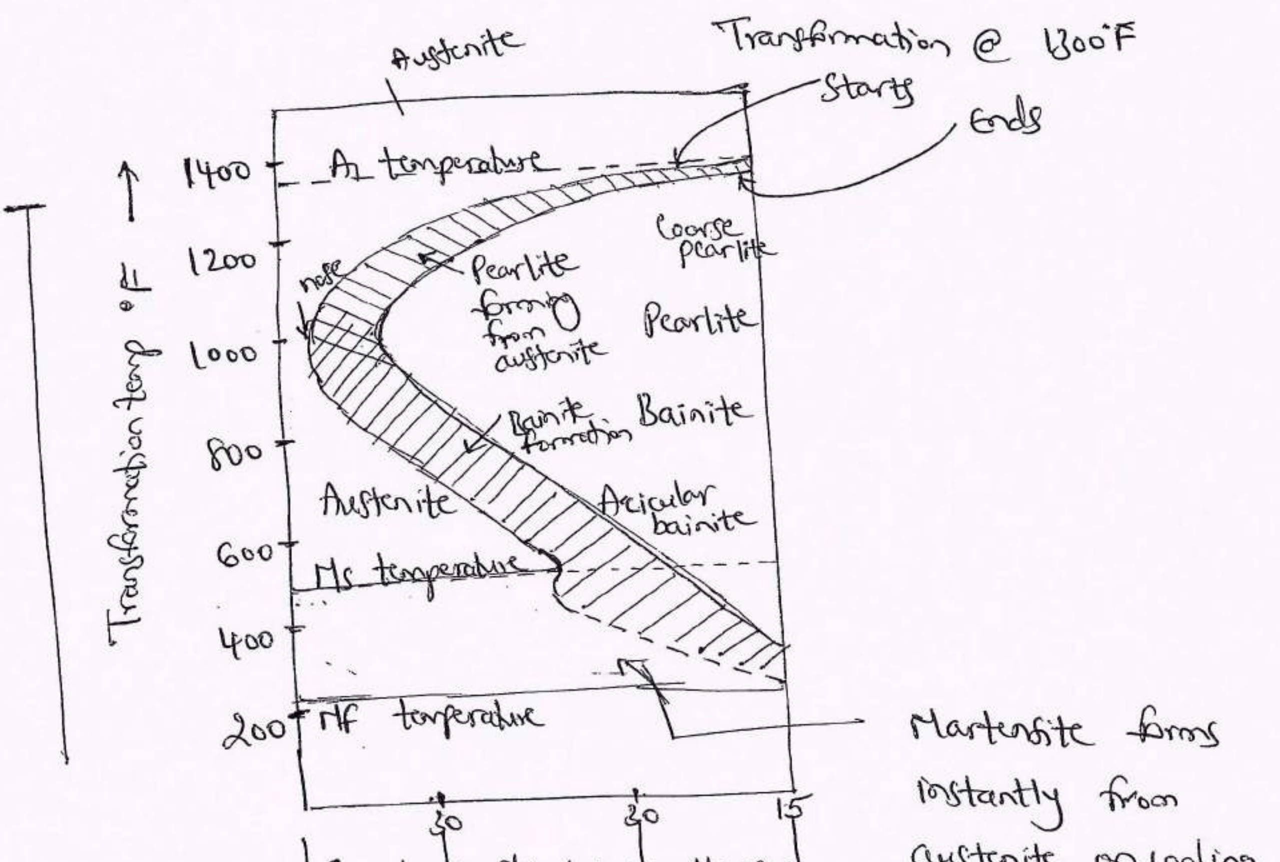
i) heating the steel above critical range to make it all austenite
ii) quenched @ critical cooling rate into salt bath / lead bath held in the bainitic range (b/w 205°C to 425°C)
iii) austenite ⟶ bainite (in salt bath)
iv) allowed to cool to room temp (rate is immaterial)

Adv: Greater ductility & toughness along with hardness less distortion & less quenching cracks.

