Department of Mechanical Engineering

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LECTURE NOTES

Name of the Subject: Engineering Material

Semester: 3rd **Year:** 2nd

Name of the Faculty: Debananda Behera

Engineering materials.

* Engineering materials and their Properties.

-> introduction -

- material Science and engineering plays a vital Plays role in this modern ~~ary~~ age of science and technology. various kinds of materials are used in industry, housing, agriculture, transportation.

- The knowledge of materials and their Properties of a great important for a design engineer.

-> A design engineer must be familiar with the effects which the m/fing process and heat treatment have on the properties of the materials

> Engineering material are classified 2 types.

  (I) - metals and their alloys (iron, steel, AL capper)

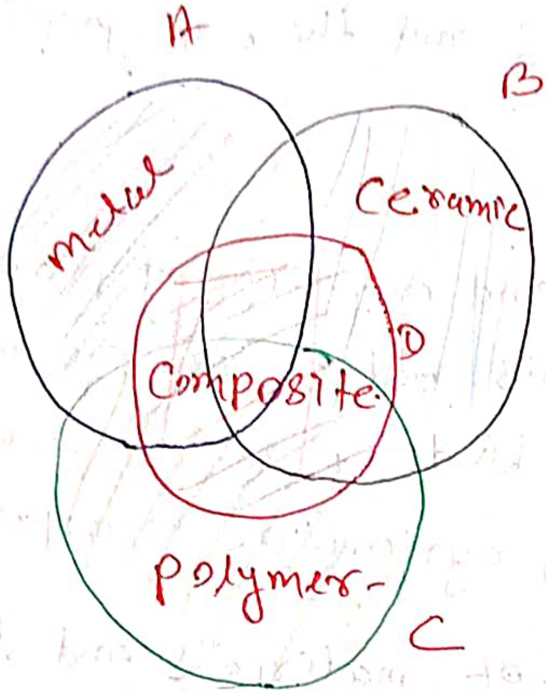
  (II) - Non- metals (glass, rubber, plastic etc)

-> metals classified 2types.

1 - ferrous metals -

~~Prossoassos~~

2 - Non - ferrous Metals -



A - metal

B - Ceramic

C - Polymer

D - Composite.

→ **Ferrous metals -**

The ferrous metals are those which have the iron as their main constituent, such as cast iron,

→ **Non ferrous metals -**

The Non ferrous metals are those which have metal other than iron as their main constituent, such as, AL, brass, tin, zinc.

* Physical properties -

→ The physical properties are employed to describe the response of a material to imposed stimuli under conditions in which external forces are not concerned.

* **Physical properties**

a- Dimensions
b - Apperance
c - colour.
d - density
e- melting point
F - Porosity
g- structure.

→ a - **Dimensions -**

Dimensions of a material it's size (length, breadth, width, diameter) and shape (square, circular, angle section etc)

→ Appearance -

- Metals themselves have got different appearance like aluminium is a silvery white metal where as copper brownish red.
- Appearance include colour, finish of a metals

→ colour -

- The colour of a material is very helpful in identification of a metal, The colour of a metal depends upon the wavelength of the light that the material can absorb.

→ Density -

It is the weigth of unit volume of a material expressed in metric units.

$$\rho = m/v$$

ρ - Density -
m - total mass
v - volume

→ melting point -

at the temp the solid metals change into molten state (liquid state)

→ Porosity -

- A metal is said to be porous if it has pores within it.
- Pores can absorb lubricant as in a sintered self lubricating bearing.
- It is the Ratio pore volume to bulk volume.

→ Structure -

It means geometric Relationships of material components.

- the arrangement of internal components of matter (crystal structure, micro structure)

* CHEMICAL PROPERTIES

→ most of engineering materials when they come in contact with other substance with they can react, tend to suffer from chemical deterioration.

- Corrosion Resistance
- chemical composition.
- acidity or alkalinity.

→ Corrosion -

- It is the deterioration of a material by Chemical Reaction with its environment.
- It Reduce the material properties and economic value of the product.
- It attacks metals as well as non-metals

* Performance Requirement

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

  exp - a component part to be used in a furnace must be of that material which can withstand high temp.

- While it is not always possible to assign quantitative values to these functional Requirements, they must be Related as precisely as possible to specified values of most closely applicable machanical, physical electrical or thermal properties.

Material's Reliability

- Reliabiliy is the degree of Probablity that the material of which it is made will Remain stable enough to Function in service for the intended life of the product with out failure.

• A material if it corrodes under certain Conditions, then it is neither stable nor reliable for those conditions.

Safety -

A material must safely perform its function, otherwise, the failure of the Product made out of it may be catastrophic in air-planes and high pressure system.

• An another example, materials that gives off spark when struck are safety hazards in a coal mine.

—x—

Chapter- 2.0

Ferrous materials and alloys

* Characteristics of Ferrous materials -

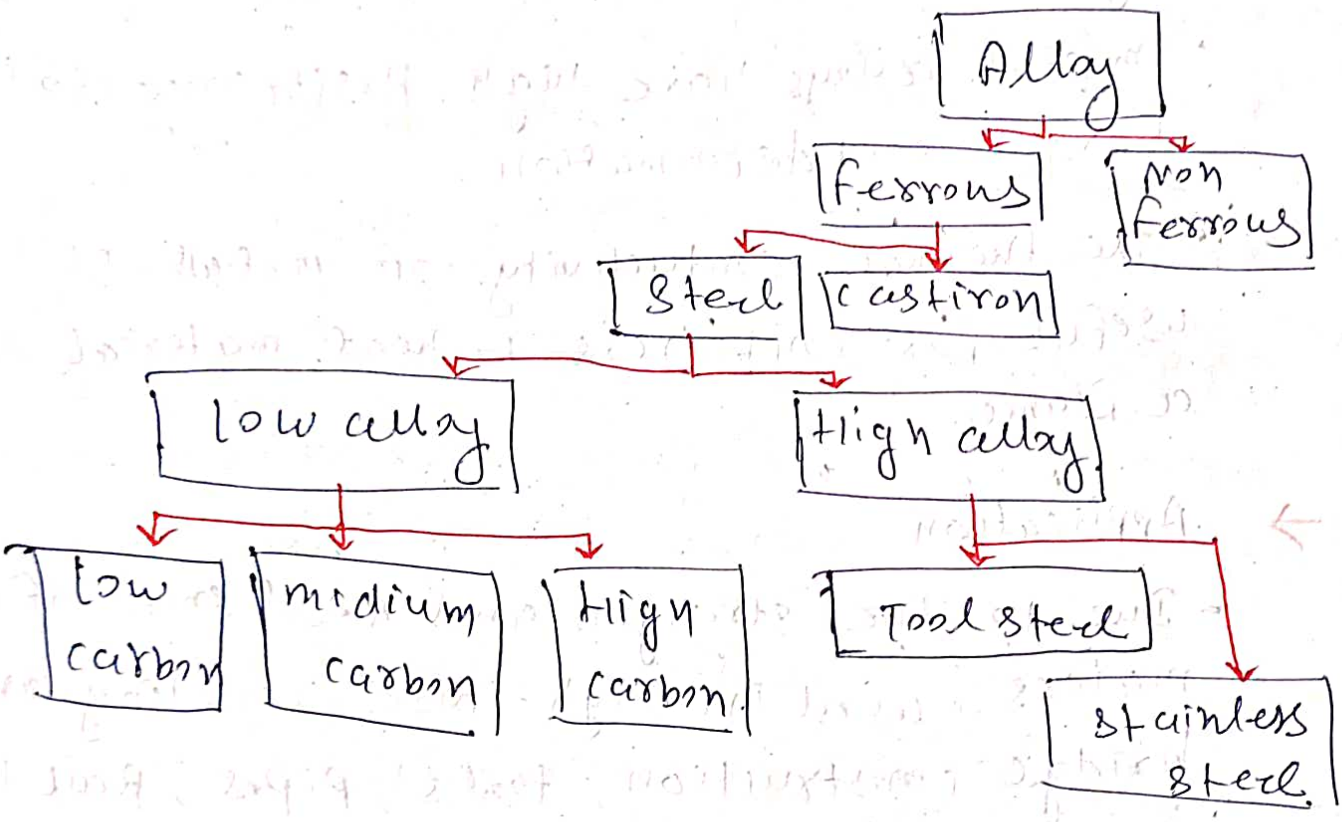
- The materials contain the iron as a base metal
- good conductors of heat and electricity
- metal alloys have high Resistance to shear torque and deformation.
- The thermal conductivity of metals is useful for containers to heat material over a flame.

