MATERIAL TECHNOLOGY

(CBCGS NOV 2018)

Q1] 1) Hume – Rothary gave governing conditions for formation of solid solutions. Discuss the conditions. **(05)**

Solution:-

Following are the conditions for Hume Rothary's Rule:

(a) Atomic Size Factor:

If the atomic sizes of solute and solvent have differ by less than 15%, it is said to have a favorable for solid solution formation. If atomic size difference exceeds 15%, solid solubility is limited.

(b) Chemical Affinity Factor:

The greater the chemical affinity of two metals, more restricted is their solid solubility and the greater is the tendency toward the compound formation.

(c) Relative Valency Factor:

If the solute metal has a different valency from that of the solvent metal, number of valance electrons per atom, called the electron ratios will be changed.

(d) Crystal Structure Factor:

Metals having same crystal structure will have greater solubility. Differences in crystal structure limit the solid solubility.

Q1] 2) Discuss the differences between slip and twinning. . **(05)**

Slip	Twinning
(a) Slip is a mechanism of deformation where one part of crystal moves, glides or slips over another part along certain planes known as slip pane.	(a) Twinning is a process by which a porton of crystal takes up an orientation which makes that portion a mirror image of parent crystal along the twinning process.
(b) Slip begins when shearing stress reaches a critical resolved shear stress.	(b) There is no critical resolved shear stress.
(c) It takes place in several milliseconds.	(c) It takes place in few microseconds.
(d) Stress required to produce slip is less.	(d) The stress required to produce slip is more.
(e) Slip is more common in BCC and FCC metals.	(e) Twin is more common in HCP metals.
(f) Slip lines are observed only after plastic deformation.	(f) Twin lines are observed after mechanical working and annealing.

Q1] 3) Why FCC metals are more ductile than BCC and HCP metals? (05)

Solution:-

(1) In BCC metals having very less effective atoms per unit cell, they do not have a well-defined slip system and do not have a truly closed packed plane. The slip plane is the closed packed <111> direction.

(2) In HCP metals have only one plane of high atomic population i.e. (0001) plane or base plane and three closed packed <1120> directions.

(3) In FCC materials there are four sets of (111) planes and three closed packed <110> directions in each plane. So it contains 12 possible slip systems.

(4) So FCC metals contains more or sufficient number of good slip planes compare to BCC and HCP metals, that is why FCC metals are more ductile than BCC and HCP metals.

Q1] 4) What are nanomaterials? Discuss some of their applications. (05)

Solution:-

(A) Nanomaterials:-

Nanostructured materials or Nanomaterials may be defined as those materials whose structural element clusters, crystallites or molecules have dimensions in the 1 to 100 nm range.

(B) Applications:-

(1) Fuel cells:

A fuel cell is an electrochemical energy conversion device that converts the chemical energy

from fuel (on the anode side) and oxidant (on the cathode side) directly into electricity.

(2) Carbon nanotubes:

Carbon nanotubes (CNTs) have chemical stability, good mechanical properties and high surface

area, making them ideal for the design of sensors and provide very high surface area due to its

structural network. Since carbon nanotubes are also suitable supports for cell growth, electrodes

of microbial fuel cells can be built using of CNT.

(3) Catalysis:

Higher surface area available with the nanomaterial counterparts, nano-catalysts tend to have

exceptional surface activity. For example, reaction rate at nano-aluminum can go so high, that it

is utilized as a solid-fuel in rocket propulsion, whereas the bulk aluminum is widely used in

utensils.

(4) Elimination of Pollutants:

Nanomaterials possess extremely large grain boundaries relative to their grain size. Hence, they are very active in terms of their chemical, physical, and mechanical properties. Due to their enhanced chemical activity, nanomaterials can be used as catalysts to react with such noxious and toxic gases as carbon monoxide and nitrogen oxide in automobile catalytic converters and power generation equipment to prevent environmental pollution arising from burning gasoline and coal.

Q1] 5) What are limitations of Plain Carbon Steel? Explain effect of alloys on phase transformations. **(05)**

Solution:-

(A) <u>Limitations of Plain Carbon Steel</u>:-

(1) Cannot be strengthened beyond 690 MPa without loosing ductility and impact strength.

(2) Not deep hardenable.

(3) Low corrosion resistance.

(4) Rapid quenching leads to crack and distortion.

(B) <u>Effect of alloying elements on phase transformations</u>:-

(1) The phase transformation temperatures in iron-iron carbide diagram are A_1, A_3 and A_4 in the steel region. During heating of steel at A_1 (727°C) pearlite converted into austenite of FCC structure. If heated above (910°C) last trace of α-ferrite will convert into Υ-austenite and if it further heated above 1400°C (A_4), Υ will be converted into δ-ferrite in BCC structure. These transformation are reversible on cooling.

(2) Austenite stabilizers (Nickel, Copper, and Nitrogen) are more stable in austenite region of steel. These elements raise the A_4 temperature lower A_1 and A_3 temperature as shown in Fig (a). Due to this more austenite region by reduction of ferrite region.
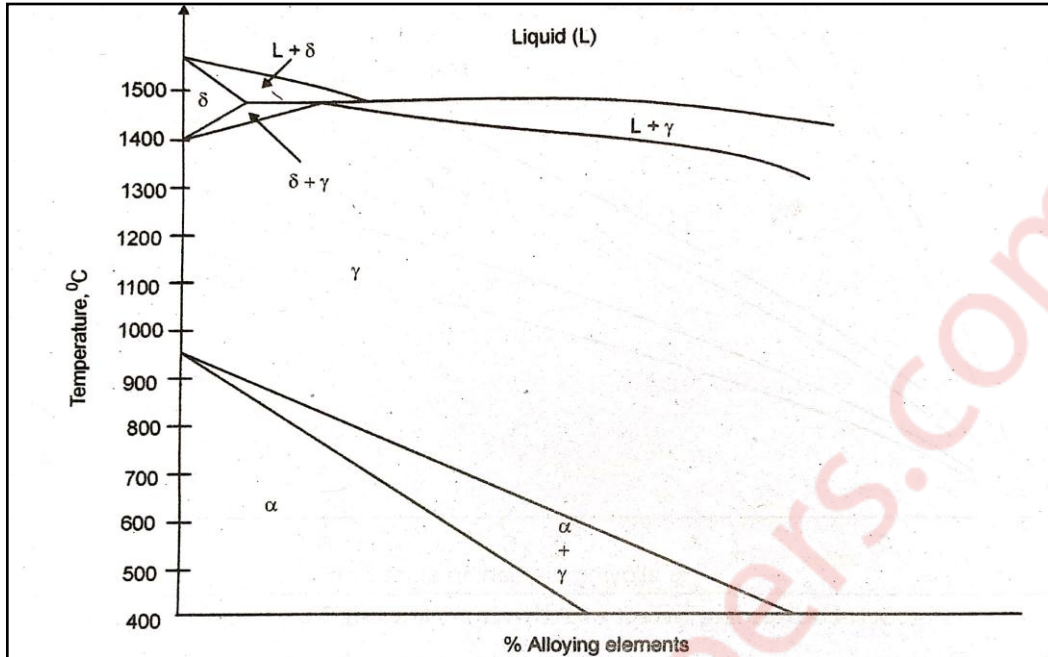
Fig (a): Effect of austenite stabilizers on Fe-Fe3C Daigram

