A LECTURE NOTE
ON
TH 3- ENGINEERING MATERIAL
SEMESTER -3

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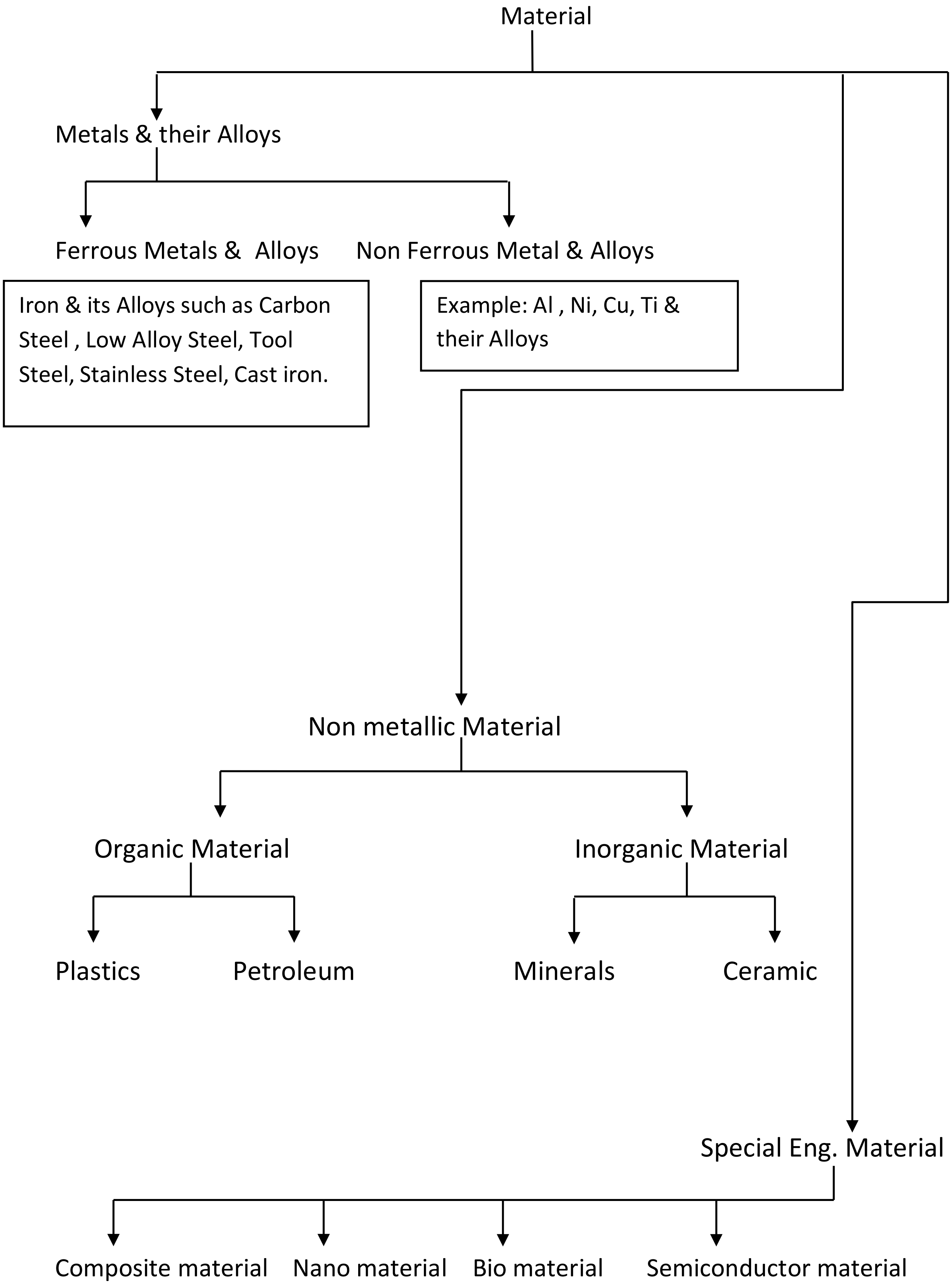
Classification of Engineering Material



Ferrous Material:

Ferrous materials are those materials whose main constituent is Iron.

Non Ferrous Materials:

These are the metals & alloys whose main constituent is not iron. Some other metal such as Cu , Al is its main constituent.

Properties of Material:

Properties of material are the characteristics of matter which differentiate one material from the other.

The major properties of material to be studied for selection of material in engineering field are:

1. Physical properties
2. Chemical properties
3. Mechanical properties

Physical Properties:

A materials physical properties denote the physical state of material. Physical properties include

1. Density
2. Specific Heat
3. Thermal Expansion
4. Conductivity
5. Melting Point
6. Porosity
7. Crystal Structure
8. Appearance

Chemical Properties:

Properties that describe how a substance changes into a completely different substance are called chemical properties.

Example of chemical properties are:

1. Oxidation resistance
2. Corrosion resistance
3. Flammability
4. Toxicity

Oxidation resistance:

The ability of metallic materials to resist chemical degradation of the surface caused by the action of air or other gaseous mediums at high temperatures.

Corrosion resistance:

Corrosion resistance is a basic property which prevents the deterioration of a material caused by reaction with surrounding environment. Corrosion attacks metals as well as non-metals.

Flammability:

Flammability is the ease with which a combustible substance can be ignited or the degree of difficulty required to cause the combustion of a substance.

Toxicity:

Toxicity is the degree to which a chemical substance or a particular mixture of substances can damage an organism.

Mechanical properties of Materials:

1. Strength
2. Stiffness
3. Elasticity
4. Plasticity
5. Ductility
6. Brittleness
7. Malleability
8. Toughness
9. Hardness
10. Machinability
11. Creep
12. Fatigue

Strength:

- It is the ability of a material to resist the externally applied forces without breaking.

- The internal resistance offered by a part to an externally applied force is called stress.

Stiffness:

It is the ability of materials to resist elastic deformation or deflection under the action of load.

Mathematically:

$$\text{Stiffness (K)} = \frac{\text{Load (W)}}{\text{Deflection } (\delta)}$$

Unit: KN / mm or N / mm

This property is considered during selection of material for spring manufacturing.

Elasticity:

It is a property by virtue of which a material regains its original dimension after removal of load. Elasticity is measured by Young’s Modulus or Modulus of Elasticity.

Unit – N / mm^2

Plasticity:

- It is the property by virtue of which the material does not regain its original shape after removal of load . I retains its deformed shape permanently.
- This property of the material is necessary for forging & rolling process.

Ductility:

- It is a property by which materials can be drawn into wires with the application of a tensile force.
- Ductile materials have the ability to flow or elongate under load. Example : Cupper , Aluminum , mild steel , nickel, zinc, tin & lead.
- The ductility of a material is commonly measured by means of percentage elongation and percentage reduction in area in a tensile test.

Brittleness:

It is the ability of a material by which it can develop crack under load or it can break suddenly.

Example : Wood , Concrete , Cast iron.

Malleability:

It is the property by virtue of which the material is able to be converted in to thin sheets.

Materials which are more elastic are also more malleable.

Example : Steel , Copper, Al, Brass, Bronze etc.

Toughness:

- It is the property by virtue of which a material is able to resist shock or impact loading.
- Impact loading means applied load fall from a height.
- The amount of energy absorbed per unit volume within elastic limit is know as Resilience.
- In the deign of springs toughness or resilience of material is considered.

Hardness:

- It is the property by which the material is able to resist scratches, marks or wear & tear.
- It also measures the ability of a material to cut another metal.
- Harness is independent of the weight of a material.

Brittle materials are more hard example: Glass, cast iron , concrete.

Machinability:

- It is the property of a material which refers to the ease with which a material can be cut.
- Machinability of a material can be measured by measuring the energy required to remove a unit volume of the material, keeping all machining parameters constant.
- It may be noted that brass can be easily machined than steel.

Creep:

- When a part is subjected to a constant stress at high temperature for a long period of time , it will undergo a slow and permanent deformation called creep.
- This property is considered in designing internal combustion engines, boilers and turbines.
- Super alloys resist creep failure as they can with stand high temperature for a prolonged period without developing stress.

Fatigue:

Fatigue is the property of mater by virtue of which the material fails under stress less than yield stress due to cyclic nature of stress.

Fatigue failure is responsible for 90% of mechanical failure.

Performance Requirement:

Performance requirement of an equipment or object is to be studied at the time of selection of its material to avoid failure of the object.

For example a component part to be used in a furnace must have high temperature resistance property.

It is not possible to assign quantitative values to all functional requirements. Hence while designing a component all the properties are to be considered to make reliable product which is also be cost effective.

Material's reliability:

- 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 for the intended life of the product without failure.
- A material if it corrodes under certain condition, then , it is neither stable nor reliable for those condition.

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. As another example, materials that gives off spark when struck have safety hazards in a coal mine.

FERROUS MATERIALS AND ALLOYS

CHARACTERISTICS OF FERROUS MATERIAL

- The main constituent of ferrous material is iron.
- Carbon, sulphur, manganese and phosphorous may exist in different proportion in different ferrous material.
- Iron , steel and other alloys of iron are known as ferrous material.
- These materials have good tensile strength and durability.
- Ferrous materials are magnetic in nature.
- These materials are good conductor of heat and electricity.
- Ferrous materials have high resistance to shear deformation.
- They are prone to rust.

STEEL

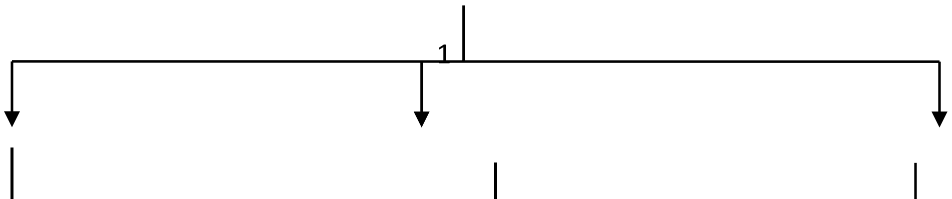
- Steel is a ferrous material, where the amount of carbon present is up to 1.5 percent and I is in the combined form.
- In other words steel is an alloy of iron and carbon where carbon content is up to 1.5 percent . This steel where only iron and carbon present is known as plain carbon steel.