→ Application

- Due to the strength and Resilience of maters, used in high-Rise, building and bridge construction, tools, pipes, Rail tracks
- Corrosion Resistance property makes them useful in food processing plant eg. steel.
- Cast iron is strong but brittle, and its compressive strength is very high. So it used to castings, engine body, machine base
- mild steel is soft, ductile and high strength so it used to structural, workshop, house-hold furniture etc.

- Carbon steels are used for cutting tool due to their hardness, strength and corrosion resistance properties.

Classification -



→ Steel - it is an alloy of Iron and carbon in which carbon content is up to 2%.

0.8 - 2.1%.

→ Cast iron - in cast iron carbon content is 2% to 6.67%.

Type of cast iron - white, malleable gray, compacted graphite.

→ Low carbon steel -

- Carbon content in the Range of 0.0 to 0.3%
- It has good weldability and machinability.
- Cold working needs to Improve the strength

→ Medium carbon steel -

- Carbon content is the Range of 0.3 - 0.8%.
- It can be treated - austenitizing, quenching and then tempering.
- metal we get tempered martensite
- Low hardenability.
- Addition of Cr, Ni, Mo improve the heat treating capacity.
- Application - Railway wheels and tracks gears, crankshafts.

→ High carbon steel - Carbon content 0.8 - 2%.

- High hardness and strength (High 'c' content)
- Hardest and least ductile.
- used in hardened and tempered condition.
- Add Cr, V, W bec strong carbide forms
- used to tool and die, Bec high hardness and wear Resistance property.

→ **Tool steel -**

- Their suitability comes from their distinctive hardness, Resistance to abrasion, their ability to hold a cutting edge, and their Resistance to deformation at elevated temp.
- It is generally used in a heat treated State.
- many high carbon & tool steels are also more resistant to corrosion due to higher ratios of elements such as vandium.
- Carbon content betn 0.7 %. and 1.5%.

→ **Stainless steel -**

It is an alloy of Iron with a minium of 10.5%. Chromium. Chromium produces a thin layer of oxide on the surface of the steel.

- Stainless steel also contains ~~varying~~ varying amount of carbon, silicon, manganese, Nickel and molybdenum.
- Nickel and molybdenum may be added to impart the enhanced Formability and increase corrosion Resistance.

→ Plain carbon steel -

It is an alloy of iron and carbon with content up to 1.5%. although other element such as silicon, mangenese may be present.

* carbon steel classified

- low carbon steel
- medium carbon steel
- High carbon steel.

→ Low carbon steel -

- Dead mild steel (0.05 to 0.15% of C)
It used for making steel wire, sheet, screws Pipe, nail, chain etc.

•• mild steel containing 0.15 to 0.2% carbon → is used for making camshafts, sheets, strips for blades, welded tubing, forging, drag line.

••• mild steel containing 0.2 to 0.3% carbon used to making valves, gears, crank shafts connecting Rods, Railways axles etc.

→ **Medium carbon steel** -

Steel containing 0.3 to 0.7% 'C'.

- Steel containing 0.35 to 0.45% 'C' is used for connecting Rod, wires & Rod, Spring clips, gear shaft, key stock, Shafts and brakes lever, etc.

- Steel containing 0.45 to 0.55% 'C' is used for Railways coach axles, axles and crank pins on heavy machine, crank shaft.

- Steel containing 0.6 to 0.7% cabron used to drop forging die and die blocks, clutch dies plate punches, set screws, thrust washers.

→ **High carbon steel**

* Steel containing 0.7 to 1.5% 'C'

- Carbon containing 0.7 to 0.8% used for Cold chisels, Jaws for vice, wheels for Railway service, wire for structural work automatic clutch disc. hacksaw.

- carbon 0.8% – 0.9%. used for Railway rail, machine chisels, punches & dies, music wires.

- carbon 0.9 to 1.0%. used to leaf & coil springs, keys, speed discs, pins.

- carbon 1.0 to 1.3%. used for making files, thread metal dies, twist drills, machine tools, metal cutting tools,

- Steel containing 1.3 to 1.5% carbon is used to making drawing dies, metal cutting saws, paper knives, tool for turning process.

* Alloy steel –

Steel is considered to be alloy steel when the maximum of the range given for the content of alloying element exceeds one or more of the following things.

Mn – 1.65%, Si – 0.6%, Cu – 0.6%.

AL, B, Cr up to 3.99%.

Cu, Mo, Ni, Ti, W, V element added to obtain a desired alloying effect.

→ Low and medium alloy steel.

~~[struck]~~ - In low and medium alloy steel alloying element is not exceeding 10%.

(1) - 1st symbol : 100 times the average % of carbon.

2 - 2nd, 4th, 6th etc symble : Elements.

3 - 3rd, 5th, 7th etc. symbele : % of element multiplied by factor as follows.

Element	multiplying factors.
Cr, Co, Ni, Mn, Si & W	4
AL, Be, V, Pb, Cu, Nb, Ti	10
P, S, N	100.

4 - last element : It indicates special characteristics.

→ High alloy steel -

total alloying element is more than 10%

For example - X10Cr, 18Ni9 S3

(X high alloy steel), (10% - 0.1% C) (Cr18 = 18% Cr)
(Ni9 - 9% Ni) S3 - picked condition.

* TOOL STEEL

Tool steel may be defined as special steel which are used to form, cut or otherwise change the shape of a material into finished

Properties of tool steel.

1 - Good toughness.
2 - good wear Resistance.
3 - v good machinability.
4 - Slight change of from during hardening.
5 - Resistance to decarburization.
6 - Resistance to softening on heating.

* Stainless steel

when 11.5% or more chromium is added to iron a fine film of chromium oxide forms spontaneously on the surfaces, The film ~~[illegible]~~ act as a barrier to retard further oxidation. rust or corrosion.

• The stainless steel basing on their micro-structure can be grouped into three metallurgical classes such as

1 Austenitic stainless steel
2 - Ferritic stainless steel

Application -

- Aircraft industry (engine parts)
- Heat exchangers in chemical industry.
- Trailers and Railways cars
- Household items

* Effect of alloying elements -

→ **Chromium** - it is joins with carbon to form Chromium carbide, thus adds to depth hardenability with improved Resistance to abrasion & wear.

→ **manganese** -

- It contributes markedly to strength and hardness
- It counteracts brittleness from sulphur.
- lowers both ductility & weldability if it is present in high ~~pess~~ percentage with high carbon content in steel.

→ **Nickel** -

- It increases toughness and Resistance to impact

- lessens distortion in quenching.
- Strengthens steels.
- Renders high - chromium iron alloys austenite
- does not unite with carbon.

→ Vanadium

- It promotes fine grains in steel
- Increases hardenability.
- Imparts strength & toughness to heat-treated steel.
- causes ~~mak~~ marked secondary hardening.

→ Molybdenum

- promotes hardenability of steel, makes fine grain
- makes steel unusually tough at various hardness steel
- Raises tensile and creep strength at high temp.
- Corrosion Resistance.

→ Tungsten -

It increase hardness.
Promotes fine grains.
Resists heat.
Promotes strength at elevated temp.

