LECTURE

NOTES

ON

Engineering Material(3rd sem)

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ENGINEERING MATERIAL

Material:

(i) Material is that out of which anything may be made.

(ii) Engineering materials are those which are design structurally develop specific property for a given appreciation.

Material Classification:

(i) According to physical, chemical & mechanical properties solid materials have usually been group into two basic types

(i) Metals & Alloys

(ii) Non-metal

(ii) Further for engineering application metals and alloy are classified as

Ferrous and Non-ferrous.

(iii) Similarly non-metals are classified as :

- Polymer
- Ceramics
- Organics
- Composite
- Semiconductor

Metals:

– Metals are composed of elements, which give up electrons to provide a metallic bond and achieve thermal or electrical conductivities.

– The metals are characterized by high thermal and electrical conductivity. Strong yet deformable under applied mechanical loads. Opaque to light.

– Metals also possess the following properties hardness. Strength, ductility, brittleness, mechanical ability, weld ability, cast ability, formability, stiffness etc.

Ferrous material:

(i) Ferrous metals are those in which the best constituents or main constituents is iron, at though other constituents are carbon, sulpher, phosphorous manganese etc. also exists in different proportion.

(ii) Properties or characteristics of ferrous material are hardness, strength, ductility, good conductor of heat and electricity, machine ability etc.

Ex.: Pig iron, wrought iron, cast iron.

Non-Ferrous metals:

(i) Non-Ferrous metals are those which do not contain iron constituents.

(ii) Metals like aluminum, copper, zinc, lead tin, gold etc. and their alloys falls under this category for metals classification.

(iii) Non-ferrous metals posses for special character like good conductivity of heat and electricity, light weight, high resistance to corrosion etc.

Non-metals:

(i) Non-metals are not able to conduct electricity or heat.

(ii) The Non-metals exists two of the three states of metal at room temperature, gases (such as oxygen) solid (such as carbon)

(iii) The non metal have non-metallic, luster are do not reflect light.

(iv) Non-metallic elements are brittle and cannot be rolled into wires or form into sheets.

Ceramics:

(i) Ceramics are usually consist of oxides, carbides, nitrides, silicate of various metals.

(ii) Ceramics are any in organic, non metallic solids proceed at high temperature.

(iii) Ceramics are partly crystalline and partly amorphous.

(iv) Ceramic materials are rock like or clay mineral materials.

Characteristics:

(i) Brittleness, abrasiveness, hardness, corrosion resistance, opaque to light, high temperature strength, rock line appearance.

Ex- Sand, brick, concrete, abrasives etc.

Organic materials (polymer):

(i) Organic materials (Polymer) are polymeric material, that are chemically based on carbon hydrogen and other non-metallic elements.

(ii) The polymers composited of a large number of repeating units (small molecules) called monomer.

(iii) A polymer is made of thousands of monomers Joint together to form large molecules of specific dimension called macro molecules.

(iv) The unique feature of a polymer is that each molecule is either a long chain or networking of repeating units. All molecules are covalently bonded together.

(v) Polymers in the form of thermo plastic (pvc, rubber, Polyethylene etc) consists of molecules that have covalent bonding within each molecule. Polymer in the form of thermo sets (Bakelite) consists of a network of covalent bonds.

(vi) Due to the kind of bonding polymers are typically eclectically or thermal insulator.

Important Characteristics :

(i) Light weight, combustion, soft, poor conductor of heat and electricity, poor resistance to temperature.

Ex- Polyethylene, Rubber, Fiber, PVC etc.

Composite :

(i) Composite materials are mixture of two or more different materials that are mechanically or metallurgical bonded together.

(ii) Usually the components do not dissolve in each other and can be physically identify by an interface between the components.

Characteristics :

(i) Strength (iv) hardness

(ii) Stiffness (iv) insulation etc

(iii) Corrosion resistance

(iii) The best example is fiber Glass a composite of Glass embedded with polymer matrices.

Semi Conductor:

– Semi conductors have electrical properties that are intermediate between the electrical conductors & insulators.

– Semi conductors are covalent in nature

– The electrical characteristic of these material are extremely sensitive to the presence of very small concentration of impurity atoms which concentration may be controlled very small vision.

For example :

Silicon, Germanium, Gallium, arsenide.

– Semi conducting material are basically are used of manufacturing of different electrical & electronics components.

Factors affecting the selection of materials for engineering application :

– Following factors are affect the selection of material for engineering purpose directly & indirectly.

– (i) Properties of material
(ii) Environmental condition
(iii) Availability
(iv) Disposability
(v) Economic factors
(vi) Physical attributes
(vii) Performance Requirement
(viii) Material reliability
(ix) Safety

Performance Requirement:

– The material of which a part is manufactured must be capable of performing its function without failure.

– For example - a component to be used in the furnace must have been of that material which can withstand high temperature.

Material Reliability:

– A material a given application must be reliable. Simply states that reliability is the degree of probability that a product and the material of which It is made will remain stable enough to function in service without failure.

Safety:

– a material must perform its function otherwise the failure of the product made out of it may be catastrophic as in air planes, turbines etc.

Properties of materials :

– Property of a material is a factor that influences qualitatively or quantitatively the response of a given material to the applied constraints like force, temperature etc.

– engineering properties of the materials are classified into different categories :

Mechanical property :

Mechanical properties give us information about the behavior of the material under the action of external force.

Ex- Strength, ductility, brittleness, creep, fatigue. Impact resistance etc.

Electrical property :

– Electrical property gives up information about the behavior of material when electric current flows through them.

Ex- Restively, conductivity, dielectric strength etc.

Thermal Properties :

Thermal property gives us information about the behaviors of the material under the action of heat.

Ex- Specific heat, thermal conductivity melting point thermal expansion.

Magnetic property :

Magnetic property gives us information about the behavior of the material under the action of magnetic field.

Ex- Permeability, Hysteresis etc.

Physical property of a material :

– Physical properties are employed to describe a material under condition in which external forces are not concerned.

– Physical property includes. Dimensions of the material - Dimensions implies that length, breadth height, diameter etc of rectangular, square ,circular or any other section.

(ii) Porosity - A material is said to be porous. If it has poros within it.

True porosity =Total pore volume/ Bulk volume

(iii) Structure: Structure means geometrical shapes of material or components, such as circular rectangular etc.

(iv) density : The density is the weight or mass of unit volume of material expressed in metric units.

Chemical property:

Most of the engineering materials when they come in contact with other substances, with which they can react, tend to suffer chemical deterioration. This necessitates the study of chemical properties of material.

– Some of the chemical properties are :

(i) Corrosion resistance: It is the loss of material by chemical reaction with the environment. Corrosion degrades material properties and reduced economic value of the material.

(2) Chemical composition

(3) Acidity

Ferrous materials

– Ferrous materials are those in which the main constituent is iron, although other constitutes like carbon, sulpher, manganese, phosphorus etc. also exist in different proportions.

– Iron, steel and their alloys fall under this category.

– Ferrous materials are the most important metals or alloys in the metallurgical& mechanical industry because of their extensive use. The wide spread use of ferrous material is accounted by three factors.

(i) Iron containing compound are exist in plenty quantity is the earth crust.

(ii) Iron, steel & there alloys may be produced by using relatively economical extraction, refining, fabrication technique.

(iii) Ferrous alloys have a wide range of mechanical & physical property

– The main disadvantages of ferrous alloy is less resistance to corrosion.

Ferrous materials are:

– Pig iron

– wrought iron gray cast iron

– cast iron white cast iron

– carbon steel malleable cast iron

Carbon steel :

– It is an alloy of iron & carbon and It is malleable.

– Carbon steels are differing from cast iron. As regards the percentage of carbon.

– Carbon steels contain from 0.10% to 1.5% carbon where as cast iron posses 1.8% to 4.2% carbon.

– Carbon steels can be classified as

(1) Low carbon steel

(2) Medium carbon steel

(3) High carbon steel

Low carbon steel or mild steel:

– Low carbon steel or mild steel contain carbon form 0.05% to 0.3% carbon.

