CBCS SCHEME

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18ME34

Third Semester B.E. Degree Examination, Jan./Feb. 2021
Material Science

Time: 3 hrs. Max. Marks: 100

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

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Calculate APF for FCC crystal structure. **(06 Marks)**
b. Discuss briefly point and line imperfections in crystals. **(06 Marks)**
c. What is Fick's law of diffusion? Explain the factors affecting diffusion. **(08 Marks)**

OR

2 a. With a stress – strain diagram for mild steel. Explain yield strength, ductility , toughness and ultimate tensile strength. **(06 Marks)**
b. Show that $\in' = \ln(1 + \in)$. **(04 Marks)**
c. A plain – carbon steel rod is subjected to a tensile load of 7000 kg. Assume no change in volume during extension, determine engineering stress, engineering strain , true stress and true - strain. The initial diameter of the rod is 13mm and the specimen under load is 12mm. **(10 Marks)**

Module-2

3 a. Discuss Type I , Type II and Type III fractures. **(10 Marks)**
b. What is Fatigue? Explain fatigue testing with a sketch. **(06 Marks)**
c. Explain three stages of Creep process. **(04 Marks)**

OR

4 a. What is a Solid solution? Discuss Hume – Rothary rules for formation of Solid - solution. **(05 Marks)**
b. Draw a neat Iron – Carbon equilibrium diagram and label all phases and write invariant reactions like eutectoid , eutectic and peritectic reactions. **(10 Marks)**
c. Derive an expression for critical radius in homogeneous nucleation and discuss the significance of this critical radius. **(05 Marks)**

Module-3

5 a. Explain Annealing , Normalizing and Hardening heat treatment processes. **(06 Marks)**
b. With the help of TTT and CCT diagrams, explain mar tempering and give one industrial application. **(10 Marks)**
c. What is Hardenability? Discuss various factors affecting hardenability. **(04 Marks)**

OR

6 a. Discuss 'Nitriding' and 'Flame – hardening' processes. **(08 Marks)**
b. With Aℓ - Cu phase diagram, explain age – hardening process. **(08 Marks)**
c. Explain properties, composition and uses of Gray Cast Iron. **(04 Marks)**

Module-4

7 a. Give a broad classification of composites. **(04 Marks)**
b. Discuss various applications of composites. **(06 Marks)**
c. Explain 'Pultrusion process' for manufacturing composites. **(10 Marks)**

OR

8 a. Discuss 'Characterization of Composites'. **(06 Marks)**

b. Explain 'Filament winding process' for producing FRPs. **(08 Marks)**

c. Calculate the modulus of elasticity, tensile strength and the fraction of the load carried by the fibre for the following composite material stresses under iso strain condition. The composite consists of a continuous glass fibre – reinforced epoxy resin produced by using 60% by volume of E – glass fiber having a modulus of elasticity of 72400×10^6 N/m^2 and a tensile strength of 2400×10^6 N/m^2 and a hardened epoxy resin with a modulus of elasticity of 3100×10^6 N/m^2 and a tensile strength of 60×10^6 N/m^2. **(06 Marks)**

Module-5

9 a. Explain types and properties of Ceramics. **(08 Marks)**

b. Explain 'Injection and Moulding' process for producing polymers. **(06 Marks)**

c. List out various applications of ceramics and polymers. **(06 Marks)**

OR

10 a. What are Smart Materials? Discuss the functioning of shape memory alloy. **(08 Marks)**

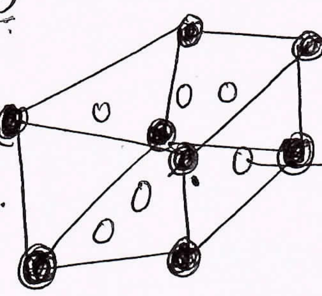
b. Explain biological and other applications of SMA. **(06 Marks)**

c. What are the factors to be considered for the Selection of materials? Discuss. **(06 Marks)**

* * * * *

1a. FCC (Face Centered cubic).

One FCC unit cell has an atom at each corner of the the cube. as well as one atom at the centre of each of the six faces.

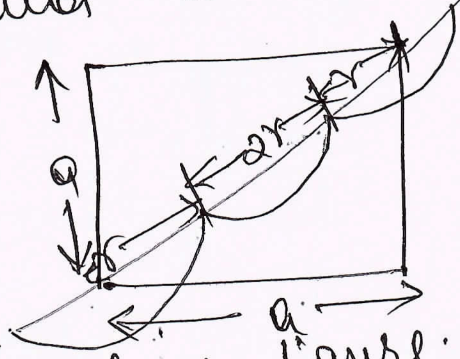


FCC

There is only 1/8th of each corner atom effectively inside the cell where as 1/2 of the vol. of each atom at the centre of the face are within the unit cell

Therefore,
Effective no. of atoms in FCC one unit cell = 8 × 1/8 + 6 × 1/2 = 4 atoms

To find 'a' in terms of 'r'



From above figure, where r = radius of the atom

$$(4r)^2 = a^2 + a^2$$

$$4r = \sqrt{2a^2} = \sqrt{2} \cdot a$$

$$a = \frac{4r}{\sqrt{2}}$$

$$APF = \frac{\text{No. of atoms} \times \text{vol. of each atom}}{\text{vol. of unit cell}}$$

$$= \frac{4 \times 4\pi r^3}{3a^3} = 4 \times 4\pi r^3/3 \times \{4r/\sqrt{2}\}^3$$

$$APF = 0.74 = 74\%$$

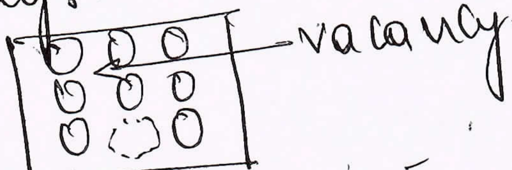
① [signature]

Q.6. Discuss briefly point & line imperfections in crystals.

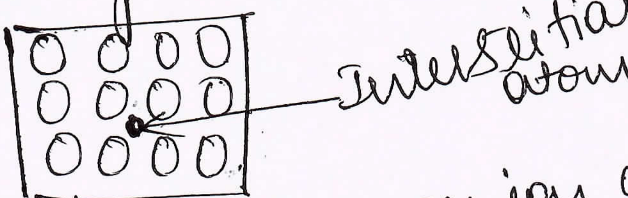
Sol Point imperfections:

i) Vacancy:- A vacancy refers to an atomic site from where the atom is missing. This may be due to imperfect packing during original crystallization.

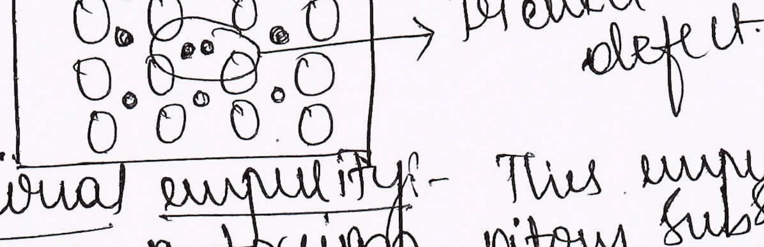
1) Schottky defect:- If two ions of opposite charges are missing but are found elsewhere in the same crystal. Called as Schottky defect.



2) Interstitialcy:- Here, a small sized foreign atom occupies the space in b/w the atoms of a crystal without dislodging any of the parent atom.



3) Frenkel defect:- When an ion of the same crystal tries to occupy an interstitial position jumping from another site, then it is called "Frenkel defect."



4) Substitutional impurity:- This impurity is created when a foreign atom substitute a parent atom in the lattice structure

2 Given

are either Compressed or pulled apart.

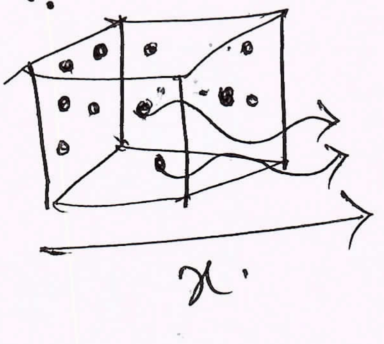
2. Screw dislocation or Cross slip:

* A screw dislocation is also a line defect formed when a part of the crystal displace angularly over the remaining part. The plane of atoms converts into a helical surface.

* Burgers vector 'b' is always parallel to screw dislocation respectively.

1.c What is Fick's law of diffusion? Explain the factors affecting diffusion.

Sol The movement of individual molecule through a substance by virtue of their thermal energy is known as molecular diffusion.



C = concentration, no. of molecules per unit.

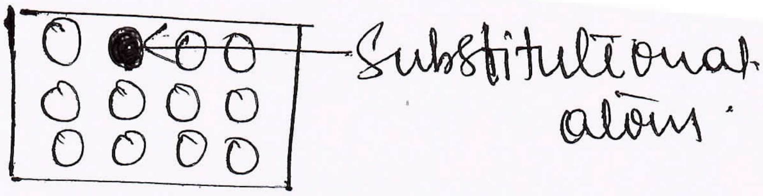
$\frac{dc}{dx}$ = Change in concentration moving from left to right

J = Flux

Factors affecting atomic diffusion.

1) Temperature:- High temperature provides the necessary activation energy to the atoms to begin diffusion. So a higher temperature initiates diffusion faster

3) Givin



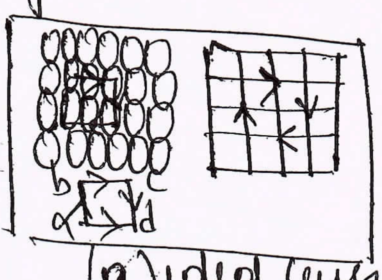
Line imperfections: Line imperfection are called dislocations. A dislocation is a line defect where a uniform alignment of a[illegible] is broken to form a discontinuity (or) a localized distortion in the crystal.

1) Edge dislocation 2) Screw dislocation or cross slip.

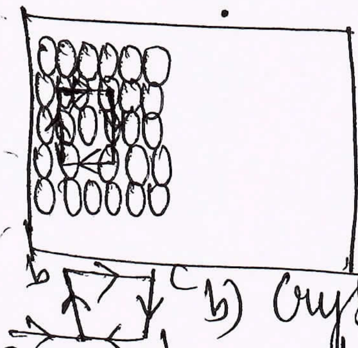
1. Edge dislocation

* Consider a perfect crystal fig (a) to be made of a number of vertical planes of atoms. If one of these vertical does not extend from top to bottom.