IRON - CARBON - SYSTEM

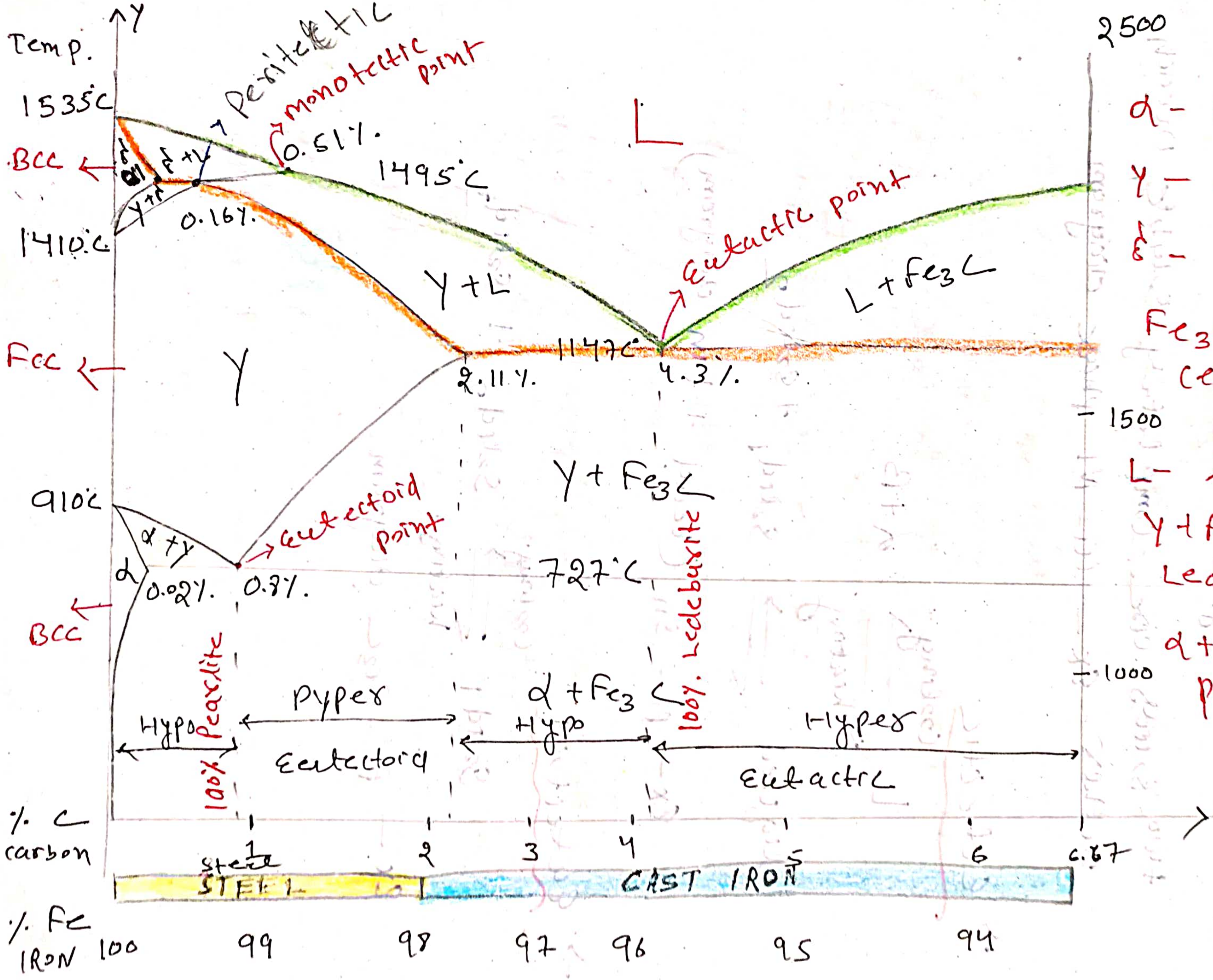
A phase in a material is defined as a region of spatially uniform macroscopic physical properties like density, atomic arrangement, crystal chemical composition etc.

Example -

iron in BCC structure, FCC structure, in liquid form and in gaseous state are different phases of iron.

In one component materials a phase is stable over a range of temp. and pressure. A homogenous solution of two or more components that may exists over a range of composition, temp. and pressure is considerd as the same phase.

Equilibrium phase diagram are normally used to show the stability of different phases in a material as function of temp. pressure and composition.



α - Ferrite

Y - Austenite

δ - Delta Iron

Fe_3C - (CM) Cementite

L - liquid

Y + Fe_3C - Ledeburite.

α + Fe_3C - pearlite

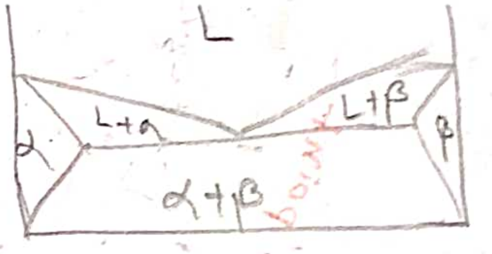
→ ISOMORPHOUS -

$$(\text{liquid}) L \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \alpha \ (\text{solid})$$

two solids are completely soluble in each outher. Ex – Cu- Ni phase diagram.

→ **Eutectic**

$$L \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \alpha + \beta$$



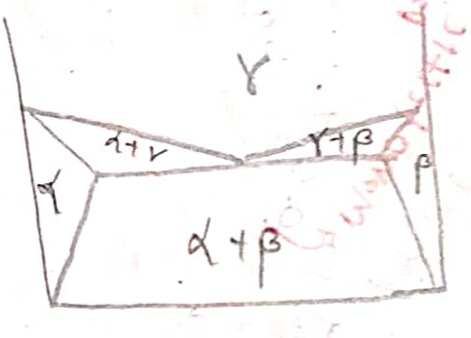
$$\text{liquid} \rightleftharpoons \text{solid}_1 + \text{solid}_2$$

Ex – pb - Sn (Lead + tin diagram)

→ **Eutectoid**

$$\text{solid}_1 \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \text{solid}_2 + \text{solid}_3$$

Ex – Fe – Fe_3C diagram.

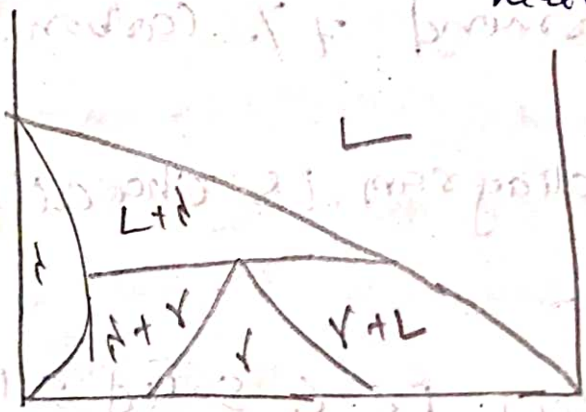


→ peritectic peritectic

$$\text{liquid} + \text{solid}_1 \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \text{solid}_2$$

Fe – Fe_3C diagram

$$L + \delta \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \gamma$$



Monotectic phases:

$$L_1 \underset{\text{Heating}}{\overset{\text{cooling}}{\rightleftharpoons}} L_2 + \alpha$$

Liquid liquid$_2$ + solid.

mixture of Pb & Cu ⇌ Lead + copper

Fe-C binary system - phase transformation

In their simplest form, steels are alloys of iron (Fe) and carbon (C). The Fe-C phase diagram is fairly complex one but we will only consider the steel part of the diagram up to around 7% carbon.

* Fe-Fe_3C phase diagram is characterized by five phases -

1. α - ferrite (BCC) Fe-C solid solution.
2. γ - austenite (FCC) Fe-C solid solution.
3. δ - ferrite (BCC) Fe-C solid solution,
4. Fe_3C (iron carbide) or cementite - an inter-metallic compound and liquid and Fe-C solution and four invariant Reactions:

→ Peritectic Reaction - at 1495°C at 0.16% C
δ - ferrite + L ⟷ γ - iron (austenite)

→ monotectic Reaction - 1495°C at 0.51% C, L ⟷ L + γ - iron (austenite)

→ eutectic reaction at 1147 °C and 4.3 % C

L ↔ γ-iron + Fe_3C (cementite).

→ eutectoid Reaction 723 °C and 0.8 % C

γ iron ↔ α-ferrite + Fe_3C (cementite)

Cementite - iron carbide: chemical formula Fe_3C, contains 6.67 % wt C. It is a typical hard and brittle interstitial compound of low tensile but high compressive strength. Its crystal structure is orthorhombic metastable phase - at 710 °C slowly decomposes to α iron and carbon.

δ-iron exists between 1410 °C and 1535 °C. It may exist in combination with the melt to ~ 0.51 % wt C. with austenite to - 0.16 % wt C and in a single phase state to 0.10 % C. δ iron has the BCC crystal structure and is magnetic.

Austenite γ (gamma) - iron :

Interstitial solid solution of carbon (up to 2.11 wt %) dissolved in iron with a fcc structure, stable up to 1410°C. Non magnetic phase.

Ferrite - (α) - iron - which is an interstitial solid solution of a small amount (upto 0.022 wt %) of carbon dissolved in iron with B.C.C. crystal structure, possesses polymorphic transformation to γ - iron at 910°C. It is the softest structure on the iron - iron carbide diagram, magnetic below 727°C

CRYSTAL SYSTEM

Crystallography - It is the branch of science that deals with the study of internal structure of crystals and it's properties.