Steels containing 0.05 to 0.15% carbons are used for making steel wires sheets, Rivets, Screws, nails, chains, etc.

– It is also known as dead mild steel & It has a Tensile strength of 390N/mm^2& a hardness of about 115 BHN (brinel hardness number)

– Mild steel containing 0.15% to 0.20% carbon has a tensile strength of 420 N/mm^2 and hardness of 125 BHN. It is used for making sheets, strips for fan blades, welded turbines forgings cam shafts.

– Mild steel containing 0.20% to 0.30% carbon has a tensile strength of 555 N/mm^2& a hardness of 140 BHN.

- It is used for making valves making, connecting rod, crank shafts, railway axle etc.

Medium carbon steel:

- Medium carbon steels contain carbon form 0.30 to 0.70%.
- Steels containing 0.35 to 0.45% carbons have a tensile strength of about 750 N/mm^2. They are used for making wire rods, connecting rods, shafts and break levers, gear shafts etc.
- It maintained hardness 200 to 300 BHN.
- Steels containing 0.45 to 0.55% carbon have a tensile strength of about 1000N/mm^2& a hardness of 300 to 400 BHN.
- They are used for making parts those are to be subjected to shock & heavy reversal stress.
- They are used for making crank shafts, axle, splines shafts etc.
- Steels containing 0.6 to 0.7% carbons have a tensile strength of 1230N/mm^2& a hardness of 400-450 BHN.
- They are used for making drop forging dies, Die blocks, Set screws, valve springs and thrust washer etc.

High Carbon Steel :

- High carbon steels contain carbon form 0.7% to 1.5%.
- Steels containing 0.7% to 0.8% carbon have a tensile strength of about 1400N/mm^2 and a hardness of 450 to 500 BHN.
- These steels are used for making cold chisels, Jaws for vices, wheels for Railway service, Hack saws etc.
- Steels containing 0.8% to 0.9% carbon have a tensile strength of about 360 N/mm^2 and hardness 500 to 600 BHN.
- These steels are used leaf spring, punch & die circular saws, machine chisels, Railway rails etc.
- Steels containing 0.9 to 1.0% carbon (High carbon tool steel) have a tensile strength of 580 N/mm^2& a hardness of 550 to 600 BHN.
- They are use for making keys, leaf springs. Punches& dies, pins etc.
- Steels containing 1.0% to 1.5% carbon are used for making taps, machine tools mandrels, railway spring etc.

– Steels containing 1.1% to 1.2% carbon are used for taps, knifes, twist drills etc.

– Steels containing 1.2 to 1.3% carbons are use for making files, reamers, metal cutting tools etc.

– Steels containing 1.3% to 1.5% carbon are used for making metal cutting saws, paper knives, wire drawn dies etc.

ALLOY STEELS:

– The usefulness of plain carbon steel is limited by its poor corrosion resistance to property and loss of strength at elevated temperature.

– This deficiency of plain carbon steel overcomes by employing alloy steel.

– Alloy steels are steel containing various alloying elements like ni, cr, mn, w, Mo, v, Co. etc.

– The objectives in adding alloying element to steel is not only to improve and extend the property of plain carbon steel but also to introduce new property that are not available in plain carbon steel.

Purpose:

– The purpose of using alloying elements are:

(i) To increase harden ability.

(ii) To increase strength at ordinary temperature.

(iii) To increase resistance to corrosion.

(iv) To increase wear resistance.

(v) To improve toughness.

(vi) To improve electric and magnetic properties.

Classification:

– Alloy Steels are classified as

Based on total alloy content:

(i) Low alloy steel: up to and including 5% alloying element.

(ii) Medium alloy steel two more than 5% but up to including 10%

(iii) High alloy steel more than 10% alloying element.

Based on Engg application:

(i) Structural grade alloy steel used in construction, transporting, Production and industrialization.

(ii) Stainless steel used in corrosion and heat resistance application.

(iii) Tool and die steel used in making forming and machining tools.

(iv) Special alloy steel used in special application.

Tool Steel:

– Tool & Die steels may be defined as special steel which have been developed to form to cut or otherwise change the shape of material into finished or semi finished product.

Properties of tool steel:

– Good toughness

– Good wear resistance

– Very good machine ability

– A definite hardening temperature

– Little risk of cracking

– A definite cooling rate.

Types of tool steel :

Symbol	**tool steel**
T	T- High speed steel
M	MO. High speed steel
D	High C. Higher Steel
A	Air hardening steel
O	Oil hardening tool steel
W	Water hardening tool steel
H	Hot work steel
S	Soft resisting steel

Effects of alloying elements:

– **Nickel:**

(i) Increases toughness & resistance to impact.

(ii) Strengthen steels.

(iii) Lowers the critical temperature of steel.

(iv) Widen the range of heat treatment.

(v) Does not unite with carbon.

(vi) Less distortion in quenching

Chromium:

(i) Chromium joints with carbon to form chromium carbides. Thus adds depth harden ability with improve resistance to abrasion & wear.

Manganese:

(i) It increases strength & hardness of the material.

(ii) It resists brittleness of the material.

(iii) Lowers ductility & weld ability If it is present in 5% of carbon contained in steel.

Molybdenum:

– It promotes harden ability of steel

– It makes steel fine grained.

– It makes steel tough of at various level

– It resists brittleness of steel.

– Enhances corrosion resistance in stainless steel.

– Increase tensile & creep strength at high temperature.

Vanadium:

– Promotes fine grains in steel.

– Increases harden ability when dissolved.

– Imparts strength & toughness to the steel

Tungsten:

– It increase hardness

– Promotes Fine grains

– Resists heat

– Promotes strength at elevated temperature

Stainless Steel:

- When 11.5% or more chromium is added to iron, a thin surface of chromium oxide forms on the iron surface exposed to air or presence of air.
- This chromium oxide surface acts as a barrier to retard oxidation, ,rust, stains &corrosion.
- As this steel cannot be stained easily It is called stainless steel
- All stainless steel can be group into 3 metallurgical classes

  (1) Austenitic

  (2) Martensitic

  (3) Ferrite.

Crystal imperfection

- A crystal is a solid composed of atoms, iron or molecules arranged in a pattern which is a repetitive in three dimensions.
- The regular repetitive arrangement of atoms are described by a three dimensional network (Space lattice)
- Space lattice is a three dimensional pattern of points called lattice point.
- Each point in the space lattice has identical surroundings. The size and shape of an unit cell is described by three edge length (a,b,c) and the angles (α,β,γ) known as lattice parameters.

Metal crystal structure:

- The crystal system found in most elements metals are either

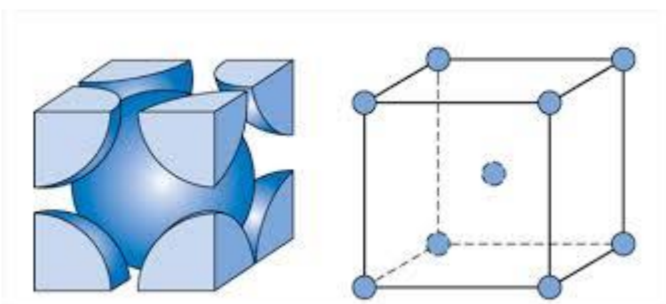
- BCC (Body centered cubic)
- FCC (Face centered cubic)
- HCP (Hexagonal closed pack)

– In BCC the unit cell has one atom at each corner and one atom at the center of the cube.

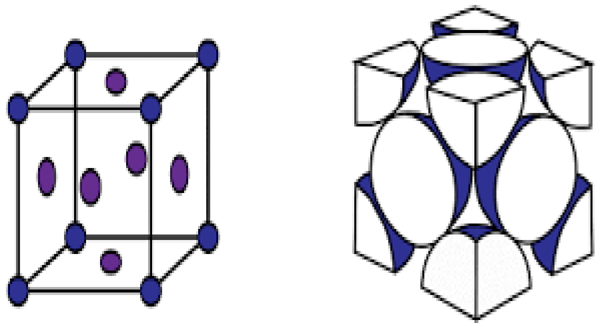
– In FCC there is one atom at each corner of the cube and one at the center of each face.