* But ends at only a part of the way within the crystal as shown in fig (b). an edge dislocation is present



(a) ideal crystal



b) Crystal with edge dislocation

* In the perfect crystal, the atoms are in equilibrium positions and all the bond length are of equilibrium value.

* Where as in an imperfect crystal, the atom do not occupy equilibrium position; & the bond length.

i) Yield strength:- yield strength is defined as the stress required to produce a small specified amount of plastic deformation.

$$\text{Yield Stress}(\sigma_y) = \frac{F_y}{A_0}$$

where F_y = Load at yield point.
A_0 = original c/s area of the specimen

ii) Ductility:- Ductility refers to the ability of a material to undergo plastic deformation under tensile load. Ductility is measured by the percentage elongation or % reduction in area before rupture of the specimen take place.

$$\%\ \text{Elongation} = \frac{L_f - L_o}{L_o} \times 100$$

or

$$\%\ \text{reduction in c/s area} = \frac{A_0 - A_f}{A_0} \times 100$$

iii) Toughness:- Toughness is defined as the ability of a material to withstand both elastic & plastic deformation. It is a measure of the energy a material can absorb before it fractures.

iv) Ultimate tensile strength

Ultimate tensile strength is defined as the maximum stress sustained by the material before fracture.

$$\text{Ultimate stress}(\sigma_u) = \frac{\text{Ultimate load}(F_u)}{\text{original cross-sectional area}(A_0)}$$

(5)

2) Crystal Structure:- If a crystal structure is distorted i.e, if there are more imperfection the rate of diffusion is increased.

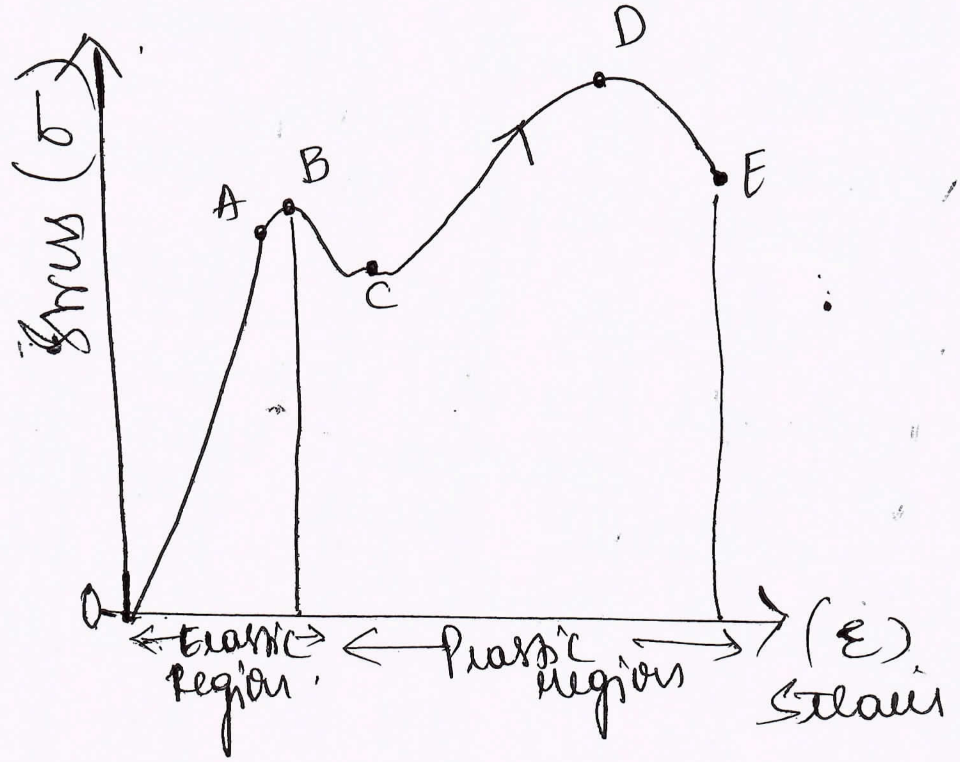
3) Atomic packing factors:- If APF is high the rate of diffusion will be decreased.

4) Grain boundaries:- The diffusion process proceeds more rapidly along the grain boundaries since it is a zone of crystal imperfections.

5) Grain size:- Since diffusion through grain boundaries is faster than through the grain themselves, a material with fine grains will have a faster rate of diffusion.

6) Atomic size:- Diffusion occurs more readily when the size of the diffusing atom is less.

Q.a)



6) Grain

Engineering Stress σ, $\sigma = \frac{P}{A_0} = \frac{68.7 \times 10^3}{132.73} = 517.35 N/mm^2$

True stress, $\sigma' = \frac{P}{A_i} = \frac{68.7 \times 10^3}{113.1} = 607.17 N/mm^2$.

Also $\sigma' = \sigma(1+\varepsilon)$

Engineering Strain, $\varepsilon = \frac{\sigma'}{\sigma} - 1$

$= \frac{607.17}{517.35} - 1 = 0.1736$.

True Strain $= \varepsilon' = \ln(1+\varepsilon)$

$= \ln(1+0.1736) = 0.16$ //.

3a. Sol

Type I or Ductile fracture

* it is characterised by slow crack propogation resulting in an extensive plastic deformation of the material before fracture. i.e. it is characterised by an appreciable amount of plastic deformation

* The fracture proceeds relatively slowly and the fracture surface is dull in appearance.

a) Highly ductile fracture :-

in this type, the material necks down to a point fracture & yields to 100% reduction in c/s area. for example soft metal like pure gold, lead etc.

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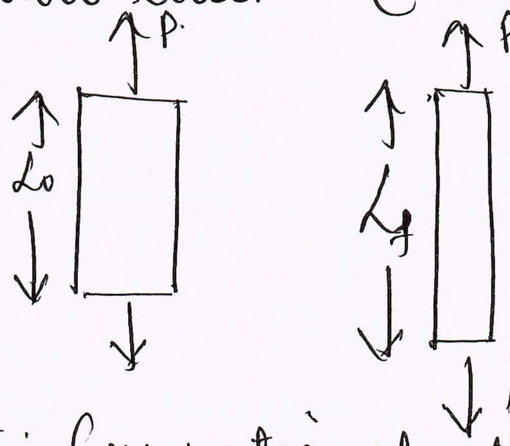
Q b. Show that $\epsilon' = \ln(1+\epsilon)$.



W.K.T. Conventional or Engineering strain

$$= \varepsilon = \frac{\delta L}{L_0} = \frac{L_f - L_0}{L_0}$$

$$\varepsilon = \frac{L_f}{L_0} - 1 \quad \text{or} \quad \varepsilon + 1 = \frac{L_f}{L_0} \quad \text{---(1)}$$

W.K.T. True strain $\varepsilon' = \int_{L_0}^{L_f} \frac{dL}{L}$

$$\varepsilon' = \ln\left(\frac{L_f}{L_0}\right) \quad \text{---(2)}$$

Substituting equations (1) in (2).

$$\varepsilon' = \ln(\epsilon + 1)$$

$$\varepsilon' = \ln(1+\epsilon).$$

Q C.
Sol. Given Load. $P = 7000$ kg
$= 7000 \times 9.81 = 68.7 \times 10^3$ N.

original diameter, $d_0 = 13$ mm

original Area $= A_0 = \frac{\pi d_0^2}{4} = \frac{\pi (13)^2}{4}$
$= 132.73$ mm^2

instantaneous diameter $d_i = 12$ mm.

instantaneous Area, $A_i = \frac{\pi d_i^2}{4} = \frac{\pi (12)^2}{4}$

d) As the load increases, the crack continues to grow in a direction parallel to its major axis.

e) Finally the fracture results due to rapid propagation of crack. The fractured surface has a characteristics fibrous appearance with one of its pieces having "cone" & another having "cup" like structure.

2) Type II or Brittle fracture:

* Brittle fracture occurs suddenly without any plastic deformation or at best with very little plastic deformation.

* It is generally characterised by a rapid propogation of crack. Like in ductile fracture, here also small cavities join together to form a crack & this crack propogates.

* But all these stages happen instantly & the material failure takes place suddenly.

* Brittle fracture in metals for example cast iron can be considered to occur in the following stages.

i) Initial plastic deformation results in the concentration of dislocations along the slip planes at obstacles which prevents further plastic deformation.

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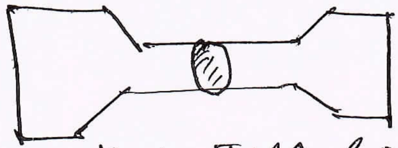


Fig:- Test Specimen

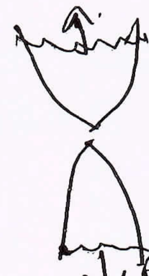
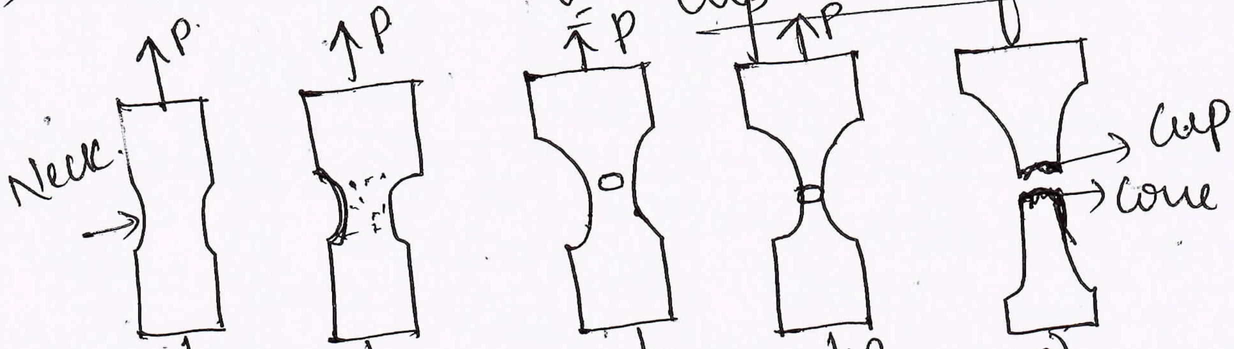


Fig:- Highly ductile fracture

b) Moderately ductile fracture or Cup-cone fracture



* Consider a steel tensile specimen is tensile test. As the specimen is loaded in tension & when once the stress crosses the yield stress, the plastic deformation of the specimen take place.
* After good amount of plastic deformation the specimen can be observed in the following stages:

a) - initial necking (or) reduction the cross section also take place.

b). - Further loading result in the appearance of small cavities or voids in the interior of C/s.

c) As the load is increased, these minute cavities join together to form an elliptic crack which has its long axis perpendicular to direction of load.