CRYSTAL - It is a solid consisting of atoms and ions ~~arrang~~ arranged in a systematic or regular pattern in 3D space gemotrically.

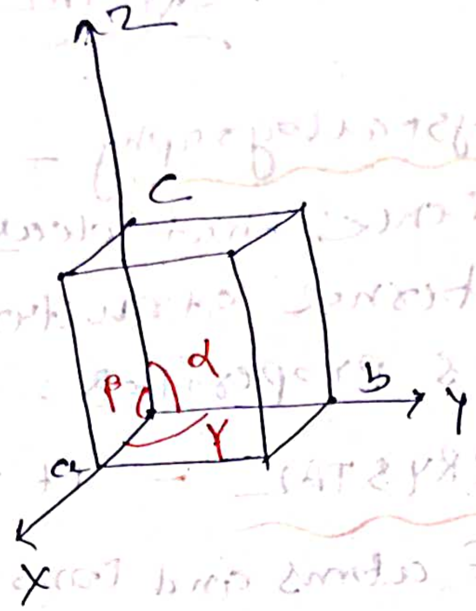
Crystal Structure - Regular 3 dimensional pattern of iron in phace.

Phace lattice - 3 dimansional array of point each of which has identical surroundings.

Unit cell - A convinient Repeating unit of a space lattic is know as unit cell.

-> Smallest group of atoms that passes the symmetry of the crystal.

-> The specific unit cell for each metal is defined by its parameters, which ~~is~~ are ~~defined by its~~. the edges of the unit cell a, b, c and the ang α (betn b & c) β (betn a & c) γ (betn a & b)

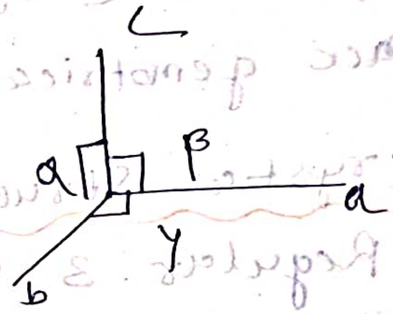


The crystal structure –

(I) – Cubic simple.

$a = b = c$

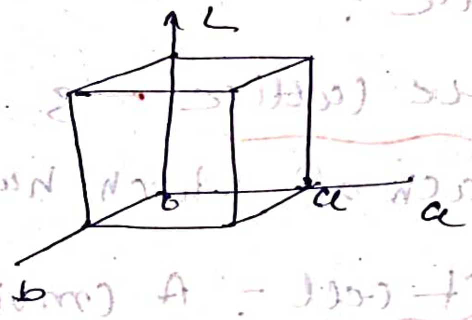
$\alpha = \beta = \gamma = 90°$



(I) – Simple

(II) – Body centred.

(III) – Face centred.



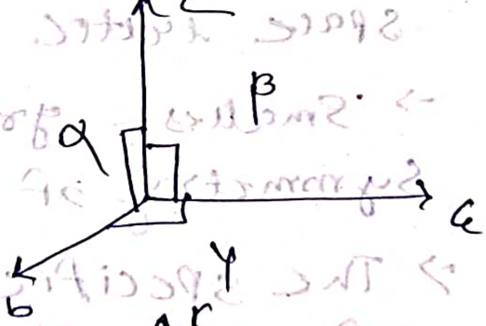
II – Tetragonal –

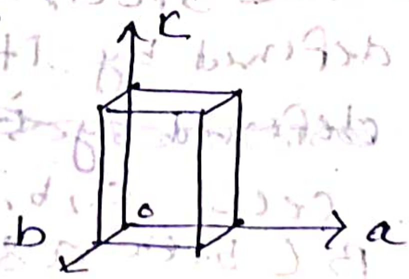
$a = b \neq c$

$\alpha = \beta = \gamma = 90°$

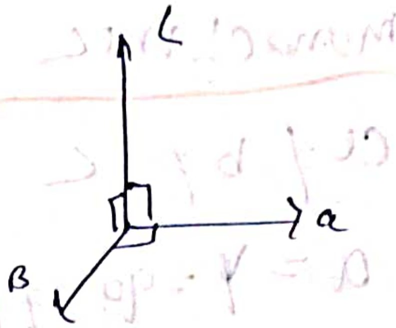
(I) Simple

(II) – Body centred.





(III) ORTHORHOMBIC



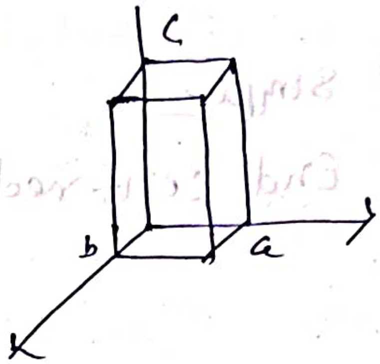
$a \neq b \neq c$

$\alpha = \beta = \gamma = 90^\circ$

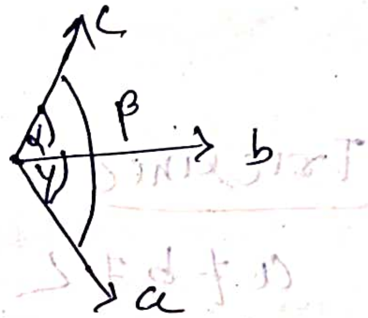
(I) simple

II – end centred

III – Body centred.



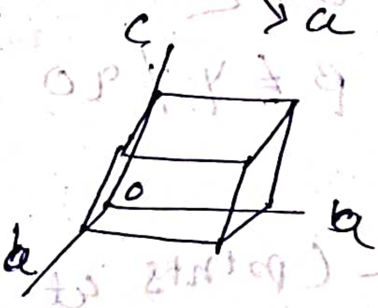
(IV) Rhombohedral.



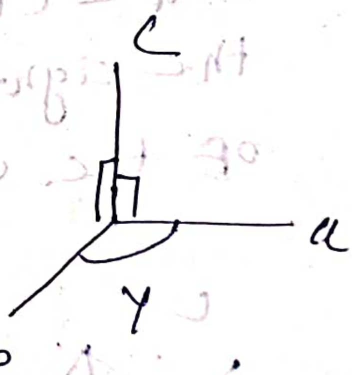
$a = b = c$

$\alpha = \beta = \gamma \neq 90^\circ$

(1) simple



(V) Hexagonal.

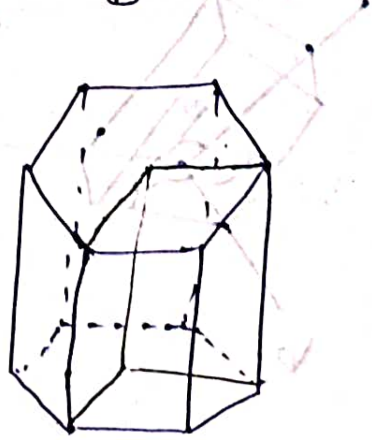


$a = b \neq c$

$\alpha = \beta = 90^\circ, \gamma = 120^\circ$

(I) simple.

(i) point at the ~~twelve~~ twelve corners of the hexagonal prism and at the centres of the two hexagonal face.



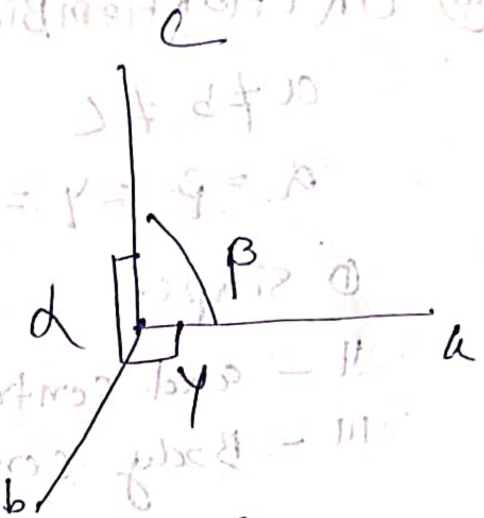
Monoclinic

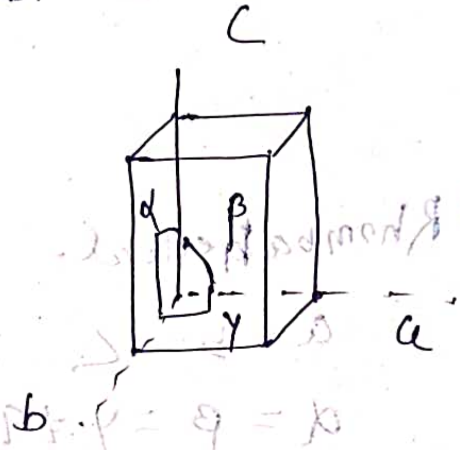
$a \neq b \neq c$

$\alpha = \gamma = 90^\circ \neq \beta$

(i) simple

(ii) End centred.