26. a. **T.T.T. diagram for Eutectoid steel :**

Time – Temperature – Transformation diagram is also known as S – curve, C – curve, Bain's curve or Isothermal transformation diagram.

– It shows relationship b/w temperature and time taken for decomposition transformation to take place in a metal when transformation is isothermal.



T.T.T. diagram features:

- Austenite is stable above A1 temp line & below this it is unstable, i.e, it can transform into pearlite, bainite or martensite.

- There are variations in the structure & rate of transformation.

- Transformations @ temp b/w 1300°F to 1020°F result in the characteristic lamellar microstructure of pearlite.
  If transformation temp is high coarse parlite is obtained.
  " " " " low fine " " "

- At still lower temp (up to 465°F) transformation becomes more sluggish & the transformation product is bainite.

- At the foot of TTT diagram, there are 2 lines Ms (240°C or 465°F) & Mf (-50°C)

  Ms - Martensite start temp

  Mf - " finish temp.

  Martensite is formed by the diffusionless transformation of austenite on rapid cooling to a temp below 465°F.

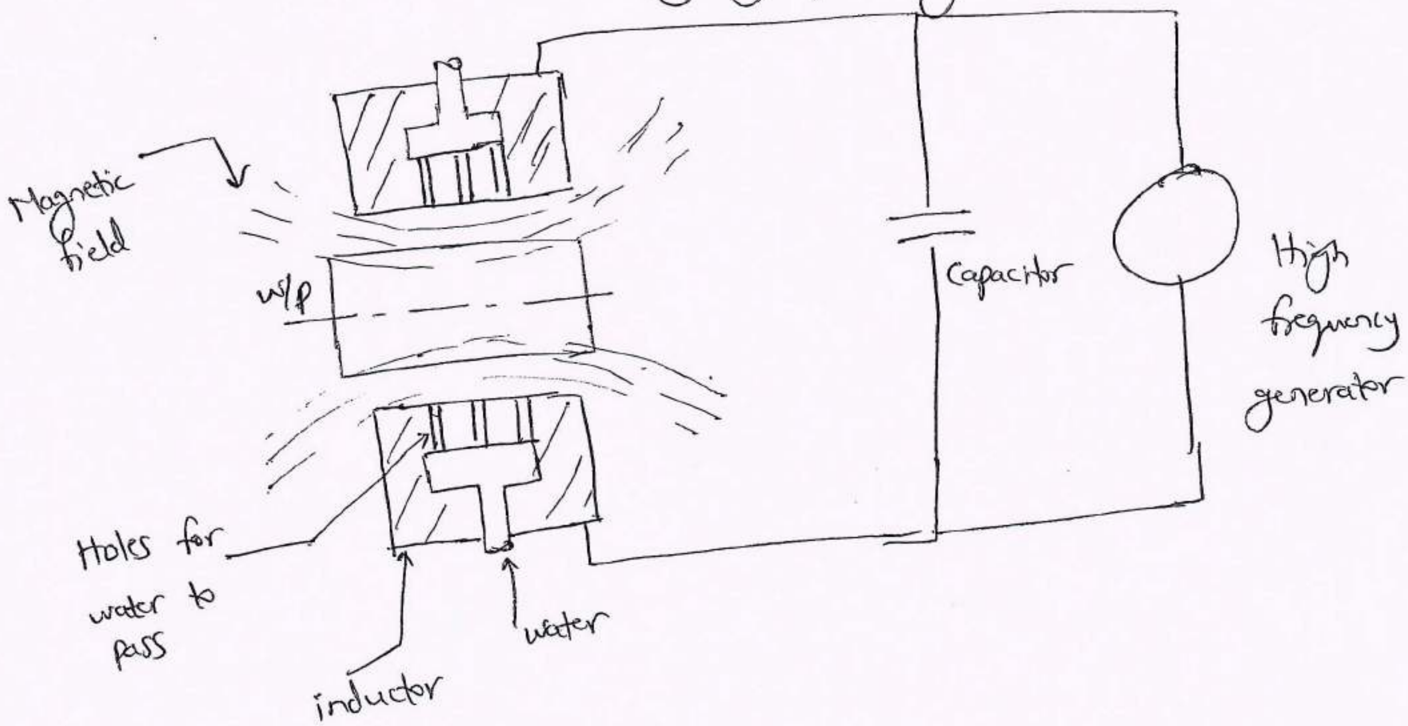
Gowri

Q6b. Induction Hardening:

Induction hardening involves:

i) heating medium carbon steel by means of alternating magnetic field to a temperature within or above the transformation range (the hardening temp is about 750 to 800°c)

ii) followed immediately by quenching.