(3) Ferrite stabilizers (Chromium, Tungsten, Vanadium, Molybdenum, Aluminium and Silicon) are more stable in ferrite region. If these elements are added to steel, they increase ferrite region by reducing austenite region in iron-iron carbide diagram. These elements increase ferrite region by raising A_1 and A_3 temperatures and lowering the A_4 temperature as shown in Fig (b).
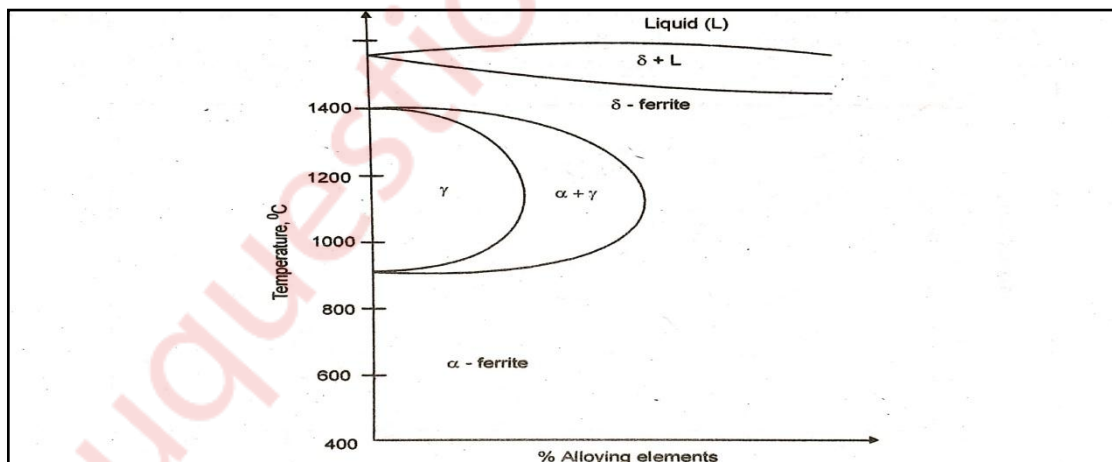

Fig (b): Effect of Ferrite Stabilizers on Iron-Iron Carbide Daigram

Q2] 1) Define cooling rate. Describe various cooling curves on TTT diagram. What factors affect critical cooling rate. (10)

Solution:-

A) Cooling rate:-

When the cooling curve is tangent to the nose of TTT curve, it is called as a critical cooling rate (CCR). CCR can be defined by two ways 'The slowest cooling rate at which unstable austenite can be transformed into martensite'.

OR

'The fastest cooling rate or within minimum time at which unstable austenite can be transformed into pearlite.'

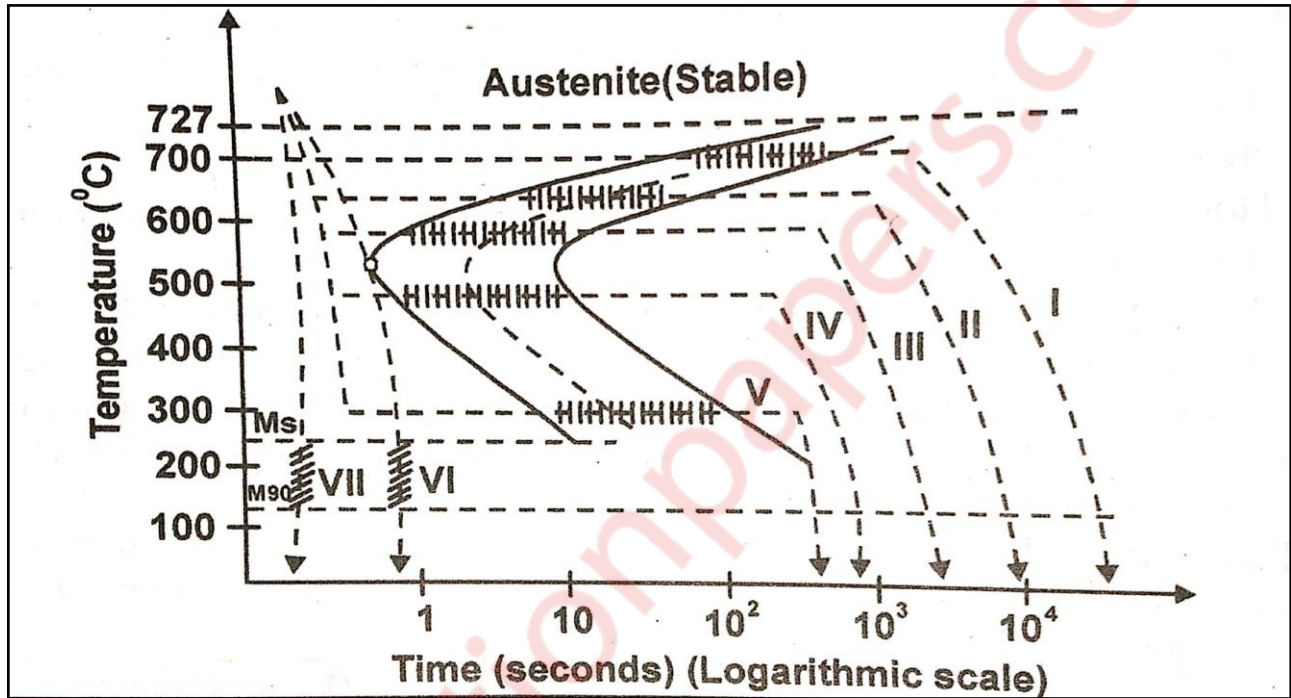B) <u>Various cooling curves on TTT diagram</u>:-

Fig :- Time-Temperature-Transformation (TTT) diagram

(1) Cooling Curve – I (Coarse Pearlite):-

The transformation product of this cooling curve will be a coarse pearlite. In TTT diagram, when cooling of unstable austenite will be carried out between 675°C to 727°C isothermally, it will transform into coarse perlite.

(2) Cooling Curve – II (Medium Pearlite):-

The transformation product of this cooling curve is medium pearlite. This transformation occurs when material cooled between 600 to 675°C at a constant temperature in TTT diagram.

(3) Cooling Curve – III (Fine pearlite):-

The transformation product of this cooling curve is fine pearlite. This transformation occurs when the material will be cooled between 500 to 600°C at a constant temperature in TTT diagram.

(4) Cooling Curve – IV (Upper Bainite):-

This cooling curve is obtained only by cooling material rapidly enough to miss the nose of the TTT curve and then held at a constant temperature for transformation. The transformation product of this curve is upper bainite.

(5) Cooling Curve – V (Lower Bainite):-

This cooling curve is obtained by cooling material rapidly enough to miss the nose of TTT curve just above 210^oC temperature (Ms). Hold it at constant temperature for transformation.

(6) Cooling Curve – VI (Critical Cooling Rate):-

This curve is tangent to the nose of TTT curve. It is the slowest cooling rate at which austenite can be transformed into martensite. It is 140^oC/sec. for eutectoid steel.

(7) Cooling Curve – VII (Martensite):-

This curve is obtained by very fast cooling rate (350^oC/sec). The transformation product of this curve is martensite.

(C) Factors affecting critical cooling rate:-

(1) Carbon content:-

With higher carbon content or alloying elements, decreases the critical cooling rate and shifts TTT curve towards right. It retards the transformation of austenite to pearlite.

(2) Austenitic Temperature:-

Higher austenitic temperature gives lower critical cooling time and increases CCR.