10 Gni

ii) Since dislocation are blocked, shear stresses build up which result in the nucleation of micro cracks.

iii) Further increase in the stress will favour the propogation of the micro cracks which finally results in failure or fracture.

3) <u>Type III or shear fracture</u>

* This type of fracture is found in ductile single crystals.
* This is promoted by shear stress & occur as a result of extensive slip on the active slip plane.
* Fracture surfaces are normally at 45° to the direction of tensile load & appear shiny owing to extensive slip b/w the surfaces before fracture.

3.b In fatigue failure, fracture of the material takes place because of repetitive or fluctuating stress is applied for some period of time; in which the cracks gradually grown until they finally reach a critical level.

Fatigue test

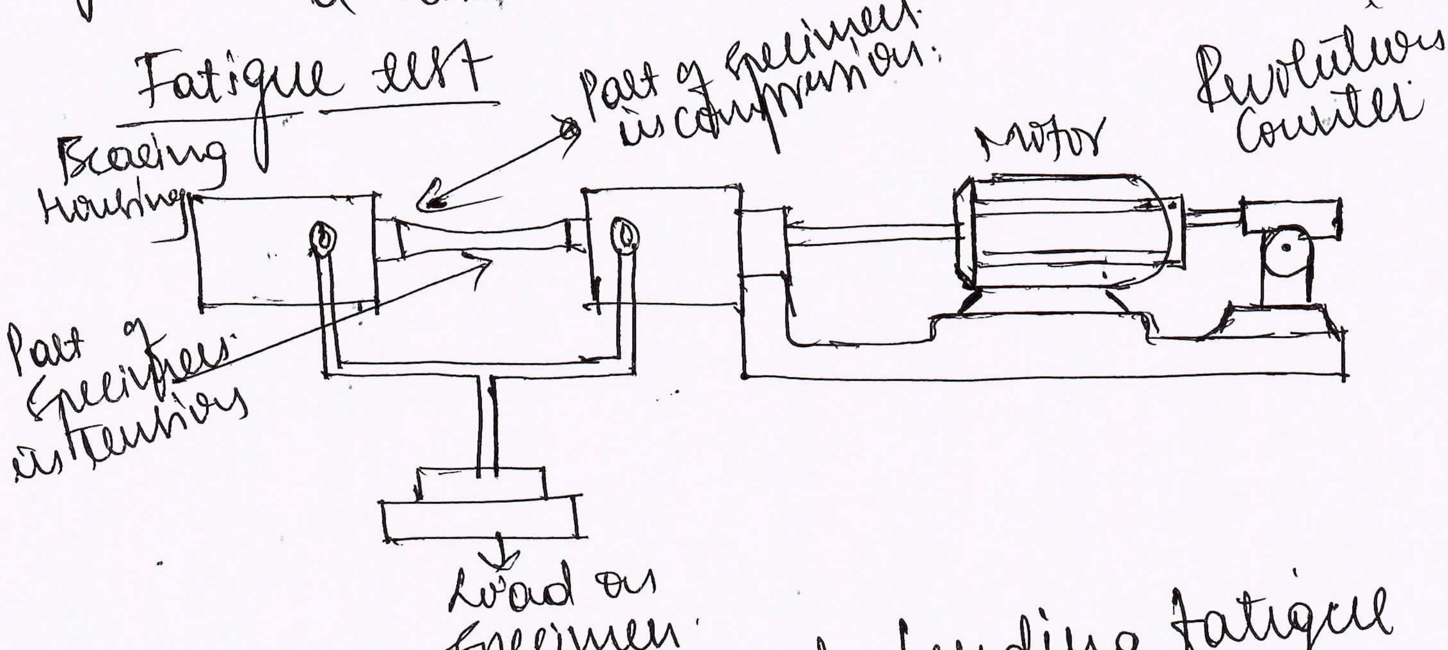


Figure 1 Reversed-bending fatigue machine

* Fatigue tests can be carried out in a number of ways depending on the type of load used to initiate / propagate a crack & cause fracture in a material.
* Fatigue test (Rotating-beam type) the machine consists mainly an electric motor, bearings & collets to support the specimen, & a revolution counter as shown in figure above.

* A weight is attached at the centre of the specimen in order to place the specimen in a state of bending. When the specimen is rotated by a motor the centre of the specimen will be under tension on the lower surface & compression on the upper surface due to the weigh

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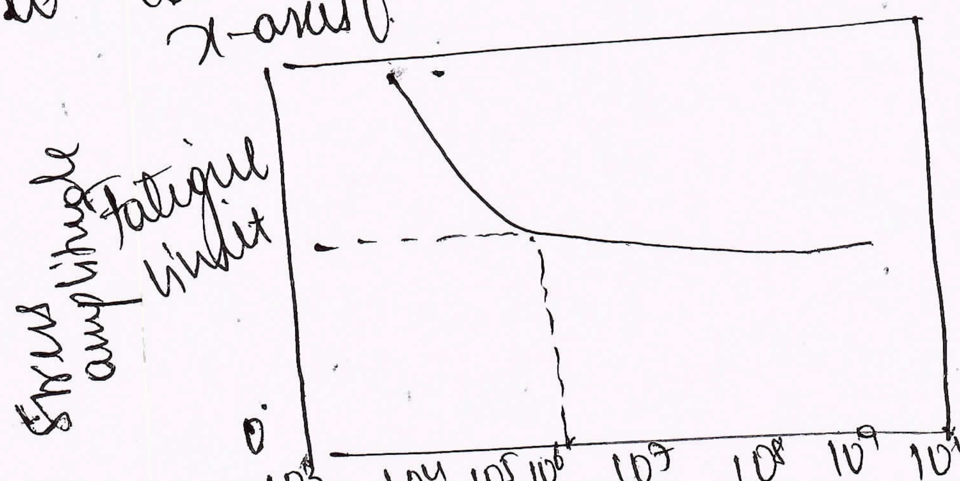
in the center of the apparatus. Hence the specimen while rotating is subjected to alternate tensile & compressive stresses.

The revolution counter records the number of cycle applied to the specimen, & when the specimen breaks, the counter automatically disengages. A no of specimens of the same material are tested under different stress levels. & the results are plotted on a semi-logarithmic scale with stress (S) on y-axis & the no of cycles (N) to cause failure of the specimen on x-axis.



No. of cycles to failure (N) on logarithmic scale

3C. Stages of Creep:-

Sol. Creep deformation upto failure in materials are divided into 3 stages & can be studied using a creep plot or creep curve plot.

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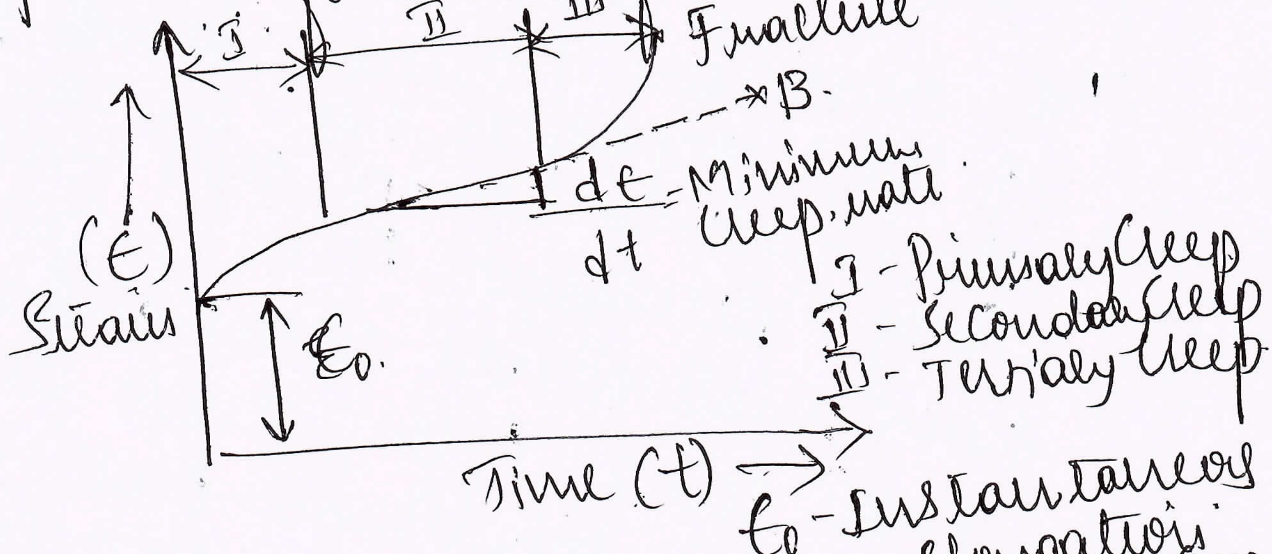
* The strain or the elongation of the specimen is then determined as a function of time.



i) Primary creep :- it is the first stage of creep which represent a region of decreasing creep rate. In this region, the rate at which the material deform decreases with time until it reaches a constant value.

* Primary creep is predominantly a period of transient creep & it is important for those materials which undergo creep at room temperature.

* Here the metal deform & undergoes strain hardening & offers more resistance to further elongation.

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ii) **Secondary creep** – This stage is a period of nearly constant creep rate. The creep rate is constant because strain hardening & recovery effect balance each other.

* The average value of the creep rate here is called as minimum creep rate.
* This is important part of the curve because most of the working components will be in this state.
* Also creep in this region take place due to viscous flow in the material & is also called as "Steady state creep".

iii) **Tertiary creep** – This stage is the period of increasing strain rate. Tertiary creep occurs when there is an effective reduction in the cross/s area due to necking or internal voids formation.

* Thus the stresses at the c/s area increases & consequently the value of the strain also increase at faster rate before the occurance of fracture.

(5) Grim

* If the stress is kept constant instead of the loads or if the true strain is taken into consideration then the resulting fracture due to the creep should be at 'B' as shown in the above graph.

4a. Sol A solid solution is simply a solution in the solid state & consist of two kinds of atoms in one type of space lattice.