Procedure:

1) High frequency currents are generated using
a) motor generators b) spark gap oscillators c) vacuum tube oscillator

2) The component to be induction hardened is placed in the inductor/coil

3) When high frequency alternating current is passed through the inductor coil, it sets up changing magnetic field.

4) When magnetic lines pass through surface of component, they induce in the component an alternating current of the same frequency but reversed in direction. Heating results from the resistance of the metal to passage of these currents.

- The temp of the surface layer rises to its upper critical temperature in few seconds (austenitic range).

5) The heated surface is then quenched by pressurised water jet through the holes in the inductor block, & hardened surface is obtained.

Application : Crankshaft, Camshaft, piston rods, cams etc.

Q6. c. :

Grey CI:

Composition: 2.5 to 4% C , 1 to 3% Si , <1% Mn, S, P.

Properties: high resistance to wear,
high compressive strength
vibration damping capacity
good castability

Applications: M/c tool structure, base
IC engine & compressor cylinder blocks
man hole covers.

White CI:

Composition: Fe & carbon is present in the form of Fe_3C & traces of silicon

Properties: very hard & brittle,
good castability, poor machinability
bright appearance

Applications: used in manufacturing of wrought iron, manufacturing of hard & abrasive resistant materials
- bearing surfaces etc.

GM. 31

SG Iron:

Composition: Fe & C in the form of nodules or Spheroids. C: 3.2 to 4.2 % C, 1 to 3 % Si, 0.3 to 0.8 % Mn, & traces of phosphorous & sulphur

Properties: Comparatively ductile, good machinability, excellent castability & wear resistance

Applications: machinery of paper industry, farm implements, power transmission equipment, construction machinery

Malleable CI:

Composition: 2 to 3 % C, 0.6 to 1.3 % Si, Fe & traces of P, S etc.

Properties: high yield strength, good malleability good wear resistance & vibration damping capacity.

Applications: Automotive industry, agricultural implements, conveyor chain links, gear case etc.

Gm.

Q 7-a

Classification of composites (based on Matrix material)

- Metal matrix composite (MMC)
- Ceramic matrix composite (CMC)
- Polymer matrix composite (PMC)

MMC: Matrix is a metal like Al, Mg, Iron, Cobalt etc.

Reinforcement is ceramic oxide or carbide or another metal.

ex: SiC reinforced in to Al matrix.

CMC: Matrix is ceramic (like Al_2O_3, SiC etc)

Reinforcement is carbon or ceramic.

ex: C/SiC composite.

PMC: Matrix is polymer (epoxy, polycarbonate, PVC etc.).

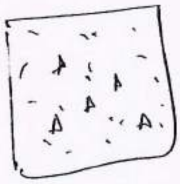
Reinforcement: glass, carbon, steel etc.

ex: glass fibre/epoxy composite.

Definition of composite: Composite is mixture or combination of 2 or more materials with different phases which has got enhanced properties than its consituent materials. Composites consist of matrix and reinforcement.

Classification of composites (based on reinforcement).

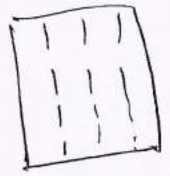
Particulate Composite



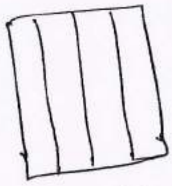
Particles (powder, flakes) reinforced in matrix.

ex: Concrete containing gravel/rocks in cement matrix.