Q2] 2) Draw Fe-Fe₃C equilibrium diagram and label the temperatures, composition and phases. **(10)**

Solution:-

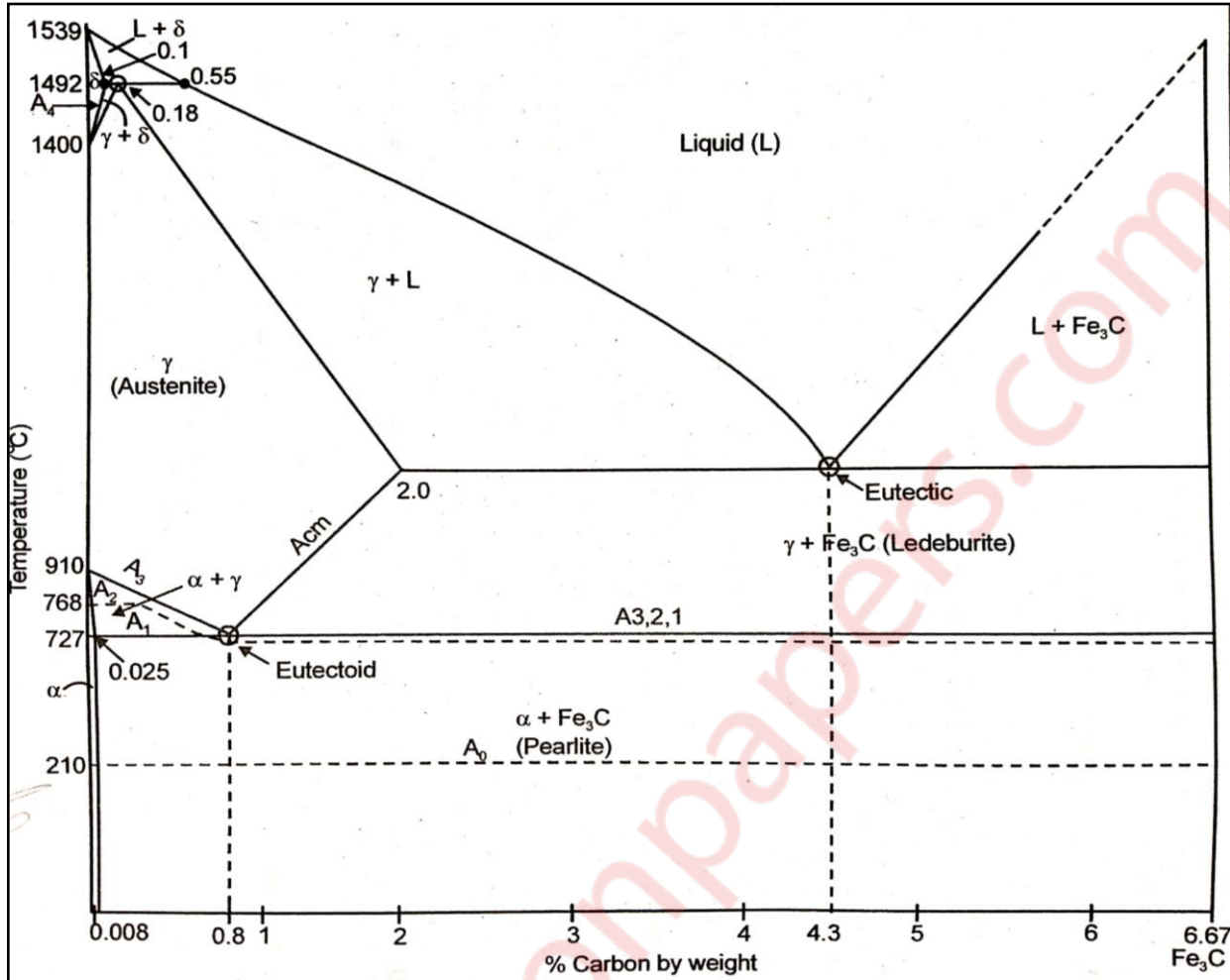A) Fe-Fe$_3$C equilibrium diagram:-

Fig: Iron-Iron Carbide Equilibrium Diagram

(B) <u>Various Temperature lines in Iron-Iron Carbide Equilibrium Diagram</u>:-

(1) A_0 (210°C):-

At this temperature line cementite changes from magnetic to non-magnetic character.

(2) A_1 (727°C):-

At this temperature, pearlite transforms to austenite during heating. This transformation occurs at a constant temperature of 727°C.

(3) A_2:-

At this temperature line ferrite changes its property from magnetic to non-magnetic during hating. This line is at 0% C and 768°C temperature up to A_3 line then it is parallel to A_3 line up to 0.8% C and 727°C temperature and then it is constant at 727°C temperature up to 6.67% carbon.

(4) A_3:-

At this temperature line the last trace of free ferrite gets dissolved to form 100% austenite. It decreases from 910ºC temperature and 0% C to 727ºC temperature and 0.8% C and then it is constant at 727ºC temperature up to 6.67% C.

(5) A$_{cm}$:-

At this temperature line, the last trace of free cementite gets dissolved to form 100% austenite. It increases from 727ºC temperature and 0.8% C to 1147ºC temperature and 2.0% C.

(6) A$_4$:-

At this temperature line, the last trace of austenite gets dissolved to form 100% δ-ferrite. It increases from 1400ºC temperature and 0% C to 1492ºC temperature and 0.1% C.

(C) <u>Various phases existing in the Iron-Iron Carbide diagram</u>:-

(1) α-Ferrite:-

Ferrite is interstitial solid solution of carbon in low-temperature B.C.C. α-iron. The solubility of carbon in α-iron at room temperature is 0.008% and increasing with increase in temperature to about 0.025% at 727ºC.

(2) Ɣ-Austenite:-

Austenite is an interstitial solid solution of carbon dissolved in F.C.C. Ɣ-iron. Maximum solubility is 2% carbon at 1147ºC temperature. The phase is stable only above 727ºC.

(3) δ-Ferrite:-

It is an interstitial solid solution of carbon in high temperature B.C.C δ-iron.

(4) Cementite (Fe3C):-

It is also called as carbide or iron carbide. It is an intermetallic compound of iron and carbon with fixed carbon content of 6.67% by weight. It is magnetic up to 210ºC.

(5) Ledeburite:-

It is eutectic mixture of austenite and cementite. It contains 4.3% C at 1147ºC temperature.

(6) Pearlite:-

It is eutectoid mixture containing 0.8% carbon and is formed 727°C temperature on very sloe cooling.

Q 3] 1) Describe cooling of eutectoid steel from liquid state to room temperature.

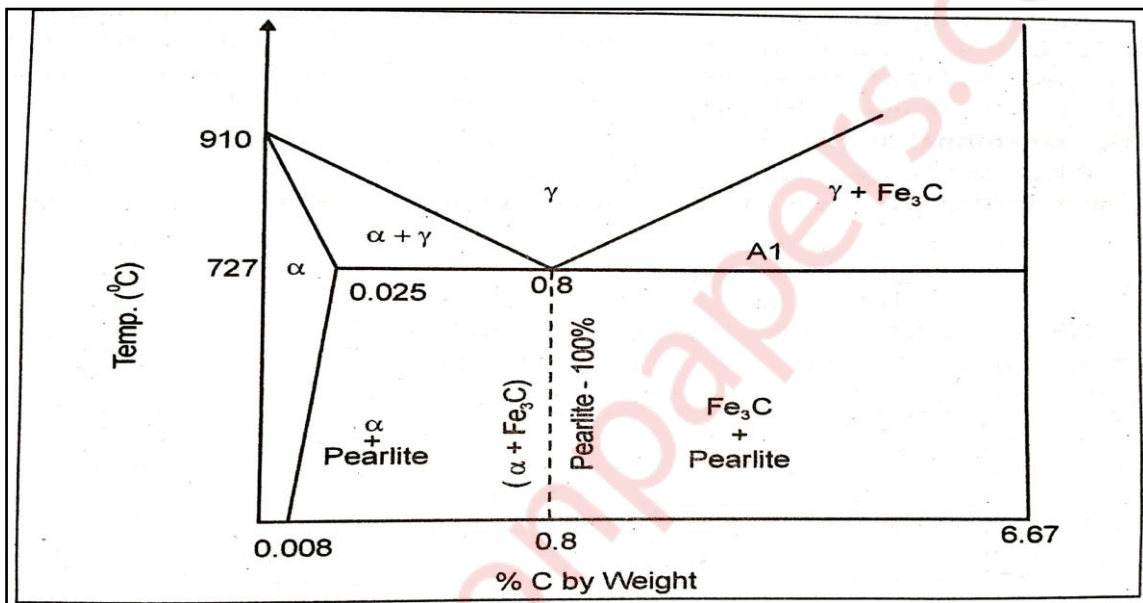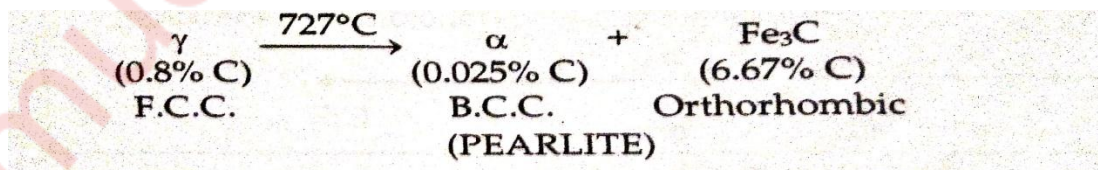**Calculate the phases in the pearlite obtained at room temperature.** **(10)**