CLASSIFICATION OF PLAIN CARBON STEEL

The plain carbon steels are classified into different groups as follows.

i) Low carbon steel which is again divided into dead mild steel and mild steel.
ii) Medium carbon steel
iii) High carbon steel

Plain carbon steel



Low carbon steel Medium carbon steel High carbon steel

Dead mild steel Mild steel

APPLICATION OF STEEL:

Types of Steel	Application
Dead mild steel	Welded and solid drawn tubes, thin sheets and wire rods. Forgings , stamping, structural sections such as angles and channels, plants for boilers and ships, bars and rods, wires, tubes and castings.
Medium carbon steel	Drop forgings, boiler drums, marine shafts and axles, rotors and discs, agricultural tools and implements, aero engine cylinders, high tensile tubes and wires, bright drawn bars, castings for automobile engine components, laminated springs for automobiles, helical springs , locomotive types, wire ropes, steel spokes, clutch plates, large forging dies, hammers and snaps for pneumatic riveters etc.
High carbon steel having	Springs, shear blades, wood chisels, cold sets, hammers
0.8% carbon	Small forging dies, boiler maker's tools
0.9% carbon	Cold chisels, cold working dies , punches and dies.
1.0% carbon	Springs, broaches, drifts, reamers
1.1% carbon	Press dies, punches, milling cutters, anvils, taps, wood working tools.
1.2% carbon	Taps, drills, screwing dies.
1.3% carbon	Files, razors , metal cutting tools for lathe, planer and

	slotter, mandrels and drawing dies.
1.4- 1.5% carbon	Lathe tools for machining harder metals, gauges, engraving tools.

ALLOY STEELS

Alloy steel are alloys of iron where in addition to carbon , other elements like silicon, manganese , sulphur and phosphorus in varying percentage present.

Few alloy steels which are called structural steel are:

1. Low alloy steel
2. Medium alloy steels
3. High alloy steel

1. Low alloy steel:

Those steels which possess alloying elements up to a maximum of 5 percentage.

2. Medium alloy steel:

Those in which the total content of alloying elements varies from 5 percent to 10 percent.

3. High alloy steel:

Those in which the content of alloying elements is more than 10 percent.

TOOL STEELS

These alloy steels have special applications in the manufacture of cutting tools used in various cutting and machining operation. There are two common types of alloy tool steels

1. **Low alloy steels**:

   Which contain silicon, chromium, manganese and tungsten as alloying elements and are capable of retaining a high degree of hardness up to a temperature of 250°C.

2. **High alloy steels**:

   Which mainly contain higher proportions of the carbide forming elements like tungsten, chromium, vanadium , etc. the presence of these carbides makes these alloys capable of retaining a high degree of hardness at elevated temperature up to 620 C. This steel respond very well to various heat treatments and obtained excellent wear resistance , high abrasion resistance and high red hardness. High speed steel (HSS) is one of this type of steel which is most commonly used in manufacture of cutting tools. The main alloying constituents are carbon , Tungsten, chromium, vanadium and molybdenum.

SPECIAL ALLOY STEELS

Stainless steels:

They are also known as corrosion resistant steels. Their principal alloying element is chromium while some other elements like nickel, manganese, etc. can also be present in small amount.

When 11.5 % or more chromium presence , a fine film of chromium oxide forms spontaneously on the surfaces. This film acts as a barrier to retard further oxidation, rust or corrosion.

EFFECTS OF ALLOYING ELEMENTS

The various alloying elements affect the properties of tool steels as follows:

1. **Chromium (Cr)**:
   - It joins with carbon to form chromium carbide, thus it improves hardenability , resistance to abrasion & wear.
   - Below 1.5% addition increase tensile strength and 12% addition imparts high corrosion resistance.

2. **Manganese (Mn):**
   - If percentage of manganese lies from 1.0 to 1.5, it increases strength and toughness.
   - Higher proportions up to 5 percent impart hardness accompanied by brittleness.
   - Still higher proportions, say between 11 to 14 percent, provide very high degree of hardness but lowers both ductility and weldability .

3. **Nickel (Ni):**
   - It improves toughness, tensile strength , ductility and corrosion resistance. Lowers the critical temperatures of steel & widens the range of successful heat treatment.

4. **Vanadium (V):**

- It improves tensile strength, elastic limit, ductility , shock, resistance . Promotes fine grain in steel.

5. Molybdenum(Mo):

- Its addition increase wear resistance, thermal resistance, hardness, ability to retain mechanical properties at elevated temperature and helps to inhibit temper brittleness.
- When added with nickel, it also improves corrosion resistance.

IRON –CARBON SYSTEM

METAL ALLOYS

- An alloy is a substance which is made up of two or more elements , out of which atleast one is a metal.
- The metal having greatest proportion in the alloy is called the base metal. All other elements present in the alloy are considered as foreign materials .
- Foreign materials which are added intentionally to obtain certain desirable properties are termed as alloying elements.
- Those undesirable elements which are present in the base metal or added accidentally during alloying process are known as impurities.
- A pure metal is comprised of a single substance whereas an alloy contains more than one constituents. Each of these constituents is known as a component. Therefore, a pure metal consists of a single component whereas an alloy can be binary (two- components) or ternary (three-components), etc.

PHASES OF AN ALLOY

- A phase is a distinct part of a system which is physically and chemically homogeneous and possesses its own distinct composition and properties.
- If there is a change in the phase there will be corresponding change in their properties .
- All the forms in which a solid alloy can exist , i.e solid solution, intermetallic compound , a mechanical mixture or a combination of these , are termed as different phases.

PHASES DIAGRAM

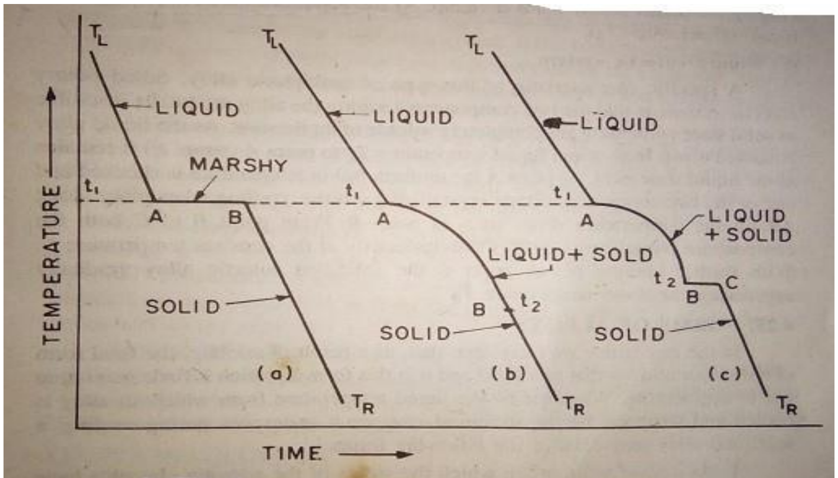
- Phase diagram is also known as equilibrium diagram or constitution diagram. These diagram represent graphically the changes occurring in the state of an alloy on account of the changes in temperature and concentration.

- The phase diagram shows the phase transformation of an alloy which occur while heating or cooling under equilibrium condition.
- This diagram are known as constitutional diagram because they indicate the constitution and nature of alloys and the composition of phases in a given system.
- When no chemical reactions occur between different components in a system, then the phase rule can be stated as $f = C - P + 2$ *or* $P \quad C + 1$
- Where, C is number of components in the system;
- P is number of phases which can co exist,
- 2 represents the no of external factors (temperature and pressure)
- *f is degree of freedom. It is the maximum number of variables that may be independently* varied without changing the number of phases in equilibrium.
- *Therefore , we conclude that the maximum number of phases in a system under equilibrium can never exceed the number of components plus one.*
- *That is in a binary system a maximum number of three phases in a ternary system four phases and so on can be in equilibrium.*

COOLING CURVE & PHASE TRANSFORMATIONS

- A cooling curve is a graph which shows the variation in temperature with time when a material is cooled down from liquid phase. It also indicates the temperature at which the phase changes in a metal or alloy system take place as they are cooled from their liquid phase. It helps in studying the structural changes which occur during solidfication of metals and alloys. Equilibrium or phase diagrams are constructed with the help of these cooling curves.
- When a metal or alloy is cooled down from its fusion state latent heat is evolved because of the changes taking place in the structure of the metal or alloy during solidification. On account of this, some stages occur during cooling at which it is observed that the uniform rate of fall in temperature is checked for a certain period.

- This specific point where the check occurs is known as critical point.
- The cooling curve for a pure metal, a binary solid solution and binary eutectic system is elaborated for describing the use of cooling curve in phase diagram.



Cooling curves for (*a*) Pure metal or compound, (*b*) Binary alloy or solid solution, and (*c*) Binary eutectic system or partially miscible solid solution.

COOLING CURVE FOR PURE METAL

- The melting temperature of any pure material (a one component system) at constant pressure is a single unique temperature . The liquid and solid phases exist together in equilibrium only at this temperature . This temperature is known as critical point temperature.
- As shown in the above graph (curve a) the liquid metal cools down from its liquid state (temperature T_L) to temperature t_1 (Point A). At this point (critical point) solidification starts and continues upto point B, where the metal becomes fully solid. From point A to B the temperature remains constant and latent heat is evolved .
- During this period the metal is in a marshy state, i.e partly liquid and partly solid. As the metal is further cooled below point B it approaches the room temperature (T_R). The specific heats of liquid and solid metal will determine the slopes of the lines T_L-A and B-T_R respectively.

BINARY SOLID SOLUTION

- The initial portion of the cooling curve (T_L-A) for a binary solid solution, i.e two metals forming a solid solution, is exactly similar to that of the pure metal. But , during solidification from point A to B i.e as the temperature changes from t_1 to t_2, there is a continuous fall of temperature , unlike in pure metal where it was constant during this stage. At point B the complete mass becomes solid. As cooling continues below point B (temp t_2) the solidified metal approaches the room temperature (T_R).

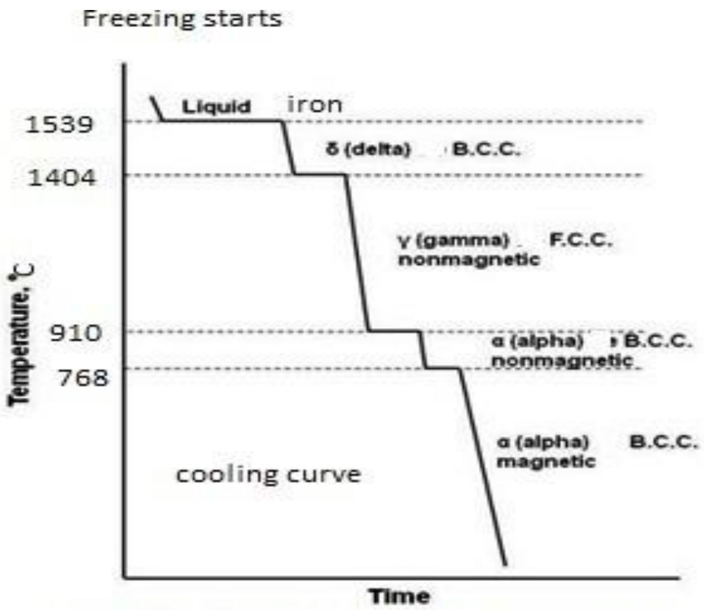
BINARY EUTECTIC SYSTEM

- A specific characteristic of this type of multiphase alloy, called binary eutectic system is that the two components forming the alloy are totally insoluble in solid state while they are completely soluble in liquid state. As the liquid alloy is cooled down from some liquid temperature T_L to point A (temp. t_1) it remains in the liquid state only.
- At point A the uniform fall in temperature is checked and one of the two components starts crystallising . Further cooling takes place along AB till the temperature drops to t_2 at point B. from point B to C both the components crystallise (solidify) simultaneously at the constant temperature t_2. with further cooling below point C the solidified eutectic alloy gradually approaches the room temperature T_R.