Hume-Rothery rule for formation of solid solutions

i) Crystal structure factor:- For complete solid solubility of two elements they should have same type of crystal lattice structure.

ii) Relative size factor:- The atoms of solute & solvent should have same atomic size approximately.

iii) Chemical affinity factor:- For a substitutional solid solution to form the two metals should have very less chemical affinity.

iv) Electronegativity:- Electronegativity is the tendency to acquire electrons. Higher the electronegativity of the

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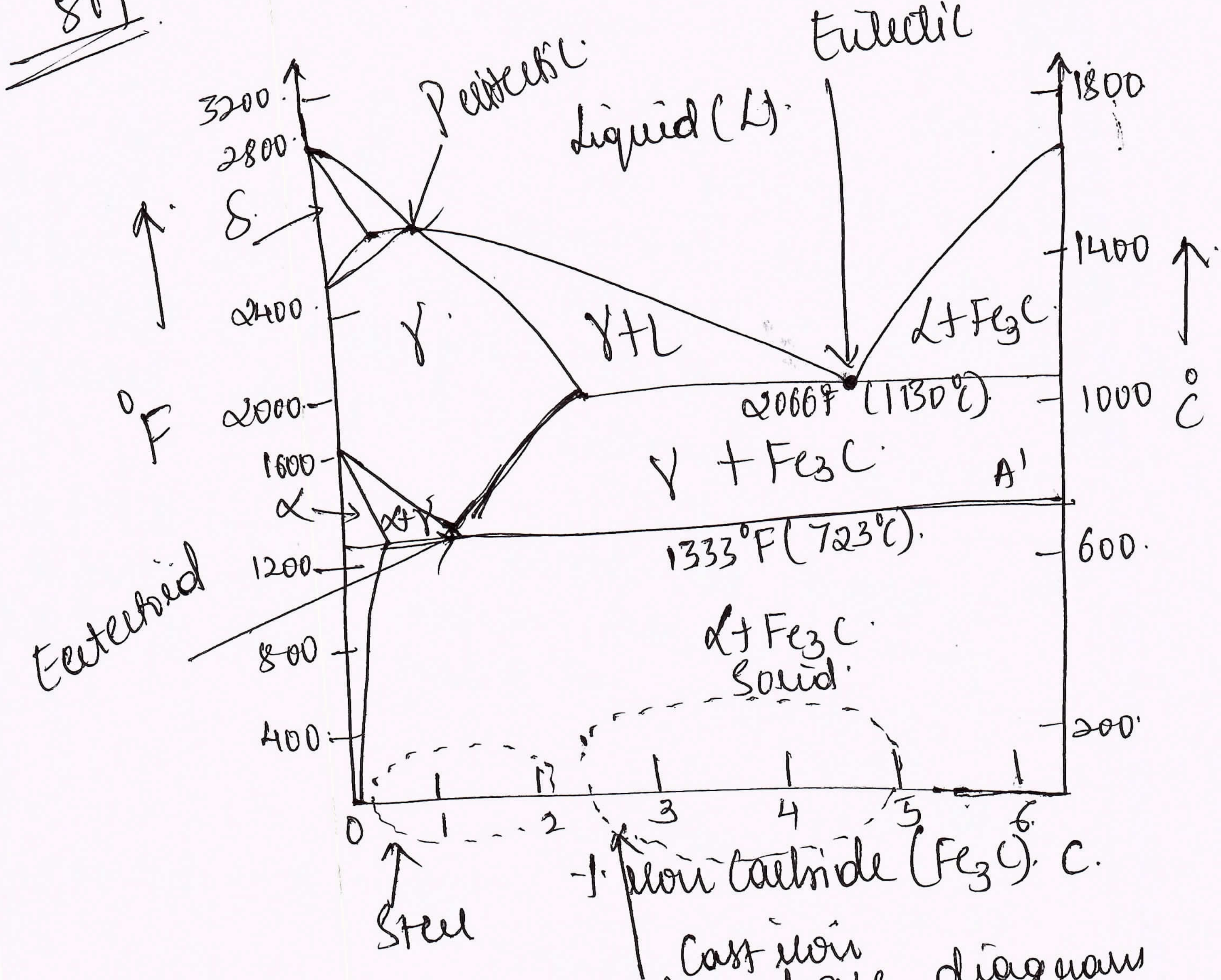
two elements, greater will be the chances of forming an intermediate phase rather than a solid solution.

4b. Sol] Iron-Carbon equilibrium Diagram.



A above figure shows the phase diagram contains certain points specified by particular temperature, pressure & composition at which multiple phase can coexist in equilibrium. Any change in these variables cause the disappearance of phases i.e., phase are not in equilibrium anymore.

(17) Given ...

These points are known as invariant points & they represent an invariant reaction

There are three invariant reactions are present in $Fe_3C - C$ system

i) Eutectic reaction
ii) Eutectoid reaction
iii) Peritectic reaction

Eutectic reaction:- Binary systems with limited solubility are of eutectic type. it is so called because an alloy system having a eutectic composition melts at lowest possible temperature than all other compositions of the binary alloy.

The point at which the solid & liquid phases co-exist under equilibrium condition is known as the eutectic point

Reaction

$$\text{Liquid} \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \text{Solid}_1 + \text{Solid}_2$$

Eutectoid transformation

* Eutectoid reaction is similar to eutectic reaction except that it features a solid to solid transformation where one solid phase is converted into two solid phases upon cooling.

18) Gu..

$$\text{Solid 1} \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \text{Solid 2} + \text{Solid 3}$$

Ex:- Fe-C system undergoes eutectoid transformation at 723°C for a composition of 0.8 wt-% C in iron.

Peritectic reaction

A Peritectic reaction is also an invariant reaction where three phases co-exist under equilibrium conditions.

$$\text{Liquid} + \text{Solid 1} \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \text{Solid 2}$$

Ex:- Fe-C system undergoes peritectic reaction at 1495°C for a composition of 0.16 wt-% carbon in iron.

4C

Sol

* Homogeneous nucleation is one occurring in perfectly homogeneous materials such as pure liquid metals.
* Homogeneous nucleation is the occurrence of ordered groups of atoms forming small zones of higher than average density.
* Nucleation of the supercooled grain
* Thus total free energy change for a particle of radius r. $\Delta f = -4/3\pi r^3 \Delta F v + 4\pi r^2$

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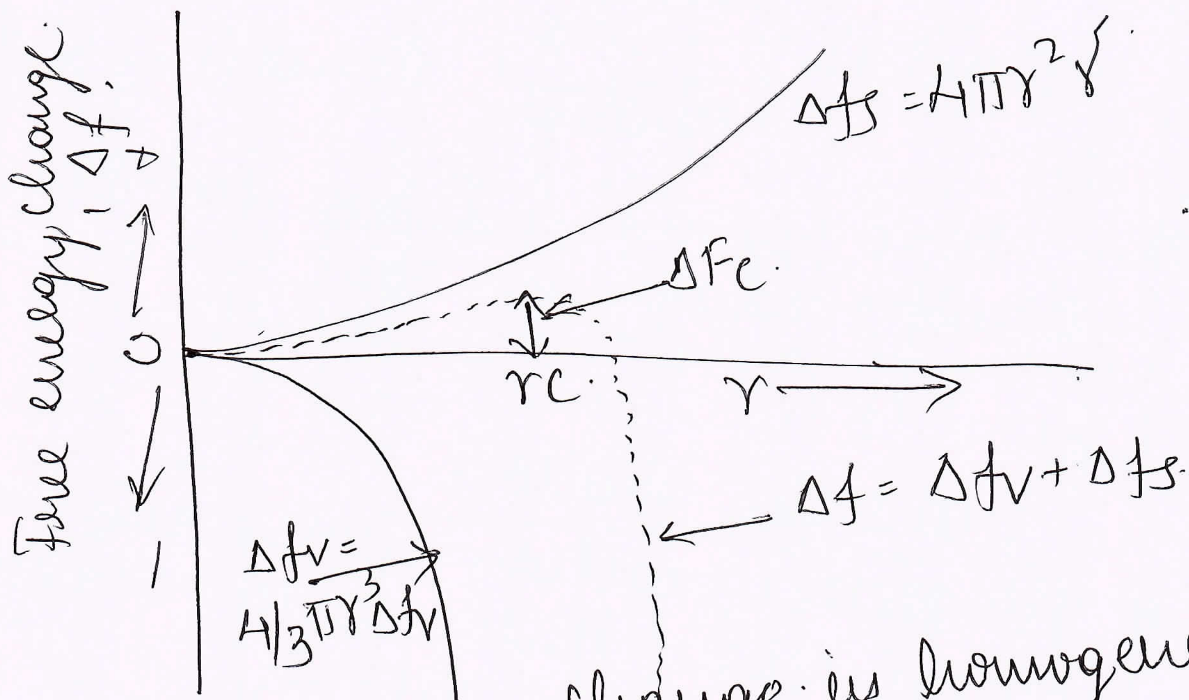

Free energy change in homogeneous nucleation.

* Above figure shows that as the particle radius increases, the free energy of also increases till the particle grows to a critical radius (r_c), & thereafter an increase in particle radius accompanies with decrease in free energy & so much that the free energy become negative also.

* Particles having radius less than (r_c) tends to redissolve & thus lower the free energy.
* Particles having radius more than (r_c) tend to grow & lower free energy. Such particles are known as nuclei.

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* Critical particle radius & critical free energy can be calculated by maximizing equation

$$\Delta f = -\frac{4}{3}\pi r^3 \Delta f_v + 4\pi r^2 \gamma$$

$$\frac{\Delta f}{\Delta r} = 0 = -3 \times \frac{4}{3}\pi r_c^2 \Delta F_v + 2 \times 4\pi r_c \gamma$$

$$\boxed{r_c = \frac{2\gamma}{\Delta F_v}}$$

5a Sol

Annealing primarily is the process of heating a metal a metal which is in metastable or distorted structural state to a temperature which will move the instability or distortion & then cooling so that the room temperature structure is stable and/or strains free.

Purpose of annealing are:-

* Inducing a completely stable structure
* Refining & homogenising the structure.
* Reducing hardness.
* Improveing machinability.
* Removing residual stresses.