– In HCP there are two lattice basal planes in the form of regular hexagon with an atom at each corner of the hexagon and one atom at the center of Basel plane another plane that provides three additional atoms to the unit cell is situated between the top & bottom plane.

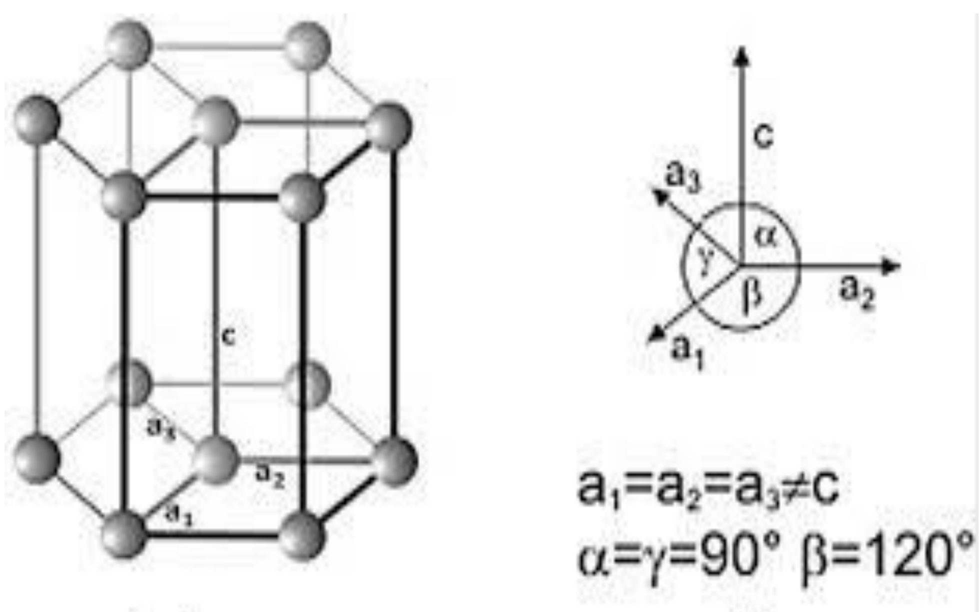
BCC (Body centered cubic)



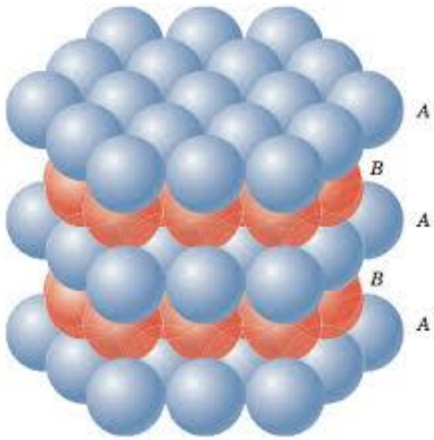
Two representations of FCC Crystal Structure



HCP (Hexagonal closed pack)



(a) (b)



Types of crystals

– Briefly crystal are two types :

– (1) Idle crystal:

An Ideal crystal the atomic arrangement is perfectly regular &continuous throughout.

– (2) Real crystal:

Real crystal as in cast or welded object is never perfect.

Lattice Distortion, various Imperfections, irregularities and other defect are generally present in them.

Crystal defect:

– Crystal defect as meant as lattice irregularities having one or more of its dimensions.

– The crystal defect affects the mechanical properties of material. Such as strength, hardness, ductility, toughness etc.

Classification of crystal defects:

– All defects and Imperfection of crystal can be confidently classed under 4 main division namely

(i) Point defects: Vacancy
Impurity
Electronic defect

(ii) Line defects: Edge dislocation

Screw dislocation

(iii) Surface defects: Gain Boundary

Tilt Boundary

Twin Boundary

(iv) Volume defects:

Point defect:

– Point defects are localized disturbances of the crystal lattice involving one or several atoms.

– These imperfection are introduced by the movement of atoms. When they gain energy by heating.

– In a crystal lattice point defect is one which is completely local in it's effect.

– In a crystal lattice point defect is one which is completely local in its effect. For example vacancy, impurities, interstitial etc.

– The introduction of point defect into a crystal increases its internal energy as compare to that of idle crystal.

_ Following are the types of point defects.

Vacancy:

– A vacancy is produced when an atom is missing from a normal size.

– Vacancies are introduced into the crystal during solidification at high temperature.

– At temperature very few vacancies are present on crystal but these number increases as temperature is increased.

– A vacancy implies an unoccupied atom position within crystal lattice.

– Vacancies may occur as a result of imperfect packing during the original crystallization or they may arise from the thermal vibration (Randomly movement of atoms by thermal equilibrium) of atoms at temperature, because as thermal energy is increased there is a higher probability that individual atoms will sump out there position of lowest energy.

– The atoms surroundings a vacancy tend to be closed together there by disturbing the lattice pattern.

Schottky defect:

– Scotty defect is pair of vacancy in an ionic bonded material that is both an anion and a action are found missing from the lattice.

Frankel defect:

– In an ionic solid structure sometimes an ion jumps from a normal lattice point to one interstitial side lining behind a vacancy this results in a vacancy interstitial pair called frankel defect.

Impurities

– Impurities give rise to compositional defect.

– Impurities may be small particles (such as slag inclusion in metal) embedded in the structure or foreign atoms in the lattice.

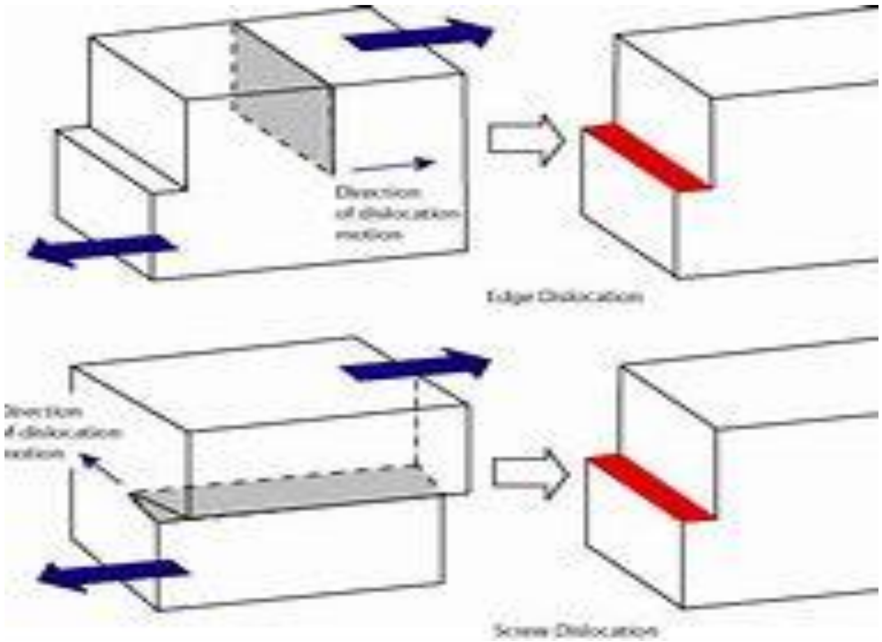
– Impurity or foreign atoms are introduced into crystal structure as substitution or interstitial atoms that is foreign atoms either occupied lattice side from which the regular atoms are missing or they occupied position between the atoms of the Idle crystal. Impurities may considerable disturbed the lattice.

– A controlled addition of impurity to a very pure crystal is the basic of producing many electronic devices.

– Impurities defects occur in metallic co-valiant& ionic bonded solids & play a very impotent role in much solid state process. Such as electrical & thermal conductivity, phase transformation etc.

Line Defect or dislocation:

– Line defects in crystalline solids are defects that cause lattice distortion around a line. A part of the line of atoms will be missing from its regular site & this missing row at atoms is called as a Dislocation.