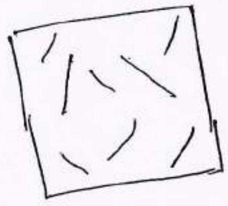
Fibre reinforced Composite



discontinuous & aligned



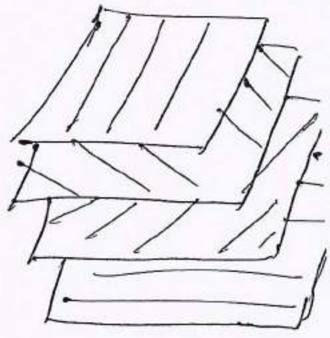
continuous & aligned.



discontinuous & randomly oriented.

ex: FRP (Fibre reinforced plastic).

Laminate Composite.



— Various layers of material stacked one above the other to give stiffness & strength.

ex: plywood, aramid-aluminium laminate.

Q.7.b.

Metal matrix composites (MMC)

- MMC contain metal (with ductile property) as matrix and reinforcement as carbon, boron fibers or SiC / alumina particles. Matrix materials used are alloys of aluminium, magnesium, titanium, copper etc.

- Advantage is that, they can be used at higher service temperatures and reinforcement improves specific stiffness, strength, abrasion resistance etc.

- Processing of MMCs involves 2 steps:
  i) Synthesis - introduction of reinforcement into matrix
  ii) Shaping operation (to give the required form)

  One of the technique used is stir casting process.

- MMCs are used in - engine components consisting of Al-alloy matrix reinforced with alumina & carbon fibers. MMCs are used in aerospace components - space shuttle orbitter, parts of Hubble telescope.

Ceramic- matrix composites

- CMCs contain ceramic as matrix material and reinforcement also (mostly) as ceramic in the form of particulates, fibers or whiskers.
- CMCs are fabricated using hot pressing, hot isostatic pressing and liquid phase sintering techniques.
- Matrix materials - alumina (Al_2O_3) or Zirconium oxide (ZrO_2)

  reinforcements - Silicon carbide (SiC), Al_2O_3 etc.

Applications: automobile & aircraft gas turbine engines, Cutting tool inserts for machining of hard metal alloys.

Q7C. Advantages of composite materials:

- Most of the composites are non corrosive, chemically stable
- Composites have high strength to weight ratio & stiffness to weight ratio (Suitable for aerospace & automotive applications).
- Composites have good resilience property (ability to deform & spring back)
- PMC & CMC are good thermal & electric insulators.
- MMC exhibit excellent strength, hardness properties.
- Versatile manufacturing processes are used to produce composites, this reduces number of individual parts & fasteners.
- Most of the composites are compatible with adhesives and surface coatings done on them. (makes the process simpler).

Disadvantages of composite materials:

- Material cost is little bit expensive
- Specialised manufacturing processes are required.
- Mass production techniques are yet to be evolved.

Q 7c. (Contd)

Applications of composite materials :

1. Aerospace application: Composites are extensively used in aerospace applications, because of high strength to weight ratio & high stiffness to wear ratio. Components made up of composites are fairings, leading & trailing edge wing components, fuel tanks, floors, fuselage etc.

2. Automobiles: front & rear panels of buses, some structural parts, seating hoods, moulded head lamps, seating, some of the doors etc.

3. Military applications: parts of fighter aircrafts, submarines, armoured vehicles, bullet-proof jackets etc.

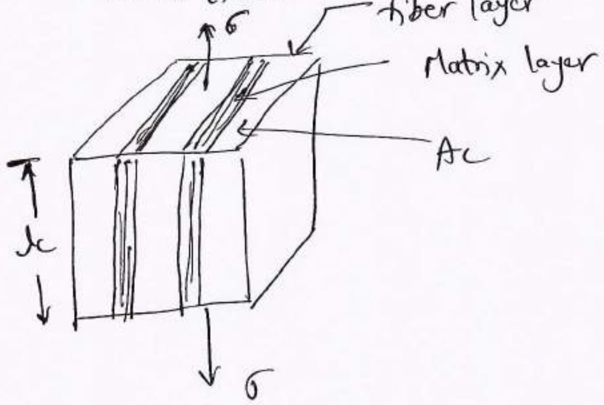
4. Biomedical applications: Orthopaedic applications such as bone fixation plates, hip joint replacement, dental applications etc.