Normalizing:

Normalising or air quenching consists in heating steel to about 40°C-50°C above its upper critical temperature & if necessary, holding it at that temperature for a short time & then cooling in still air at room temperature

* Normalising produces microstructure consisting of ferrite & pearlite for hypoeutectoid steel

Normalising purpose:

* Produce a uniform structure
* Reduce internal stresses
* improve structures in welds
* Produces a harder & stronger steel than full annealing

Hardening

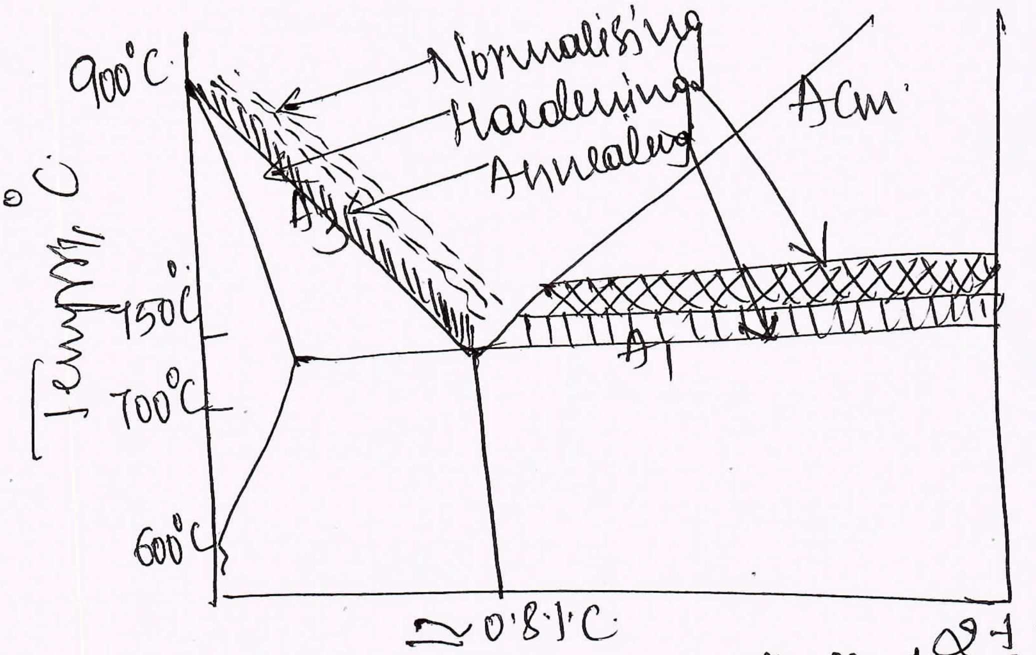
* Hardening is that heat treatment of steel which increases its hardness by quenching.
* Tools & machine parts required to undergo heavy duty service are oftenly

Procedure:-

* Steel with sufficient carbon (0.35-0.70)
* is heated 30 to 50°C above A3 line (from figure)
* is held at that temperature from 15 to 30 mins. per 25 mm of C/S
* is cooling rapidly or quenched in a suitable medium.

(22) Gu...

To produce desired rate of cooling & a suitable hardened steel.



Heat Treatment temperature for Carbon Steels.

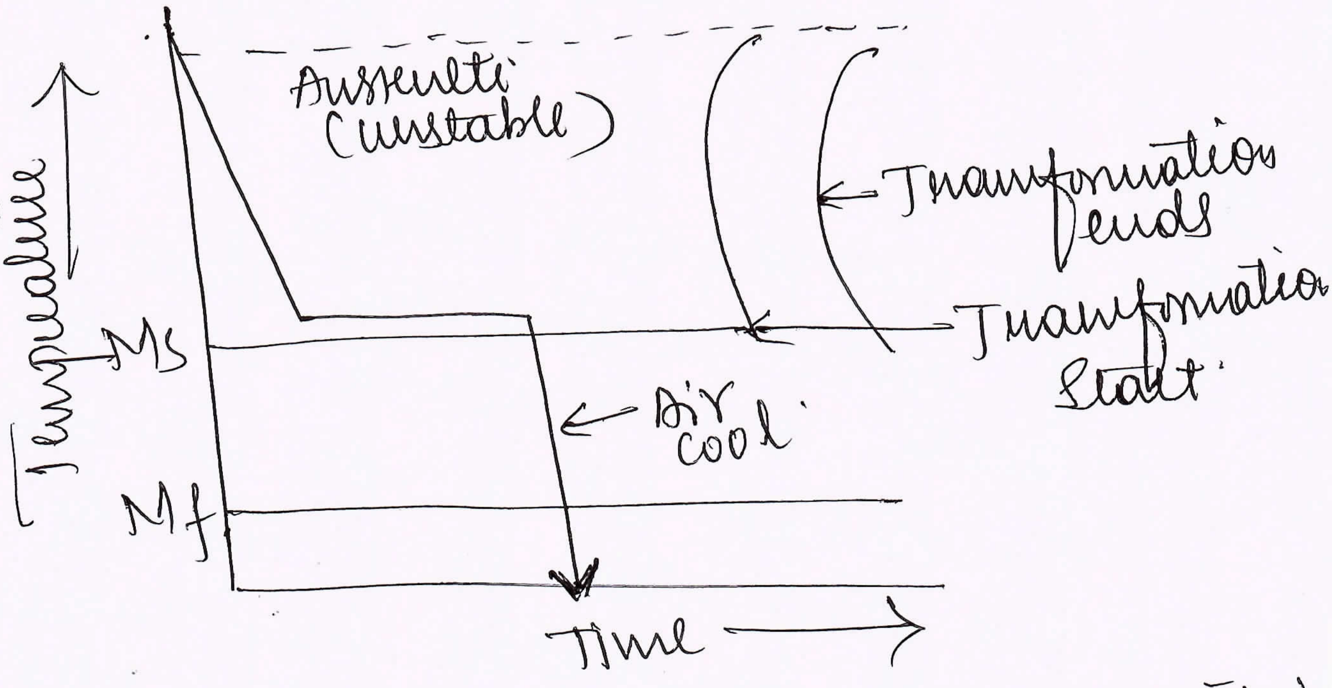
5b
8M. In martempering, steel is
i) Heated to above the critical range to make it all austenite, is then,
ii) Quenched into a salt bath maintained at a temperature above the Ms & is held at this temperature long enough until the temperature is uniform across the section of the workpiece without transformation of the austenite.
iii) Subsequently cooling the workpiece in air through the martensite range

(3) (i+ii+iii)

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

- The steel thus obtained may be further tempered in order to increase ductility.

- Large section cannot be mar treated by martempering because the time required to obtain temperature uniformity exceeds the start of transformation of austenite into bainite.



5C Sol * Hardenability is the ability of a material to get hardened as a result of hardening heat treatment process.

Factors affecting Hardenability.

(Q) Grain...

i) Composition of steel & the method of manufacture.

ii) Quenching medium & the method of quenching.

iii) Section (thickness) of steel.

iv) Composition of steel:- For plain carbon steels, As % of carbon increases,

v) Austenitic grain size:- with increase in austenite grain size before quenching hardenability increases.

vi) Homogeneity of austenite:- Non homogeneity of austenite tends to decrease hardenability of steel.

6a Sol

Nitriding: It is process by which a case of hardened steel can be achieved.

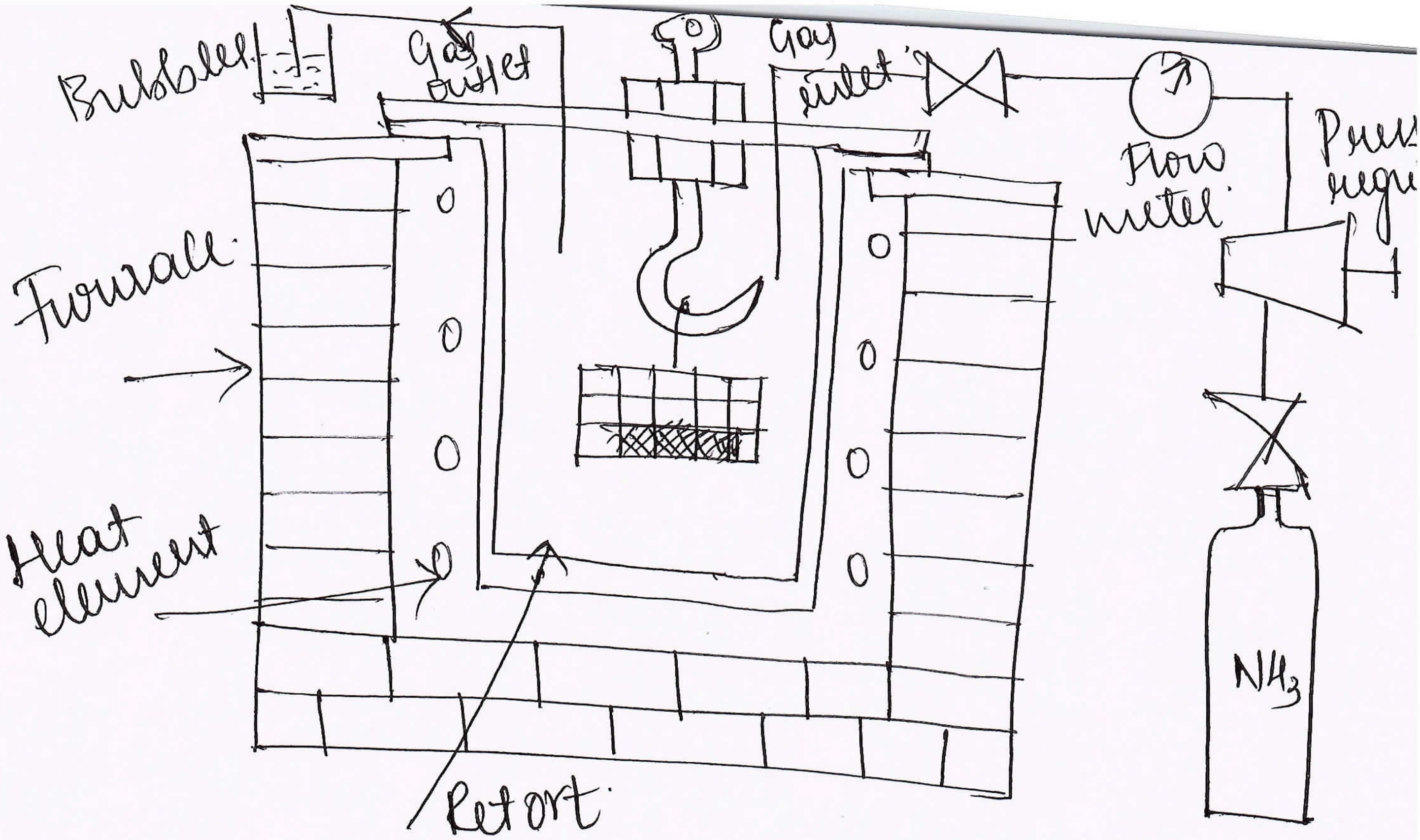
* In nitriding, the steel piece is heated in a furnace b/w 500-600°C & at the same time is exposed to ammonia gas (NH_3).