Fig: Eutectoid Transformation Diagram

(A) <u>Cooling of eutectoid steel from liquid state to room temperature</u>:

(1) Above diagram shows eutectoid transformation of steel where cooling of eutectoid steel from liquid state to room temperature process occur.

(2) Eutectoid transformation in the Fe-Fe₃C diagram is at 727°C temperature and 0.8% carbon and is as follows:-


(3) Austenite (ϒ) of 0.8%C decomposes at 727°C temperature and forms mixture of ferrite (0.025%C) and Fe₃C (6.67% C). This eutectoid mixture is called as pearlite.

(B) <u>Calculation</u> <u>of</u> <u>phases in pearlite obtained at room temperature</u>:-

(1) Pearlite consists of alternate lamellae of ferrite and cementite.

(2) For calculating the amount of ferrite and cementite in pearlite at room temperature we apply lever arm rule as shown below:-
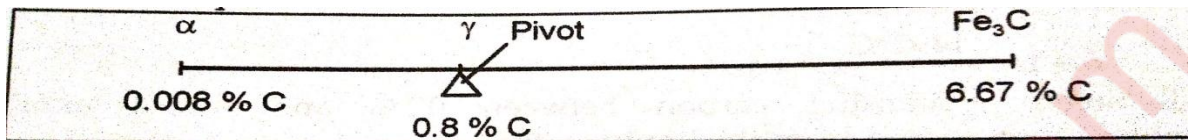
$$\% \text{ Amount of ferrite} = \frac{Opposite\ arm\ length}{Total\ arm\ length} \times 100$$

$$= \frac{(6.67 - 0.8)}{(6.67 - 0.008)} \times 100$$

$$= 88.10\%$$

$$\% \text{ Amount of cementite} = \frac{(0.8 - 0.008)}{(6.67 - 0.008)} \times 100 = 11.9\%$$

Amount of ferrite in pearlite at room temperature is 88.10% and amount of cementite in pearlite at room temperature is 11.9%.

Q 3] 2) Describe micro-structures for:- (i) White cast iron (ii) Malleable cast iron (iii) Grey cast iron (iv) Nodular cast iron (v) Mild steel **(10)**

Solution:-

(i) <u>White cast iron</u>:-

A fracture surface of this alloy has a white appearance, and thus it is termed as white cast iron.
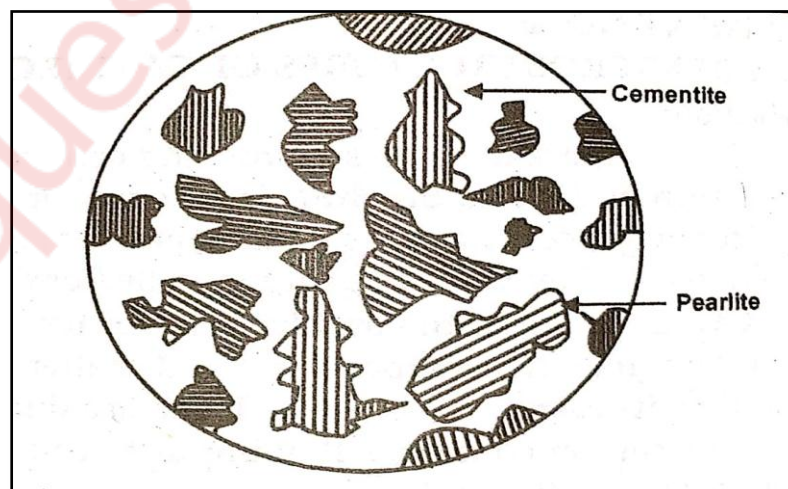

Fig: Microstructure of White Cast Iron

As a consequence of large amounts of the cementite phase, white iron is extremely hard but also very brittle, to the point of being virtually unmachinable. It contains 4% Carbon and 0.5% Silicon.

(ii) <u>Malleable cast iron</u>:-

The microstructure is similar to that of nodular iron which accounts for relatively high strength and appreciable ductility or malleability.
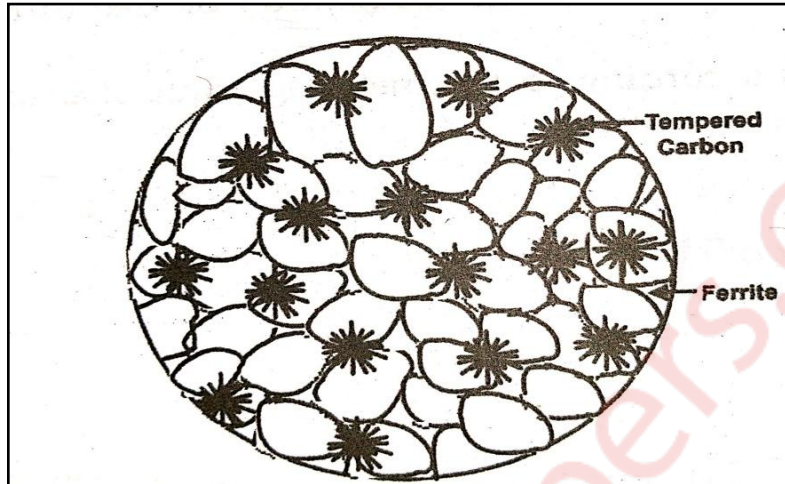

Fig; Microstructure of Malleable Cast Iron

If the cooling is slow, the cementite from pearlite decomposes into ferrite and graphite.It contains 4% Carbon and 0.5% Silicon.

(iii) <u>Grey Cast Iron</u>:-

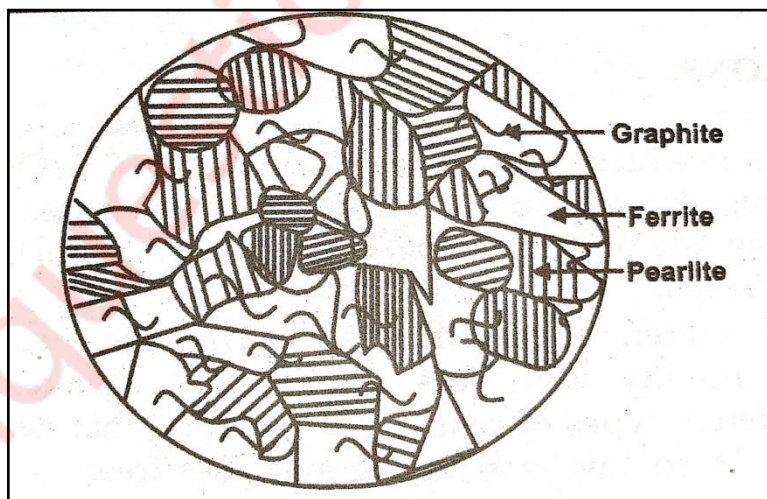The cast irons containing graphite in the form of flakes (whorl like shape) are called as grey cast irons.