5. Sports equipment: tennis racket, golf stick, hockey sticks, helmets, boats, ropes etc.

6. Others: wind turbine blades, construction materials, furnitures, household articles, etc.

Q8. a. Expression for Young's modulus of composite:

i) Isostrain condition: (uniform strain)



Load on composite structure (P_c)

$P_c = P_f + P_m$ — (1)

P_f = load on fiber (reinforcement)
P_m = load on matrix

Since $\sigma = \frac{P}{A}$ & $P = \sigma A$

eqn (1) can be written as

$\sigma_c . A_c = \sigma_f . A_f + \sigma_m A_m$ — (2).

where A_c, A_f & A_m - are area fractions of composite, fiber and matrix respectively.

multiplying eqn (2) by length l

$\sigma_c . A_c . l = \sigma_f . A_f . l + \sigma_m . A_m \times l$.

$\sigma_c . V_c = \sigma_f . V_f + \sigma_m V_m$ — (3) (Area x length = volume)

since volume fraction of composite = 1 ($V_c = 1$)

$\sigma_c = \sigma_f . V_f + \sigma_m . V_m$. — (4)

[signature]

Let ϵ be the strain

$$\epsilon_c = \epsilon_f = \epsilon_m \quad \text{(equal strain condition)}$$

$\therefore$ Divide eqn (4) by ϵ.

$$\frac{\sigma_c}{\epsilon} = \frac{\sigma_f \cdot V_f}{\epsilon} + \frac{\sigma_m \cdot V_m}{\epsilon}$$

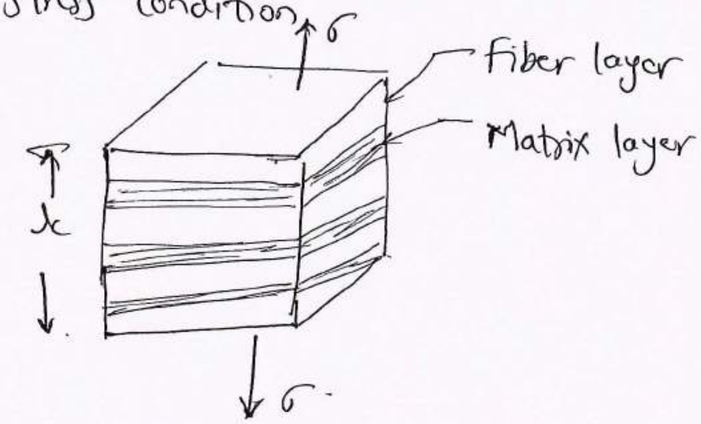
$$\frac{\sigma_c}{\epsilon_c} = \frac{\sigma_f}{\epsilon_f} \cdot V_f + \frac{\sigma_m}{\epsilon_m} \cdot V_m$$

$$E = \frac{\sigma}{\epsilon}$$

$$\boxed{E_c = E_f \cdot V_f + E_m \cdot V_m}$$

(iso-strain condition).

ii) Iso stress condition



Iso stress or equal stress condition,

$$\sigma_c = \sigma_f = \sigma_m \quad -(1)$$

Total strain of the composite ϵ_c,

$$\epsilon_c = \epsilon_f + \epsilon_m \quad -(2)$$

$$\epsilon_c \cdot V_c = \epsilon_f \cdot V_f + \epsilon_m \cdot V_m \quad -(3)$$

V_c, V_f & V_m are volume fractions of composite, fiber and matrix respectively. & $V_c = 1$.