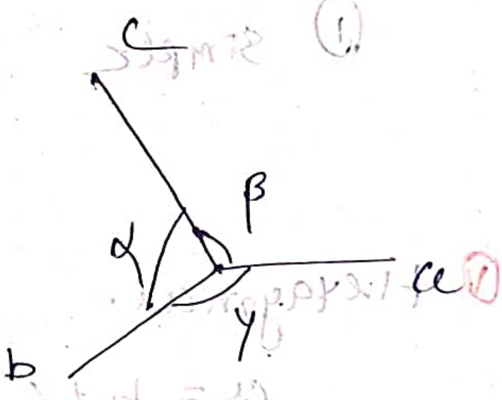


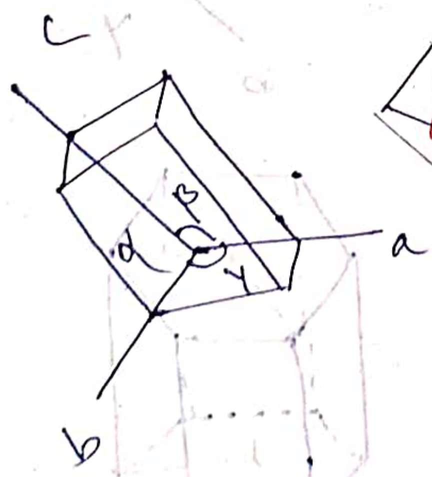
Triclinic

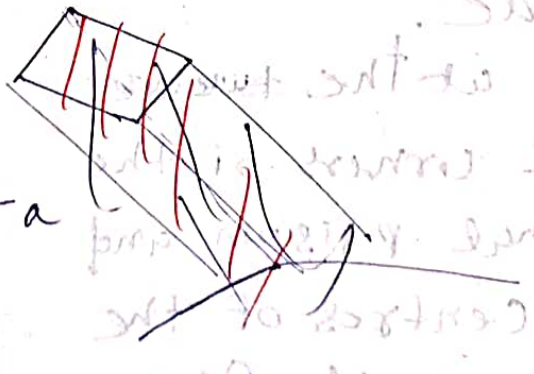
$a \neq b \neq c$

$\alpha \neq \beta \neq \gamma \neq 90$

Simple (points at the eight corners of the unit cell)







An ideally perfect crystal is one which has the same unit cell and contains the same lattice points through the crystal.
The term imperfection / defect is generally used to describe any deviation of the ideally perfect crystal from the periodic arrangement of its constituents.

Point Defects -

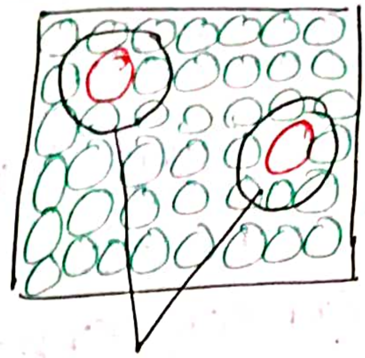
Point defects are the irregularities or deviations from ideal arrangement around a point or an atomic in a crystalline substance.

→ VACANCY DEFECT

- Atom missing from an atomic site.
- occur due to imperfect packing during crystallisation.
- This result in decrease in density of the substance.
- Number of vacancy defects depend on temp.

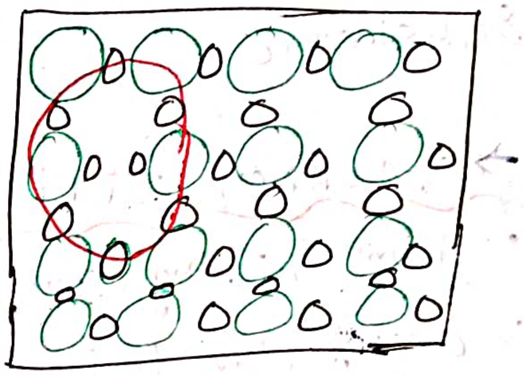
Interstitials Defect

- Addition of an extra atom within a crystal structure.
- This defect increases the density of the substance.
- Causes atomic distortion.
- vacancy and interstitials are inverse phenomena.



→ SCHOTTKY DEFECT

- pair of anion and cation vacancies.
- In order to maintain electrical neutrality, The number of missing cations and anions are equal.



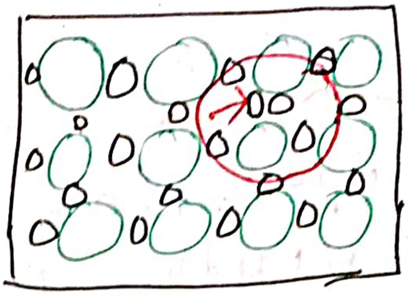
- It also decreases the density of crystal.

Eg = Alkali halides such as NaCl, KF etc.

FRENKEL DEFECTS

- cation being smaller get displaced to interstitial voids.
- Combination of vacency and interstitial atom.

- No Chang in the density.



- Eg - AgI, CaF_2

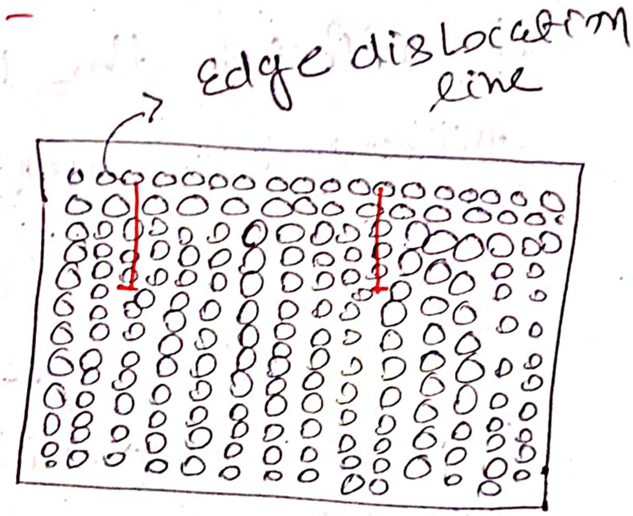
Line Defects

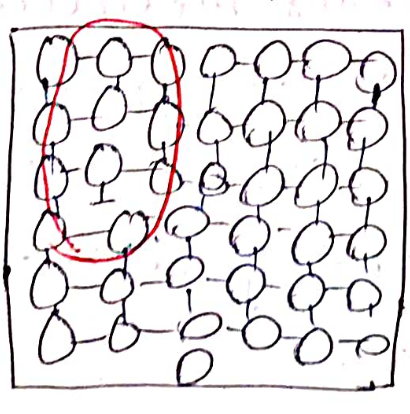
Line defects are the irregularities or deviations from ideal arrangement in entire rows of lattice points.

- Interatomic bonds significantly distored in immediate vicinity is dislocation line.
- Dislocation affects the mechanical properties.

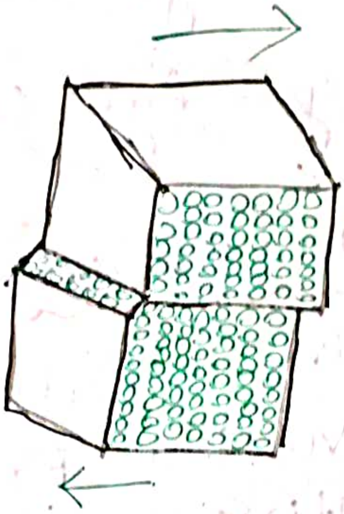
EDGE DISLOCATION -

An extra portion of a plane of atoms, or half-plane the edge of which terminates with in the crystal.





Screw dislocation.-



- The upper front portion in the following figure has been sheared by one atomic distance to the right Relative lower front portion.

- The screw for such defect is derived from the fact that lattice planes of the crystal spiral the dislocation line.

* Effect of imperfection on material properties.

It affected the characteristics like mechanical strength, electrical properties and chemical Reaction.