Fig: Microstructure of Grey Cast Iron

Mechanically, gray iron is comparatively weak and brittle in tension as a consequence of its microstructure. If the cooling rate is fast it shows pearlitic grey cast iron and if cooling rate is very slow pearlite from cast iron decomposes to ferrite.

(iv) <u>Nodular Cast Iron</u>:-

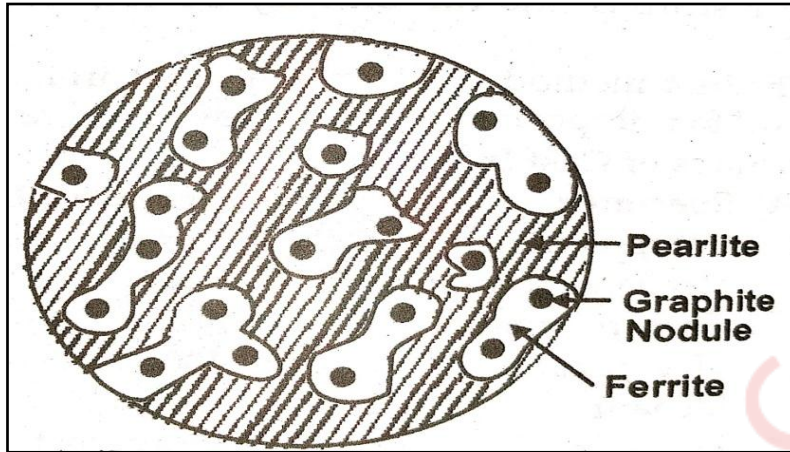It is a cast iron in which the graphite is present in the form of nodules or spheroids.

Fig: Microstructure of nodular cast iron

If nodular cast iron cools fast it shows the pearlitic structure and if the cooling rate is slow pearlite decomposes into ferrite and shows ferrite and shows ferrite malleable cast iron structure.

(v) Mild steel:-

Conventional mild steel has a relatively simple ferritic microstructure; with low carbon content and minimal alloying elements making it soft and formable. Mild steels have relatively low strength, but excellent formability.
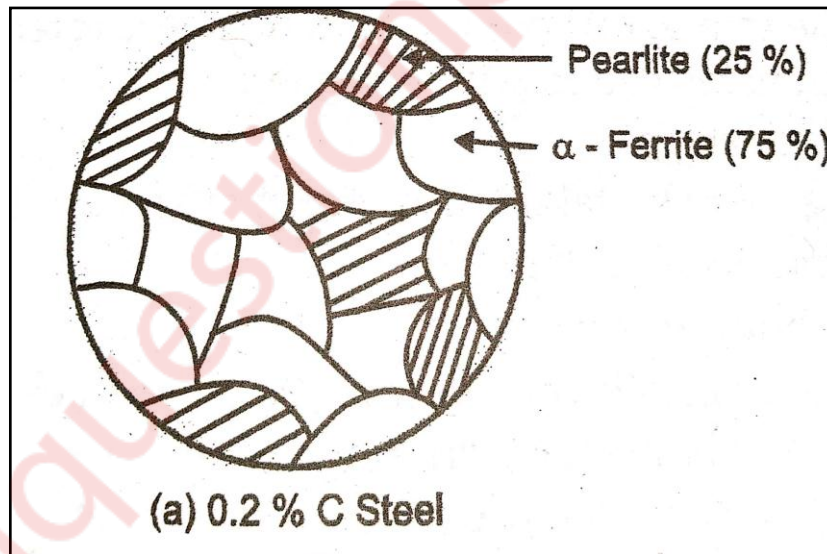

Fig: Microstructure of mild steel

Q4] 1) What is strain hardening? Explain the phenomenon on the basis of dislocation theory. **(06)**

Solution:-

(A) Strain Hardening:-

Strain hardening or work hardening is a phenomenon which results in an increase in hardness and strength of metal when subjected to plastic deformation at a temperature lower than the recrystallization range (cold working).

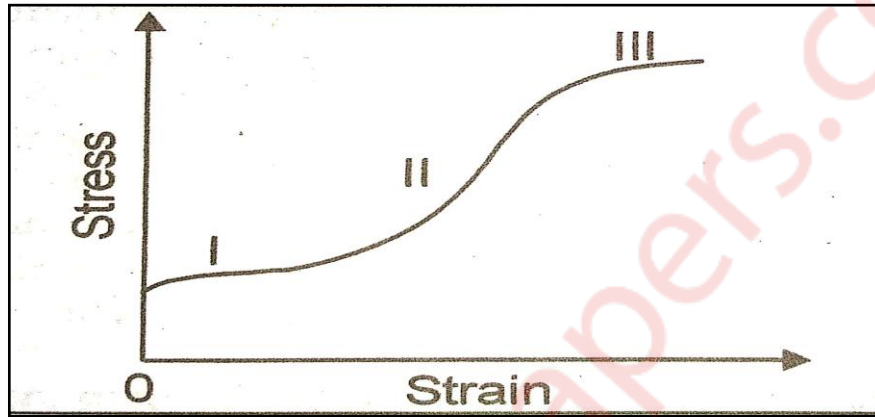(B) <u>Strain hardening on the basis of dislocation theory</u>:-

Fig: Strain Hardening

Above figure shows the stress strain curve of FCC single crystal. The three stages of strain hardening are distinguished as follows:-

(i) Stage – I [Easy Glide Region]:-

This stage follows immediately after the yield point. Dislocations are able to move over a relatively large distance without encountering barriers.

(ii) – II [Linear Hardening Region]:-

This region shows a rapid increase in strain hardening rate. In this region, slip occurs on both primary and secondary slip systems. As a result, several new lattice irregularities may be formed which will include Forest dislocations, Comer-Cottrell barriers and jog produced either by moving dislocations cutting through forest dislocations.

(iii) Stage – III [Parabolic Hardening Region]:-

It is a region of decreasing rate of strain hardening. At high stress value or temperature in region III, the dislocations held up in stage – II is able to move by a process that had been suppressed at lower stresses and temperature. The screw dislocations which are held up in stage – II , cross slip and possibly return to the primary slip plane by double cross slip. By this mechanism dislocations can by-pass the obstacles in the glide plane and do not have to interact strongly with them. For this region, stage – III exhibits a low rate of work hardening.

Q4] 2) What is fatigue? Explain the method of testing metals for fatigue.   (08)

(A) <u>Fatigue</u>:-

With frequent stress fluctuations, the material may fail at stress level far below its static ultimate tensile strength is called as 'Fatigue Failure'. Fatigue failure in material occurs when it is subjected to repeated loading and vibrations.