∴ Eqn (3) becomes

$$\epsilon_c = \epsilon_f \cdot V_f + \epsilon_m \cdot V_m \quad -(4)$$

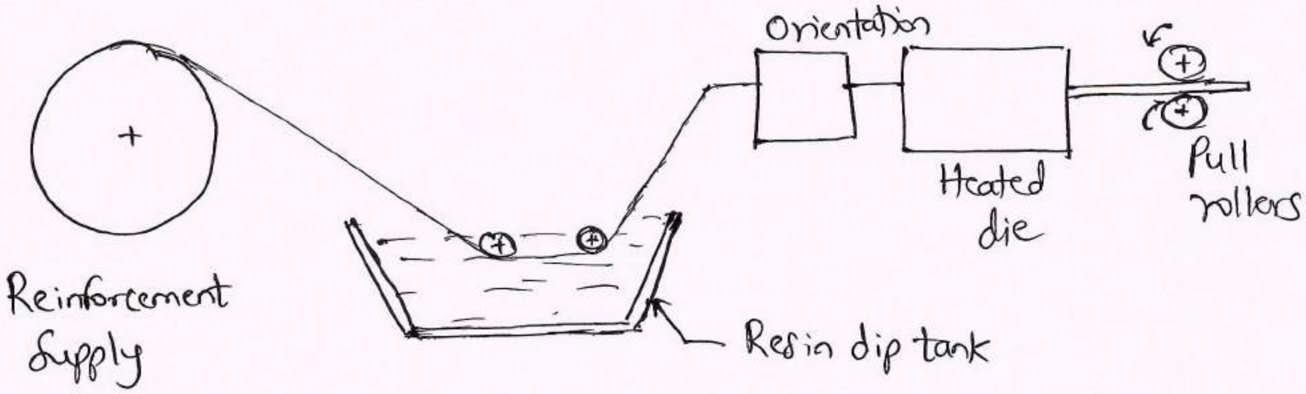
we know that, Strain $\epsilon = \frac{\sigma}{E}$ – substituting in (4)

$$\frac{\sigma}{E_c} = \frac{\sigma}{E_f} \cdot V_f + \frac{\sigma}{E_m} \cdot V_m$$

$$\boxed{\frac{1}{E_c} = \frac{V_f}{E_f} + \frac{V_m}{E_m}}$$

iso stress condition.

Q 8. b. <u>Pultrusion process</u> :



- Continuous pultrusion process is used for the manufacturing of fiber-reinforced plastics of constant cross section such as structural shapes, beams, channels, pipe and tubing.
- Process is schematically represented in the figure.
- In this process, continuous strand fibers are impregnated in a resin bath and then are drawn through a heated steel die that determines the shape of the output material (stock).
- Very high strengths are possible with this material because of the higher fiber concentration and orientation parallel to the length of the stock being drawn.

Q9. a.

Ceramics: Ceramic materials are inorganic non metallic materials that consist of metallic & non metallic elements bonded together primarily by ionic/ covalent bonds. These materials are very hard & brittle in nature. Ex: Silica, aluminium oxide, clay, silicon carbide etc.

Different types of ceramics :

* Glass – consists of SiO_2 added with Na_2O, CaO etc.
  used in construction, automobiles, laboratory apparatus, bottles etc.

* Cermets – ceramics (cer) + metal (met) = cermet.
  ex – Titanium nitride (TiN), titanium carbo nitride (TiCN)
  used in cutting tools, mould & die

* Cements – used in construction

* abrasives – silicon carbide, alumina (aluminium oxide)
  used in manufacture of grinding wheels, superfinishing & lapping/honing tools.