ALLOTROPIC FORMS OF IRON

- Iron is a soft and ductile metal. Melting point of iron is 1539 C. It is an allotropic metal i.e it exists in different lattice structures at different temperatures . Its main allotropic forms are delta ( ), gamma ( ), and alpha ( ). Above 1539 C iron is in liquid state. During cooling at 1539 C temperature remains constant till entire liquid iron solidifies and changed to form having Bcc structure.
- Temperature starts reducing from 1539 C to 1404 C after solidification of entire liquid iron where iron gets cooled. Again at 1404 C another phase transformation takes place where iron changes to iron having Fcc structure iron is non magnetic.

- During cooling again temperature of iron starts reducing from 1404 C to 910 C. At 910 C, there is a sudden check in the fall of temperature and another phase transformation takes place. It continues till the entire iron is transformed to iron with Bcc structure. iron is nonmagnetic above 768 C.
- At 768 C iron is not transformed from Bcc structure but its magnetic property changes and below 768 C it becomes highly magnetic.



cooling curve and allotropi transformations in iron

PHASE TRANSFORMATIONS IN IRON-CARBON SYSTM

- During casting , heat treatment , metal forming or when the alloy solidifies from liquid state , grain formation takes place. During these metallurgical processes phase transformation takes place.
- Due to this phase transformation various microstructures developed and properties of the alloy change.

PRINCIPAL MICRO-CONSTITUENTS OF AN IRON- CARBON SYSTEM

- When melted alloy allowed to cool from liquid phase at different rates of cooling, the following micro-constituents are formed.

AUSTENITE

- The solid solution of ferrite and iron carbide in gamma iron is known as austenite. It is soft and non magnetic. This solid solution carries max 1.8% carbon at 1130 C. Below 723 C it changes into pearlite and ferrite .

FERRITE

- It is a Bcc phase of iron in which very small amount of carbon can be dissolved. It is purest form of iron and is very soft, ductile but highly magnetic.

CEMENTITE (Fe3C)

- It is a very hard and brittle interstitial compound of iron and carbon. It has high compressive strength and low tensile strength . It is magnetic below 200 C.

LEDEBURITE

- It is an eutectic mixture of austenite and cementite . It is formed at around 1130 C and carries 4.3% carbon.

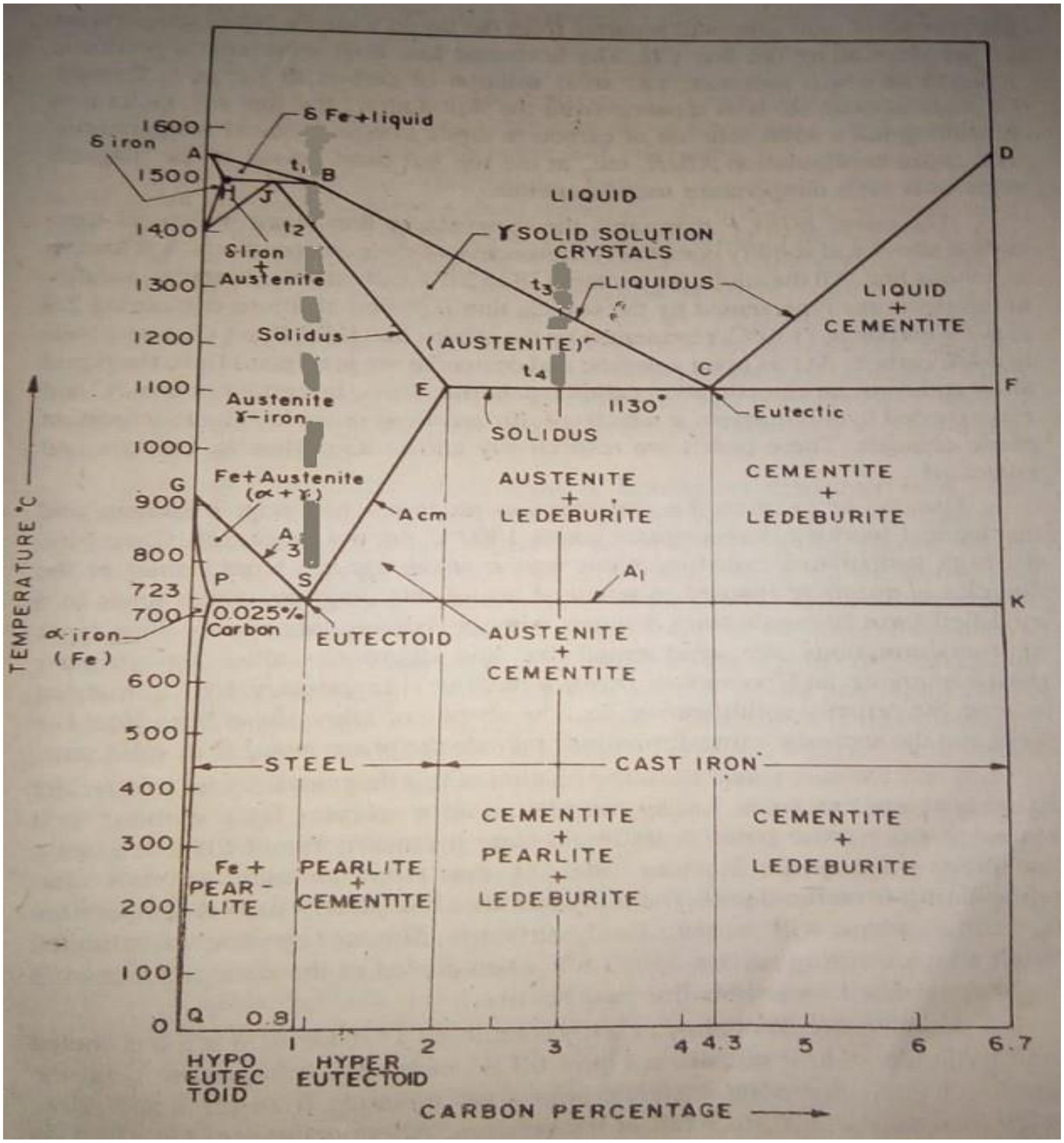
PEARLITE

- It is a mechanical mixture of ferrite and cementite . It is produced by decomposition of austenite through an eutectic reaction. Steel with 0.8 percent carbon converted to fully pearlitic structure i.e alternate layer of ferrite and cementite. This steel with 0.8 percent carbon is known as eutectoid steel. Steel with less than 0.8 percent carbon is known as hypoeutectoid steel and having more than 0.8 percent carbon is known as hypereutectoid steel.

- Other important micro-constituents are Bainite, Martensite, Troostite and Sorbite. These micro-constituents resulted during Heat treatment of steel.

IRON CARBON EQUILIBRIUM DIAGRAM:

This diagram graphically represent the effects of temperature and composition on all the phase present in iron carbon alloys i.e plain carbon steels and cast irons. This diagram is constructed by plotting the temperature along the ordinate and the carbon percentages along the abscissa. Apart from indicating the temperature ranges and carbon percentage in the alloy it also indicates the boundaries at which the phase change take place.



- Above the curve ABCD the alloys remain in liquid state irrespective of their composition. The curve ABCD represents the temperature line along which solidification of the alloy starts. It is known as liquid us line .
- Point A on the curve represent the melting point (1539°C) of pure iron.
- Point D on the curve represents the melting point (1550°C) of cementite (iron carbide).
- Curve AB represents separation of δ iron crystals from liquid.
- Curve BC represents separation of austenite crystals from liquid metal.
- Curve CD represents separation of cementite crystal from liquid.
- The horizontal line HJB represents a peritectic reaction in which austenite (solid solution of carbon in γ – iron) is formed.

The curve AHJECF represents the temperature line along which all iron-carbon alloys will solidify completely. It is known as solidus line.

The curve HJE represents the temperature line for steel alloy containing 0.18 % to 2.0% carbon, along which the alloy will solidify.

The curve ECF is the solidus line for cast iron (containing 2.0% to 6.7% carbon).

Point C corresponds to 1130°C and 4.3% carbon in the alloy , which is known as eutectic point.

At this point austenite and cementite are precipitated from liquid alloy and form ledeburite.

Curve EC represents solidification of the alloy containing carbon content of 2% to 4.3% which is known as hypoeutectic alloy. In this case the solid phase will contain austenite and ledeburite.

Curve CF represents complete solidification of alloy containing 4.3 % to 6.7 % of carbon known as Hypereutectic alloy. Here solid phase will contain cementite and ledeburite.

In the secondary transformation zone i.e the transformation occurs in iron –carbon alloys in solid state one salient point is represented by S is known as eutectoid point. Point S corresponds to 723 °C and 0.8% carbon in solid phase. At this point ferrite and cementite separate simultaneously to form a new structure called pearlite.

Steels having less than 0.8% carbon are called hypoeutectoid steels and those having more than 0.8% carbon are known as hypereutectoid steel . The steel which contain exactly 0.8% carbon is known as eutectoid steel. The hypoeutectoid steel below the line GS results ferrite and pearlite.

Similarly ,hypereutectoid steels below the line ES will consist of pearlite and cementite.

CRYSTAL IMPERFECTION

- A crystal or crystalline solid is a solid material whose constituents (such as atoms, molecules or ions) are arranged in an ordered pattern and its surface regularity reflects its internal symmetry.
- This pattern is periodic in three dimension.
- In other words, Whenever atoms arrange themselves in an orderly repetitive three dimensional pattern, a crystal is formed.
- A perfect crystal is constructed by the infinite regular repetition of identical structural units or building blocks in space .
- All metals are crystalline, where atoms are arranged in a definite periodic order.

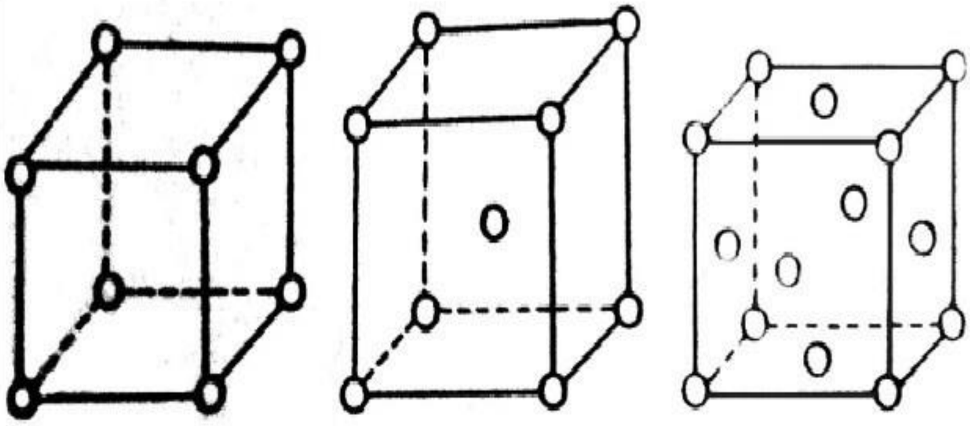
CLASSIFICATION OF CRYSTALS

- On the basis of periodic arrangement of atoms, crystals are grouped into seven systems.