- A dislocation may be defined as a disturbed region between two substantially perfect parts of crystal.
- Dislocation is a line defect in a crystal structure where by a part-plane of atoms is displaced from its symmetrically stable position in the array.
- The dislocation is responsible for the phenomenon of slip, by which most metals deform plastically.

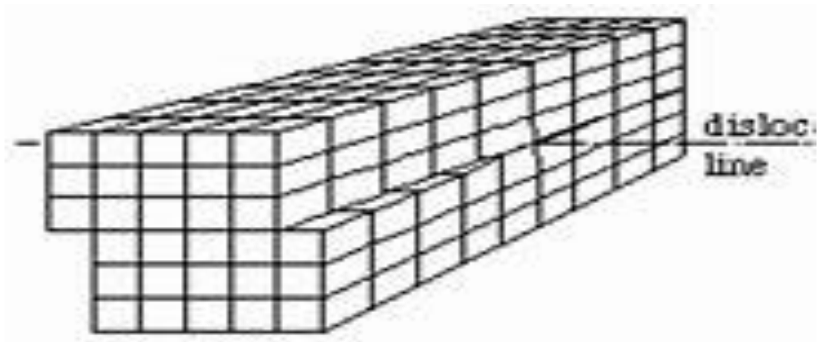
– The two basic types of dislocation are edge dislocation & screw dislocation.

– Dislocations are created during the solidification of the material or when the material is deformed.

Edge dislocation:

– An edge dislocation as created in the crystal due to the insert of extra half plans of atoms.

– The atoms above the edge of the extra plane as squeezed together and are in a state of compression.



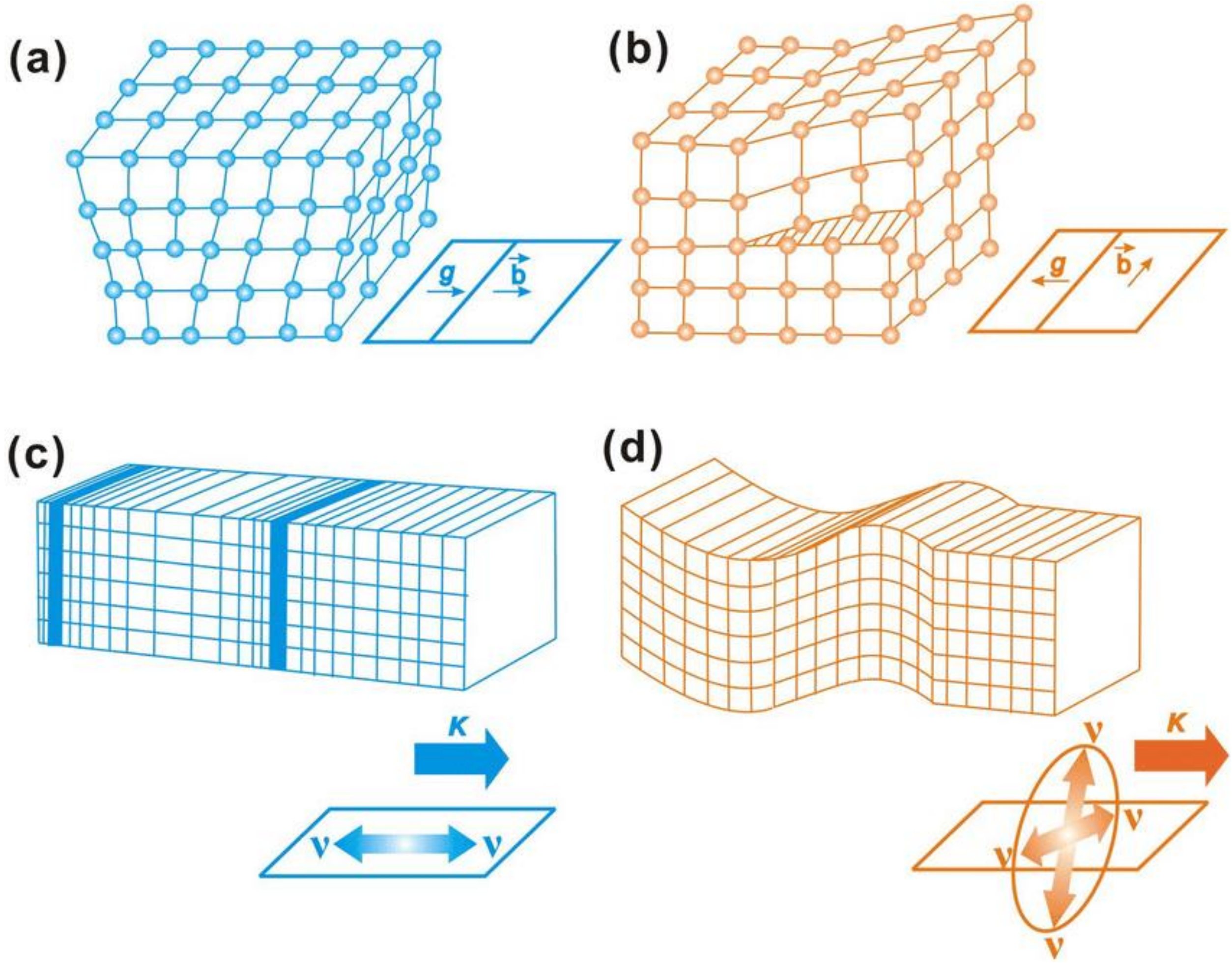
– Just below the extra plane the atoms are pulled apart and are in a state of tension.
– There is an extra energy due to the distortion in the region immediately surrounding the edge of the incompletely plane.
– The edge dislocation is said to be positive denoted by '⊥' with the entry of extra plain from the top of the crystal 'T' indicates negative dislocation in which the entry of extra plane from the bottom of the crystal.
– The dislocation line is characterized by a vector called burgers vector.
– The burger's vector of a dislocation is determined as follows:

Burgers vectors (b) :

– Starting from a point to make a loop around the dislocation, we go by m number of steps right then M steps down then m steps left and finally m steps up but the loop does not closed we need an atomic step distance to close the loop. This displacement vector required to close the loop burger's vector (b). Burgers vector is always perpendicular to the edge dislocation line.

Screw dislocation:

– A screw dislocation is imaginary by cutting a part way through prefect crystal then skewing by one atom spacing.
– The name screw dislocation is given, because it transfers an atomic plane into the surface of a helix around the dislocation line.
– In screw dislocation a region of shear strain is created along the dislocation in which energy is stored.



– The screw dislocation is represented by (or) according to it’s helical screw path direction.

– The burgers vector is screw dislocation is always parallel to the dislocation.

Causes of dislocation:

- Slip is the most important factor that causes dislocation.
- Mechanical phenomena such as strain hardening, yield point, creep, fatigue causes dislocation.
- Thermal vibration.
- Tensile, compressive and shear stress may cause various dislocations.
- Corrosion fatigue
- Crystal growth.

Deformation by slip:

– The usual methods of plastic deformation in metal is by sliding of blocks of the crystal over one another along definite crystallographic plain called slip plains.

– Slip occurs when the shear strain exceeds a critical value.

– In this phenomenon the atoms move an integral number of atomic distances along the slip plain & a slip is produced in the polished surface.

– When we view the polished surface from above with a microscope the step sources of as a line which we called slip line.

Effect of imperfection on metal properties :

– The property of engineering material safely depends upon the imperfection present within it.

– Imperfection affects material property both positively &negatively.

– The presence of imperfection is most necessary For any engineering material without which we cannot Generate deferent shapes and size.

– The imperfection which is responsible for the following characteristic of the material.

(i) Crystal Growth

(ii) Flow & Fracture characteristic

(iii) Diffusion mechanism

(iv) Electrical properties including semi-condemn behavior

(v) Creep characteristic of real metal

(vi) Oxidation & corrosion.

(vii) Plasticity

(viii) Thermal conductivity, yield strength etc.

Bearing Material

- Bearing supports moving parts such as shafts, spindles of a machine or mechanism. Bearing may be classified as

  (i) Rolling contact bearing

  (ii) Plain bearing or Flat bearing.
- Rolling contact bearing are almost made of steel that can be harden after machining. Both plain carbon steel and alloying element (Nickel, Chromium etc) are employed for different application.
- For making plain bearing an extremely wide range of different materials is Available.