* The heat from the furnace causes the ammonia to decompose into hydrogen & nitrogen (N_2).

* Nitrogen reacts with elements in the steel to form nitrides in the outer layer of the steel providing high hardness & wear resistance.

* Nitriding time range b/w 1-100 hours depending on steel composition & depth of hardening desired.

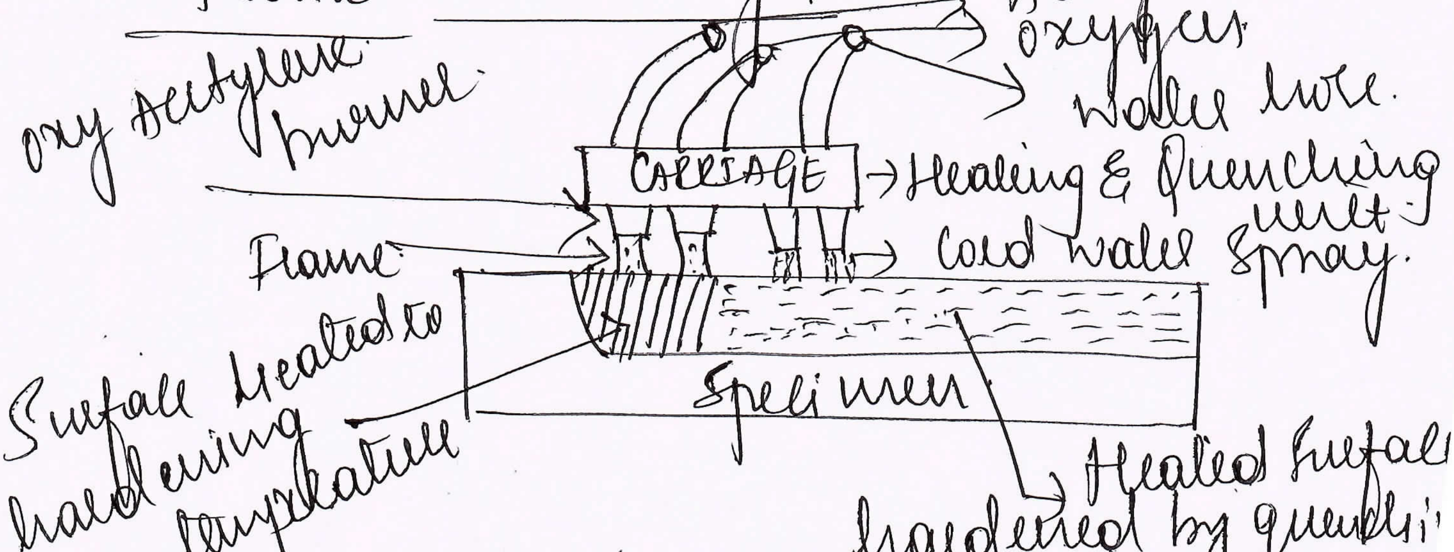
5) Given



$$2NH_3 \longrightarrow 2N + 3H_2$$

Nitriding

Flame hardening



→ It is a process of selective hardening, which involves heating the surface of a steel specimen with oxy-acetylene flame in the austenite range & then immediately quenching the surface of the specimen by cold water to get martensite.

→ Then only heated surface become hard & core part remains

→ The depth of hardening depends on the heat supplied per unit surface area per unit time (i.e) faster the movement lesser the depth of hardening.

→ The figure represents progressive flame hardening where the heating torch moves over a stationary workpiece followed by quenching used for surface hardening of lathe guide ways.

6b. Age hardening of Al-Cu alloys.

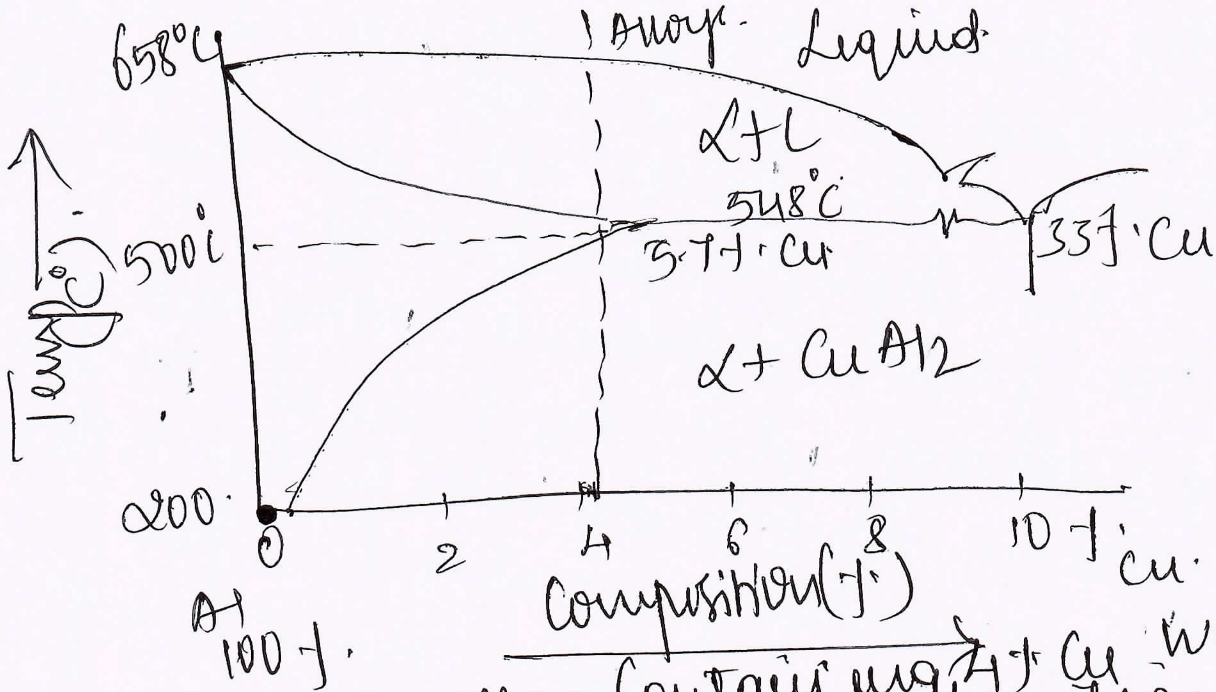
Sol

* In steels, hardening heat treatment is carried out by quenching so as to form martensite with the help of high rate of cooling.

* But in non ferrous metals there is no such concept & hardening takes place by a method called age-hardening.

* In this method, metals harden due to precipitations of a sub microscopic constituents from a super saturated solid solution in its microstructure.

* The figure represents Al-Cu phase diagram & the process is described as follows.



* At 500°C, an alloy containing 4% Cu would be made up of grains of solid solution "α".
* If this alloy is cooled from 500°C at a very slow rate, the microstructure would contain grains of solid solution α & a thick precipitate of the intermetallic compound cuprous aluminate ($CuAl_2$).
* But if the alloy is quenched from 500°C, the structure would contain only the solid solution α which is now super saturated. This is an unstable state & a fine precipitate of $CuAl_2$ comes out of α with the passage of time.
* The sub microscopic particles has a hardening effect on the metal. Therefore this method of hardening of metal due to their aging is known as age-hardening.

(28) Gui…

6.C: **Properties of Grey Cast iron:**

High Compressive Strength

* Grey cast iron has high compressive strength & that's why it is widely used in posts & columns of building.

Tensile Strength

* There are different varieties of Grey cast iron & their tensile strengths varies accordingly.

Resistance to deformation

* Grey cast iron is highly resistant to deformation & provides a rigid frame.

Composition of Grey Cast iron:

* Carbon (up to 4%): The carbon content of the grey cast iron later on gets converted to graphite after going through a series of chemical reactions. This graphite content is responsible for strength.
* Silicon (up to 3%): Silicon is mainly added for the de-oxidation process so that the carbon added does not get oxidized to the iron carbides.
* Manganese (0.8%): Manganese increases the toughening of the overall structure
* Sulfur (0.07%): it act as a stabilizing element for manganese & improve the toughness of the Grey cast iron

* Chromium (0.35%):- Chromium improves the temperature range & hardness of Grey cast iron

* Vanadium (0.15%):- Vanadium improves the wear & tear resistance.

Uses of Grey Cast Iron

* Can be used in producing heavy-duty machine tools, bed, presses, high pressure hydraulic parts, frame, gears, piston rings
* Can be used in producing gear, cylinder bars, flywheels etc.

* Suitable for producing cover body, protective cover, frame, hand wheels, hammer, pipe, valve etc.

79. ## Classification of Composites materials

Sol Composite materials are generally classified based on two distinct levels i.e based on the type of matrix material & based on type of reinforcement material.

Based on type of matrix material
a) Metal matrix Composites (MMC)
b) Ceramic matrix Composites (CMC)
c) Polymer matrix Composites (PMC)

30 [signature]

Metal matrix Composites (MMC)

* In MMC, matrix is made from metal or alloy.
* The reinforcement material is usually in the form of fibre or small sized particles made from ceramics or metallic materials.
* MMC's offers favorable properties like high specific strength, stiffness, high operating temperatures, low co-efficient of thermal expansion, wear resistance.
* MMC's also offers few disadvantages like high density, low ductility & high fabricating costs.

Ceramic matrix Composites (CMC)

* Generally considered ceramic matrix is silicon carbide, Al_2O_3
* The reinforcement material is usually in the form of fibre made from ceramic materials like silicon carbide, Al_2O_3 - SiO_2.
* CMC's offers favorable properties like high melting points, good corrosion & oxidation resistance, stability at elevated temperatures.
* CMC's also offers few disadvantages like high brittleness & crack resistance.

Nyui

* CMC's are usually used in disc brakes of airplanes & leading edges, gas turbine engine components, combustion linear seals, bearing of water station pumps.