  The systems are :

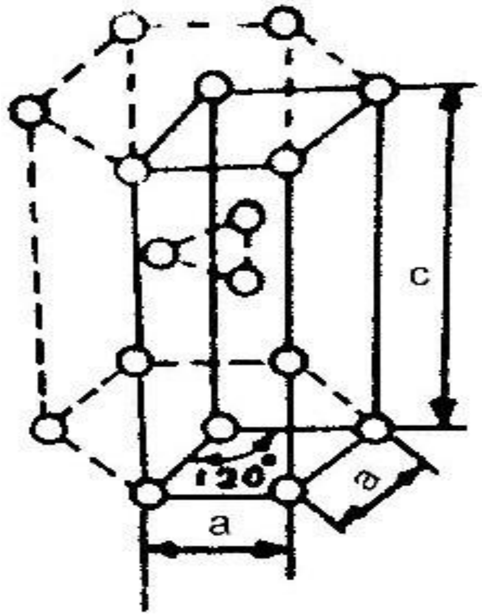
- Cubic, tetragonal, orthorhombic, rhombohedral, hexagonal, monoclinic and triclinic.
- Most of the metals and alloys belong to cubic and hexagonal crystal structure. So these two types of systems are shown below:
- In crystal structure, the smallest unit is one unit cell which characterizes the specific arrangement and location of atoms.
- There are three types of unit cells with cubic crystal structure such as SC, BCC, FCC.

CUBIC CRYSTAL STRUCTURE



Simple Cubic (SC) Body Centred Cubic (bcc) Face Centred Cubic (fcc)

Hexagonal Crystal Structure



Example: Metals like Be, Mg and Zn

IDEAL CRYSTAL

- In ideal crystals, the angles between the faces which determine the crystal form are same.

CRYSTAL IMPERFECTIONS

- Crystals are not perfect.
- All crystals are not composed of identical atoms on identical sites throughout a regularly repeating 3D lattice.
- These imperfection influence the characteristics like mechanical strength, electrical properties and chemical reactions.

CLASSIFICATION OF IMPERFECTIONS

- Defects are classified into points defects, line defects , surface defects and volume defects.

POINT DEFECTS

- A point defect in a crystal lattice is totally localised . A lattice structure is said to contain point defect , if either an atom is missing or is in an irregular place.
- In crystal lattice, internal energy of the crystal increases and free energy of the structure decreases due to presence of point defects.

TYPES

- Vacancies, interstitialcies and impurities are example of point defects.

VACANCIES

- A vacancies means a vacant site i.e absence of an atom from a normally occupied site within a crystal lattices.
- These vacancies occur due to imperfect packing of atoms during original crysalizsation or due to increased thermal energy resulting in thermal Vibration of atom.

SCHOTTKY DEFECT

- It is closely related to vacancies.
- This defect occurs when an atom or an ion is dislocated from a normal lattice site inside and is relocated in some position on the surface of the crystal.

INTERSTITIALCIES

- When an atom is displaced from a regular site and occupies an interstitial site, an interstitialcy is formed.
- It also gives rise to lattice distortion because interstitial atom tends to push the surrounding atoms apart.
- The smaller the size of interstitial atoms ,smaller the defect.

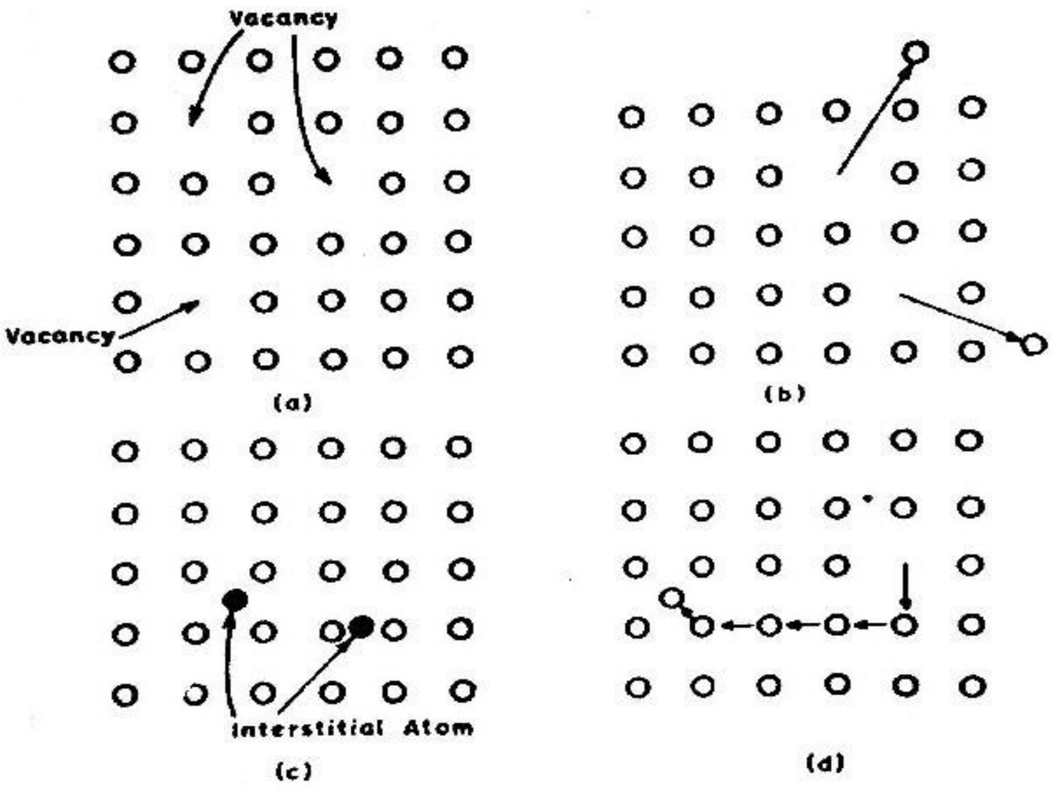
FRANKEL DEFECT

- It is closely related to interstices.
- In this, an atom in a crystal leaves its site and occupies an interstitial site in the crystal structure .
- The vacancy so caused and the interstial atom are known as Frankel Defect.
- This defect is more pronounced in open structures than close packed structures.

IMPURITIES

- Impurities are foreign atoms which are present in the crystal lattice. Impurity atoms may occupy either interstitial or substitution position.
- It is a small atom occupies an interstitial void space between atoms at lattice points of the crystal.

VARIOUS TYPES OF POINT DEFECTS



(a) Vacancy , (b) Schottky defect, (c) Interstitialcy, (d) Frankel defect

LINE DEFECTS

- The main two-dimensional or line defects are dislocations.
- A dislocation is a linear disturbance of the atomic arrangement of a crystal.
- Along the line of dislocation atoms in a solid are arranged anomalously.
- The crystalline order is restored on either side of a dislocation but the atoms on one side have moved or slipped.

CAUSES OF LINE DEFECT

- Dislocations are generated and move when a stress is applied.

Types:

Dislocation are of two types:

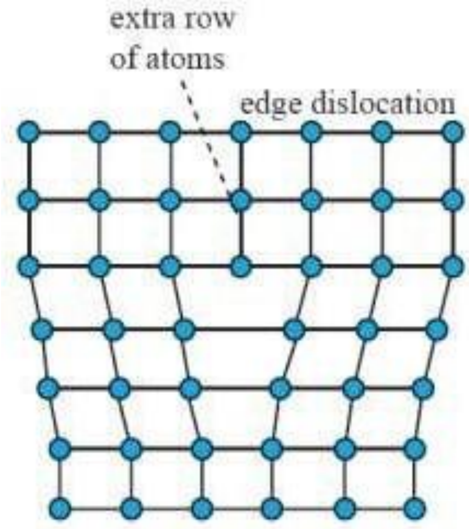
1. Edge dislocation or Taylor or wan dislocation
2. Screw dislocation or Burger's dislocation

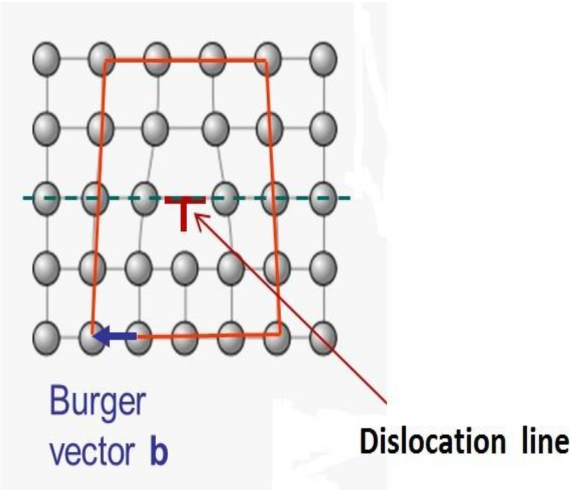
EFFECTS

- Slip occurs due to dislocation, which causes plastic deformation of metals .dislocation causes other mechanical phenomena like fatigue , strain hardening etc.

EDGE DISLOCATION

- When within a crystal structure atoms are removed from a portion of a plane , an edge dislocation occurs at the end of the remaining extra half plane of the atoms.
- An edge dislocation is always accompanied by the zones of compression and tension.
- In edge dislocation the burger vector is perpendicular to the direction of dislocation.