Properties:

- Bearing material should have low coefficient of friction.
- It should provide good wear resistance.
- It should have ability to withstand bearing pressure.
- It should have high compressive strength.
- It should have fatigue strength.
- It should possess adequate strength at high temperature.
- Be such that it can be easily fabricated.
- It should have high thermal conductivity to dissipate heat generated due to friction between the bearing shaft & rotating shaft.
- It should have good casting.
- It should have non corrosive properties.
- It should be economical in cost.

Types of bearing material:

The following are widely used bearing material :

(i) Copper Base Alloy

(ii) Cadmium Base Alloy

(iii) Tin Base Alloy

(iv) Lead Base Alloy

(i) Copper Base Alloy:

(i) The copper based alloys are the most impotent bearing alloys. These alloys are harder and stronger than white metals (lead base & tin base alloys)

(ii) Copper based alloys generally used for bearing which is subjected to heavy pressure.

(iii) The copper alloys are broadly classified into the following two groups.

(i) Copper zinc alloys (Brass) in which zinc principle alloying metal.

(ii) Copper tin alloys (Bronze) in which tin is principle alloying metal.

Brass:

(i) The most widely used copper zinc alloys is Brass. This is fundamentally a Binary alloys of copper with zinc is 50%.

(ii) By adding small quantities of other element. The proportion of brass may be gradually changed. For example the addition of lead (1% to 2%) improves the machining quality of Brass.

(iii) It has a greater strength than that of copper But has a lower thermal and electrical conductivity.

(iv) Brasses are good resistances to atmospheric corrosion.

(v) It can be easily fabricated.

Bronze:

(i) The term bronze covers a large number of copper alloys with varying percentages of tin, zinc & lead.

(ii) Bronze is one of the oldest known bearing materials.

(iii) Bronze is easily worked.

(iv) Bronze has good corrosion resistances.

(v) Bronze is resalable hard.

Composition:

	(I)	(II)
Cu	80%	85%
Sn	10%	15%
PB	10%	–

(vi) Tin Bronze (10 to 14% remaining copper) is used in the machine and engine industry for bearing bushes made from thin world drawn tubes.

(vii) Copper based alloys are employed for making bearings required to resist heavier pressure such as in railway.

Cadmium based alloys :

(i) Cadmium based alloys bearing are not very popular because high price of cadmium.

(ii) These bearing alloys poses greater compressing strength than tin base alloys.

Composition :

	(i)	**(ii)**	**(iii)**	**(iv)**
Cd	98	98	98.5	94.75
Ni	2	–	–	3%
Ag	–	1%	1%	1.50
Cu	–	1%	0.5	–
In	–	–	–	0.75%

Properties :

(i) Low coefficient of friction.

(ii) High fatigue strength

(iii) High load caring capacity

(iv) Low wear poor corrosion resistance.

Uses :

(i) Cadmium based alloys are used in automobile and air craft industries.

Lead or tin base alloy :

(i) The lead base or tin base alloys are known as white metal & are usually referred to as Babbitt.

(ii) They may be divided as

(i) The high tin alloys with more that 80% tin & No lead.

(ii) The high lead alloys which more than 80% lead & 1 to 12% tin.

(iii) The alloys with intermediate percentage of tin and lead.

(iv) In addition to tin & lead these Babbitt metal or white metal also content antimony & copper also.

Tin base alloy :

Tin (Sn)= 88%

Antimony (Sb) = 8%

Copper (Cu) = 4%

Property :

(i) Tin base alloy low coefficient of friction.

(ii) Tin base alloys are preferred for heavier load.

(iii) Tin base alloys poses good resistance to corrosion.

(iv) Tin base alloys are costly and find application in steam turbines high speed engine generators etc.

Lead based alloys:

Composition:

Lead (pb) - 75%

Tin (sn) - 10%

Antimony (sb) - 15%

Properties:

(i) Lead based alloys are softer and brittle.

(ii) Lead based alloys are chipper than tin base alloy.

(iii) Lead base alloys are suitable for light & medium loads.

(iv) Lead base alloys find application in manufacturing collapsible, automobile industries, rail road construction etc.

Spring Material

(i) Spring stores mechanical energy therefore the spring material remains under highly internal stressed.

(ii) The choice of material for springs depends upon the operating condition. For example most heavily loaded springs are made up of steel piano wires, springs of which have to corrosion at fabricated of stainless steel & phosphorus bronze etc.

Types :

The commonly employed spring materials are

(i) Copper based spring material

(ii) Iron based spring material

(iii) Nickel based spring material

(iv) Special based spring material

Copper based spring material:

(i) Copper based spring material posess :

(i) High electrical conductivity

(ii) Good resistance to corrosion.

(iii) Lack of magnetic properties.

(ii) Copper based spring material can be classed on

(i) One Which can be hardened by cold forming

(ii) Others which can be hardened by heat treatment

(iii) Various copper based spring materials are

Phosphorus Bronze

(Cu – 92%, Sn-8%)

Uses :

High quality springs forSwitches, relays& Contact etc.

Brass:

(cu-67%, zn-23%)

Uses: switches and contacts

Nickel Silver:

(Cu-56%, Ni-18, Zinc - 25%)

Uses:

High quality spring for switches, contacts and other electrical equipments.

Beryllium copper:

(Cu -98, Be-2%)

Uses :

Brush, relays, switches etc. with relatively good resistance to wear good conductivity good resistance to corrosion.

Iron based spring material :

(i) A good spring steel posess high

(i) modulus of elasticity

(ii) elastic limit

(iii) fatigue strength

(iv) creep strength

(ii) Steel is used for making deferent types of spring such as

(i) Helical spring

(ii) Leaf spring

(iii) Plate spring

(iv) Cone spring

(v) Torsional spring

(iii) Iron based spring materials are

(i**) Stainless steel**

Composition: Cr=18%

Ni = 8%

C =0.1% - 0.2 %

Fe = Remainder

Uses:

(i) It is used in application requiring high resistance to corrosion.

(ii) Also used as valve springs in flow meter

(2) **Steel piano wire** :

C = 0.7% to 1.0%

Mn = 0.3% to 0.6%

Fe = Remainder

Uses:

(i) Small size helical spring

(3) Oil hardened spring wire :

C = 0.55 – 0.75%

Mn = 0.3% – 0.9%

Fe = Remainder

Uses :

Weighing machines, cars, truck & automobiles.

Hard drawn tube spring wire :

C= 0.5% – 0.75%

Mn = 0.6% – 1.2%

Fe = Remainder

Uses :

Where the stresses are low or where the high degree of uniformity is not essential or where fatigue loading is not involved.

Chromium vanadium spring steel:

Composition:

C = 0.5%

Cr = 0.2 – 0.9%

Mn = 0.8 – 1.1%

V = 0.07 – 0.12%

Fe = Remainder

Uses:

Railway carriages, engines, automotives valves etc.

POLYMER

– Polymerization may be defined as the process of growing large molecules for small ones.

– Polymerization links together monomers. Monomers are small molecules which combined end to end to form a large molecule known as polymer.

– The word "mer means a unit", monomer stands for a single unit & polymer means many unit joint together by a chemical reaction. Known as polymerization reaction.

– Examples of polymers are:

(i) Wood

(ii) Starch

(iii) Resin

(iv) PVC

(v) Polyethylene

(vi) Epoxiesetc.

– An example of polymerization reaction is the joining of ethylene molecules into a large molecule resulting polyethylene called polythene.

Characteristics:

(i) Good corrosion resistance.

(ii) Low coefficient of friction.

(iii) Good mold-ability

(iv) Excellent surface finish

(v) Poor tensile strength

(vi) Poor temperature resistance

(vii) Low mechanical properties

(viii)can be produced transparent and in different colors.

Classification of Polymer :

– According to the mechanical response at elevated temperature polymers may be classified as :

(i) Thermoplast or thermo plastic polymer

(ii) Thermosets or Thermo setting polymer.

