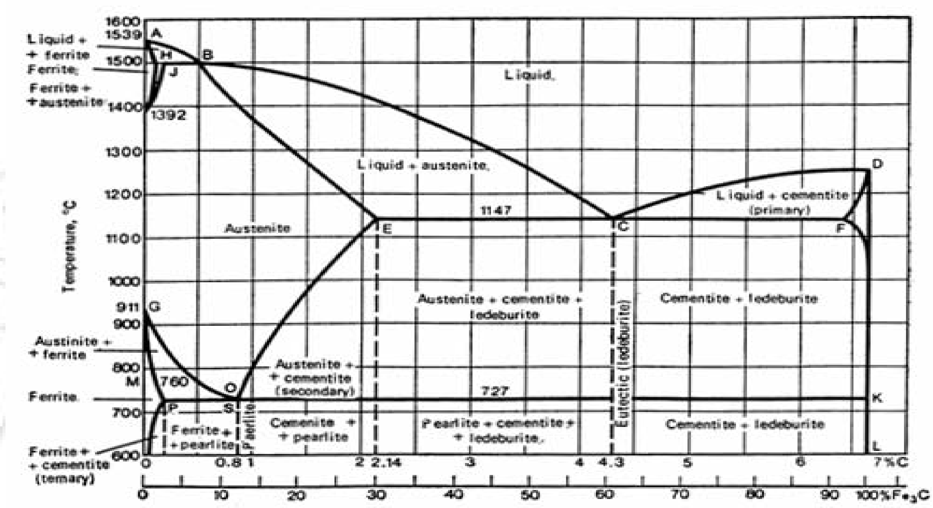
Q.No.1. Solve any five.

a. *Draw the Fe-Fe3C diagram and label all the important temperatures, composition and phases in the diagram. Write the invariant transformations seen in the diagram.* 10

Ans:



Invariant Transformation:-

1. Peritectic Transformation:-

- S1 + L → S2
- δ + L → γ

0.1% 0.55% 0.18%

δ γ L

0.1% 0.55% 0.18%

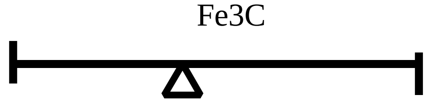
- Amount of δ = 82.2% Amount of L = 17.8%

2. Eutectic Transformation:-

- L → S1 + S2
- L → γ + Fe3C

4.3% 2 % 6.67%

Pearlite L Fe3C



0.8% 4.3% 6.67%

- Amount of Pearlite = 40.4% Amount of Fe3C = 59.6%

3. <u>Eutectoid Transformation</u>:-

- S → S1 + S2
- γ → α + Fe3C

0.8% 0.025% 6.67%

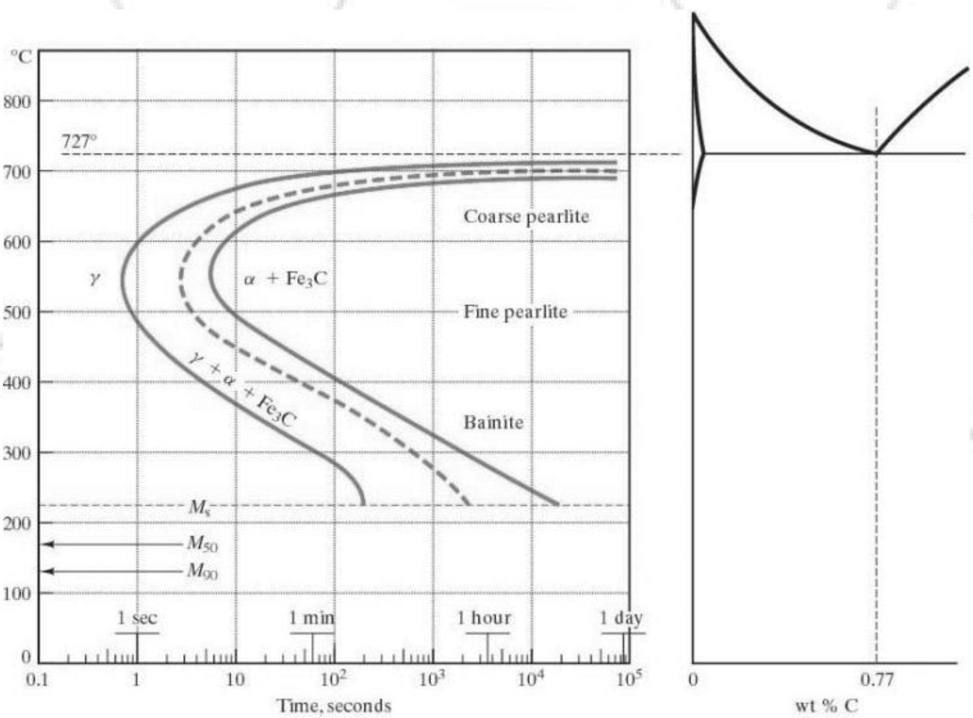
α γ Fe3C

0.008% 0.8% 6.67%

- Amount of α = 88.10% Amount of Fe3C= 11.9%

b. Draw a neat and labeled TTT diagramfor eutectoid steel. Superimpose the CCT, CCR and various other cooling curves shoing a different transformed product. *10*

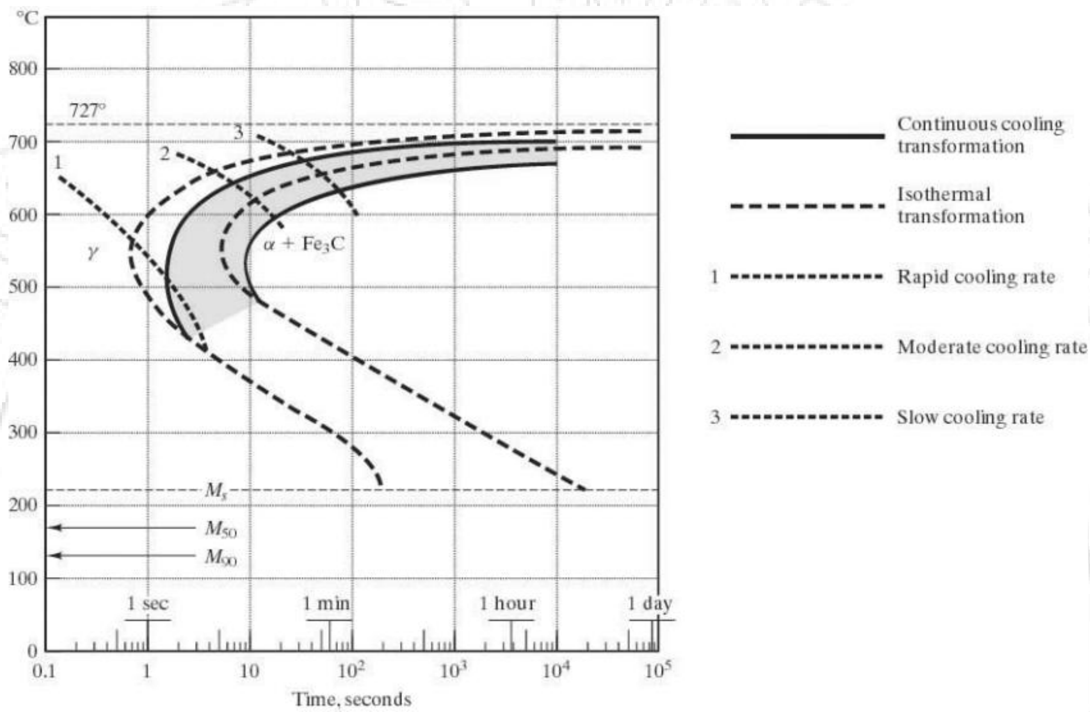
Ans:



1. Cooling curve I-Course Pearlite
2. Cooling curve I-Medium Pearlite
3. Cooling curve I-Fine Pearlite

4. Cooling curve I- Upper Bainite
5. Cooling curve I- Lower Bainite
6. Cooling curve I- Critical Cooling rate
7. Cooling curve I- Martensite

The CCT TTT diagram for eutectoid steel (Superimposed on an IT for comparison)