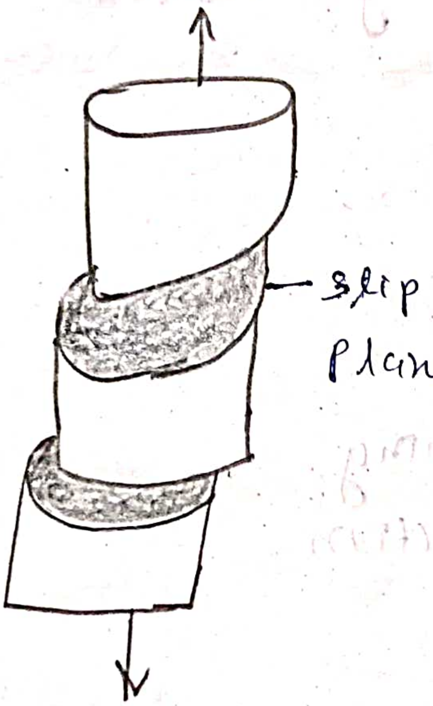
- Imperfections account for crystal growth diffusion mechanics, annealing and precipitation, besides this, other metallurgical phenomena, such as oxidation, corrosion yield strength, creep fatigue and fractures are governed by imperfections.

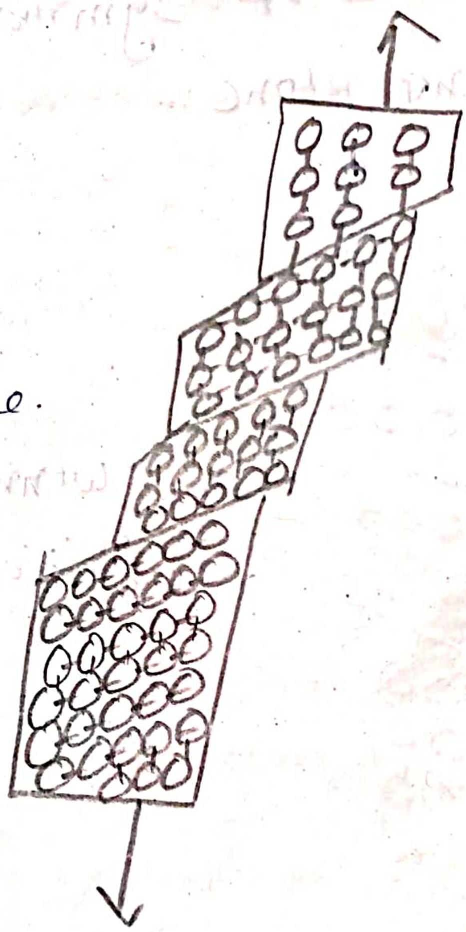
Slip –

Slip is the prominent mechanism of plastic deformation in metals.

It involves sliding of blocks of crystal over one other along definite crystallographic planes, called slip planes.

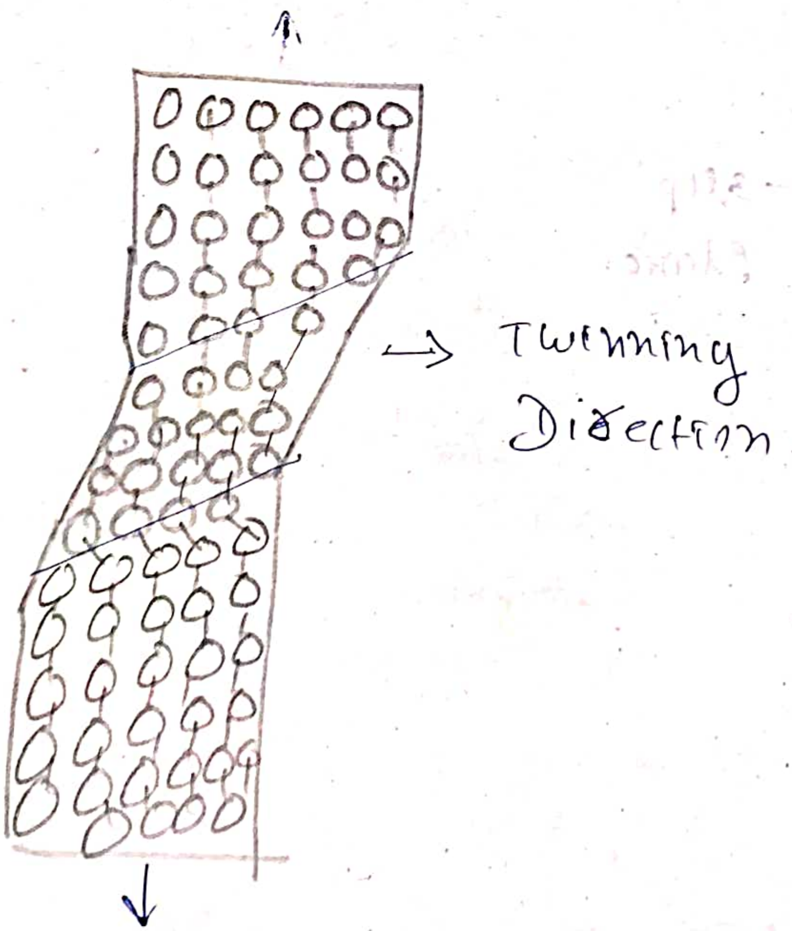
- It is analogous to a deck of cards when it is pushed from one end. Slip occurs when shear stress applied exceeds a critical value.





Twinning -

- Portion of crystal takes up an orientation that is related to the orientation of the Rest of the untwined lattic in a definite symmetrical way.
- The twinned portion of the crystal is a mirror image of the parent crystal.
- The plane of symmetry is called twinning plane.



Effect of deformation on metal properties.

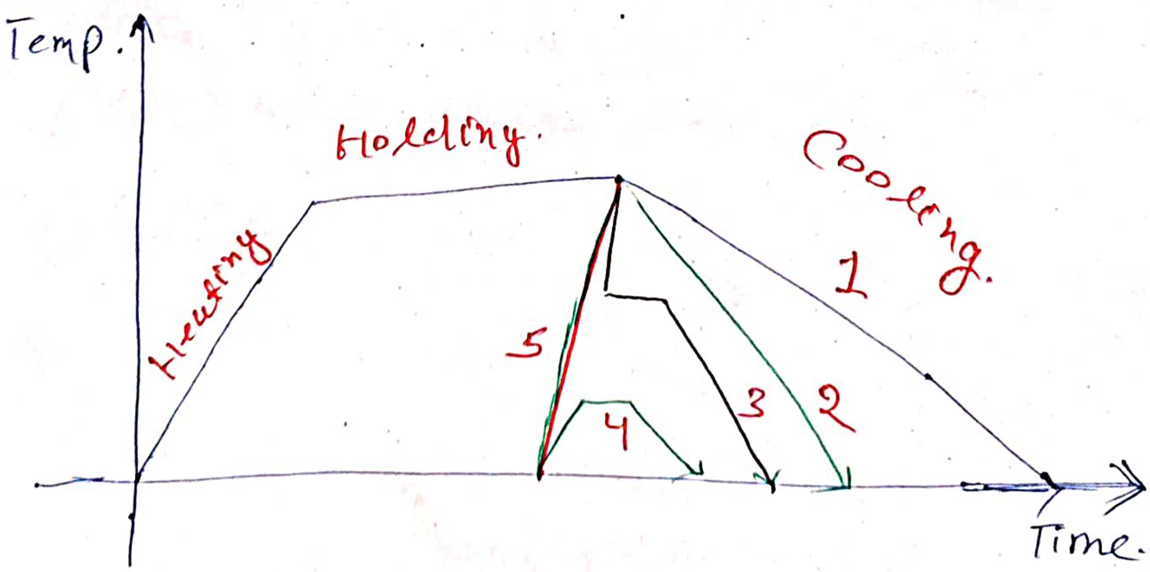
The mechanical properties ~~affted~~ affected by deformation (plastic deformation).
The deformation process like Rolling, Forging, extrusion, drawing strain hardening takes places, so hardness changes.

HEAT TREATMENT

Heating a material to a temperature holding it at that temp. for a period of time followed by cooling at specified rate is called Heat treatment.

Heating → Holding — cooling

- Heat treatment process is a series of operations involving the Heating and cooling of metals in the solid state.
- Its purpose is to change a mechanical property or combination of mechanical properties so that the metal will be more useful, serviceable, and safe for definite purpose.



(Time & temp more imprtc.)

1- Annealing - slow cooling - coarse pearlite.