Thermo plats or Thermo plastic polymer :

- Thermo plastic polymers soften when heated (and even liquify) & hardened when cooled this process is totally reversible and may be repeated.
- Thermoplasts have low melting temperature & can be repeated by molded & remolded to the desired shapes. They have a resell value.
- Thermo plasts are relatively soft & ductile.
- These materials are normally fabricated by the simultaneously application of heat & pressure.
- Some commercially available thermo plasts are:

PVC (Poly Vinyl Chloride)

- The polymers are produced by polymerizing vinyl compound.
- It is relatively low in cost.
- It offers good toughness strength & abrasion resistance.
- It is self extinguishing with low moisture absorption.
- They have good electrical insulation property
- They are widely used to manufacture, rain courts, hand bags, tubes, pipes etc.

Poly Ethylene:

- These polymers are produced by polymerization ethylene molecules.

Properties:

(i) It is light and odorless. It offers chemical resistance &don't absorb moistures.

(ii) It is an excellent electrical insulator.

Uses :

(i) These are widely used as insulating coating for electric wires, pipes, bottles, buckets, carry bags, etc.

Polystyrene:

(i) The polymers are produce by polymerizing styrene compounds. They have high resistance to chemicals. It is low cost and ability to be made crystal cleared hard & Glossy surface.

Uses:

(i) They are widely used as refrigerator door liner, Radio & television cabinet, food container.

Thermo setting polymer :

(i) These polymers become soft during their 1st heating & become permanently hard when cooled. They don't soften upon subsequent heating.

(ii) They cannot be recycle & don't melt, so that they don't have resell value. If heated to excessive temperature. The polymer Degradation takes place.

(iii) Thermo sets are generally harden stronger & more brittle.

(iv) Some commercially available thermo sets are:

Phenol :

(i) Phenolic or phenols are produced by the poly condensation of phenol and thermal dehyde.

(ii) It offers excellent strength, resistance to heat.

(iii) It shows chemical resistance property & relatively low on cost.

(iv) They are widely used for making electric iron handles, fan motor, switch covers etc.

Melamine:

(i) These polymers are produced by the co polymerization of melamine's and formal dehyde.

(ii) They have excellent tensile strength.

(iii) It is the hard set plastic known & dimensional stability

(iv) It offers low moisture absorption & Flame resistance.

(v) It is moderate in cost.

Uses:

(i) Melamine's are used for plastic crockery, automobile parts etc.

Epoxies:

(i) These polymer is produced by the condensation of epochlrohydrin & Dioxy diphenyle propane.

(ii) They have excellent adhessive property.

(iii) It offers chemical resistance & low moisture absorption.

(iv) It offers good toughness and electrical insulation property.

(v) It is relatively expensive.

(vi) They are widely used for bonding the material together such as wood, plastic, metal etc.

(vii) They are also used the manufacturing of high voltage, insulating material, laminates, varnish.

Elastomer :

(i) Elastomers commonly referred to as rubber are hydrocarbon & polymeric materials, Similar in structure like plastic.

(ii) The American society for testing and materials ASTM defines as elastomeric is a polymeric material which at room temperature can be stressed to at least twice of its original length & immediate release of the stress will return quickly to approximate its original length.

Characteristics:

(i) They are non-crystalline in structure. They are non-conductors of electricity.

(ii) They are high resistance to chemical & corrosion.

(iii) They have relatively low soften temperature.

Properties of Elastomer :

(i) High resilience or energy storing capacity.

(ii) Good tensile strength.

(iii) Excellent abrasion resistance & oil resistance.

(iv) Good compression strength & hardness.

Non-ferrous metal

Pure aluminum

Aluminum is a silver white metal & It poses the following characteristics:-

(i) It is a light metal.

(ii) It is very good conductor of heat & electricity

(iii) Aluminum has higher resistance to corrosion

(iv) Aluminum is non-magnetic in nature

(v)Aluminum has soft and ductile

(vi) Aluminum&its alloy can be cast, forged, welded, extruded, rolled etc.

Uses :

(i) Transformation industries

(ii) Structural frame work

(iii) Engine parts, doors, window frames decorative parts components of automobile parts, beat parts, refrigeration, food preparation equipments, storage container, wires, tubes, pipes, etc.

AluminumAlloys:

(i) Aluminum forms a wide range of Alloy with alloying element like copper manganese, silicon, magnesium, zinc, titanium etc.

(ii) The most commonly used aluminum alloys are Duralumin & Y-alloy

Duralumin :

Composition :

Cu = 3.5 – 4.5%

Mg = 0.4 – 0.7%

Mn = 0.4 – 0.7%

Si = 0.7%

Al = Remainder

Properties:

(i) High tensile strength after heat treatment.

(ii) High machinability.

(iii) It shows excellent hardness property.

(iv) Non-magnetic & corrosion less

(v) Excellent casting & forging properties.

Uses :

(i) It is used for making air craft & automobile parts,

(ii) It is used as bars, sheets tips, tubes, rivets etc.

(iii) It is used for making cables.

(iv) It is used in surgical & orthopedic works.

(v) It is used for non-magnetic instruments.

Y- alloy :

Composition:

Cu- 4%

Ni- 2%

Mg- 1.5%

Al- Remainder

properties

(i) It shows better strength than aluminum.

(ii) It maintains excellent strength & hardness at elevated temperature.

(iii) It can be easily casted & hot worked.

Uses:

i) It is extensively used for IC engine components, like piston, cylinder heads, crank case, engine head.
ii) It is also used for die casting pump & pump rod.

IRON-CARBON SYSTEM

– The iron carbon diagram is the most important subject in the study of ferrous metallurgy; it provides the basis understanding the properties & the heat treatment of the steel including the effect of alloying element in alloy steel.

Equilibrium phase diagram:

– The important metallurgical changes that takes place when a mixture of different material or metals, is gradually cooled from liquid state to solid state are best described with the help of an equilibrium phase diagram.

– Phases are characterized by the boundaries across which discontinuity exist in the physical property. Even a pure metal can exist in different phases like solid, liquid & gases, at different temperature & pressure.

– A convenient way of describing this phase Transformation diagrammatically, where the phases are different combination of temperature & composition is indicated such a diagram is called an equilibrium phase diagram.

– Phase diagrams are graphically representation of phases in the system at various temperature pressure & composition.

– The phase diagrams are constructed by using equilibrium condition. The word equilibrium means that the process are carried out of slow cooling slow heating

– Depending on the number of components are called as Unary, Binary, and Ternary**.**

Classification of phase diagram :

– The phase diagrams are widely used as binary diagrams.

– Binary phase diagram are constructed when only two elements are present in the alloy.

– The most important Binary alloys system are classified as

(1) Components completely soluble in liquid state.

– Completely soluble in the solid state

– Insoluble in the solid state.