Sr. No .	Transformation	Isothermal temperature range TTT dig (°C)	Cooling rate in CCT Dig (°C/sec)	Hardness (RC)	Microstru-cture
	Course Pearlite	675-727	1	1-15	Course cementite in the matrix of ferrite
	Medium Pearlite	600-675	3	16-30	cementite in the matrix of ferrite
	Fine Pearlite	500-600	5	31-40	Fine particles of cementite in the matrix of ferrite

	Upper Bainite	-	Just below nose of CCT	40max	Fine cementite ferrite, Feathery appearance
	Lower Bainite	-	Just above 210° (MS)	50-60	Fine cementite ferrite, Acicular (needle) appearance
	Martensite	-	350	64	Zigzag plate like appearance

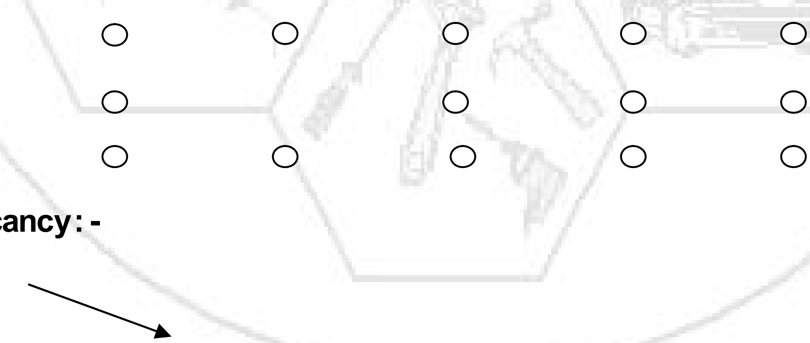
Q.No 2. a.

What are point defects? How are they created? What is their effect on the properties of materials? *10*

All the atoms in a solid possess vibrational energy and at all temperature above absolute zero , there will be a finite no. of atoms which have sufficient energy to break the bonds which hold them in their equilibrium position. Once the atoms are free from their lattice site, they give rise to point defects. Also, due to the presence of impurity atoms point defects are likely to come in the crystals.

Point defects are classified as

1)



Vacancy :-

Production :-

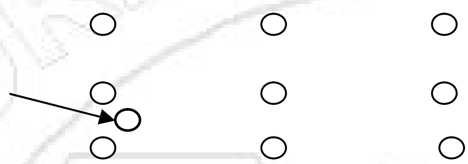
1. Rapid quenching

2. Intermediate compound
3. Bombardment of the metal with high energy nuclear particles.
4. Plastic Deformation of jogs
5. Oxidation

Effect on Properties of material:-

1. Reduce yield strength and tensile strength
2. Affects on physical properties

2) Interstitially:-



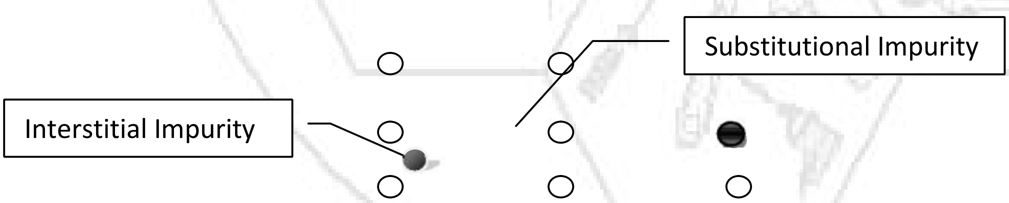
Production:-

1. Bombardment of the metal with high energy nuclear particles.
2. Process of formation of solid, liquid and gaseous state
3. Plastic deformation

Effect on Properties of material:-

1. Not effect on mechanical behavior
2. Increase in Interstitialcy, increase in electrical conductivity & magnetic flux density

3) Impurity atoms



Production: -

Undesirable Property presence responsibility for degradation of behavior and contamination of composition

Effect on Properties of material:-

1. Reduce electrical conductivity

2. Reduce chemical resistivity
3. Reduce Mechanical formability

4) Frankel Imperfection

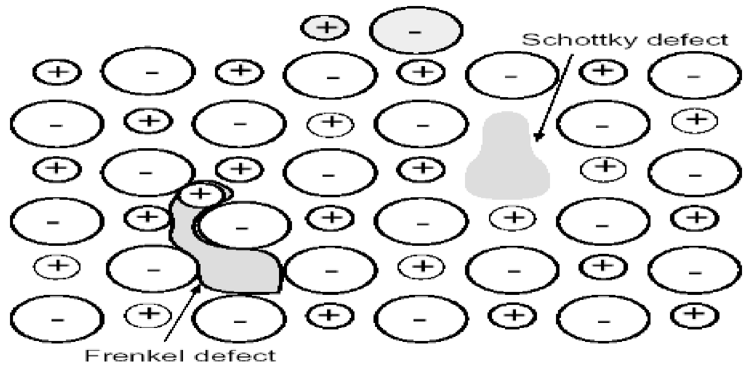


Figure 4 Point defects in ionic solids.

Production: - 'Cation-vacancy and Cation interstitial' pair occur in ceramic.

Effect on Properties of material:-

Increase in kinetics of diffusion and phase transformation

5) Schottky imperfection

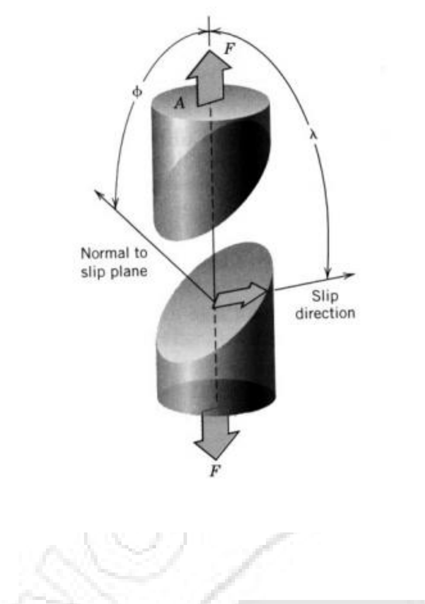
Production: - Anion Vacancy & Cation vacancy pair is occur in ceramic

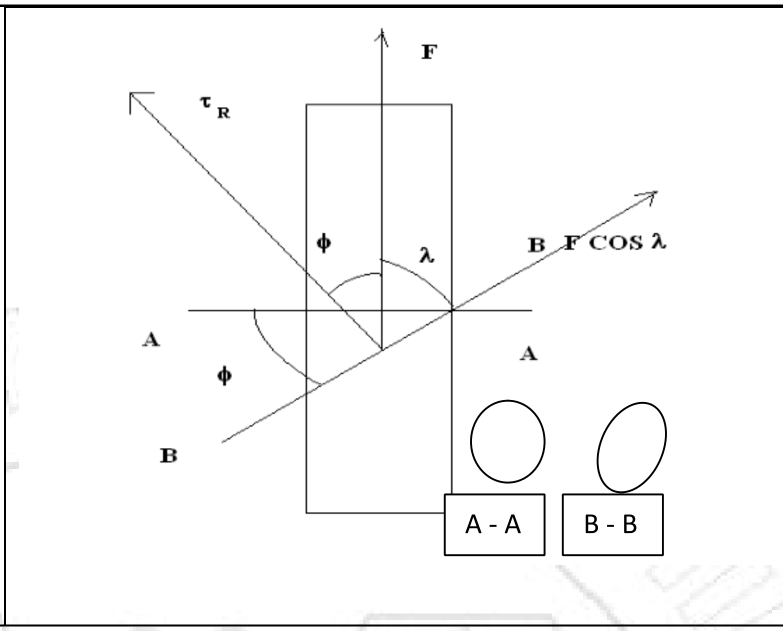
Effect on Properties of material: - Increase in kinetics of diffusion and phase transformation

Q.No. 2. *b.*

Derive an expression for CRSS. What are the factors affecting CRSS? Discuss the deformation of BCC and FCC metals *10*

Ans:





Cylindrical Single Crystal

$$\cos\phi = \frac{Ao}{As}$$

$$As = \frac{Ao}{\cos\phi}$$

$$\tau_{RSS} = \frac{\text{Force in the slip direction}}{\text{Transverrs e c/s area}}$$

$$\tau_{RSS} = \frac{F\cos\lambda}{A_s},$$

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

τ_{RSS} is max, When $\lambda = \phi$ is max(45 $^\circ$)

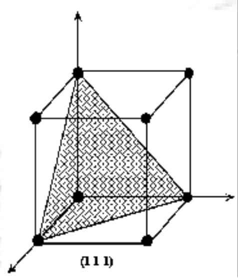
$$\tau_{RSS} = \frac{1}{2}\frac{F}{Ao}$$

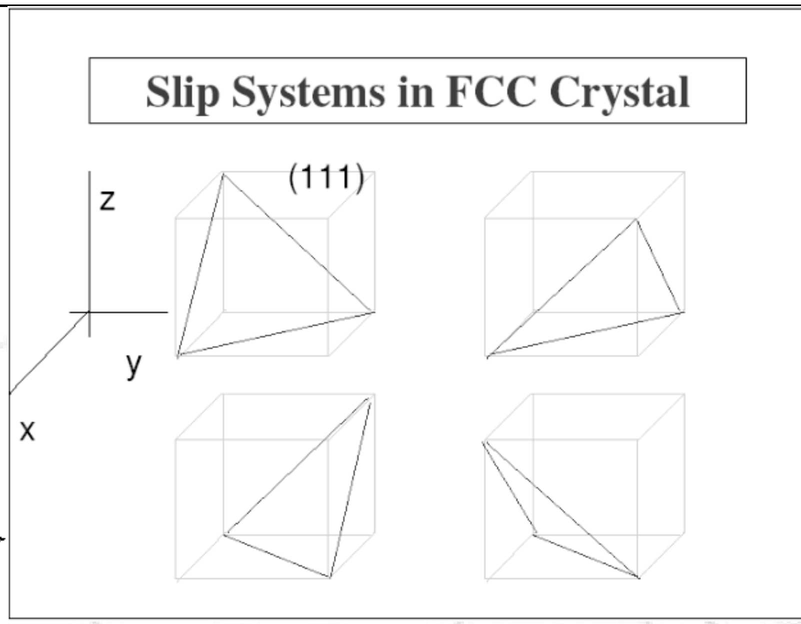
Factors Affecting on CRSS:-

1. Shear stress max, when $\Phi=\lambda=45°$
2. Shear stress is zero, when $\Phi=90°$ or $\lambda=90°$
3. Slip does not occur, if there is no shear stress. At last fracture will done.

Defomation of BCC & FCC:-

FCC





Structure	Slip Plane	Slip Direction	No. of slip system= (No. of slip plane *No. of slip direction)
FCC	{111}	<110>	4*3=12
BCC	{110}	$<\bar{1}11>$	6*2=12
	{211}	$<\bar{1}11>$	12*1=12
	{321}	$<\bar{1}11>$	24*1=24

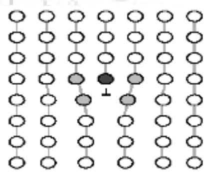
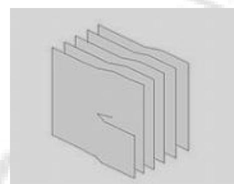
Q.No. 3. *a.*

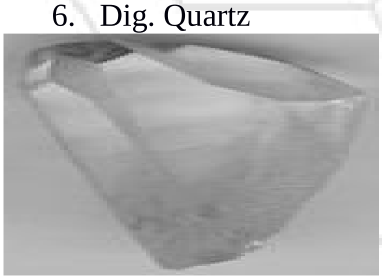
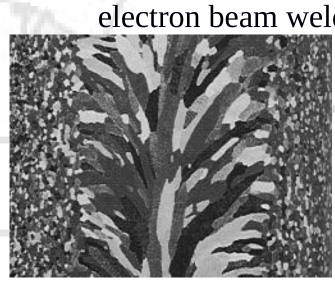
Differentiate between i) Edge and Screw dislocation ii) Single crystal and poly crystal

10

Ans:

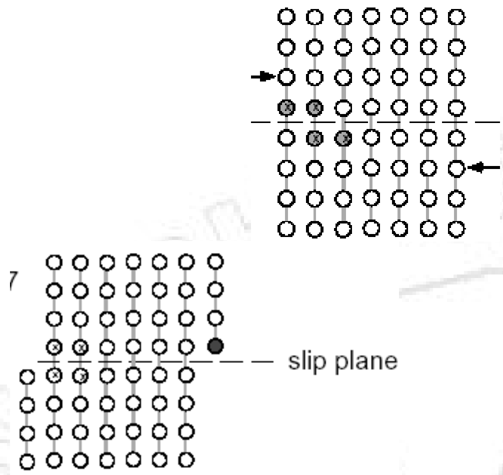
Edge Dislocation	Screw Dislocation
1. If one of the plane is not continuous from top to bottom or bottom to top and ends part way within crystal, it is called as edge dislocation	1. If plane of atoms follows dislocation in a helical or screw path then it is called as screw dislocation

2. Types:- 1) +ve (inverted T) 2) –ve (T)	2. Types:- 1)Clockwise 2)Anticlockwise
3. Dislocation line is perpendicular to Berger vector	3. Dislocation line is parallel to Berger vector
4. Direction of dislocation line movement relative to Berger vector is parallel	4. Direction of dislocation line movement relative to Berger vector is perpendicular
5. It can be removed from slip plane by dislocation climb mechanism	5. It can be removed from slip plane by dislocation cross-slip mechanism
6. Dig. 	1. Dig. 

Single Crystal	**Poly Crystal**
1. Arrangement of atoms is in a periodically repeating pattern is called as single crystal	1. If the arrangement of atoms Having No such regularity is called as Poly crystal
2. Only one grain or crystal	2. Made up of large no. of small grains
3. No grain boundary	3. Grains are separated by grain boundary
4. Single crystal specimens are considered only ideal condition for study of material properties and behavior in the laboratory.	4. These are actually used in engg application
5. e.g. Space Lattice SCC, FCC, BCC, HC, etc	5. e.g. Non-crystalline Metals Polymers etc.
6. Dig. Quartz 	6. Dig. Nb-Hf-W plate with an electron beam weld. 

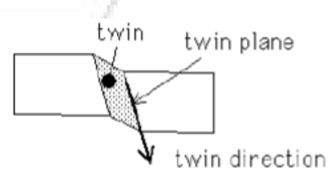
Q.No. 3. b. Illustrate and discuss the process of slip and twinning. *10*

Ans:



1. The permanent displacement or sliding of atoms over the other is called as slip
2. Due to plastic deformation, crystal is divided into layers or slip blocks which are displaced in reference to each other. They are separated by thin layers in which a considerable displacement of atoms takes place.
3. Slip occurs when the shear stress exceeds a critical value.
4. Slip Plane- A plane on which slip occurs
5. Slip direction – A direction in which slip occurs
6. Slip in HCP,FCC,BCC

Structure	Slip Plane	Slip Direction
HCP	(0001)	[11$\bar{2}$0]
FCC	(111)	[110]
BCC	(110)	[$\bar{1}$11]
	(211)	[$\bar{1}$11]
	(321)	[$\bar{1}$11]



Macroscopic shape deformation

Twin:-

1. Twinning is a process in which atoms in a part of crystal subjected to stress rearrange themselves so that orientation of the part changes in such a way that the distorted part becomes mirror image of the other part.
2. Twinning occurs by plastic deformation or thermal treatments.
3. Stress required to propagate twinning is appreciably less than that required to initiate it.
4. Twin Plane- A plane on which Twinning occurs
5. Twin direction – A direction in which Twinning occurs
6. Slip in HCP,FCC,BCC

Structure	**Twin Plane**	**Twin Direction**
HCP	$(10\bar{1}2)$	$[10\bar{1}\bar{1}]$
FCC	(111)	[112]
BCC	(112)	[111]