2 - normalizing - faster cooling. - Fine Pearlite.
(Air cooling)

3 - Austempering - ~~cool~~ cool it very fast but, then hold it at a certain temp. - Bainite.

4 - Tempering - cooling very fast then Reheat, Then cool it again - Temper martensite

5 - Quenching (Hardening) - very fast cooling. (put into water/oil) - martensite.

* Annealing -

It is the process for softening materials or to bring about required changes in properties such as machinability, mechanical or electrical properties.

- The annealing process consists of heating the steel to or near the critical temp. to make it suitable for febrication.

• [A material can be annealed by heating it to a specific temp. and then letting the material slowly cool to ~~room~~ room temp. in an oven.]

(Critical temp - temp. at which crystalline phase change occurs)

• Normalizing -

It differs from annealing in that the metal is heated to a higher temp. and then Removed from the furnace for air cooling.

• The purpose of ~~a~~ normalizing is to Remove the internal stresses induced by heat treating, welding, casting, forging, forming or machining.

NOTE -

annealing - nucleation low and growth Rate is high - so it gives coarse pearlite.

normalizing - ~~nucle~~ nucleation high and growth Rate is low. so it gives fine pearlite.

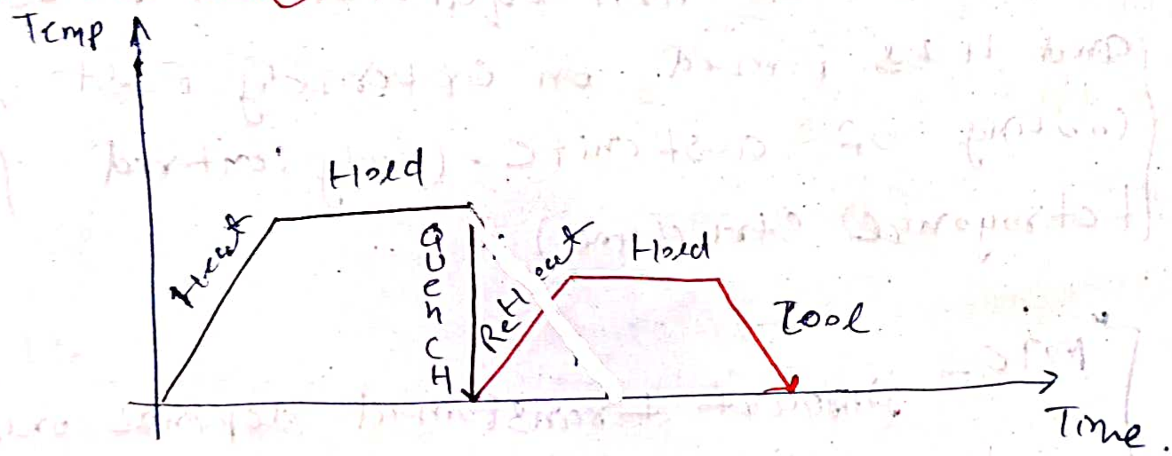
Austempering -

when a austenite is quenched below the nose of the C curve but above Ms and then that austenite is allowed to transform.

-> Cool it very fast -> hold for some time -> then Recool the material.

- It used for improve the mechanical properties.

Tempering -



-> In the process Heat -> Hold -> Quench -> Reheat (below the eutectoid temp.) - Hold -> Cool.

- It Reduce the brittleness of steel.

Quenching -

→ In this process cool ~~by~~ it Rapidly to put it in the oil and water.

- It is done to increase the strength and wear properties one of the pre- ~~Requisti~~ Requisites for hardening is sufficient carbon and alloy content.

- In this process we get martensitie

(Martensitie - non equilibrium phase and it is formed on extremely fast cooling of austenite. (Body centred tetragonal structure)

[NOTE - Amount transformed depends only the upon temp and not on time]

- No change in composition.

Surface Hardening -

- In order to process considerable strength to withstand forces acting on them and to withstand wear or their surface,
- The parts must be made of tough materials and provided with a hard surface by introducing carbon or nitrogen on its surface with core remaining soft.
- It provides us a hard and wear resistant surface, close tolerance in machining parts and tough-core combined with a higher fatigue limit and high mechanical properties in core.

Hardenability -

It is defined as property of a steel to be hardened by quenching and determined the depth and distribution of hardness ~~for~~ throughout a section obtained by Quenching.

- - alloying elements -
- Carbon content
- Grain size of steel.

- The homogeneity of starting steel

*. NOTE –

Ease of hardening a steel by formation of martensite on quenching (very fast cooling)

Ease = slow quenching Rate

Slower in the quenching Rate higher is hardenability.

NON - FERROWS ALLOYS

Duralmin – It is the oldest alloys of Aluminium. Its composition is 3.5–4.5% copper
0.4–0.7% manganese.
0.4% silicon
0.4% – 0.7% magnesium.
0.5% Iron.
AL – % (next)

- Its tensile strength increase from 1.55–1.86 ton/cm², yield point from 1.04– 2.325 t/cm² and hardness from 65 brinell to 95 brinell.
- used for highly stressed structural components. aircrafts and automobile parts (front axle, levers, connecting rods, spares)
- Also it used for surgical and orthopedics work for non magnetic and other instrument parts.

Y- alloys – (nickel-containing AL Alloy)

- It is a high strength casting alloy which Retains its strength and hardness at high temp.
- Its % of composition – 4% magnesium, 2% Nickel 0.6% manganese. Rest of aluminium.

- Its ultimate strength is 2.12 tons/cm^2 but chill costing after heat treatment show a strength of 3.1 tonnes/cm^2.

- It is extensively used for pistons, cylinder heads and crank case of internal combustion engine.

Copper alloys -

* Copper aluminium alloys -

- AL gets hardened and strength by the addition of copper.

- It is used alloys for castings are those containing up to 12% copper and ultimate strength ranging from 1.12 - 4.185 t/cm^2.

- It is used for automobile piston, crank case, cylinder heads, connecting Rods.

Copper-Tin -

These bearing alloys containing greater proportion of tin with copper and antimony and know as white metals.

In this type having composition of 86% tin 10.5% antimony copper has tensile strength of 0.996 ton/cm², elongation 7.1%. with brinell hardness of 33.3 and compressive yield point of 4.3.

- It is used in main bearings of motors & aero engines.

*– Babbit

- It can be one of several alloys used as a bearing surface in plain bearing.
- Its composition is 82.3% tin, 3.9% copper 7.1% antimony.
- ~~A cheaper babbit metal used for bearings.~~
- They are use as liners in bronze or steel backing and are prepared for higher speed, excellent embedability, conformability, ability to deform plastically used in IC engine, purpose bearings.

Phosphor bronze -

It isa member of the family of copper alloys. It is composed of copper that is alloyed with 0.5-11% of tin and 0.01-0.35% phosphorus, and may contain other element to confer specific properties.

- It is used for springs, bolts, electrical switches, sliding parts.
- It this alloy where Resistance to fitgue wear, and corrosion are Required. (corrosion Resistance)

BRASS -

It is an alloy made primarily of copper and zinc.

Composition - 36% zinc and 64% Cu.

- Corrosion Resistance, low friction
- used in musical instruments, electric parts, wire, tools, machining parts.

copper - nickel

In this alloy of copper that contains nickel and strengthening elements, such as iron and ~~mac~~ manganese.

- Copper content typically varies from 60 - 90%.
- Despite ~~this~~ its high copper content cupronickel is silver in colour.

- It has ~~and~~ excellent Resistance to seawater corrosion. low macrofouling Rates, good Fabricability.

~~Composition~~ - ~~10 - 15% antimony.~~
~~15% Cu,~~
~~20% Tin.~~

- It is used for - evaporator of turbine, pipes for nuclear and fossil fuel power plant.
- heat exchanger tubes, pumps, water boxes.

- Predominating element of Lead alloys, zinc alloys and nickel alloys.

* Lead alloys -

The tin is Replaced by lead base alloys and contains - 10 - 15% antimony, 15% Cu, 20% Tin and 60% lead.

- These alloys are cheaper than tin base alloys, but not strong and do not possess the load carrying capacity strength decreases with increasing in temp. An alloy containing 80% Lead, 15% antimony and 5% tin or 20% antimony generally used for long bearings with medium loads

* Zinc alloys -

These alloys used in the form of tooling plate and easy and speed of fabrication.

Brasses - Alloys of Cu and Zn.