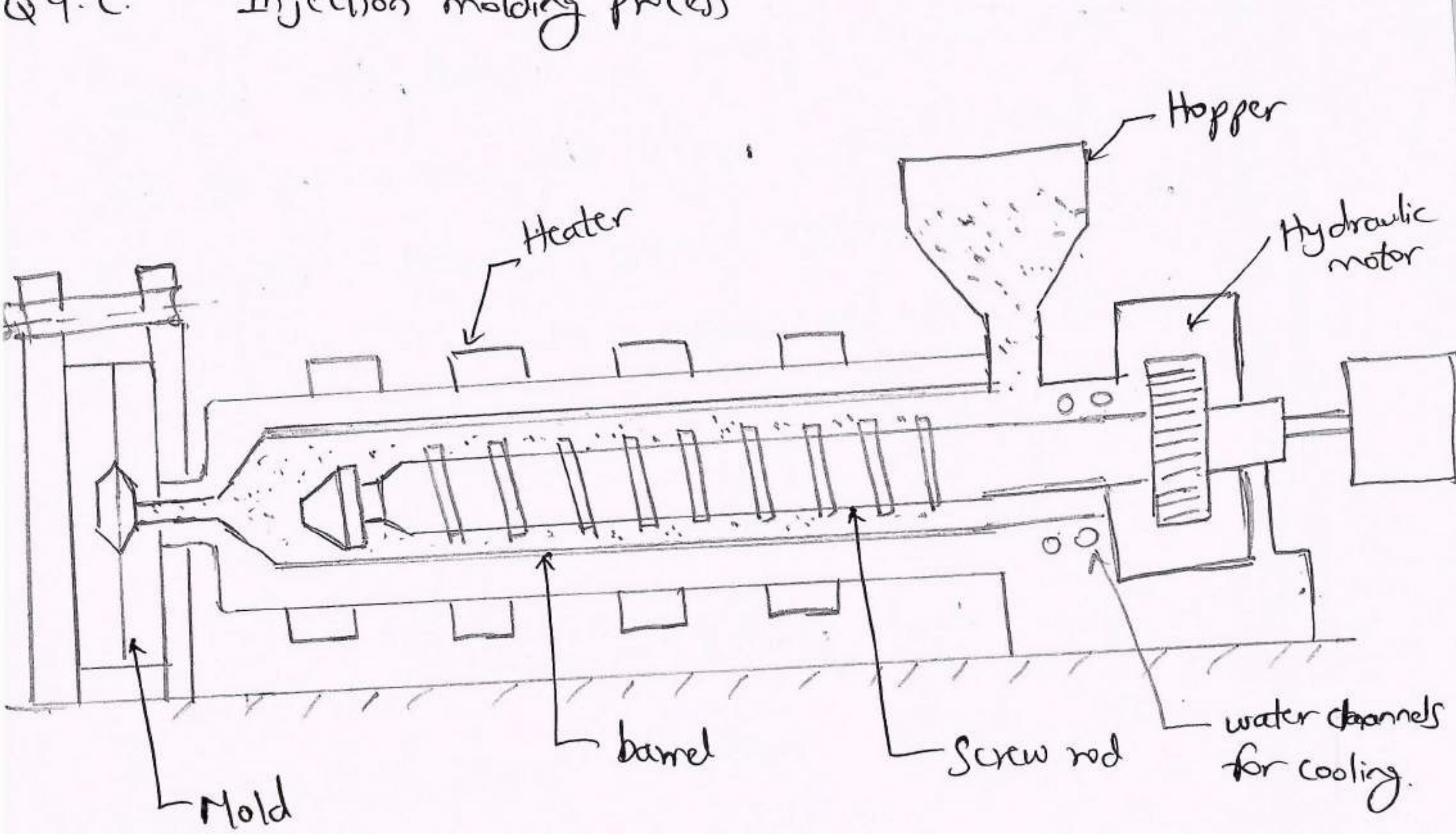
Gms. 45

Q9. b.

Thermoplastic	Thermoset
- Soften under heat & harden under cooling, reaction is reversible.	- Cure at high temp & reaction is irreversible.
- Covalent bond b/w monomers & wanderwall interaction b/w monomer chains.	Strong cross link & 3D network of covalent bonds.
- Synthesised by addition polymerisation	Condensation polymerisation.
- Processing methods - injection molding, blow molding, roto molding, thermoforming.	Compression molding, transfer molding, reaction injection molding
- lower in molecular weight	high in molecular weight.
- low melting point, low tensile strength, stiffness, brittleness	high melting point, high tensile strength, stiffness, brittleness.
- ex: ABS, polypropylene, polyethylene, polycarbonate polyvinyl chloride, nylon	resin, phenolic, urethane, polyester resin.