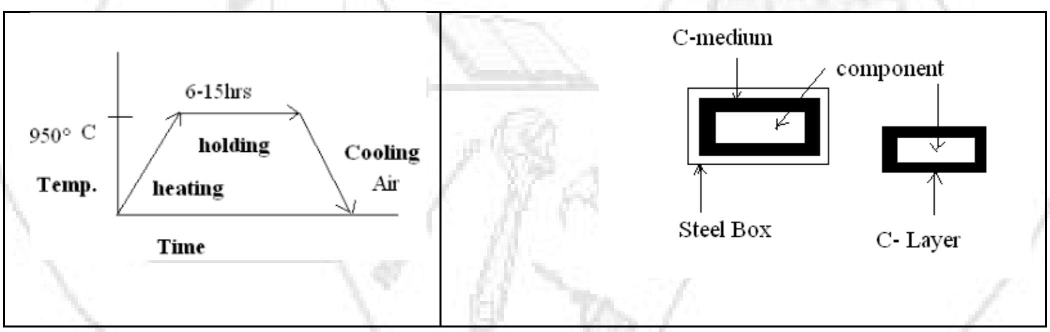
Q.No. 4.a. Discuss the principle, process and applications of Carburising. *10*

Ans:

The method of increasing carbon on the surface of steel is called as carburizing. It consist of heating steel in austenitic region in contact with carburizing medium, holding at this temperature for a sufficient period and cooing to room temperature

Types: -

Pack Carburizing: -



Process Reaction: -

$$2C_{(Charcoal)} + O_{2(air)} \longrightarrow 2CO$$

$$2CO_{(dissociation)} \longrightarrow CO_2 + C$$

$$CO_2 + C_{(Charcoal)} \longrightarrow 2CO$$

Energizing reaction

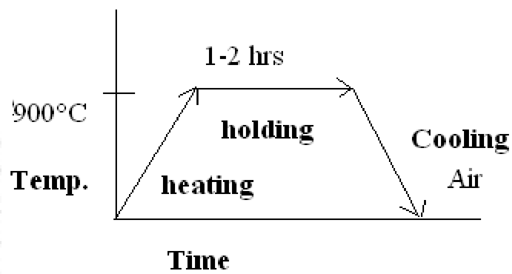
$$BaCO_3 \longrightarrow BaO + CO_2$$

Application: –

It is used to produce relatively thick carburized cases (1mm or more), Where extreme uniformity in carbon content is not essential.

Gas Carburizing:-

Dig.



Carburizing Medium:-

Natural Gas, Coke Oven gas, Butane/Methane/Ethane/Propane

Process:-

1. All above gases are partially burnt in furnace or diluted with carrier gas to produce required carbon potential at work surface.
2. Carrier Gas is made in generator- Mixture of N2, H2, and Co.

Reaction: -

$$CH_4 \longrightarrow 2H_2 + C$$

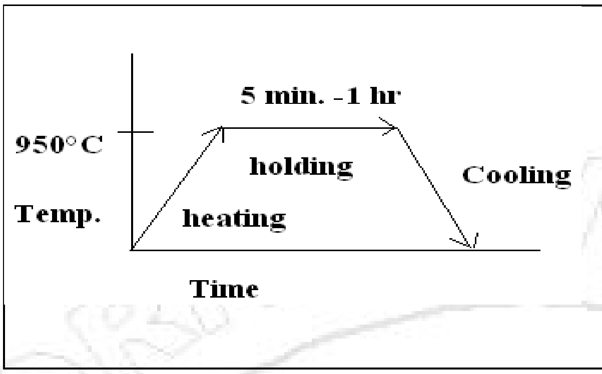
Water gas reaction

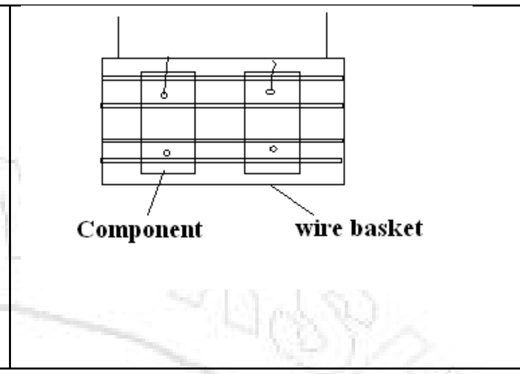
$$CO + H_2 \longrightarrow H_2O + C$$

Application:-

1. Used to obtain relatively thin cases of high uniformity
2. Case depth from 0.2-0.5mm can obtain in 1-2 hrs at 900°C
3. Particularly suited For Large volumes Production and provides for accurate control of case depth and surface carbon content.

Liquid Carburizing:-





Carburizing Medium:-

$NaCN = 20 - 50\ \%$

$NaCO_3 = upto\ 40\ \%$

$NaCl\ /\ BaCl_3 = Balance$

Process:-

$$2\,NaCN + O_2 \longrightarrow 2\,NaCNO$$

$$3\,NaCNO \longrightarrow NaCN + Na_2CO_3 + C + 2\,N$$

Application:-

1. It used for the rapid production of relatively thin carburized cases on small components.
2. Case depths from 0.1-0.5mm can be obtained in a period of ½ - 1 hr as usual carburized temperature

Q.No. 4. b.

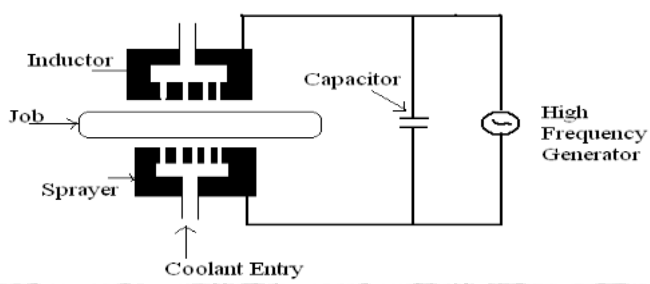
How do the surface hardening methods differ from case hardening? Discuss the process of induction hardening *10*

Ans:

Surface Hardening Process		Case Hardening Process	
1.	Without change in chemical composition	1.	change in chemical composition
2.	Carbon medium is not require	2.	Carbon medium is require

3.	Water spray and high temperature is require	3.	Not require
4.	Case structure shows marten site and core shows pearlitic or bainitic structure	4.	Surface shows carbides and nitrides
5.	Process carried out at 3000°C	5.	Process carried out at 900°C
6.	Clean Process	6.	Dirty Process
7.	Few seconds to get harden surface	7.	Several hours require to get harden surface
8.	High Productivity	8.	Low productivity
9.	Costly process	9.	Cheap process
10	After this light final grinding or lapping operation can require	10.	After this Core, case, tempering process require
11	Types:- Flame, Induction	11.	Types:- Carburizing, nitriding, carbonitriding, cyaniding

Induction Hardening Process:-



Process:-

1. Heating:-
By passing AC frequency through inductor, produce electromagnetic induction. Heat up to austenitic region

2. Quenching:-
Spray and water / coolant and convert austenite into marten site on surface

3. Frequency and case depth:-
It is observed that higher case depth (4.5-8mm)can be obtain at lower frequency(1000Hz)and Thin cases (0.25-0.75mm)can be produced at higher frequency (1000,000Hz).Longer duration of heating (5sec) produces higher case depth (2.8mm)and lower duration of heating (1sec) produces less case depth (0.60).

4. Advantages:-

1. Fast heating process
2. No scaling and decarburization
3. Easy control on depth of hardening
4. Continuous hardening for large size is possible
5. More case depth(upto8mm)can be possible

5. Disadvantage:-

1. Irregular shape can not harden
2. Unit cost is high

6. Application:-

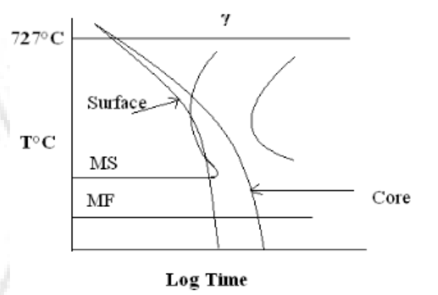
1. Applicable for electrical conductor-steel ,CI, etc
2. Long axle shafts and similar components

Q.No. 5. a.