Polymer matrix Composites (PMC):-

* are generally considered polymer matrix are thermosets & thermoplastics.
* The reinforcement material is usually in the form of fibre made from materials like glass, carbon, graphite, boron, aramides. etc
* PMCs offers favorable properties like light in weight, abrasion & chemical resistant, high strength & stiffness along the direction of reinforcement.
* PMCs also offers few disadvantages like low impact strength & low tensile strength.
* PMC's are usually used in aerospace application like rotor blades & hulls, wings, landing gears, marine applications like propeller shafts, rudders, boat hulls. Automotive parts like exterior body panel, battery trays, engine components

(37)

7b.
Sol

Application of Composite materials.

* Aircraft industry:- used in rotor blades, fin, rudders, wing body, Fuel tanks, Propeller blades, landing gear doors, helicopter frames.

* Space crafts:- Rocket motor casing, rotor blades, heat shields & nozzles, panel doors, turbine & combustion chamber components.

* Automobiles:- car front end parts, side doors, seating, bonnets, head lamps, engine, components, leaf springs, disc brakes, etc.

* Construction:- Doors, door hinges, window frame, water tanks, furniture, sanitary wares, interiors, pipes. etc.

* Sports equipments:- Badminton racquets, tennis racquets, golf stick, hockey stick, helmet, bicycle frame, etc.

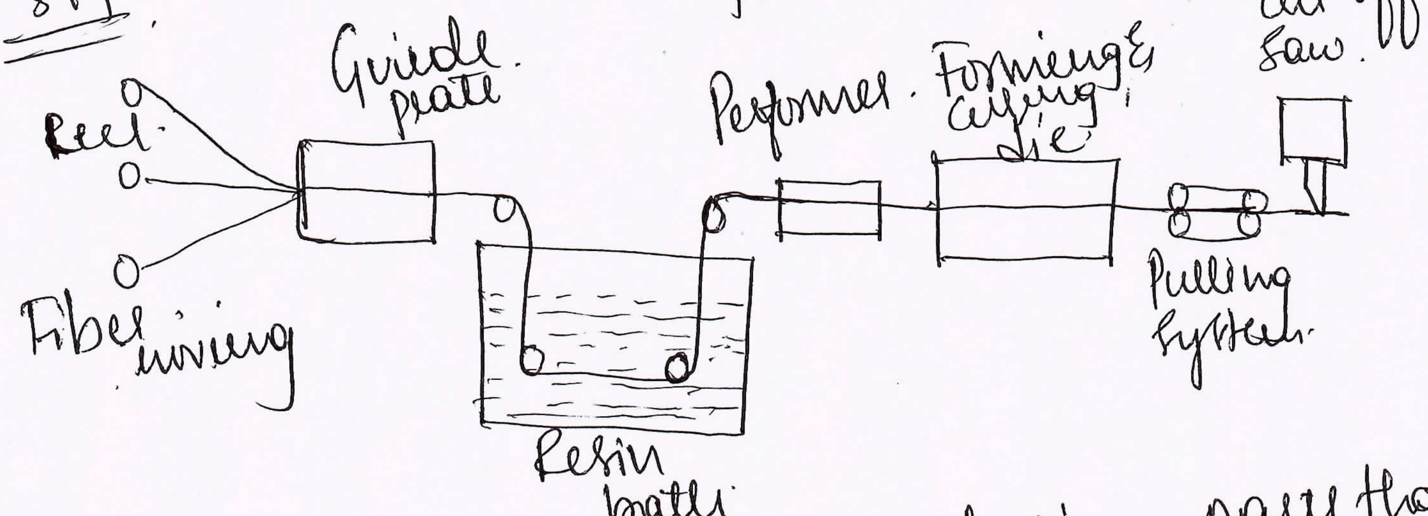
* Biomedical industry:- orthopaedic application like bone fixation plates, joints replacement, dental application like crown replacement, etc.

3) Given

* Marine industry:- Boat hulls, fans & blowers, valves & strainers, gear cases, propeller vanes etc.
* Military:- Submarine components, armoured vehicles, bullet proof vests etc.

7C
8M

Pultrusion process



* It is process used for producing parts that have constant C/s profile such as I-beam, channels, tubes, pipes etc.
* The pultrusion process starts with the pulling off raw fibers from the reel & guide through a resin bath such that fiber reinforcement becomes completely impregnated with resin.
* The resin is usually a thermosetting resin & is sometimes combined with filler, catalyst & pigments.

1) Guim.

* The wet fibers exit the baths & enter the Performer where the excessive resin is squeezed out from the fibers & pre-compacted to the approximate profile.

* The Performed fibre is passed through the heated steel or aluminium die which has the similar shape of the product.

* The heat energy transferred inside the die activities the curing of resin, changing it from liquid to solid.

* At last the cured product is cut based on desired lengths.

8 a

Sol. The characterization of the composites is nothing but establishing the various properties of composites by considering the method of preparation based on rule of mixtures, reinforcement orientation, thickness of the specimen, surface treatment like chemical treating of matrix & reinforcements etc.

(35)

and finally on the type of tests considered based on the Universal standards.

* The specimens prepared based on the considerable criteria is cut according to the standards (ASTM standards) & tested under controlled atmosphere & the obtained results are tabulated for the comparative study b/w them.

* The various tests for mechanical properties includes tensile test, compression test, fatigue test, impact studies, drop loading test, & wear studies, hardness test etc. the final state of specimen after can be considered for microscopic studies like SEM & thus analysed.

*8b Filament winding process.

Sol. * It is an automated process primarily used for producing hollow, generally circular or oval cross sectional components such as pipes & tanks.

(36) Given

* The Continuous strands of glass fiber is fed from a reel, passes through a resin bath (matrix) before being wound on the mandrel in the desired orientation

* The Shape of the mandrel is similar to the internal geometry of the desired component

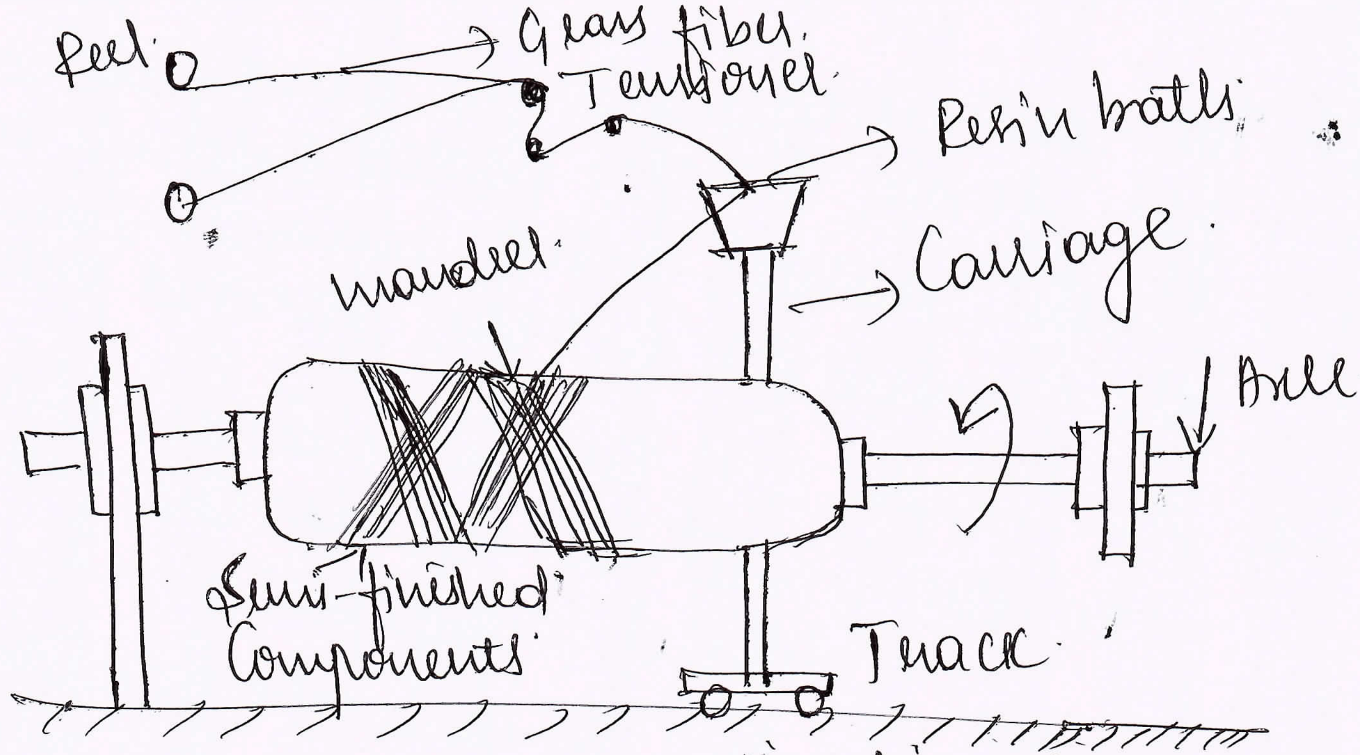
* The mandrel rotates at a predetermined speed while the carriage carrying the resin bath moves horizontally

* Consolidation pressure is achieved through tensioning the fiber as they are wound onto the mandrel.

* Once the mandrel is completely covered with desired thickness, it is placed in an oven to solidify the resin.

* Once the resin is cured mandrel is removed leaving the hallow final product.

(37) Gu



Filament winding process

8C

Sol

Given data :- $E_f = 72400 \times 10^6 \, N/m^2$

$\sigma_f = 2400 \times 10^6 \, N/m^2$, $E_m = 3100 \times 10^6 \, N/m^2$

$\sigma_m = 60 \times 10^6 \, N/m^2$

$V_f = 0.6$; $V_m = 0.4$

i) Iso Strain Condition :- $E_c = E_f V_f + E_m V_m$

$\therefore E_c = (72400 \times 10^6 \times 0.6) + (3100 \times 10^6 \times 0.4)$

$E_c = 44680 \times 10^6 \, N/m^2$

$\sigma_c = \sigma_f V_f + \sigma_m V_m$

$\sigma_c = (2400 \times 10^6 \times 0.6) + (60 \times 10^6 \times 0.4)$

$\sigma_c = 1464 \times 10^6 \, N/m^2$

(38)

Fraction of load carried by fiber is given

$$\frac{P_f}{P_c} = \frac{E_f V_f}{E_m V_m + E_f V_f} = \frac{(72400\times10^6\times0.6)}{(3100\times10^6\times0.4)+(72400\times10^6\times0.6)}$$

$$\frac{P_f}{P_c} = 0.972 \Longrightarrow 97.2\%$$ of the load is supported by fibers

ii) Iso Stress Condition; $E_c = \frac{E_f \cdot E_m}{V_f E_m + V_m E_f}$

$$E_c = \frac{(72400\times10^6)\times(3100\times10^6)}{(0.6\times3100\times10^6)+(0.4\times72400\times10^6)}$$

$$\Rightarrow \therefore E_c = 7282\times10^6\ N/m^2$$

9.a

Sol. **Types of ceramics**

Ceramics can be classified on the basis of their industrial applications or structure as follows:-

1) Based on function:-

1) Abrasives → Carborundum, Alumina etc.