Sgn.

Q9.C. Injection molding process



* Injection molding process is used for processing of thermo-plastics in mass production

* In this process, the plastic granules are fed from the hopper in to the barrel which is heated with the help of bands.

* A screw rod actuated by hydraulic motor forces the granules against the walls of barrel & also inside. This melts the plastic.

* When sufficient plastic is melted, the rotation of screw stops & plunger like motion injects the "shot" of molten plastic through runner-gate system in to the mold.

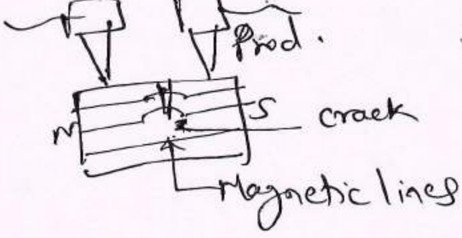
* Mold is normally watercooled for quick solidification of the plastic.

* Then the molded component is ejected out with suitable mechanism given in the machine.

Q10. a. Different non destructive methods used for assessing residual life.

* Magnetic particle inspection
* Dye penetration test
* X-ray method
* Ultrasonic test

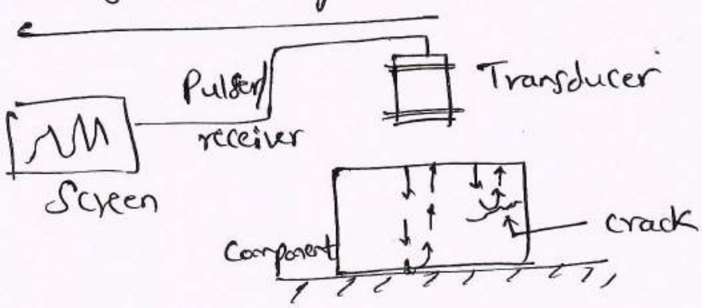
Magnetic particle inspection: Here the part is sprinkled with ferromagnetic powder and subjected to strong magnetic field. Presence of flaw/crack lines interrupts the magnetic flux. The flux leakage results in interference with magnetic lines of force and magnetic particles accumulate near discontinuity. With this surface/subsurface cracks & hence the residual life of the component can be detected.



Dye penetration test: The fluorescent dye is sprayed onto the surface to be tested. The dye will come to surface because of capillary effect (if crack is present).

- Then it is observed under UV radiation & cracks are easily noticed.

Ultrasonic inspection:



- Here high frequency sound wave (15MHz) is transmitted into component & wave propogates through the material.

- When there is crack part of the wave energy is reflected back from the crack surface and reflected wave signal is transformed into electric signal and is displayed on the screen.

Sgd.

Q10. b. Smart materials:

These are the materials which have the ability to sense external environmental stimuli (temperature, stress, light, humidity and electric and magnetic fields) and respond to them by changing their properties (mechanical, electrical or appearance) structure or functions. Such materials are called as smart materials.

Smart materials or the systems that use them consist of sensors and actuators. The sensor detects the change in the environment and the actuator performs the specific function.

Smart materials
- Shape memory alloys
- Piezoelectric ceramics.

Shape memory alloys: These are metal alloys that once strained, revert back to their original shape upon an increase in temperature above a critical transformation temperature. This is because of change in crystal structure above the certain temperature.

ex: Usage of stent (for biomedical application) for expanding narrowed arteries. The deformed stent is first delivered to the appropriate position and then it expands to original shape because of body temperature.

ex: NiTi alloys.

Piezo electric materials: These materials produce an electric field when exposed to a mechanical force. Conversely, a change in an external electric field will produce a mechanical response in the same material. Such materials are used to detect undesirable vibrations in the machines and critical products.

Ex: quartz, berlinite, topaz

HOD
Mechanical Engineering
KLS Vishwanathrao Deshpande
Institute of Technology
Haliyal-581329

Staff: (Gurunath Hevandi)