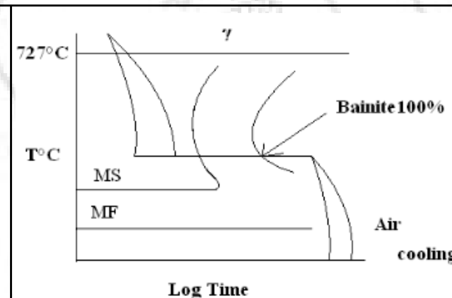
Discuss the following heat treatments: i) Austempering ii) Normalizing iii) Subzero treatment *12*

Ans:

1) Austempering:-



Cooling of large size components



Austempering Process

Process:-

1) Heating – Above austenite temperature
2) Holding-For several hours for complete transformation in austenite
3) Cooling – cooling rapidly in salt bath held in Bainite range(usually 220°°C-450°C
4) Transformation-Austenite into Bainite (100%)
5) Cooling in air

Advantages:-

1. High Impact strength
2. High notch toughness at high hardness level
3. Dimensional stability
4. Less chances of cracking
5. It gives same hardness as compared to hardening and tempering

Disadvantages:-

1. Limited to section thickness upto 20mm
2. Wide range of property variation can not be possible
3. Process is applicable only to high hardenability steels
4. Process is expensive

Application:-

Manufacturing of gauges

2) Normalizing:-

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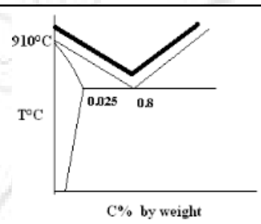
<td>
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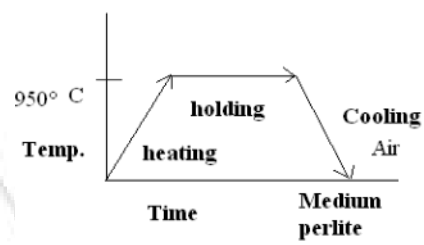
<td>
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<tr>
<td>Normalizing temperature range</td>
<td>Tree stages</td>
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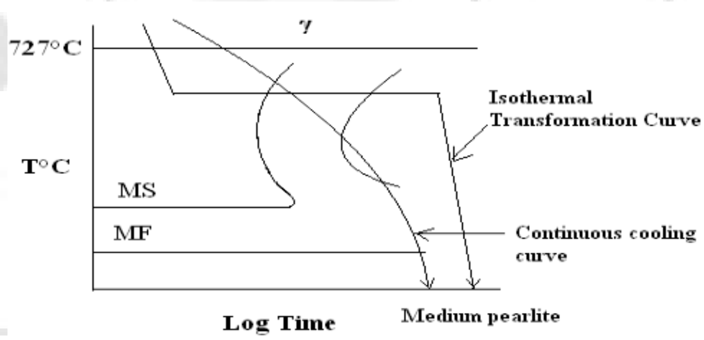
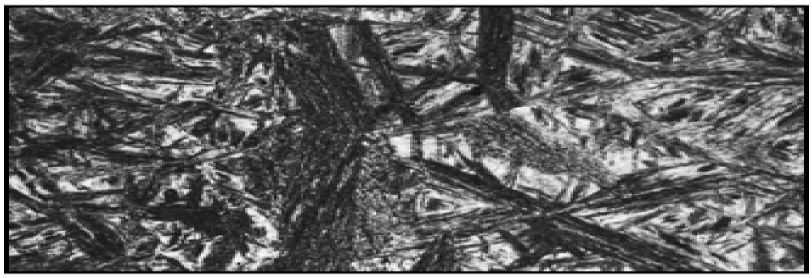


Normalizing in TTT Dig

Process:-

1. Heating –
1. Hypoeutectoid steel=A3+50°C
2. Hyper-eutectoid steel=A1+50°C
2. Holding:- 1 hour for each 25mm diameter Thickness
3. Cooling:- Cooling medium-Air

Microstructure: -



Austenite to medium Pearlite transformation

Purpose: -

1. To improve machinablity
2. To modify and refine cast dendrtic structures
3. To refine grains
4. To make steel suitable for further heat treatments
5. To relieve internal stresses

Advantages: -

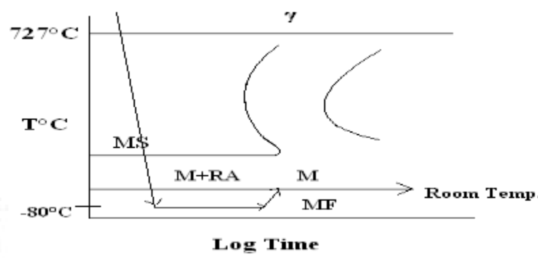
1. Faster than annealing
2. Required less furnace time as compared to annealing

Application

1. To modify properties
2. To make uniform grains of forged, rolled, extrusion processed components
3. To improve machinablity of low carbon and high carbon steel

3) <u>Subzero treatment: -</u>

1) For elimination of retained austenite from marten site after hardening, the process is called as sub zero treatment.
2) Below MF line, retained austenite is transferred into marten site
3) If there is delay in hardening subzero less retained austenite will transferred into marten site
4) Process is used to eliminate retained austenite from hardened component like tool steel and die steel



Subzero tretment for HSS

Cooling medium	**Min. Temperature obtained (T°C)**
Ice +Salt (NaCl)	-23
Ice +Calcium Chloride	-55
Acetone + Dry Ice (Frozen CO2)	-76
Liq. Air	-183
Liq. N2	-196
Liq. H2	-253
Liq. Helium	-269

Q.No. 5. b. *What are CI? Discuss the various types of CI with their properties and applications.*

08

Ans:

Cast Iron:-

- 2 - 6.67% C
- Casting is only suitable process hence name Cast iron

Types: - Gray CI

- Graphite in the form flakes
- C-3.2-3.7%, Si-2-3.5%, S-0.06-0.1%, P-0.1-0.2%, Mn-0.5-1.0%,

Properties:-

1) Excellent damping capacity
2) Good compressive strength
3) Good bearing properties
4) Fairly good corrosion resistance
5) Excellent machinablity

Application:- Machine base, engine frame, drainage pipe, weights, pump housing, cylinder and piston of IC engine, flywheel lift counter weight, steam turbine housing, sever cover, frames guards

Nodular CI:-Ductile iron, SG iron

- Graphite's in the form of spheroids
- Produced from GCI by addition of nodulizing agent like Mg, Ca, Ba, LI, and Zr.

Properties:-

1. Ductile
2. Tough
3. TS38-80Kg/mm2
4. Elongation-6-20%
5. Hardness-100-300BHN

Application:- Tractor parts, crank shafts, Piston cylinder head, Electrical switch motor frame, hoist drum, drive pulley flywheels, elevator buckets, furnace door dies, bearing blocks, etc

Meehanite CI:-

1. High duty
2. Fine uniform, non overlapping graphite flakes
3. Graphite flakes controlled by $CaCl_2$
4. Produced from GCI

Properties:-

1. TS-25-40Kg/mm2
2. Good machinability
3. Better response to heat treatment than GCI

Application:- It is used for machine parts subjected to wear such as gears, brake drums, steam engine cylinder, etc.

White CI:-

1. No Graphite
2. All C is in the form of Fe_3C
3. C-2.3-3%, Si-0.5-1.3%, S-0.06-0.1%, P-0.1-0.2%, Mn-0.5-1%

Properties:-

1. Higher hardness, brittleness

2. High wear resistance
3. Good compressive strength
4. Lack of machinablity

Application: - Liners for cement mixer, wearing plates, drawing dies, road roller surface, extrusion nozzle

Malleable CI:-

1) Malleablizing process

$$Fe_3C \longrightarrow 3Fe + C$$

2) C-2-2.65%, Si-0.9-1.4%, S-0.05%, P-less than 0.18%, Mn-0.25-0.55%
3) Types 1) pearlitic 2) ferritic 3) ferrite –pearlitic

Properties:-

1) Ductile
2) Toughness
3) Machinable
4) TS-25-70Kg/mm2
5) Elongation-6-8%
6) Hardness-80-275BHN

Application:- Crankshaft, gears, links, axel, Pipe fitting, valves, farm equipments, brg. Blocks

Q.No. 6. a.