* nickel alloys -

Nickel is one of the most important metals which used as pure metal and alloys with other metals.

- Nickel copper - nickel copper silicon alloy.
- Nickel copper tin with lead.
- Nickel Chromium - with Iron or Cobalt
- Nickel silicon -
- - Nickel manganese, nickel aluminium.

Low alloy materials like P-91, P-22 for power plants and other high temp services, high alloy materials like stainless steel grades of duplex, super duplex materials.

Low alloy materials -

which process slowly cooled micro structure, similar to these of plain carbon steel on the same condition namely pearlite, pearlite pluse Ferrite, These alow alloy know as pearlite steel.

High alloy steel.

which posses slowly cooled micro structure, consisting either of martensite, austenite or Ferrite plus carbide particle, It is more than 8% in the case of steels.

Bearing material

Introduction -

when a lubricant film can't completely separate the moving parts of a bearing friction and wear increase.

- The Resulting friction heat combined with high pressure promotes localized welding of the two Rubbing surface. Thes welded contact points break apart with relative motion and metal is pulled from one or both surface decreasing the life of the bearing.

- Steel or cast iron, are used as bearings bec they easily weld together.

Classification of Bearing material.

1- Tin Based Babbitt

2- lead based Babbitt

3- Cadmium Based bearing material.

4- Copper based Bearing material.

→ Composition & uses of different type of bearing material.

Name	composition.	uses
Tin Based Babbitt	85% Sn, 10% Sb, 5% Cu.	High speed bearing bushes in steam and gas turbine, electric motor, blower, pump etc.
Lead Based Babbitt	85% Pb, 12% Sb, 8% Sn	Railway wagon bearing.
Cadmium Based	95 Cd - 5% Ag & small amount of iridium	medium loaded bearing subjected to high temp.
Copper Based	80% Cu, 10% Pb 10% Si	Heavy duty bearing

Properties of Bearing material

- It should have enough compressive and fatigue strength to possess adequate load carrying capacity.
- It should have good plasticity for small variations in alignment & fittings.

- good wear ~~Resist~~ Resistance to maintain a specified fit.
- Low coefficient to avoid excessive heating.
- Should resist vibration.
- High thermal conductivity.
-

engineering material-

Polymer-

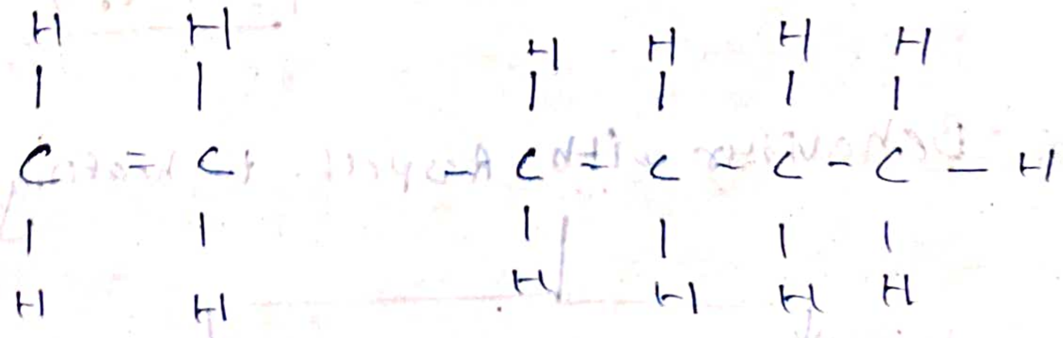
The plastic is an organic substance and it consists of natural or synthetic binders, or resins with or without moulding compounds-
The plastic is manufactured by the polymerization.

monomer-

The simplest substance consisting of one Primary chemical are know as the monomer.

Polymerization -

monomers are to be combined to form plymers by the process know as polymerization.
Polymeric material consists of a large number of these long chain molecules.



monomer
Etylene C_2H_2

Polymer polyethylene.
$(C_2H_2)n$

The properties such as strength, rigidity and clastricity are considerably improved by the polymerization and it further leads to the manufacture of plastics is an economy way.

Classification of plastic.

1 - Behaviour with respect to heating.

2 - structure and

3 - Physical and chemical properties.

NOTE -

composition of plastic.

Organic Polymers + cabron + O_2 + Nitrogen + Sulphur.

* Behaviour with Respect to heating.

→ Thermoplastic

→ Thermosetting

* Structure → Homogeneous / Heterogenous -

* Physical and Chemical properties -

Rigid plastic ← → semi-Regid plastic.

Soft plastic ← → elastomers -

Thermo plastic -

The thermo plastic group is the general term applied to the plastics with which becomes soft when ~~be~~ heated and hard when cooled.

- It can be cooled and heated several times.
- It can be Recycled.
- When it is heated, they melt to a liquid. They also freeze to a glassy state when cooled enough.

Note - Heat → liquify.
Cool → solidify -

Properties -

- It allow plastic deformation when it is heated
- They are brittle and glossy.
- Good resistance to creep.

Application -

- used for electronic application (wire cover, switch Bord)
- Electrical machines, tubes covered.
- electrical insulation, handels of tools.
- making ropes, belts, pipes etc.

Thermo setting plastics.

The thermo setting plastics is the general term applied to the plastics wich become rigid when moulded at sutiable pressure and temp.

- when the temp. range ~~bt~~ 122°c to 172°c they set permanently and further application of heat does not alter their from or soften them.
- But at the temp. of about 343°c the charring occurs. This charring is a peculiar characterstic of the organic substances.

Processing - A + B = C
(mix 2 components → cure.)

Properties -

These are soluble in alcohol and certain organic solvents, when they are in thermo-plastic stage.

- These are durable, strong & Hard.

Used / application -

- electronic chips -
- Fibre - reinforced composites.
- Dental fillings -
- ~~mean edge~~
- Engineering application plastics.
- spectacle lenses.

* Properties of elastomers -

These plastic are soft and elastic materials with low modulus of elasticity. they deform considerably under load at Room temp. and return to their original shape, when the load is Released, ~~the~~ the extensions can Range up to ten times their original dimensions.

Composites and ceramics -

Classification -

The composite materials are shortened as composites. They are formed by combining two or more different materials to make better use of their virtues and by minimizing their difficiencies.

- Each material retains its physical or chemical properties separate and distinct with in the finished product.

1- Strong load carrying material know as Reinforcement

2- weaker material know as matrix.

1 Reinforcing fibres -

i - It provides strength and rigidity.
ii - It helps to supports structure load.
iii It devided in to 3 types -

(i) - glass fibres.
ii - carbon fibres.
iii - Aramid fibres.

- Glass fibers are the heaviest having greatest flexility and the lowest cost.
- Aramid has moderate stiffness and cost
- carbon moderate to high in cost, slightly heavier than aramid but lighter than glass fibres.
- carbon is the strongest.

2 - matrix -

I - It works as a binder.

II - It maintains the position and orientation of the Reinforcement.

III - It balances the load betn the Reinforcement.

IV - It protects the reinforcement degradation.

V - It provides shape ~~reinforcement~~ and form to the structure.

Composites natural -

wood - cellulose fibres plus polysaccharide.

Bones, teeth and mollusc shells.

= hard ceramic + organic polymer.

man made composites -

1. mud + straw.
2. Bricks made up straw + mud
3. Plywood.
4. Concrete, plastic, MMC, CMC

* Classification and used of ceramics -

A ceramic material is an inorganic, non metallic, often crystalline oxide, nitride or carbide material.

(I) - Clay products
II - Refractories -
III - Glass -

Clay products -

The products which are used tiles, terra-cotta, porcelain, bricks, stoneware's & earth wares.

1 - Common tile (ii) - Encaustic tiles.

Common tile

(i) - Alahabad tiles, corrugated tiles, Flat tiles

(ii) - the tile able to Resist high temp.

Refractories

It is a material that is Resistant to decomposition by heat, pressure, or chemical attack and Retains strength and form at high temp.

- Refractories are Inorganic, non metallic Porous and heterogeneous.

- Application -

used in furnaces, kilns, incinerators, and reactors,

Glass -

these ceramics have an amorphous phase and one or more crystalline phase and are produced by a so-called controlled crystallization" in contrast to a spontaneous crystallization, which is usually not wanted in glass manufactuory.

- glass ceramics have interesting properties like zero porosity, high strength, toughness,
- low or even negative thermal expansion, high temp. stability
- use for electrical insulators, architectural cladding, heat exchangers and regenerators
-