(B) <u>Fatigue Testing</u>:-

The fatigue testing can be conducted using rotating beam fatigue testing machine as shown in figure as following:
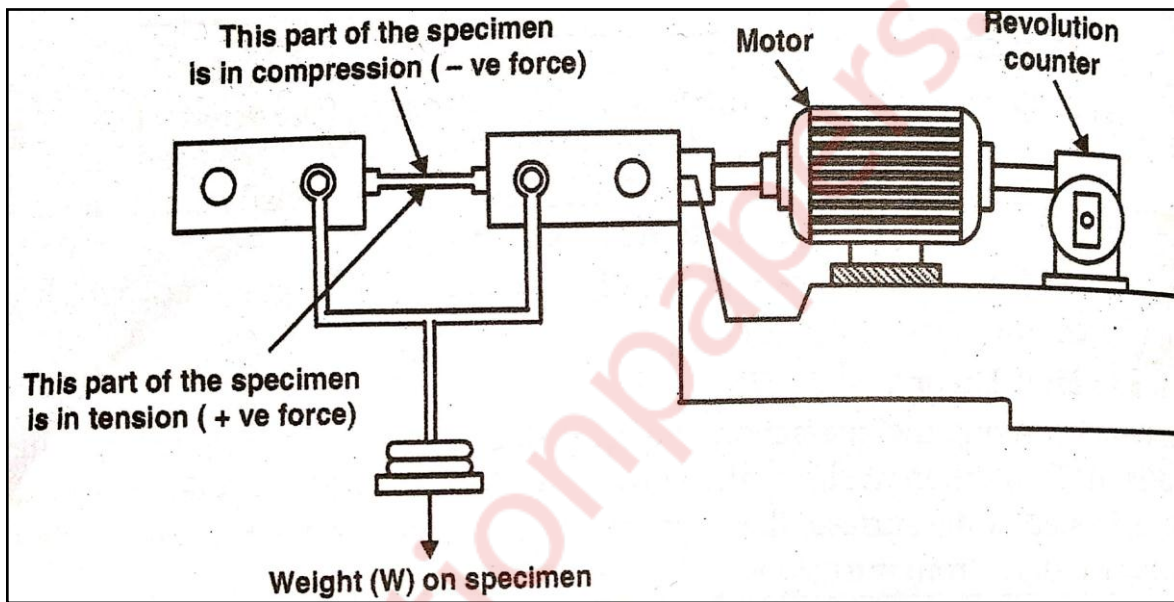

Fig: Rotating Beam Fatigue Testing Machine

(1) The fatigue specimen is gripped on to a motor at one end to provide the rotational motion whereas the other end is attached to a bearing and also subjected to a load or stress.

(2) When the specimen is rotated about the longitudinal axis, the upper and the lower parts of the specimen gauge length are subjected to tensile and compressive stresses respectively. The test proceeds until specimen failure take place.

(3) The revolution counter is used to obtain the number of cycles to failures corresponding to the stress applied. When specimen breaks then the counter automatically disengages.

(4) Increasing weight applied to the fatigue specimen results in a reduction in a number of cycles to failure. We can use the experimental results to construct an S-N curve.

Q4] 3) Define creep. Draw the creep curve and explain the stages of creep.   (06)

(A) <u>Creep</u>:-

Creep is a slow plastic deformation of metal under constant stresses at a constant temperature for prolonged period. Generally, the test is carried out in a furnace. Change in deformation or strain is measured with respect to time.
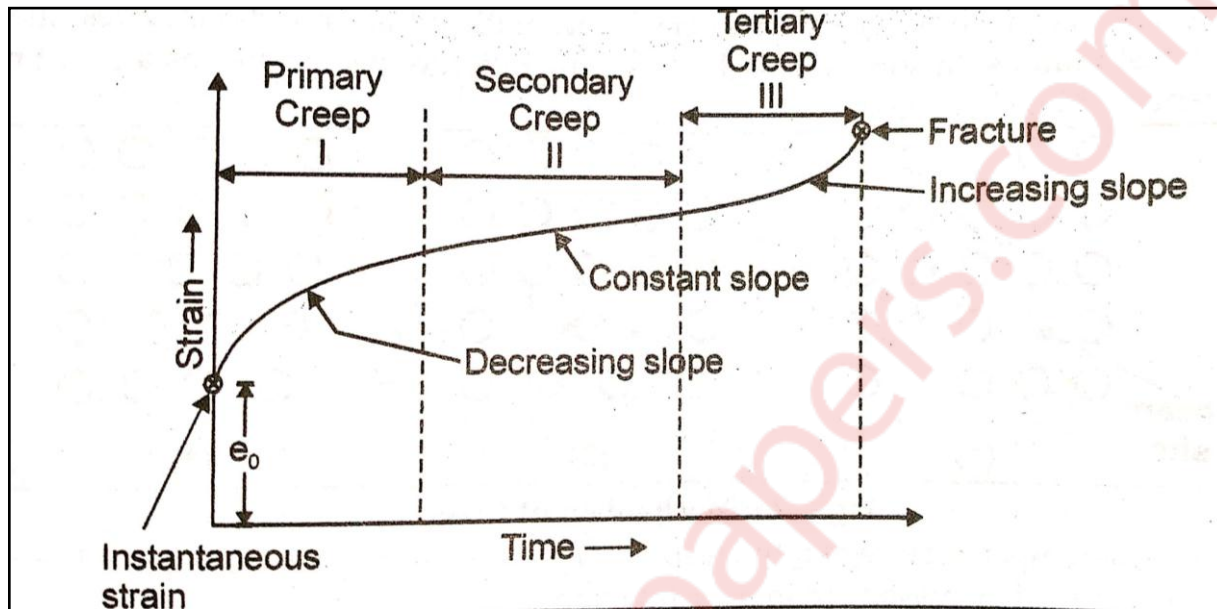
(B) <u>Creep Curve and Stages of Creep</u>:-

Fig: Creep Curve

(1) Primary Creep:-

The primary or transient creep is a decreasing creep rate because of the work hardening process resulting from deformation.

(2) Secondary Creep:-

During secondary or steady state creep, the deformation continues at an approximately constant rate. During this process, a balance exists between the rate of work hardening and rate of softening because of recovery or recrystallization.

(3) Tertiary Creep:-

If the stress is sufficiently high and the temperature is also high, there is a tertiary stage in which the creep rate accelerates until a fracture occurs. In this stage, there is the void formation and extensive crack formation occurs.

Q5] 1) Explain critical resolved shear stress (CRSS) and derive an expression for the same. What is the effect of alloying and temperature on the CRSS of any system.   (10)

Solution:-

(A) <u>Critical resolved shear stress</u>:-

In response to an applied tensile or compressive stress, slip in single crystal commences on the most favorably oriented slip system when the resolved shear stress reaches some critical value, termed as 'Critical Resolved Shear Stress'.

(B) <u>Derivation for expression of Critical Resolved Shear Stress</u>:-

Consider,

A_0= Cross-sectional area of cylindrical single crystal

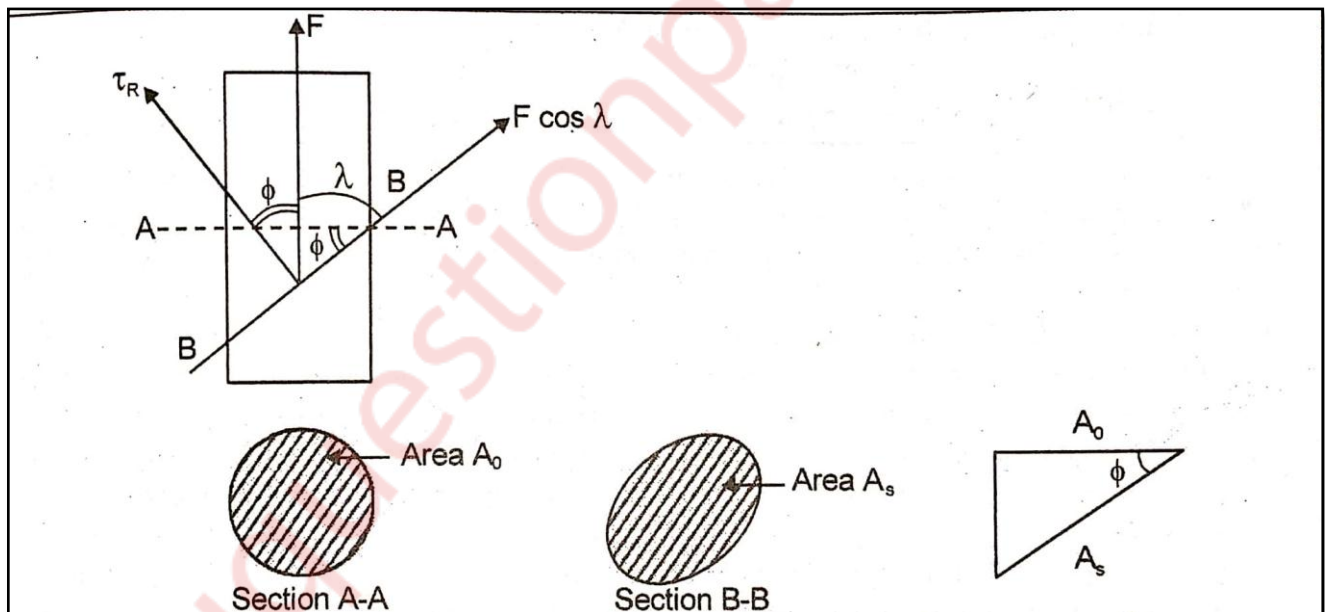Φ = Angle between the normal to slip plane and the tensile axis