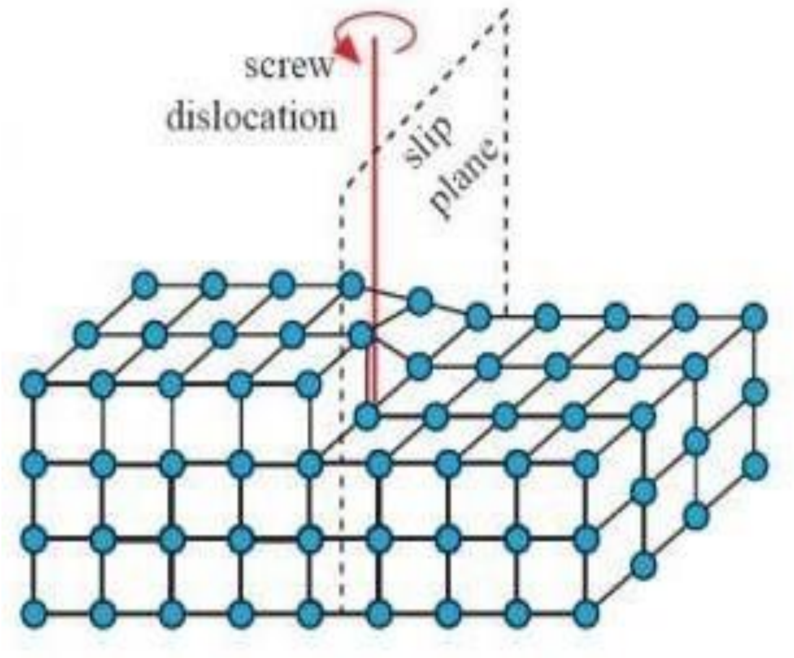




- The atoms just above the slip plane are in compression and those just below the slip plane are tension .
- A stress field , therefore always surrounds such dislocation.
- When the extra row of atoms is above the slip plane it is called positive and is denoted by sign When the extra row of atoms is below the slip plane, it is called negative edge dislocation and is represented by sign T .

SCREW DISLOCATION

- In this type of dislocation the displacement of atoms occurs in two different planes which are mutually at right angles to each other.
- The lattice points displaced around the dislocation in the lattice follow a helical path, and it is for this reason that it is named as screw dislocation.
- In screw dislocation the burger vector lies parallel to the direction of dislocation.



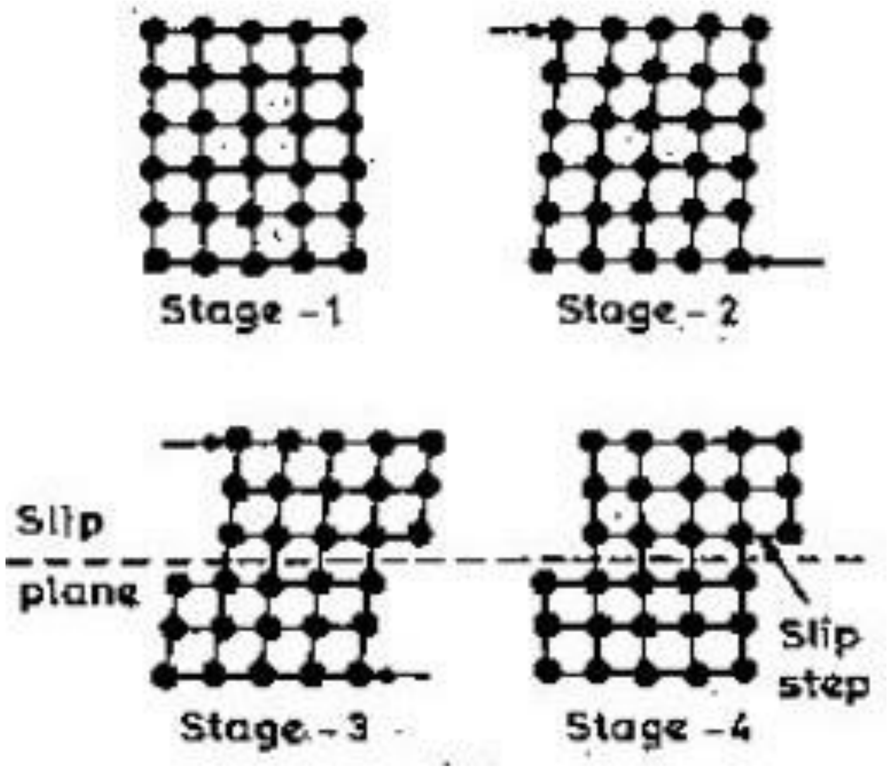
EFFECT OF IMPERFECTION ON MATERIAL PROPERTIES

- It affects or influence the characteristics like mechanical strength, electrical properties and chemical reactions.
- The role of imperfections in heat treatment is very important. Imperfections account for crystal growth , diffusion mechanism, annealing and precipitation, besides this, other metallurgical phenomena, such as oxidation, corrosion, yield strength, creep, fatigue and fractures are governed by imperfections.
- Imperfections are not always harmful to metals. Sometimes they are generated to obtain the desired properties. For example, carbon is added to steel as interstitial impurity to improve the mechanical properties and this properties are further improved by heat treatment.

DEFORMATION BY SLIP AND TWINNING

Slip: –

- Metals deform plastically by slip. Slipping is facilitated in the presence of dislocation.
- Slip is defined as the process or mechanism by which a large displacement of one part of the crystal relative to another along particular crystallographic planes takes place.
- There may be one or more slip planes and one or more slip directions in each crystal. Slip begins when the shearing stress acting along the slip planes in the direction of slip exceeds a certain value known as critical shear .
- Slip planes are planes of high atomic densities while the direction of slip along these planes is always the direction of highest atomic density.
- The displacement of dislocations takes place in such a manner that the displaced atomic blocks do not revert back to their original shapes and locations even after the external force is withdrawn resulting in a permanent deformation.



TWINNING

- Other than slip, twinning also gives rise to plastic deformation in crystals. It may be called as a special case of slip movement. As shown in the figure the two regions called perfect regions, shown on either side of the disturbed region, carry atoms of which the positions are not disturbed during the process. The atoms contained between the two parallel twinning planes lie in the disturbed area known as twin band or distorted region. The positions of these atoms are changed as a result of twinning.

- Under this mechanism the applied stress acts along the twin planes and under the action of this stress the direction in which this plane moves is called the direction of twinning.

- This process makes the region lying between the two twin planes to shear in a homogeneous manner.

- While the two portions of the crystal lying on either side of the twin planes remain undistorted.

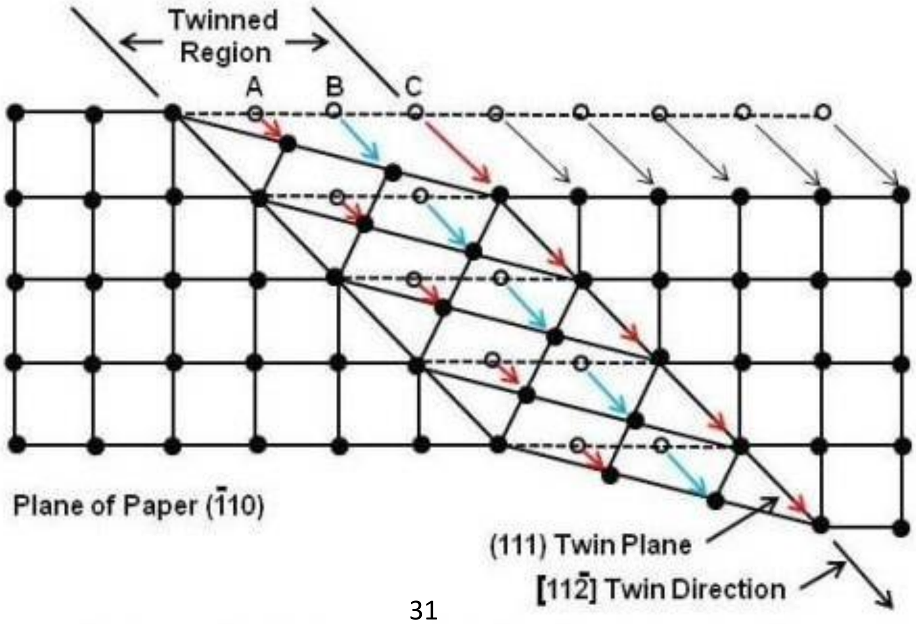
- The process of plastic deformation by twinning does not occur as frequently as slip. A metal will deform by twinning normally when it can not deform by slip.

- The cubic metals having fcc, bcc or hcp structures deform by twinning only under special conditions, such as at low temperatures or during fast forming processes.

- Iron for example, will twin when shock load (impact) is applied to it or if the applied stress nears its brittle state. Similarly, in hcp crystals twinning may occur when the applied stress is almost normal to the slip plane.

- Twinning normally occurs:

1. During mechanical deformation, called mechanical twinning.
2. During annealing after plastic deformation, called annealing twinning



EFFECT OF DEFORMATION ON MATERIAL PROPERTIES

- The mechanical properties are greatly affected by deformation i.e plastic deformation. The deformation process like rolling, forging, extrusion, drawing. Strain hardening takes place, so hardness changes. Elasticity changes, cracking takes place, grain growth takes place. Residual stress are produce in cold working.

HEAT TREATMENT

DEFINATION:

Heat treatment is the process of heating of solid metal to specified temperature, holding them at that temperature for sufficient time to obtain uniform metal structure and then cooling the metal at a predetermined rate in a suitable media to acquire desired internal structure and desired properties.

PURPOSE OF HEAT TREATMENT

The objective of this process is to make the metal better suited, structurally and physically, for some specific applications. Heat treatment may be undertaken for the following purposes.

(i) To relieve internal stresses set up during operations like casting , welding , hot & cod working
(ii) For improving mechanical properties like hardness, tensile strength, toughness and ductility.
(iii) Refinement of grain size.
(iv) Improving machinability
(v) Changing internal structure to improve their resistance to heat , wear and corrosion.
(vi) To soften them to make suitable for operations like cold rolling and wire drawing.
(vii) To improve their electrical and magnetic properties.
(viii) To make their structure homogenous so as to remove coring and segregation.
(ix) To drive out trapped gases.

ANNEALING

Annealing involves heating to predetermined temperature, holding at this temperature and finally **cooling at a very slow rate**. The temperature to which the steel is heated and the holding time are determined by various factors such as chemical composition of steel, size and shape and final properties required. The various purposes for this treatment are to

(i) Relieve internal stresses developed during solidification, machining, forging, rolling or welding.

(ii) Improve or restore ductility and toughness.

(iii) Enhance machinability.

(iv) Eliminate chemical non-uniformity.

(v) Refine grain size.

(vi) Reduce the gaseous contents in steel.

(vii)Obtain certain changes in some mechanical , electrical and magnetic properties.

(viii) Produce desired micro structure.

Annealing process is classified into five different types. These are:

1. Full annealing
2. Process annealing
3. Spheroidise annealing
4. Diffusion annealing
5. Isothermal annealing

1. FULL ANNEALING:

This process involves heating of steel to a temperature about 30°C to 50° C above the higher critical point for hypoeutectoid steels and by the same amount above the lower critical point for hypereutetoid steels , holding it at that temperature for sufficient time to allow the internal changes to take place and then cooling slowly.

For cooling the specimen is allowed approximately 3 to 4 minutes time at elevated temperature per mm thickness of the largest section. Cooling from high temperature is usually done in the furnace itself by allowing a fall of temperature at the rate of 10 to 30° C per hour. This fall of temperature is allowed to continue till the temperature of the specimen come down to 30° C below the lower critical temperature.