Define fatigue failure. How are materials tested for fatigue analysis? Draw and explain the S-N curve. *10*

Ans:

Fatigue Failure:- With frequently stress fluctuations the material may fail at a stress level far below its static ultimate tensile strength is called as fatigue failure. E.g. Aircraft, compressor, pumps turbine, etc

Fatigue testing:-

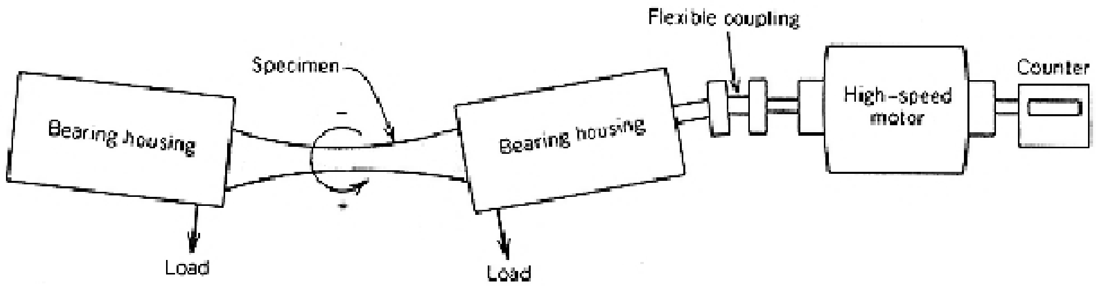


Figure 3 Rotating Bending Testing Machine [Callister, 1994].

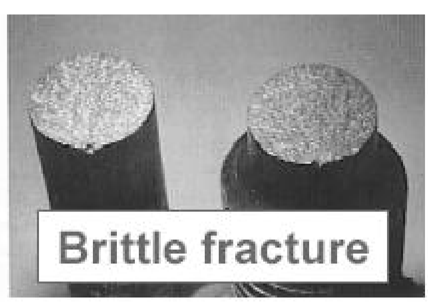
1. Wohler's testing machine
2. Specimen is in the form of cantilever and loaded at one through ball bearing
3. Rotate by high speed motor
4. Counter is attached to count the no. of rotations
5. At any instant, upper surface-tension, lower surface-compression
6. In one rotation-component undergoes two cyclic fluctuations of stress
7. No. of cycle vary-failure vary with applied stress
8. "Higher stress-lower cycle, lower surface – more cycles" require to cause failure

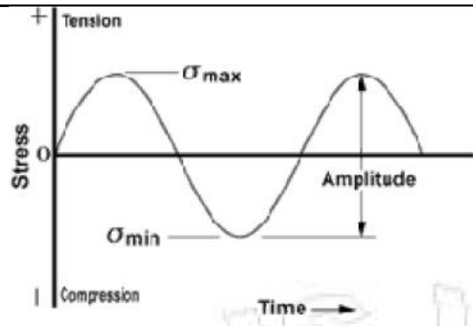
S-N Curve:-

1. Tension/compression loading:- Completely reversed cycle
Max. Stress = Min stress

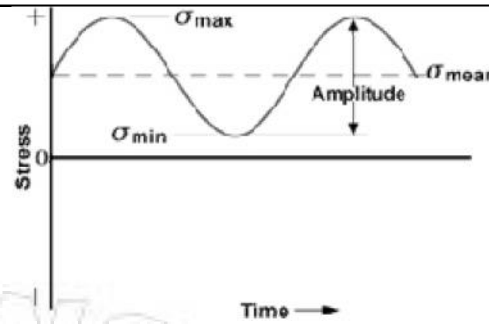
2. Tension/tension loading:- Repeated stress cycles
Max. Stress ≠ Min stress

3. Spectrum loading:- Complicated stress cycle
Periodic unpredictable overloads due to gust on aircraft

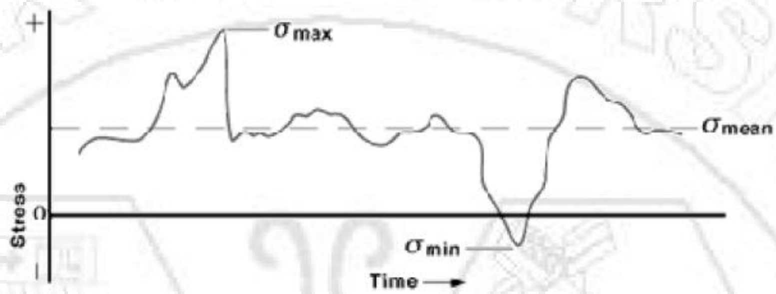




Tension/Compression Loading



Tension/Tension Loading



Spectrum Loading

Q.No. 6. b.

What are the characteristics of brittle failure? Discuss Griffith's theory and derive Griffith's equation. *10*

Ans:

Brittle fracture:-

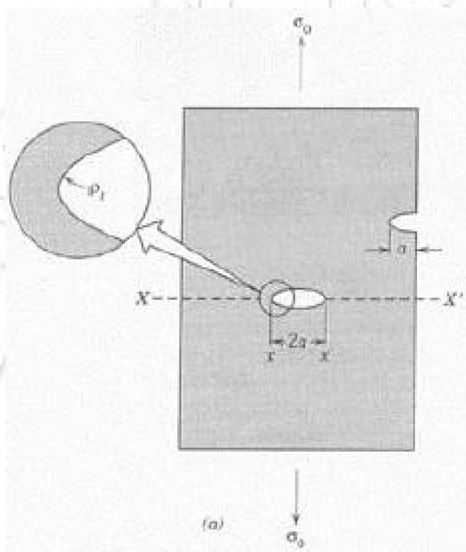
1. Brittle fracture is common in glass, ceramics and other refractory's which show a short elastic region followed by immediate fracture.
2. Technologically, brittle failure may be reduced by deep polishing the material surface to remove micro-cracks or by devising composite materials where a very strong brittle phase is embedded in a matrix which tends to oppose micro-crack propagation.
3. Takes place without any appreciable deformation and by rapid crack propagation.
4. Types-Transgranular Intergranular
5. No plastic region in stress - strain curve
6. Necked eye appearance:-
1. no sign of plastic deformation
2. Lines and ridges that radiate from the origin of crack
3. For very hard and fine grained metals-no discernible pattern

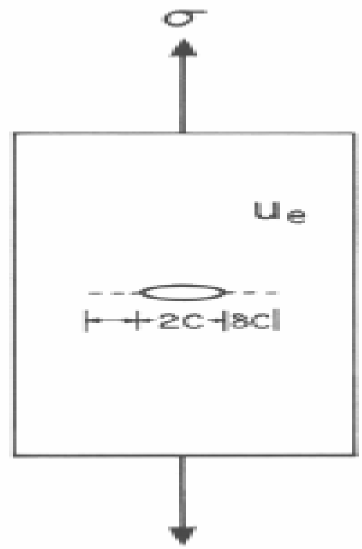
Griffith's theory:-

"There are micro cracks in the metal that cause local concentration of stress to values high enough to propagate the crack and eventually to fracture of metal
A crack will propagate when the decrease in elastic strain energy is at least equal to energy required to create the new cracks surface."