λ = Angle between slip direction with the tensile axis

A_s = Transverse cross-sectional area of crystal.

$$=\frac{A_0}{\cos \phi}$$

F_s = Resolved force in the slip direction

$$= F \cos \lambda$$

Section A-A   Section B-B

As per above figure,

$$\cos \phi \quad = \frac{A_0}{A_s}$$

$$A_s \quad = \frac{A_0}{\cos \phi} \qquad\qquad ...(1)$$

Thus, critical resolved shear stress (τ_{RSS}) acting on slip plane and in the slip direction is

$$\tau_{RSS} = \frac{Force\ in\ the\ slip\ direction}{Transverse\ cross-sectional\ area}$$

$$\tau_{RSS} = \frac{F \cos \lambda}{A_s} \qquad\qquad ....(2)$$

Put value of 'A$_s$' as per equation (1) in the equation (2)

$$\tau_{RSS} = \frac{F \cos \lambda}{\frac{A_o}{\cos \phi}}$$

$$\tau_{RSS} = \frac{F}{A_o} \cdot \cos\phi\ Cos\lambda.$$

$$\tau_{RSS} = \frac{\sigma}{m}$$

Where, $\qquad \sigma = \dfrac{F}{A_o}$

$$m = \frac{1}{\cos\phi\ Cos\lambda.}$$

(C) <u>Effect of alloying and temperature on CRSS</u>:-

The thermal mobility increases with a rise in temperature but critical shear stress decreases.

Q5] 2) What is hardenability? What are factors affecting hardenability? Explain Jominy End Quench test. **(10)**

Solution:-

(A) <u>Hardenability</u>:-

The hardenability of metal alloy is the depth to which a material is hardened after putting it through a heat treatment process. It is the capability of an alloy to be hardened by heat treatment.

(B) <u>Factors affecting hardenability</u>:-

(a) The mean composition of the steel.

(b) The homogeneity of austenite.

(c) The grain size of the austenite.

(d) The undissolved carbides and nitrides in the austenite.

(C) <u>Jominy End Quenched test</u>:-

(1) In this test , the specimen dimensions and test conditions are standardized as per A.S.T.M. The specimen is of cylindrical shape with 25.4 mm diameter and approximately 100 mm in length has machined shoulder at one end as shown in fig (a).

(a) Jomny Standard specimen
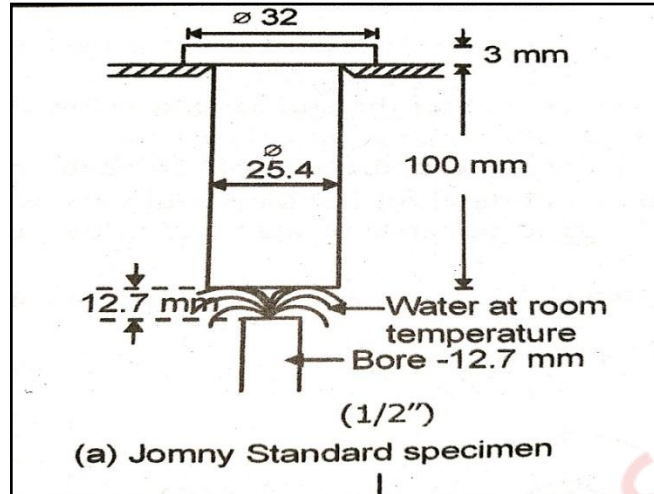
(2) The specimen is heated up to austenite temperature and held at constant temperature for 1 hour and quickly transferred to a fixture (quenching jig).

(3) Water is pumped through the jet at the bottom of the specimen. Free height of water is ad is justed approximately 65 mm. Water is allow to flow from the bottom end through a pipe inside diameter of 12.7 mm for about 20 minutes. The pressurized water forms a complete umbrella over the bottom surface of the specimen as sown in fig (b).

(b) Jomny Apparatus
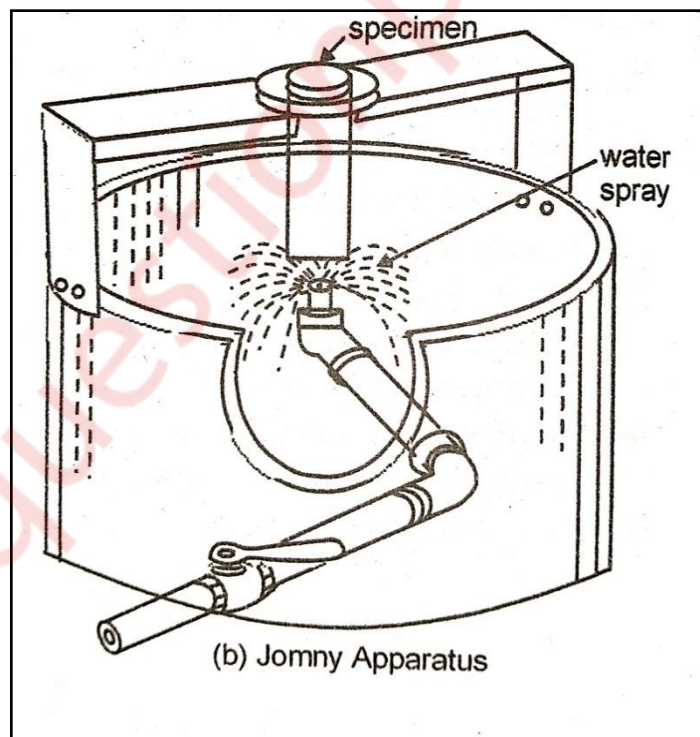
(4) The cooling rate is maximum at the quenched end of the specimen where usually full hardening occurs and reduces steadily towards air cooled i.e. all possible rates of cooling from water quenching to air cooling are obtained on single test piece.

(5) After quenching, Two flat surfaces are ground opposite to each other along the length of the specimen. The hardness is measured at intervals of 1.6 mm distance from the quenched end. The hardness values are plotted as a function of distance from the quenched end and resulting curve is called jominy hardenability curve.
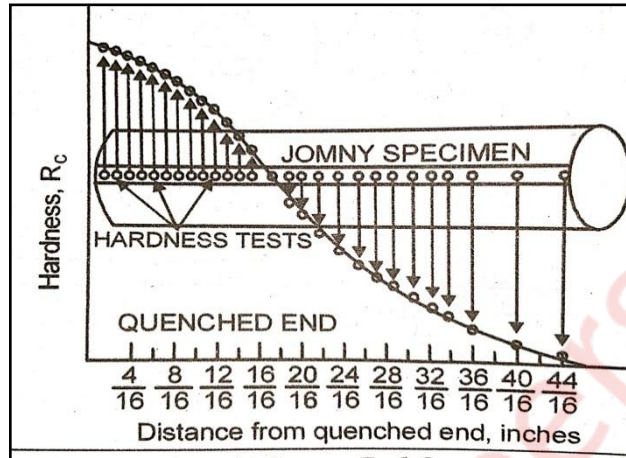
Q6] 1) Discuss the importance of recrystallization annealing. (05)

Solution:-

Importance of recrystallization annealing:-

(1) Recrystallization annealing is a heat treating process used to modify the properties of cold-worked metal.