2) Fire clay products → Bricks, porcelain tiles etc.

3) Cementing product → All cements, lime etc.

4) Glasses → Soda lime glass, Lead glass, Borosilicate glass etc.

5) Rocks → Igneous, Sedimentary & metamorphic
6) Minerals → Quartz, Calcite etc.
7) Clay → Kaolinite, Montmorillonite
8) Refractories → Magnesite, Silica bricks etc.

ii) Based on Structure:-

1) Crystalline Ceramics →
   a) Single phase ceramics. for example: MgO, NaCl.
   b) Multiphase ceramics for example: MgO-Al_2O_3.

2) Atomic bonding → a) Covalent bonding Ex: SiC.
   b) Ionic bonding. Ex: MgO

3) Non-Crystalline Ceramics → Natural & Synthetic glass.

Properties of Ceramics :-

1) Chemical Properties

* Most ceramics are highly resistant to all chemicals.
* The are completely resistant to oxidation at high temperature

2) Optical Properties:-

* Several types of glasses are used for windows & optical lenses.

* Special glasses are used in selective transmission or absorption of certain wave lengths such as infrared & ultraviolet rays.

3) Thermal Properties

* Ceramics have very low thermal Conductivity since they do not have free flowing electron in their outermost shells as seen in metals.

4) Mechanical Properties

* Ceramics have low tensile strength.

* They generally fail due to stress concentration on cracks, pore etc.

* They posses high compressive strength.

5) Electrical Properties

* Ceramics are often used for electric insulation.

* Many ceramic have a dielectric constant value up to 100 & very low dielectric losses.

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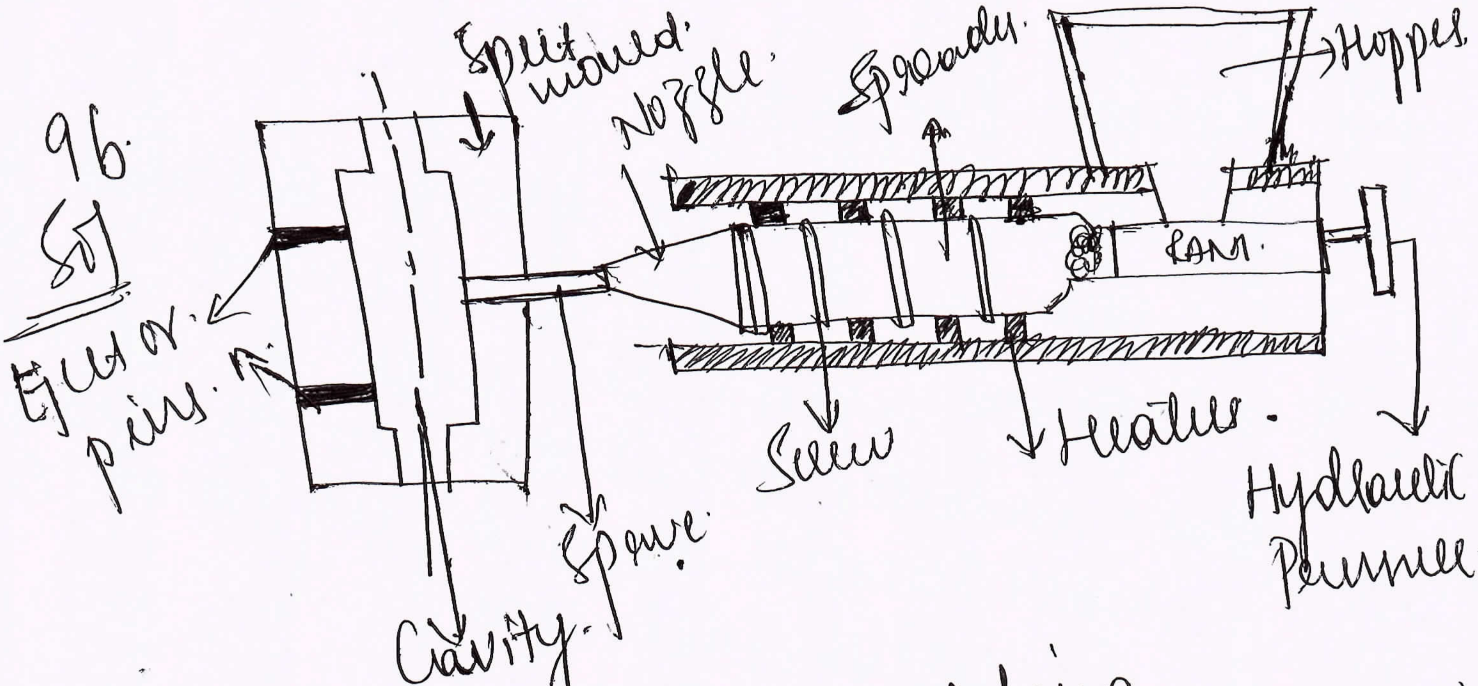

Injection moulding

* The above figure illustrates the injection moulding process.
* Here a pre calculated quantity of plastic material in the form of powder pallets along with necessary additives are fed into hopper.
* The hopper then feeds the plastics materials onto heated injection unit
* A motor runs the screw rod, which force the plastic material along the heating section causing the plastic material to reach molten state
* The screw rod also acts as reciprocating ram, which rapidly moves forward inject the molten plastic into the water cooled mould.

* Ram pressure is maintained until the part cools and solidifies.

* The mould halve is opened & the finished product is ejected by means of ejector pins.

9c Sol

Application of ceramics

1) Traditional usage :- Bricks, tiles, sand, cements, chimneys, mortar, glasses, plaster, crockery, etc.

2) Automotive :- Brake discs, catalyst support, water & fuel pumps, components, crankshaft housing part.

3) Aerospace :- Ceramic engine, airframe, space shuttle tiles. etc.

4) Electronics :- Capacitors, insulators, semi conductor, dielectrics, etc.

5) Machines :- Cutting tools, furnaces, armour plates, burners, Pyrometer etc.

Applications of plastics

(B) Thermosetting Polymers

i) Epoxies → Adhesives, electrical moulding machines & structural components.

ii) Silicon → Laminate, strips high temperature resistance, components

iii) Poly ester :→ Helmets, fans, chairs

Thermo plastic polymers

i) Nylone :- Covers, gears, bearing, ropes, handles

ii) Poly ethylene :- plastic cover bags, tumblers, ice trays, toys tubes.

iii) Poly styrene :- Battery cases, wall tiles plates, trays, etc

10a. Smart materials

Sol

* Smart materials are designed material having one or more properties that can be significantly changed in a controlled fashion by means of external - intrinsic such as stress, temperature, moisture, electric or magnetic field etc.

ii) Shape memory alloys. They are those materials, even after being deformed have the ability of remembering & returning to their original shape & size upon appropriate heat treatment

(4) Given

* Deformation is normally carried out at relatively low temp, whereas shape-memory effect happens due to heating.
* Among the materials that are capable of recovering significant amount of deformation, the best known are Nickel-titanium alloys (NITINOL) & some copper based alloys.
* When a shape memory alloy is in its cold state, the metal can be bent, stretched & will hold those shapes until heated above the transition temp of alloy. Upon heating, the metal changes to its original shape until deformed again.

10 b Sol

Biological applications of SMA

* The first cardiovascular device developed with SMA was "Simon filter". This filter represents a new generation of device that are used for blood vessels interruption in to prevent pulmonary embolism.

(45) Gun

* SMA are used as catheters, retainers clot filters, surgical anchors, bone plates, intra-aortic balloon pump, laparoscopic tools etc. during surgical procedure on human beings.

* Stents implanted in the arteries to improve blood flow can be made from SMA.

* SMA have a large number of orthopedic applications for example the spinal vertebra spacer made from SMA is inserted b/w two vertebrae.

* Plates made from SMA are used as casts where there are fracture in facial areas, nose, jaw etc.

Other applications of SMA

Robotic applications

* SMA have been used in robotic application since 1980s. Robots in which SMA are used are rolling, walking, climbing, jumping, swimming, snaking, crawling, Humanoid robots.

(46)

* Automotive application

SMA can be used in the mirror systems in modern vehicles due to the versatility of SMA.

Ex: General motors came up with SMA materials in active louvers, Grab handle, Air dam, Air vent etc.

* Aerospace application

SMAs have been used in aerospace since 1970s used in hydraulic line coupling which is used in F-14 fighter jets.

* Some of the parts of plane are made up of SMA are wing etc, wing, Landing gear, Fuse lage, Stabilizer, Fin.

10 C Factors affecting the selection of materials for engineering purposes

Sol

a) Properties of materials

* The most important factor while for engineering design is the properties of the materials in relation to their intended use.

* The properties of the material define specific characteristic of the materials & form a basis for predicting.

behaviour of the material under different conditions.

b) Performance requirements

* The material of which a part is composed must be capable of embodying or performing a part's functions without failure.

For example, a component part to be used in a furnace must be of that material which can withstand high temperatures.

c) Material reliability

* A material in a given application must also be reliable. A material which is made, will remains stable enough to function in service for the intended life of the product without failure.

D) Safety

* A material must safely perform its function, otherwise, the failure of the product systems made out of it may be catastrophic in air-planes & high pressure systems.

(48) Gu

E) <u>Physical attributes</u>

Physical attributes such as configuration size, weight, & appearance sometimes also serve functional requirements.

F) <u>Environmental Conditions</u>

The environment in which a product operate strongly influences service Performance.

G) <u>Availability</u>:

Material must be readily available and available in large enough quantity for the intended applications.

(Prof. Gururaj. Hatti). 1/3/2022

(HOD)

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