– Partially soluble in the solid state

– Peritectic system

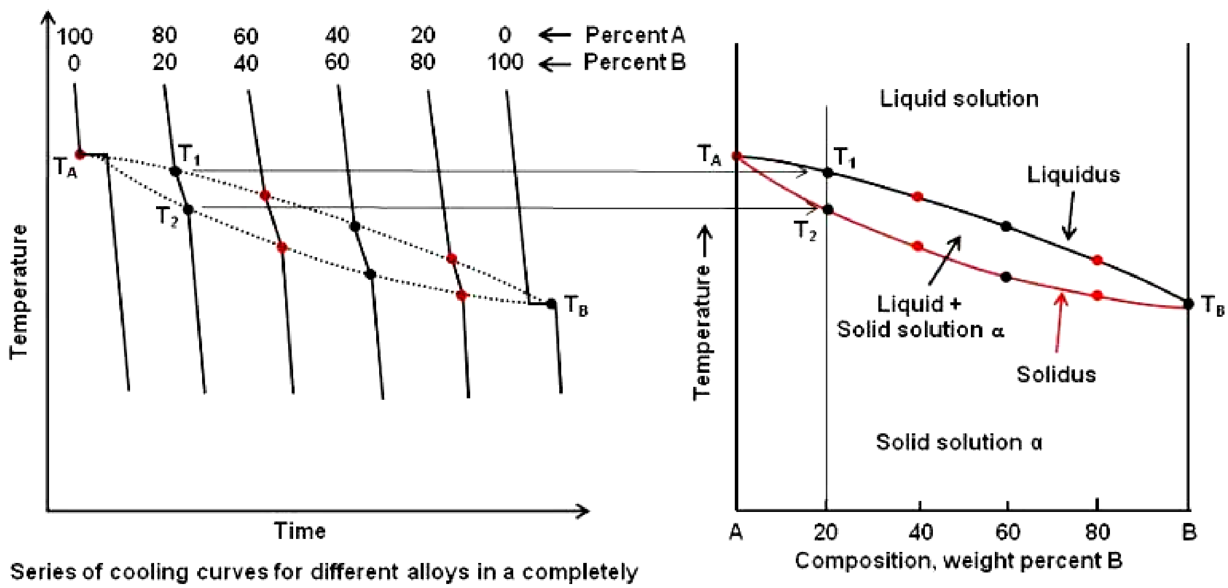
(2) Transformation in solid state

– Eutectic Reaction

– Periotectoid Reaction

Cooling Curves :

– A method to determine the temperature at which phase changes (liquid↔ solid) occur in an alloy system consist of following the temperature as a function of time as times different alloys in the system are very slowly cooled. The data obtain in this manner from a cooling curve for each of the alloy.



Series of cooling curves for different alloys in a completely soluble system both in the liquid and solid states

Phase diagram of two metals completely soluble in the liquid and solid states

Construction of Phase Diagram from Series of Cooling Curves

Cooling curve for pure metal:

(i) Liquid metal cools for cooling's from P to Q 1st crystal begin to form at point Q.

(ii) From Q to R the melt liberates latent heat in such amount that the temperature from Q to R remains constant until the whole mass has entirely solidified between Q to R. The mass is partly liquid and partly solid on further cooling from R to S the metal cools & solidified & tends to rich at room temperature.

(ii) The slope of P-Q. &R-S lines depend upon the specific heat of liquid and solid metal respectively.

Cooling curve from a binary solid solution:

(i) Curve portion P-Q is similar to pure metal, this binary systems consisting of two metals forming a solid solution.

(ii) However in a binary system during phasing period the temperature does no remain const.

(iii) Rather it drops along line Q-R till the whole mass is solid at point R

(iv) The dropping trend indicated that the alloy does not solidify. It possess a phasing does not maintain range which is due to the changes in the composition of solid & liquid phases.

(v) The solid cools along R-S to attempt the room temperature.

Cooling curve for a binary eutectic system.

(i) In this system the two components are completely soluble in liquid state, but entirely in the insoluble in the solid state.

(ii) Liquid cools along P-Q until temperature Q is reached.

(iii) At Q the component that is in excess will crystallizes & the temperature will draw along Q-R.

(iv) At point R the liquid compositions have been reached at which the two components crystallizesimultaneously from the solution (R-S).

(v) Then It cooling from S to T as usual in solidify Figure

Iron allotropy:

– Iron is relatively soft & ductile in nature. Iron has meting point of 1539^0C.

– Iron is allotropy metal which means it exists more than one types of lattice structure (BCC/ FCC) Depending upon temperature.

– In normal room temperature iron is BCC in lattice arrangement where as at 908^0C. it changes to FCC & then at 1403^0C. It backs to BCC & again vice versa.

– Another change occurs at about 770˚C (Curie point) at which the magnetic property of iron disappears& It becomes non-magnetic.

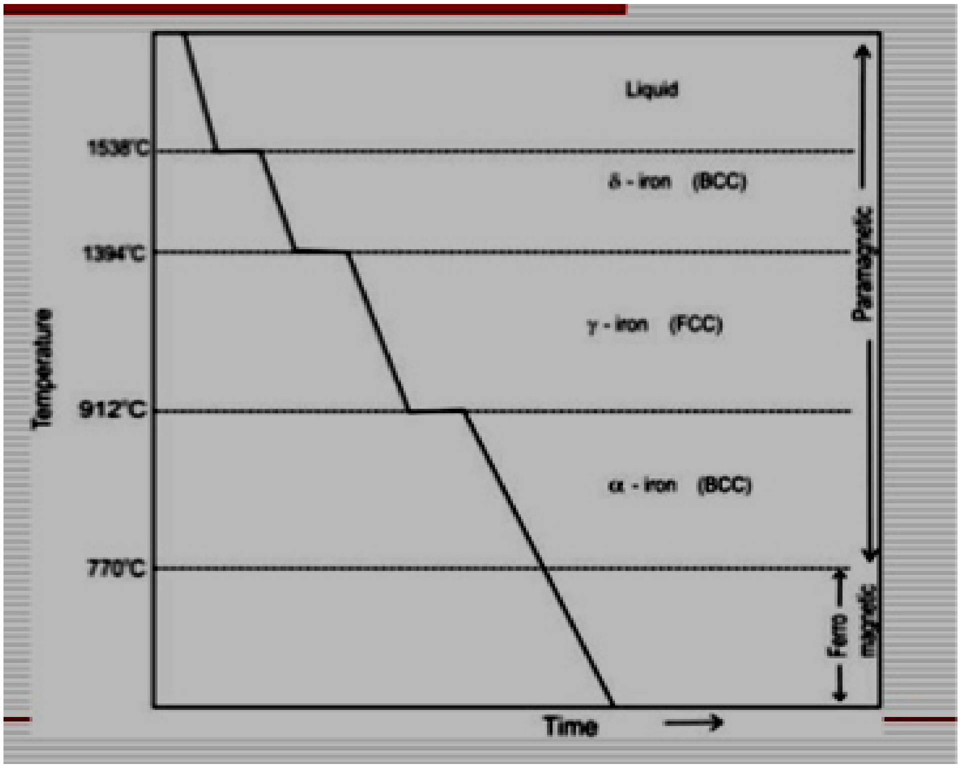
– The iron remains Non-magnetic until the temperature drops back below the Curie point upon which it's magnetic property reappear.

– In the figure iron is molted above 1539^0C & it solidify in the BCC б-form.

– On further cooling at 1400^0C a phase change occur & the atoms rearrange themselves into ᵞ-form which is FCC. Structure and non magnetic in nature.

– On steel further cooling at 910^0C another phase change occurs from FCC Non-magnetic ᵞ iron to BCC Non magnetic α iron.

– Finally at 768^0C the α iron BCC. Becomes magnetic without change in lattice structure.



(Cooling Curve for Pure Iron)

α – ferrite

γ– Austenite

б – ferrite

Fe_3C – Cementite

Iron carbon Alloy:

– Iron carbon alloys are widely used in practical application because it gives mechanical properties.