(2) Many metal fabrication processes involve cold-working, such as cold rolling sheet and plate, wire drawing, and deep drawing. Due to metallurgical changes that occur to a metal during cold working, the ductility of a metal decreases as the amount of cold-working increases.

(3) There comes a point when additional cold working is not possible without causing the metal to crack. At this point, it is necessary to anneal the metal if continued cold-working is required. The specific annealing process used is called recrystallization anneal.

(4) During this annealing process, metallurgical changes occur that returns the metal to its pre-cold-worked state. These changes result in a reduction of the metal's yield and tensile strength and an increase in its ductility, enabling further cold working.

(5) In order for these changes to occur, the metal must be heated above its recrystallization temperature. The recrystallization temperature for a particular metal depends on its composition.

(6) In addition to enabling additional cold-working, recrystallization annealing is also used as a final processing step to produce metal sheet, plate, wire, or bar with specific mechanical properties. Control of the annealing temperature and time, heating rate up to the annealing temperature, and amount of cold-working prior to anneal is important for obtaining the desired grain size, and therefore the desired mechanical properties.

Q6] 2) A slowly cooled steel contains 50% ferrite and 50% pearlite at a room temperature. Determine the amount of total ferrite and cementite present in the alloy.

(05)

Solution:-

For calculating the amount of ferrite and cementite at room temperature we apply lever arm rule as shown below:-
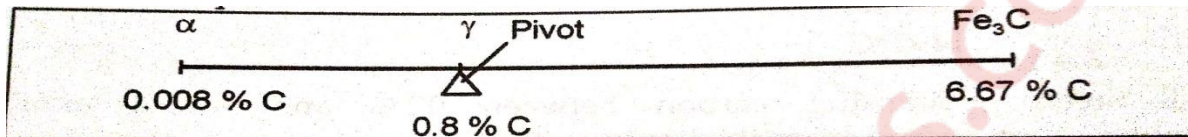
$$\% \text{ Amount of ferrite} = \frac{Opposite\ arm\ length}{Total\ arm\ length} \times 100$$

$$= \frac{(6.67 - 0.8)}{(6.67 - 0.008)} \times 100$$

$$= 88.10\%$$

$$\% \text{ Amount of cementite} = \frac{(0.8 - 0.008)}{(6.67 - 0.008)} \times 100 = 11.9\%$$

Amount of ferrite in pearlite at room temperature is 88.10% and amount of cementite in pearlite at room temperature is 11.9%.

Q6] 3) Calculate upper bound and lower bound values for density and young's modulus for a composite made of silicon carbide particles with volume fraction 0.2 and aluminium matrix. Given that density of silicon and aluminium is 3.15 and 2.70 mg/m^3 respectively and their modulus is 420 and 70 GPa respectively. **(05)**

Solution:-

Given:-

Volume fraction, f = 0.2

$P_f = P_{Sil} = 3.15$ mg/m^3 = 3.15 × 10^{-6} Kg/m^3

$P_m = P_{Al} = 2.70$ mg/m^3 = 2.70 × 10^{-6} Kg/m^3

$E_f = E_{Sil} = 420$ GPa

$E_m = E_{Al} = 420$ GPa

(A) Calculation of upper bound in terms of density:-

$P_c = f \times P_{f\ +} (1\text{-}f)\ P_m$

$\quad = 0.2 \times (3.15 \times 10^{-6}) + (1\text{-} 0.2) \times (2.70 \times 10^{-6})$

$\quad = 2.79 \times 10^{-6}\ Kg/\ m^3$

(B) Calculation of lower bound in terms of density:-

$P_c = \dfrac{1}{[\dfrac{f}{Pf} + \dfrac{(1-f)}{Pm}]}$

$\quad = \dfrac{1}{[\dfrac{0.2}{(3.15 \times 10-6)} + \dfrac{(1-0.2)}{(2.70 \times 10-6)}]}$

$\quad = 2.78 \times 10^{-6}\ Kg/m^3$

(c) Calculation of upper bound in terms of Young's Modulus:-

$E_c = f \times E_{f\ +} (1\text{-}f)\ E_m$

$\quad = 0.2 \times (420) + (1\text{-} 0.2) \times (70)$

$\quad = 140\ GPa$

(D) Calculation of lower bound in terms of Young's Modulus:-

$E_c = \dfrac{1}{[\dfrac{f}{Ef} + \dfrac{(1-f)}{Em}]}$

$\quad = \dfrac{1}{[\dfrac{0.2}{(420)} + \dfrac{(1-0.2)}{(70)}]}$

$\quad = 84 GPa$

Q6] 4) What are smart materials? Where are they used? (05)

Solution:-

(A) <u>Smart materials</u>:-

Smart materials are those that change one or more of their properties (shape, color, size, etc.) when

subjected to an external stimulus. These materials possess adaptive capabilities and perform better than ordinary, materials. They are considered smart because their in-built sensing and actuation capability.

(B) Applications:-

(1) Piezoelectric:-

Generate an electric charge in response to applied mechanical stress and vice versa.

(2) Magnetostrictive:-

Change in dimension of ferromagnetic material in magnetic field and vice versa

(3) Phase transition dependent:-

"Remembers" its original shape and after being deformed returns to its original shape when heated.

(4) Electro/Magneto Rheological Materials:-

Change is viscosity in response to electric/magnetic field

Q6] 5) Discuss the principle and practice of Nitriding. (05)

Solution:-

(A) Principle of Nitriding:-

Nitriding is a case hardening process by which nitrogen contents at the surface of the steel is increased. It is based on the fact that active nitrogen can be absorbed by ferrite phase of iron and certain other metallic elements.
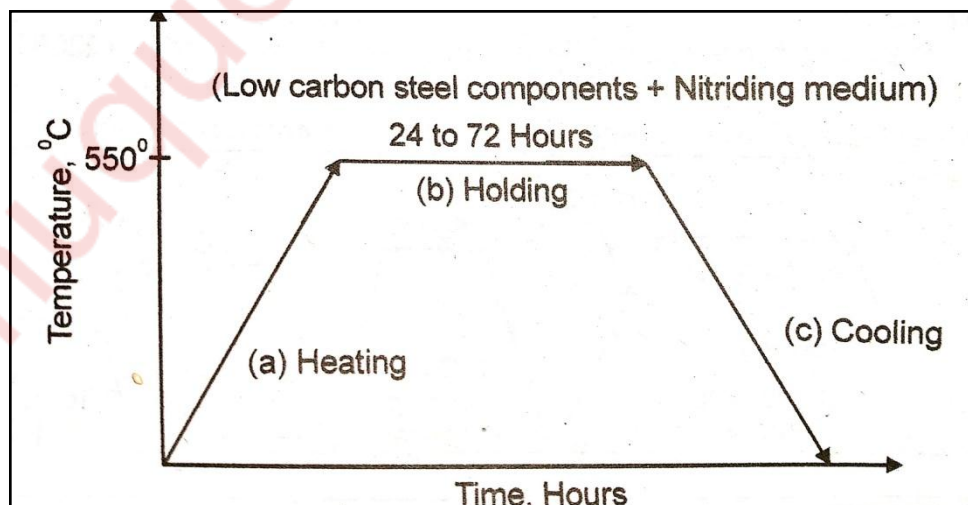
(B) Nitriding Process:-

Fig: Nitriding Process

(1) In this process low carbon steel components are heated in contact with a source of atomic nitrogen at a temperature of 550°C. The atomic nitrogen diffuses into steel and combines with iron and certain alloying elements present in steel and forms respective nitrides. This nitride increase the hardness and wears resistance of steels.

(2)The steel components are held at a constant temperature 550°C for 24 to 72 hours for the addition of atomic nitrogen layer on surfaces up to room temperature.