When steel is heated to the annealing temperature its structure is converted into homogenous single phase austenitic form and then slow cooling enables the transformation of austenite into pearlite plus ferrite or pearlite plus cementite, depending upon the percentage of carbon content. These constituents are comparatively softer and hence the steel gets softened by this process, together with an appreciable amount of increase in its ductility and toughness.

2. PROCESS ANNEALING:

In this process the metal is heated to a temperature slightly below the lower critical temperature (that is between 550° C to 650 °C). held their for sufficient time to allow recristalization and then cooled at a slower rate in air.

This process is known as low temperature annealing or soft critical annealing or commercial annealing. By this process ductility, resistance and machinalibility increases and internal stresses are removed but hardness id reduced to some extent.

This process is highly useful for mild steel and low carbon steel to remove stresses generated due to cold working and soften the metal to be ready for further deformation without failure due to fracture.

3. SPHEROIDISE ANNEALING:

Main objective of this process is to produce a structure of steel having well dispersed spheroids of cementite in ferrite matrix.

This method is mainly used for high carbon steel to improve their machinability and is used for low carbon steels only when strength is to be increases to undergo some other heat treatment process.

In this process the steel is heated to a temperature slightly above the lower critical point (between 730° C to 770°C) depending upon the carbon percentage, holding it at that temperature for sufficient time and then cooling it in the furnace to a temperature of 600° C to 550° C followed by slow cooling to room temperature in still air.

4. DIFFUSION ANNEALING:

In this process the metal is heated to a temperature between 1100° C to 1200°C that is diffusion temperature of steel , held for a short period for completion of diffusion and cooled down to between 800°C to 850° C , keeping inside the shut off furnace for 6 to 8 hours and further cooled down to the room temperature in air.

This process is used for removing heterogeneity in the chemical composition of steel ingots and heavy castings before applying full annealing .

5. ISOTHERMAL ANNEALING:

This process consist of heating steel to austenite state , cooling it to a temperature of about 630° C to 680° C at a relatively faster rate , holding it at this temperature isothermally for some time and then cooling it to the room temperature at rapid rate. during the isothermal holding full decomposition to pearlite structure takes place and the metal become soft.

This process is widely used for alloy steels to save cooling time for obtaining pearlite structure .

NORMALIZING

Normalizing is a process of heating steel to about 40-50°C above upper critical temperature, holding for a relatively shorter period of time (about 15 min) and then cooling in still air or slightly agitated air to room temperature. After normalizing the resultant microstructure is ferrite plus pearlite for hypoeutectoid steels, total pearlite for eutectoid steels and pearlite plus cementite for hypereutectoid steels . In case of alloy steels the final structure is sorbite plus ferrite.

Objectives achieved through normalizing are:

1. Internal stresses caused during previous operation are removed .
2. Internal structure is refined to fine grains.

3. Mechanical properties of steel are improved.
4. Impact strength ,yield point and ultimate tensile strength of steels are improved.

Rolled and forged steels possessing coarse grains due to high temperatures involved are subjected to normalizing. Normalized steels are generally stronger and harder than fully annealed steels but are less ductile.

It can be concluded that to improve the mechanical properties normalizing process is preferred but to attain better machinalibility , softening and greater removal of internal stresses annealing process is employed.

HARDENING

Hardening consists of heating to hardening temperature (30° C to 50 °C above higher critical point for hypoeutectoid steels and by the same amount above the lower critical point for hyperutectoid steels) , holding at that temperature for sufficient time to attain austenitic structure , followed by rapid cooling such as quenching in water oil or salt baths. High hardness developed by this process is due to phase transformation with rapid cooling.

In this process due to rapid cooling , austenite is changed to martensite which is a very hard substance. The hardened steel becomes very brittle and hard.

Though this process is applied to all cutting tool, all machine parts made from alloy steel , dies and machine parts subjected to heavy duty work, the process is followed by tempering in order to remove extra brittleness , relieve stresses and obtain better mechanical properties.

TEMPERING

The process which consists of heating hardened steel below the lower critical temperature, holding it at that temperature for sufficient time, followed by cooling in air or at any other desired rate, is known as tempering.

This process enables transformation of martensite into tempered martensite (α+Fe3C).

This treatment lowers hardness of the hardened steel marginally but improves ductility. The higher the tempering temperature and tempering time , the more is the restored ductility and toughness of the steel. Proper tempering treatment results in optimum combination of mechanical properties than annealing and normalizing .

STRESS RELIEVING MEASURES:

Stress relieving does not change the material’s structure and does not significantly affect its hardness. Stress relieving is a heat treatment process where a metal or alloy is heated to a predetermined temperature below its lower transformation temperature followed by cooling in air.

The primary purpose of this process is to relieve stresses that have been absorbed by the metal from metal forming or metal machining processes.

By this process the residual stresses in the structure is minimized as a result of which the risk of dimensional change during further manufacturing or final use of the component is reduced.

SURFACE HARDENING

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

It is carried out by following operations

(a) carburising

(b) Nitriding

(c) Carbonitriding

(d) Cyaniding

(e) Induction hardening

(f) Flame hardening.

CARBURISING

It is the process of producing a hard surface on low carbon steel parts. In this process the steel is heated to 870° C to 950° C and at this alleviated temperature carbon is infused into the surface of steel by diffusion from carbon monoxide gas.

There are three methods of carburising such as

(a) Pack or solid carburising

(b) Gas carburising

(c) Liquid carburing.

PACK OR SOLID CARBURIZING

In this process, in first stage the metal is enclosed in a cast iron or steel box containing a material rich in carbon and heated to a temperature slightly above the critical point and allowed to remain at that temperature for a sufficient time and then allow to cool slowly within the box and then removed.

In second stage the metal is reheated to about 900° C and then quenched in oil so that its structure is refined , brittleness removed and the core becomes soft and tough. The metal is then reheated to about 700° C and quenched in water or oil to obtained hardnebility of the outer casing which was soften during the preceding operation.

LIQUID CARBURIZING

For Liquid carburizing liquid salt bath of cyanide ,chlorides and carbonates are prepared and the parts to be case carburized immersed in them. Heating of the bath is done by means of electrodes immersed in the bath. Stirring of the bath is necessary to ensure uniform temperature . if the entire component is to be carburized then no additional treatment is necessary, but if only some selected portion of the component are to be carburized the remaining potions are covered by copper plating.

Temperature for liquid carburing vary from 843° C to 927 °C. After carburising is over the components are removed from the bath and quenched in water, oil or brine. Some major advantage of this process are uniform heating , very little deformation of article greater depth of penetration possible.

GAS CARBURIZING:

In gas carburizing process the components are either suspended in the gas furnace from hooks or are heated in a horizontal rotary type gas carburizer and hydro-carbon rich gases like natural gas (methane, propane etc) mixed with carbon monoxide or carbon dioxide is fed into the furnace to maintain a controlled atmosphere. There is a provision for exhausting the spent gases into atmosphere.

After the parts have been soaked in the carburizing chamber they are directly quenched without being exposed to atmospheric air. It is found that a 4 hours heating in a gas carburizing temperature of about 927 °C enables a depth penetration of about 0.5 mm to 0.75 mm.

The main advantages of this process are a superior surface finish on the component, controlled heating, accuracy of desired case depth.

NITRIDING:

Nitriding is a surface hardening process. The introduction of nitrogen into the outer surface of steel parts in order to give an extremely hard, wear resisting surface is called nitriding. It is based n the absorption of nitrogen by the metal and no quenching is required.

This process can be performed both in gaseous atmosphere as well as in salt bath.

In gas nitriding the parts are heated in an atmosphere of ammonia to a temperature between 480 C to 630 C and held there for a fairly long period for Nitrogen to decompose from ammonia and to combine with the alloying elements in steel to form nitrides.

It is used for various automotives, airplane and diesel engine parts like cylinders, sleeves, liners etc.

Hardenability

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

In other words Hardenability is the ease of formation of martensite by quenching.

The main factors affecting hardenability are:

(a) Alloying elements (Addition of alloying elements to carbon steels will increase their hardenability only except addition of cobalt.)

(b) Carbon content

(c) Grain size of steel

(d) The homogeneity of starting steel

(e) Homogeneity obtained in the austenite before quenching .

DIFFERENT BEWEEN HARDNESS AND HARDENABILITY:

HARDNESS	HARDENABILITY
Measure of resistance to plastic deformation.	Ease of formation of martensite by quenching

EFFECT OF HEAT TREATMENT ON PROPERTIES OF STEEL:

During heat treatment by controlling cooling rate , holding time and temperature , steels properties are controlled.

The required properties at the cutting edge of the steel cutting tool are high hardness high wear resistance, good thermal conductivity and toughness and minimum brittleness.

These properties are obtained with the help of various heat treatment processes. The main heat treatments required for the forge tools are annealing ,normalizing, hardening and tempering.

EFFECT OF IMPORTANT HEAT TREATMENT PROCESSES ON PROPERTIES OF STEEL:

HEAT TREATMENT PROCESS	EFFECT ON PROPERTIES OF STEEL

1. Annealing	• Increase ductility and toughness relieve internal stress refine grain structure. • Increase machinability.
2. Normalising	• Increase impact strength yield point and ultimate tensile strength.
3. Hardening	• Increase hardness and brittleness.
4. Tempering	• Reduces hardness marginally but increases toughness.

NON - FERROUS ALLOYS

Alloys whose base metal is any other metal but not iron are known as non ferrous alloys.

COMPOSITION , PROPERTIES AND USAGE OF AUMINIUM ALLOYS:

1. **Duralumin**: Composition—
   Aluminium-95%
   Copper (cu)- 4%
   Magnesium (Mg)-0.5%
   Manganese (Mn) – 0.5%

   Properties-
   - High tensile strength.
   - Light in weight.
   - Low corrosion resistance.
   - Can be age hardened.

   Uses-
   - It is available in various forms like bars, tubes and sheets and used for highly stressed structural components.
   - Duraumin sheets with a thin film of Al on its surface (trade name is Alcad) are used in aircraft industry.
   - It is used in automobile industries.
   - It is used for surgical and orthopaedics works for construction of instrument parts.

2. **Y-alloy:**
   Composition- Aluminum – 93%
   Copper (cu)- 4%
   Nickel (Ni)- 2%
   Magnesium (Mg)- 1%

   Properties-
   - High strength and hardness at elevated temperature.
   - By quenching and agehardening the alloy develops very good mechanical properties.

Uses-

- Used for piston, cylinder heads and crank case of internal combustion engine.

3. **Copper- Aluminum alloy or Aluminum Bronze**

Aluminum bronze is of two types

Type-1

Hot working Aluminum Bronze

Composition:- Aluminum- 8% to 14%
Copper – 92% to 86%
Sometimes a little iron is added.

Properties-

- It possesses good strength.
- High corrosion resistance.
- Good heat resistance

Uses –

- Production of gears, pinions, valve seats guides in I.C. engine.