Assumptions:-

1. Elliptical lens shaped crack- length 2C
2. Unit thickness
3. Crack run from front to back
4. Longitudinal tensile stress σ
5. Crack increases in length
6. U is surface energy /unit area
7. No (elastic) energy stored in volume of crack
8. Elastic energy released, crack introduced





∴ Elastic strain energy that has been realeased /unit volume of crack

$= \frac{1}{2} *$ **stress * strain**

For each upper surface & lower surfase of crack

1)Total elastic energy / unit volume (Ue) when crack introduced =

$Ue = (\frac{\;}{4}(2C^{2})t) * \frac{1}{2} * \quad e * 2$

Where, = stress applied

e = strain

E = youngs Modulus

t = unit thickness

c = length of crack

$E = \frac{\;}{e}$

$Ue = (\frac{\;}{4}(2C^{2})t) * \frac{1}{2} * \quad \frac{\;}{E} * 2$

$Ue = \frac{\;}{E}$

2) Total surface energy is

$U\sigma = 4C(\gamma + P)$

Where, γ = energy require

to produce unit area of new surface

3) The change in energy during crack form,

ΔU = Total surface energy + elastic energy realeased

$$\therefore \Delta U = 4C(\gamma + P) + (-\frac{\pi C^2 \sigma^2}{E})$$

$$\therefore \Delta U = 4C(\gamma + P) - \frac{\pi C^2 \sigma^2}{E}$$

$$\therefore \frac{d\Delta U}{dC} = 0$$

$$\frac{d(4C(\gamma + P) - \frac{\pi C^2 \sigma^2}{E})}{dc} = 0$$

$$4(\gamma + p) = \frac{2\pi\pi C^2}{E}$$

$$\sigma^2 = \frac{4(\gamma + P) * E}{2\pi\pi}$$

$$\sigma critcal = \sqrt{\frac{2E(\gamma + P)}{\pi C}}$$

Q.No. 7. Write short notes on any four of the following: *20*

Ans:

a. *Stainless Steel: -*

Austenitic stainless steels are iron-chromium-nickel alloys which are hardenable only by cold working. Nickel is the main element varied within the alloys of this class while carbon is kept to low levels. The nickel content may be varied from about 4% to 22% - higher values of nickel are added to increase to ductility of the metal. When chromium is increased to raise the corrosion resistance of the metal, nickel must also be increased to maintain the austenitic structure. These alloys are slightly magnetic in the cold-worked condition, but are essentially non-magnetic in the annealed condition in which they are most often used. The austenitic types feature adaptability to cold forming, ease of welding, high-temperature service, and, in general, the highest corrosion resistance. Following are brief descriptions of some of our most commonly ordered stainless steels:

Type 302 - stainless steel is a general purpose material with greater corrosion resistance but less work hardening than Type 301. This is the basic alloy of the austenitic group often referred to as 18:8. Machinablity - 40% drawing or stamping - good Welding - very good, tough welds.

Type 304 stainless steel has lower carbon to minimize carbide precipitation. It is less heat sensitive than other 18:8 steels. Used in high-temperature applications. Machinablity - 45% drawing or stamping - very good. Welding - very good, tough welds.

Type 304L stainless steel has an extra low carbon content to avoid harmful carbide precipitation in welding applications. Its corrosion resistance is comparable to type 304. Machinablity - 44% drawing or stamping - very good. Welding - very good, recommended for welding.

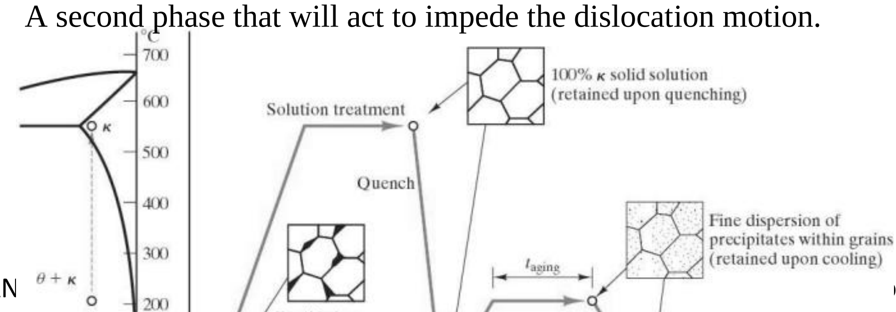
Type 316 stainless steel contains molybdenum for better corrosion resistance - particularly to pitting. Machinablity- 45% drawing or stamping – good, welding - very good, tough welds

Type 316L stainless steel has a carbon content lower than 316 to avoid carbide precipitation in welding applications. Machinablity - 45% Drawing or stamping – good, Welding - very good, recommended for welding.

Q.No. 7.b. Precipitation hardening:-
Ans:

Precipitation hardening, or age hardening, provides one of the most widely used mechanisms for the strengthening of metal alloys.
Precipitation Hardening is a heat treatment in which the strength of an alloy is increased from introducing particles that act as obstacles to slip motion. Not all alloy systems are amenable to this strengthening mechanism. The alloy system must have:

1. A terminal solid solution with decreasing solid solubility as temperature decreases
2. A second phase that will act to impede the dislocation motion.



The procedure to produce the microstructure of a precipitation hardened alloy is:

1. Solution Treat (Solutionize)

Heat to the point where you have a single phase solid solution.

2. Quench:- To get a metastable super-saturated solid solution.

3. Age (Precipitation heat-treat)

Heat at an intermediate temperature such that diffusion is appreciable for an appropriate amount of time in order to precipitate out the second phase particles. The nature of these second phase precipitates depend on the time and temperature of the aging process. You want the second phase particles to be of optimal size to produce the maximum obstacle to slip motion. This turns out to be when the size of the precipitate is such that the crystal structure of the precipitate and the matrix phase are coherent. These are called Gunier-Preston Zones.

4. Cool

Be careful:

1. Do not overage. (When Precipitation particles grow to a size where they do not add significant strength.)
2. Do not put the material in an application where temperature may overage it.
3. Be careful of natural aging (aging that can occur at room temperature. (As opposed to artificial aging which is when the material is inadvertently put at an elevated temperature.)

Q.No. 7. *c.* Chromizing and its application:-

1. Definition: - Chromizing is known as an enrichment of the surface region of steels with chromium by thermochemical treatment. During this treatment chromium atoms diffuse at temperatures between 900°C and 1000°C into the surface of the workpiece.
2. Hard Chromizing:-If the steel which is to be chromized contains enough carbon (minimum 0,35%), a corrosion and wear resistant chromium layer will be formed on the surface of the workpiece during the Chromizing treatment. If necessary, the workpiece can be heat treated after diffusion coating.
3. Soft Chromizing:-On steel with low carbon content a chromium carbide layer cannot be formed. Instead, a chromium diffusion layer builds up during the Chromizing process which can reach up to 200µm in thickness and a chromium content of up to 35%. The high chromium content endows the workpiece with an excellent resistance against corrosion and oxidation while maintaining its ductility.

Q.No. 7. *d.* High Speed Steel

Types and their properties:-

High speed steels belong to the Fe-C-X multi-component alloy system where X represents chromium, tungsten, molybdenum, vanadium, or cobalt. Generally, the X component is present in excess of 7%, along with more than 0.60% carbon. (However, their alloying element percentages do not alone bestow the hardness-retaining properties;

they also require appropriate high-temperature heat treatment in order to become true HSS; see History below.)

The grade type T1 with 18% tungsten has not changed its composition since 1910 and was the main type used up to 1940, when substitution by molybdenum took place. Nowadays, only 5-10% of the HSS in Europe and only 2% in the United States are of this type.]

In the unified numbering system (UNS), tungsten-type grades (e.g. T1, T15) are assigned numbers in the T120xx series, while molybdenum (e.g. M2, M48) and intermediate types are T113xx. ASTM standards recognize 7 tungsten types and 17 molybdenum types.[5]

The addition of about 10% of tungsten and molybdenum in total maximizes efficiently the hardness and toughness of high speed steels and maintains these properties at the high temperatures generated when cutting metals.

Alloying compositions of common high speed steel grades (by %wt)								
rade		**r**	**o**	**W**		**o**	**n**	**Si**
1[6]	.65–0.80	.75–4.00		1 7.25–18.75	.9–1.3		.1–0.4	0.2–0.4
2	.95	.2	.0	6 .0	.0			-
7	.00	.8	.7	1 .6	.0			-
35	.94	.1	.0	6 .0	.0	.0		-
42	.10	.8	.5	1 .5	.2	.0		-
Note that impurity limits are not included								

M2

M2 is a high speed steel in tungsten-molybdenum series. The carbides in it are small and evenly distributed. It has high wear resistance. After heat treatment, its hardness is the same as T1, but its bending strength can reach 4700 MPa, and its toughness and thermoplasticity are higher than T1 by 50%. It is usually used to manufacture a variety of tools, such as drill bits, taps and reamers. Its decarbonization sensitivity is a little bit high.[7]

M35

M35 is similar to M2, but with 5% cobalt added. The addition of cobalt increases heat resistance.