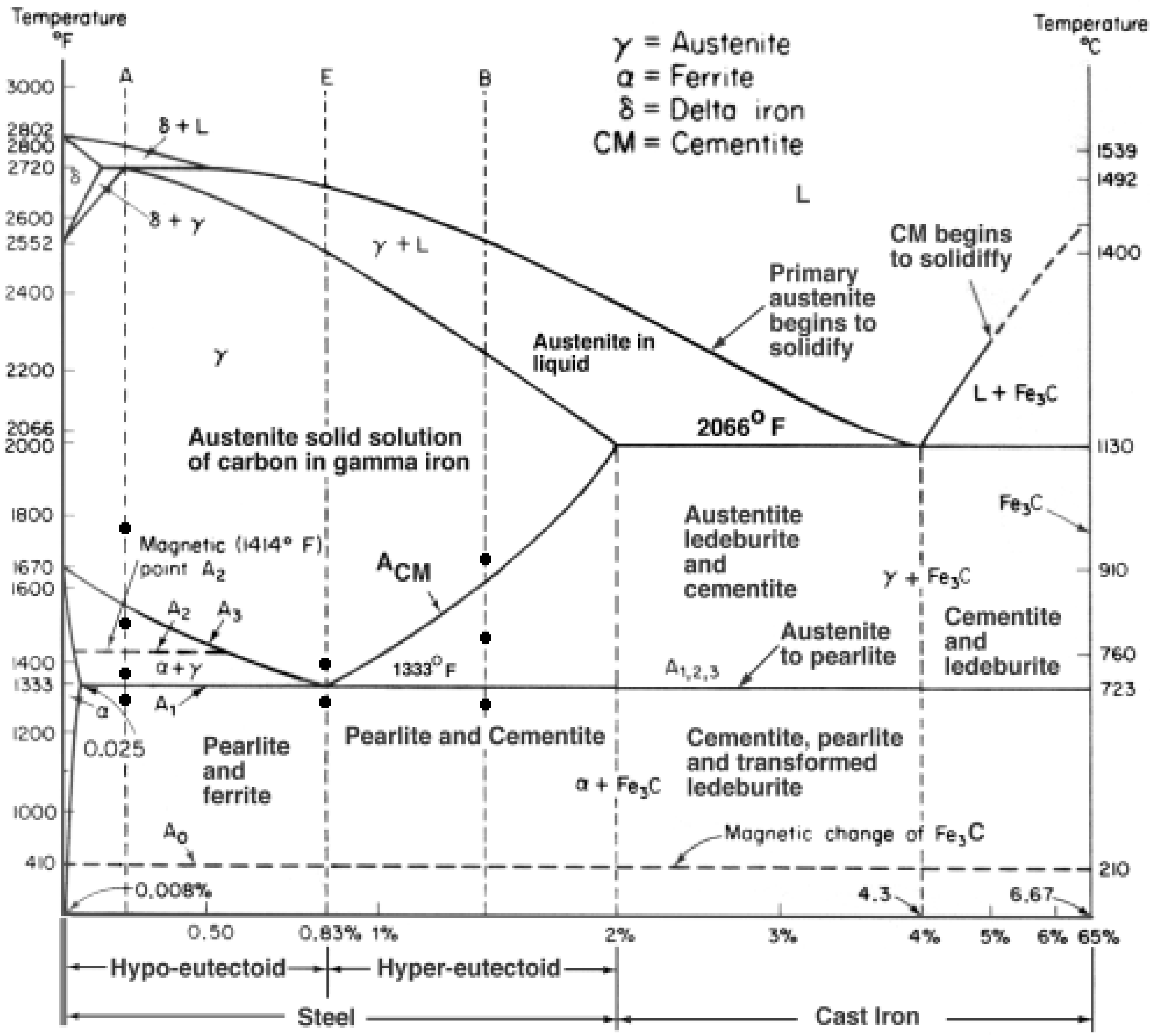
– The alloying elements in carbon, chromium, Nickel, silicon, manganese, etc. But the most important alloying element is carbon.

– Carbon forms solid solution & inter metallic compound with Iron.

– The internal compound of iron and carbon is carbide or cementite, which contains 6.67% carbon by weight.

– The phase diagram which shows iron carbon alloy is drawn by taking Iron, carbide, as components and the diagram is known iron carbide equilibrium diagram.

– In diagram the vertical time at the left represents the pure Iron.



– Various phases exiting in Iron carbon equilibrium diagram are:

(a) Alpha (α)ferrite:

(i) Ferrite is the name given to the interstitial solid solution of carbon in α-ferrite.

(ii) It has BCC crystal structure.

(iii) The solubility of carbon in α-ferrite is 0.008% at room temperature which increases 0.025% at 723 C.

(iv) It is the softest structure & ductile in nature that appears in iron carbon diagram.

(v) It is strongly ferromagnetic up to 768^0C after which it becomes Non-Magnetic in Nature. This temperature is called curie temperature.

(b) Austenite or (γ) iron:

(i) It is the solid solution of carbon in γ-iron.

(ii) The maximum solid solubility carbon in γ-iron is 2% at 1130^0C.

(iii) It is a soft, ductile & Non-magnetic in nature.

(iv) It has FCC crystal structure.

(v) It is stable above 723^0C.

(c) б- Ferrite

(i) It is an interstitial solid solution in carbon in б- iron.

(ii) It is stable between the temperature 1400^0C to 1539^0C..

(iii) The maximum solubility of carbon is б-iron is 0.012% at 1497^0C.

(iv) It has BCC crystal structure.

(d) Cementite : (Fe_3C)

(i) It is an intermetalic compound of iron & carbon.

(ii) It has a fixed carbon contained that is 6.67% by weight.

(iii) It has a complex crystal structure having 12 iron atoms & 4 carbon atoms in a unit cell that is 3:1 ratio.

(iv) It is hard & brittle in nature & having low tensile strength.

(v) It is the hardest structure that appears in iron- carbon diagram.

Difference Reactions occurring in iron carbon carbon equilibrium diagram.

(a) Peritectic reaction(P):

б + L ---1497^0C--→ ᵞ

(0.1%C) (0.5%C) (0.18%C)

– At temperature 1497^0C liquid having composition 0.5% carbon react with б-ferrite having composition of 0.1% carbon and give a single solid phase that is Austenite (ᵞ) having composition 0.18% carbon.

(b) Eutectic Reaction(E) :

L ---1130^0C--→ ᵞ + Fe_3C

(4.3%) (2%C) (6.67%C)

– Liquid having composition 4.3% carbon at 1130^0C transforms to 2 solid phases that is Austenite (ᵞ) and cementite (Fe_3C) having composition 2% carbon & 6.67% carbon respectively.

(c) Eutectoid Reaction (E'):

ᵞ --- 723^0C--→ α + Fe_3C

(0.8%) (0.025 %C) (6.67% C)

– Austenite having composition 0.8% carbon and at temp. 723^0C transforms to ferrite & cementite, simultaneously having composition 0.025%C & 6.67%C respectively.

- This eutectoid mixture is called as **pearlite. (α+Fe_3C).**

– It consists of thin lamellar structure of ferrite & cementite.

Critical temperatures:

- The temperatures at which phase change occurs during, heating and cooling are called critical temperature.

Eutectoid temp. (A_1):-

- The temperature at which austenite transfer to pearlite on cooling.
- This transformation occurs at 723 degree c. and is called eutectoid temperature.
- It does not depend on the % of carbon in the alloy. This temperature is also known as lower critical temperature.

Hypoeutectoid temp. (A_3):-

- It is the temperature at which free ferrite transforms to austenite while heating. It is the boundary between austenite and (γ+α) region.
- It is a function of carbon content.
- It increases from 910˚C. for 0% carbon and 723˚C. for 0.8% carbon .it is also known as upper critical temperature.

Hyper eutectoid temp. (A_{cm}):-

- It is the temperature at which free cementite transforms to austenite while heating. It is boundary between austenite and(γ+fe_3c) region.
- It increases from 723˚C for 0.8% carbon to 1130˚C. for 2% carbon.
- It is the function of carbon content. It is known hyper critical temperature.

CAST IRON

- Cast iron is the alloy of iron & carbon having carbon contain 2% to 6.67%.i.e more than the carbon content of austenite & less than that the carbon content of cementite.
- With the increase of carbon content the amount of cementite increase, which makes the cast iron hard & brittle. This becomes unsuitable for commercial application.
- Commercially cast iron contains 2% to 4% carbon & other alloying elements also present in slightly amount like Mn, Si, P, Cr, etc.
- Because of their poor ductility & malleability they cannot be subjected to any mechanical operation to get desire shape.
- They get lower melting point compare to steel. Hence they can be subjected to casting. Since casting is the only suitable process to get the desirable shape it is called as cast iron.

TYPES OF CAST IRON

- Cast irons are may be classified as**:-**
  - White cast iron
  - Gray cast iron
  - Malleable cast iron
  - Nodular cast iron
  - Chilled cast iron
  - Alloy cast iron

PROPERTIES

- They are cheapest compare to steel.
- They are easier to melt because of their low melting point .i.e. 1150^0C to 1300^0C.
- They are brittle & hard.
- They have excellent cast ability.
- Property can be easier adjusted by proper alloying & suitable heat treatment.
- They are highly corrosive resistance.