4. **Cams and rollers**

Type-2

Cold working Aluminum bronze

Composition:- Aluminum- upto 8%
Copper- rest percentage (minimum % is 92%)

Uses-

- Available in the form of tubes for condensers, heat exchangers and steam and chemical plants.
- Used for manufacturing springs.

5. **Copper- Tin**

Alloy of copper and Tin is known as bronze .
Bronze is of two types.

Type 1 (working bronze)

Composition:- Tin – upto 8%
Copper- rest percentage.

Properties:

- Superior mechanical properties than brass.
- Better corrosion resistance than brass.
- Easily cold worked (rolled, formed and drawn)

Uses:

- They are available in the form of strip, wire and sheet.

Type 2 – Hot working bronze

Composition:- Tin- more than 8%
Copper- rest percentage

Properties:

- High strength
- Better corrosion resistance

Uses:

- In the construction of sculptures, musical instruments and medals.

6. Babbit

Composition:- Tin- 85%
Copper- 5%
Antimony- 10%

Properties:

- High compressive strength or adequate load carrying capacity.
- Good plasticity.
- Good wear resistance.
- Low coefficient of friction.

Uses:

- In manufacturing of heavy duty bearings.

7. Phosphorous bronze

Composition:- Tin- 0.5 to 11 %
Phosphorous – 0.01 to 0.35%
Copper- rest percentage

Properties:

- Good load bearing capacity.
- Enough Elasticity.
- Good wear resistance.
- High corrosion resistance .
- Good electrical conductivity.

Uses:-

- Phosphorous bronze having 0.5% Tin is used for
    - Different types of springs, bolts, electrical switches with moving or sliding parts in electrical instruments.
    - Drawn tubes are used in fuel system.
- Cast phosphorous bronze (bearing bronze contains 10% and small amount of lead used as a bearing material by cold working processes.

8. Brass

Composition:- Alloys of copper and zinc. There are two main varieties of brasses.

1. Alpha brass for cold working – upto 37% Zn rest is copper.
2. Alpha beta brass for hot working – Zn- 33% to 46% rest is Cu.

Properties of α-brass:

- Very soft
- Good tensile strength and ductility
- Suitable for cold working process.

Uses of α-brass:-

- Cold rolled sheets.
- Drawn wires.
- Deep drawn and drawn into tubes.

αβ brass

Properties of αβ-brass:

- Loses strength at high temperature but becomes very plastic.
- Very good response to hot working.

Uses of αβ-brass:

- Uses for hot rolling, hot extrusion , hot stamping and casting.

9. Copper- Nickel

Composition:- Ni- 45%
Cu- 55%

Properties:

- It has high specific resistance, which is unaffected by temperature variation.

Uses:

- It is used for accurate resistors, thermocouples, Wheatstone bridge, low temperature heaters and resistances.

10.Monel metal

Composition:- Ni- 68%
Cu- 30%
Iron- 1% and small additions of Mn and other elements.

Properties:

- It has good mechanical properties and can maintain them at elevated temperature.
- It has corrosion resistance, can be cold and hot worked , cast, forged and welded.

Uses:

- It is widely used for marine parts, pump, impellers, propellers, evaporators and heat exchangers in chemical works.

PREDOMINATING ALLOYING ELEMENTS OF CERTAIN NON FERROUS ALLOYS

Predominating elements of Nickel- Base alloys are:

1. Chromium
2. Molybdenum
3. Cobalt

Base metal	Alloys	Properties	Uses
Nickel	Chromium series of high-nickel alloys	Highly resistant to corrosion at high temperature possesses . Excellent thermal shock resistance and electrical resistivity	Used for electric heating elements. One example is Inconel is used in industries for making retorts and fixtures for heat-treating furnaces.
	Ni,Cr,Mo,Alloy	Resistance to attack by verity of chemical agents. Possesses high temp strength and ductility. Have ease of forming and welding.	Used for reaction vessel heat exchanges piping and fittings, valves and pumps for handling of sulphuric acid and many other acids.

High alloy materials like stainless steel grades of duplex, super duplex materials

Duplex stainless steel

Duplex stainless steels are called “duplex” because they have two phases, austenite (face centred cubiclatice) and ferrite (body centred cubic lattice) in roughly equal proportions.

Composition:- Chromium – 20% -28%
Molybdenum- upto 5%
Nickel- upto 9%
Nitrogen – 0.05 – 0.5%
Rest is iron.

Properties:

- Better corrosion resistance particularly chloride pitting corrosion.
- Higher strength than standard austenitic stainless steels.

Uses:-

- In offshore oil and gas industry for pipe work systems, manifolds , risers etc.
- In petrochemical industry in the form of pipelines and pressure vessels. Due to less percentage of expensive Ni, life cycle cost of Duplex Stainless Steel is lowest in many application.

Super duplex stainless steel:

Composition:- Chromium – 25%
Molybdenum- 3.7%
Nickel- 7%
Nitrogen – 0.2%

Properties:

- Higher pitting and stress corrosion resistance in chloride environment than DSS. Pitting resistance equivalent (PRE) is greater than 40.
- High strength .
- High thermal conductivity.
- Low coefficient of thermal expansion.
- Good workability and weldability.

Uses:-

- Heat exchanger tubes & pipes for production and handling of gas and oil.
- Pipes in various industries which are to handle chloride.
- Mechanical and structural components.
- Utility and industrial systems, rotors, fans, shafts, press rolls where the high corrosions fatigue strength is required.
- Resistance.

Low alloy material:

P-91:

Composition:- Chromium- 9%
Molybdenum-1%
Other is iron carbon and very smaller amount of other alloying element like Mn, P, S, Si.

Properties:

- P-91 is a type of creep resistant, strength enhanced , ferritic alloy, which are steels designed to retain strength at extremely high temperatures.

Uses:-

- In power plant service in superheater coils, steam piping and headers.

P-22

Composition:- Chromium- 2-4%
Molybdenum-1%
Other is iron, carbon, Mn, P, S, Si

Properties:

- High temperature strength.
- High oxidation resistance.
- High tensile and yield strength.
- Chromium increases the hardness and strength and only minimally reduces elasticity.

- Mo increases high temperature creep strength and corrosion resistance.

Uses:

- In power plants , refineries, petrochemical plants and oilfield services where fluids and gases are transported at extremely high temperature & pressures.

BEARING MATERIAL

Introduction

Bearing support moving parts, such as shafts and spindles of a machine. Due to relative motion between two surfaces friction arises. A lubricant is used to reduce this friction.

When a lubricant film cannot completely separate the moving parts of a bearing, friction and wear increase. The resulting frictional heat combined with high pressure promotes localized welding of the two rubbing surfaces.

Due to welding of two surfaces metal is pulled from one or both surfaces and decreases life of the bearing.

Compatibility of bearing materials and absorption of lubricant upon the bearing surface, is necessary to reduce metallic contact and extend bearing life.

Classification of Bearing Material

Bearings may be classified as:

1. Rolling contact bearing i.e ball or Roller bearing .
2. Plain bearing.

Rolling contact bearings are made of steel, which are hardened after machining.

For making plain bearing many types of bearing materials are listed below :

(i) Lead or tin-based alloys
(ii) Cadmium-based alloys
(iii) Aluminum based alloys
(iv) Silver-based alloys
(v) Copper-based alloys
(vi) Sintered bearing material
(vii) Non-metallic bearing materials

Out of which composition , properties and uses of following bearing material will be discussed.

1. Copper based alloys
2. Tin based alloys
3. Lead based alloys

4. Cadmium based alloys

Properties of Bearing Material

A bearing metal should possess the following important properties.

i. It should have enough compressive and fatigue strength to possess adequate load carrying capacity.
ii. It should have adequate plasticity under bearing load.
iii. It should have good wear Resistance to maintain a specified fit.
iv. It should have low co-efficient of friction to avoid excessive heating.
v. The material should bear vibrations and shocks.
vi. It should have high Thermal conductivity so as to take away the heat produced due to friction between two moving parts.
vii. It should have the properties to form a continuous thin film of lubricant between the shaft & bearing to avoid direct contact between two rotating surface.
viii. It should possess resistance to corrosion.
ix. It should possess anti-seizure characteristic.
x. Should be cheap and easily fabricated.
xi. Possess ability to embed in itself any dirt present in lubricating oil.

Composition & uses of different type of Bearing material.

Name	Composition(Wt %)	Properties	Uses
Tin Based Babbitt	Tin- 85% Antimony -10% Copper -5%	i) Have low coefficient of friction. ii) Good ability to embed dirt. iii) Good corrosion resistance. iv) Good seizure resistance.	Used in high speed engines steam and gas turbine, electric motor, blower, pumps etc.
Lead Based Babbitt	Lead- 80% Antimony -12% Tin -8%	i) These are softer and brittle than tin base alloys. ii) These are cheaper than tin base alloys. iii) Good ability to embed dirt. iv) Good corrosion resistance. v) Good seizure resistance.	Used in Railway Wagon bearing
Cadmium Based	Cadmium-95% Silver-5% & small amount of iridium	i) Low coefficient of friction. ii) High fatigue strength. iii) High load carrying capacity iv) Low wear. v) Good seizure resistance. vi) Fair ability to embed dirt. vii) Poor corrosion resistance (using ordinary lubricants).	Suitable for Medium loaded bearing subjected to high temperature . Used in automobile and air craft industries.

Copper Based (porous sintered bronze bearing)	Copper powder - 90% Tin- 8-10% & a small amount of graphite i.e 1-3%	i) Self lubricating. ii) Resistance to corrosion.	Bearing suitable for light and medium loads. Used in Refrigerators, air-conditioners, washing machines.

SPRING MATERIAL

Springs store Mechanical energy and operates under heavy load. In case of an ideal spring , the deviation (displacement) from the rest position is directly proportional to the load it carries and after removal of the load it will return to its original position.

No spring material satisfies completely the ideal spring material characteristics but the materials which stores energy and follow the condition of restoration of original position after removal of load are used as spring material.

CLASSIFICATION OF SPRING MATERIALS:

Commonly employed spring materials are classified into following types.

1) Iron- based spring materials
2) Copper-based spring materials.
3) Nickel-based spring materials.
4) Special spring materials.

IRON- BASED SPRING MATERIALS

1. High carbon spring steel or steel pianowire

Composition:

C – 0.7 -1.0%
Mn- 0.3 – 0.6%
Fe- remaining percentage

Properties:

1. Easily worked.
2. Least expensive
3. Readily available

Uses:

Small sized helical springs . These springs are used for all purposes except under high or very low temperature and fatigue loading.

2. Alloy spring steel or Cr-v spring steel

Composition:

C- 0.5%
Mn- 1.0%
Cr- 0.2-0.9%
V- 0.07 -0.12 %

Fe- remaining percentage

Properties:

1. Withstand high stress.
2. Bear shock load or impact loading.
3. Can withstand wider temperature variation than high carbon spring steel.

Uses:

Used in Engines, Railway carriages and in automotive valves.