M42

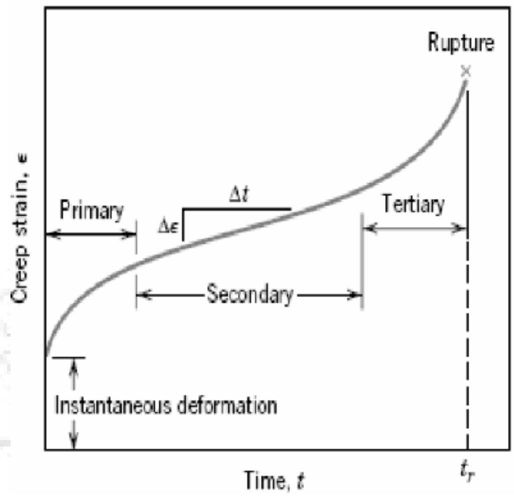
M42 is a molybdenum-chromium-vanadium-tungsten high speed steel alloy with additional 8% cobalt. It is widely used in metal manufacturing because of its superior red-hardness as compared to more conventional high speed steels, allowing for shorter cycle times in production environments due to higher cutting speeds or from the increase in time between tool changes. M42 is also less prone to chipping when used for interrupted cuts and cost less when compared to the same tool made of carbide. Tools made from cobalt-bearing high speed steels can often be identified by the letters HSS-Co.

Applications:- The main use of high speed steels continues to be in the manufacture of various cutting tools: drills, taps, milling cutters, tool bits, gear cutters, saw blades, etc., although usage for punches and dies is increasing.

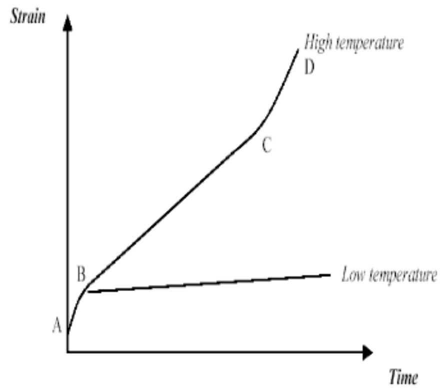
High speed steels also found a market in fine hand tools where their relatively good toughness at high hardness, coupled with high abrasion resistance and fine, made them suitable for low speed applications requiring a durable keen (sharp) edge, such as files, chisels, hand plane blades, and high quality kitchen and pocket knives.

Q.No. 7. *e.* Failure of Creep:-

Creep is the increase in the strain in a material, under stress, caused by the combined effects of time and temperature. Prolonged creep can cause fracture. It can occur at all temperatures but is only really significant well above room temperature. For example, for a metal or alloy, creep is significant for temperatures above 40% of the melting point. The success of high temperature jet engines is due to the formulation of alloys which have very low creep rates. Creep is described by *Strain versus time* graphs at constant stress and for a given temperature.



Strain



From O to A: elastic strain
From A to B: primary creep; rate of strain increase is decreasing with time; this is due to work-hardening as the dislocations get tangled up in the material thus slowing down their movement. Two common models for this type of creep predict that the behavior is described by either:

$e = \alpha \ell n t$ or $e = \beta t^m$

Where e is the strain, t is the time and the other variables are appropriate constants.
From B to C: secondary creep; steady state – constant creep rate; work-hardening is balanced by recovery due to thermal excitation of defects within the material.
From C to D: tertiary creep; aggregation of dislocations cause's voids and micro-cracks which propagate and can lead to failure at a grain boundary.
So-called Super alloys are creep-resistant at high temperatures. These are Ni-Cr alloys with small amounts of Al and Ti.

Q.No. 7. *f.* Annealing:-

Annealing is a general term that refers to heating a material and then cooling it. The amounts of heating, the time at the elevated temperatures, the rate of cooling are all essential to the final product. Care must be taken during the cooling because of the thermal gradient which might induce plastic deformation, warping, cracking. For metals an annealing process will increase the ductility and decrease the strength. This could range from merely relieving residual stresses (recovery) to returning it to the condition it had before any plastic deformation was done to it so that it has a new, stress free low energy crystal structure (recrystallization.)

The 3 stages of a full annealing heat treatment:

1. Recovery

1. Residual stresses and internal strain energy is relieved by dislocations moving into lower energy configurations
2. Strength decreases slightly and ductility increases slightly

2. Recrystallization

1. Formation of new strain-free, low energy, equiaxed, low dislocation density grains
2. T_{Rex} = temperature at which recrystallization just reaches completion in one hour. Usually this is about 1/3 – ½ the melting temperature.
3. The temperature of recrystallization is a function of
4. time
5. prior CW
6. purity
7. initial grain size
8. The more plastic deformation a material has undergone the more nucleation sites it has. Hence a finer grain structure will result for highly CW materials after the recrystallization process has completed.
9. Strength decreases and ductility increases to the previously CW condition.

3. Grain Growth:-

Once the process of recrystallization has occurred and the structure is made of completely new crystal grains, the grains will continue to grow. The driving force here is the lowering of the energy of the material because there will be less high energy grain boundaries per volume. The grain boundaries will migrate and the larger grains will grow at the expense of the smaller ones. (Much like soap bubbles.)

Some annealing procedures for Ferrous Alloys:

Stress Relief Anneal

1. Used only to relieve residual stresses (from plastic deformation, machining, no uniform cooling, phase transformation to different density phases.)
2. done at low T so that results of CW and other heat treatments are not affected

Process Anneal

a. used to negate the effects of CW
b. recovery and recrystallization but no grain growth
c. results in a fine grain microstructure
d. to avoid surface oxidation, heat to just below T_{ReX}

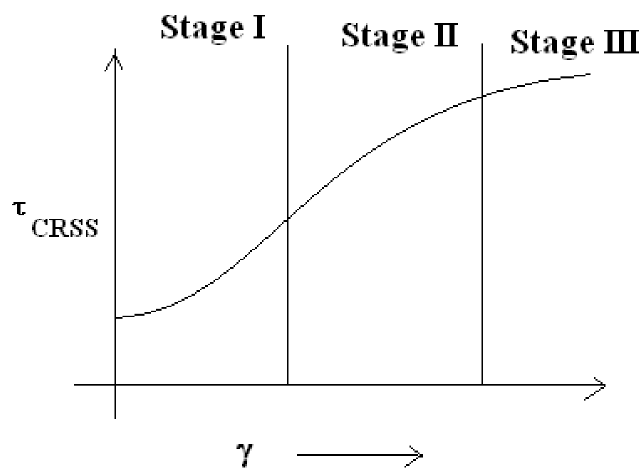
Q.No. 7. *g.* Strain/ Work hardening:-

- Strain hardening or work hardening is phenomenon which results in an increase in hardness and strength of metal when subjected to plastic deformation at temperature lower than the recrystaline temperature
- It happens due to cold working process
- Theory of work hardening:

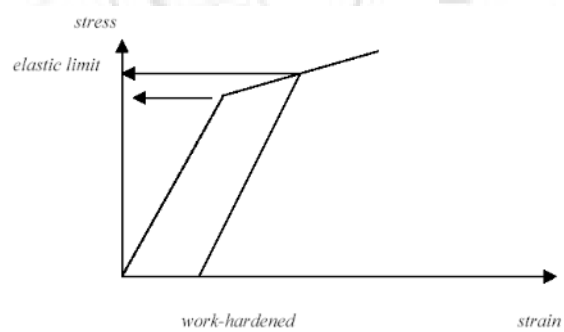
Stage I:-Easy gliding region- No work hardening

Stage II:-Linear hardening region

Stage III:-Parabolic hardening region- exhaustion hardening



- Repeated plastic deformation of the material will cause movement of the dislocations and creation of new dislocations. These will tend to bunch up causing high local densities of dislocations. This makes further slip difficult so the material has an increased strength as it displays a higher elastic limit. This makes the metal work-hardened.



- Note that the internal stresses in the material may be relieved by ***annealing*** *(*or *tempering)*. This involves heating to a relatively high temperature (compared to the melting point) and holding it there– this makes the dislocations mobile – followed by slow cooling. The resulting material will have increased ductility. Heating followed by rapid cooling is called ***quenching***. That will freeze in the defect and dislocation structures formed at high temperatures.