3. Stainless spring steel

Composition:

Cr- 18%
Ni- 8%
C- 0.1-0.2%
Fe- remaining percentage

Properties:

1. Bear high temperature i.e upto 288°C.
2. Corrosion resistant.

Uses:

Valve spring in flow meters.

COPPER-BASED SPRING MATERIALS

1. Phosphor bronze:

Composition:

Cu-92%
Sn- 8%

Properties:

1. Good Electrical conductivity.
2. Corrosion resistant.
3. Lack of magnetic properties.

Uses:

High quality springs for switches, relays and contacts.

2. Brass:

Composition:

Cu- 67%
Zn – 33%

Properties:

1. Good Electrical conductivity.
2. Corrosion resistant.
3. Lack of magnetic properties.

Uses:

Used in switches and contacts in electrical appliances.

3. Nickel silver:

Composition:

Cu- 56%
Ni- 18%
Zn – 25%

Properties:

1. Good Electrical conductivity.
2. Corrosion resistant.
3. Lack of magnetic properties.

Uses:

Used in switches and appliances where better quality spring is required.

4. Beryllium copper:

Composition:

Cu – 98%
Be – 2%

Properties:

1. Good Electrical conductivity.
2. Corrosion resistant.
3. Lack of magnetic properties.
4. Good resistance to wear.

Uses:

Used for making bushes, relays , switches with relatively good resistance to wear, good conductivity and good resistance to corrosion.

POLYMERS

Polymers is a large group of engineering material which are either natural polymers or synthetic polymers.

The word mer means a unit. So monomer represents a single unit and polymer means many units joined together by a chemical reaction.

The polymers are classified according to the mechanical responses at elevated temperature into :

a) Thermoplasts or thermoplastic polymer
b) Thermosets or thermosetting polymer.

Properties of thermoplasts

1. Thermoplastic polymers soften when heated and harden when cooled.
2. Thermoplasts are relatively soft and ductile.
3. Thermoplasts have low melting temperatures and can be repeatedly moulded and remoulded to the desired shape.
4. They have a resale value.

Application of thermoplasts:

Uses of some commercially available thermoplasts are :

i) Polyvinyl chloride is used in preparation of plastic walls and floor tile.
ii) Polystyrene is used in fluorescent light reflectors.
iii) Polymethyl methacrylate is used for preparing plastic lenses.

Properties of thermosets:

1. Thermosetting polymers become soft during their first heating and become permanently hard when cooled.
2. Thermosets are generally harder, stronger and more brittle than thermoplasts and have better dimensional stability.
3. They are usable in processes requiring high temperatures.
4. They are chemically inert compared to thermoplasts.
5. They are far superior to ordinary electric insulators.

Application:

1. Electrical insulators.
2. Preparation of paints and varnishes.
3. Lighting fixtures.

Elastomers:

An elastomer is a polymeric material which at room temperature can be stretched to atleast twice its original length and once the stress is released, it returns back to its original length.

Properties of Elastomers:

1. These plastics are soft and elastic materials with a low modulus of elasticity. The extensions can range up to ten times their original dimensions.
2. They are nonconductors of electricity.
3. Their resistance to chemical and corrosive environments is high.
4. They are low conductors of heat.
5. They have relatively low softening temperature.
6. They exhibit viscoelastic behavior.
7. They oxidize with time and changes in properties occur.

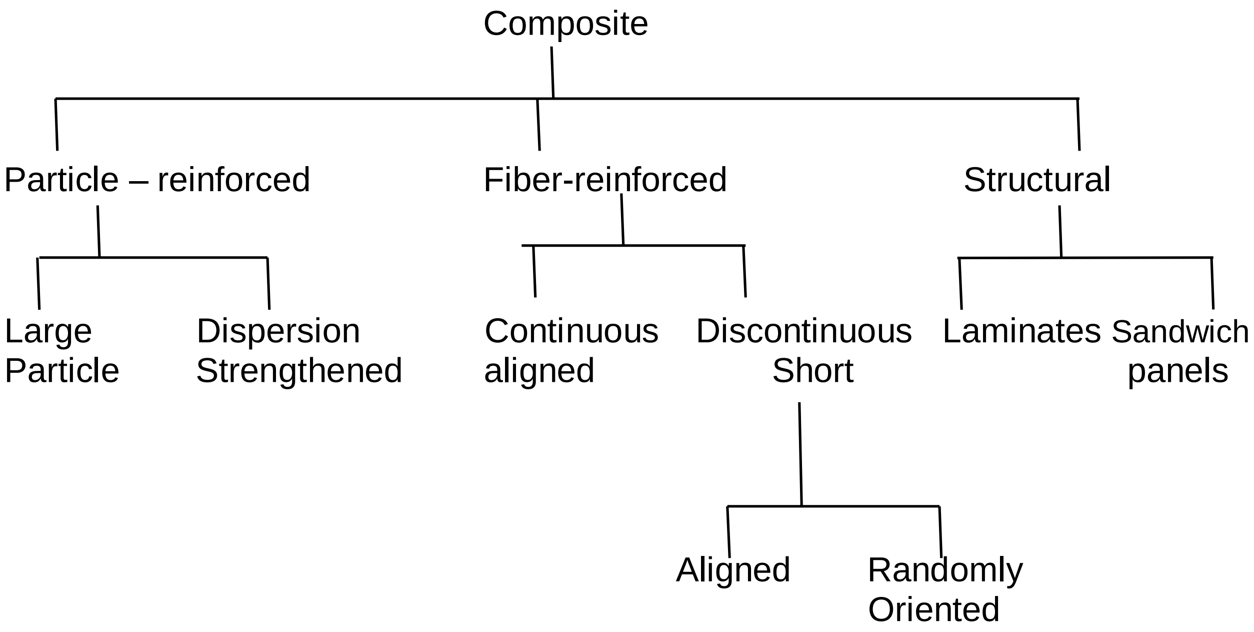
COMPOSITES AND CERAMICS

Composite materials are produced by combining two dissimilar materials.

To suit the requirements of materials needed for aerospace, underwater and transportation application , composite materials have been produced as these unusual combinations of properties could not be met by conventional alloys, ceramics and polymeric materials.

Many composite materials are composed of just two phases; one is termed the matrix, which is continuous and surrounds the other phase, often called the dispersed phase.

CLASSIFICATION OF COMPOSITE MATERIAL



PARTICLE-REINFORCED COMPOSITE:

- The dispersed phase for particle-reinforced composites is equiaxed (i.e particle dimensions are approximately the same in all direction).
- Large particle and dispersion strengthened composites are the two sub-classifications of particle reinforced composites. The distinction between these is based upon reinforcement or strengthening mechanism.

i) Large particle composites:

- The term large is used to indicate that particle matrix interaction cannot be treated on the atomic or molecular level; rather continuum mechanics is used . For most of these composites, the particulate phase is harder and stiffer than the matrix. These reinforcing particles tend to restrain movement of the matrix phase in the vicinity of each particle. In essence, the matrix transfers some of the applied stress to the particles, which bear a fraction of load. The degree of reinforcement or improvement of mechanical behavior depends on strong bonding at the matrix particle interface.
- Some polymeric materials to which fillers have been added are really large particle composites.
- Another familiar large particle composite is concrete being composed of cement (the matrix) and sand and gravel (the particulates).
- The particles should be of approximately the same dimension in all directions. For effective reinforcement, the particles should be small and evenly distributed throughout the matrix. The mechanical properties are enhanced with increasing particulate content.

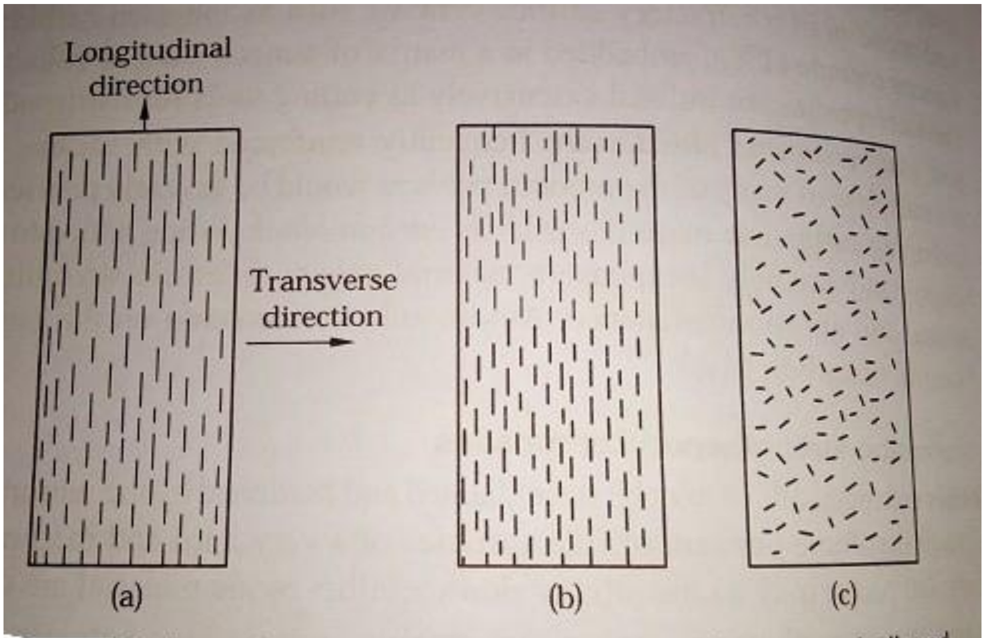
ii) Dispersion- strengthened Composites:

- Metals and metal alloys may be strengthened and hardened by the uniform dispersion of several volume percent of fine particles of a very hard and inert material. The dispersed phase may be metallic or non metallic , oxide material are often used. Again the strengthening mechanism involves interactions between the particles and dislocations within the matrix, as with precipitation hardening. The dispersion strengthening effect is not as pronounced as with precipitation hardening.

- The high temperature strength of nickel alloys may be enhanced significantly by the addition of about 3 vol % of thoria (ThO_2) as finly dispersed particles, this material is known as thoria dispersed nickel.the same effect is produced in the aluminium- aluminium oxide system. A very thin and adherent alumina coating is caused to form on the surface of extremely small (0.1 to 0.2 μm thick)flakes of aluminium which are dispersed within an aluminium metal matrix, this material is termed sintered aluminium powder (SAP).

FIBER REINFORCED COMPOSITES:

- Technologically the most important composites are those in which the dispersed phase is in the form of a fiber. Design goals of fiber-reinforced composites often include high-strength and stiffness on a weight basis. Those characteristics are expressed in terms of specific strength and specific modulus parameters, which correspond respectively, to the ratios of tensile strength to specific gravity and modulus of elasticity to specific gravity.
- The arrangement of the fibers relative to one another the fiber concentration and the distribution all have a significant influence on the strength and other properties of fiber reinforced composites.



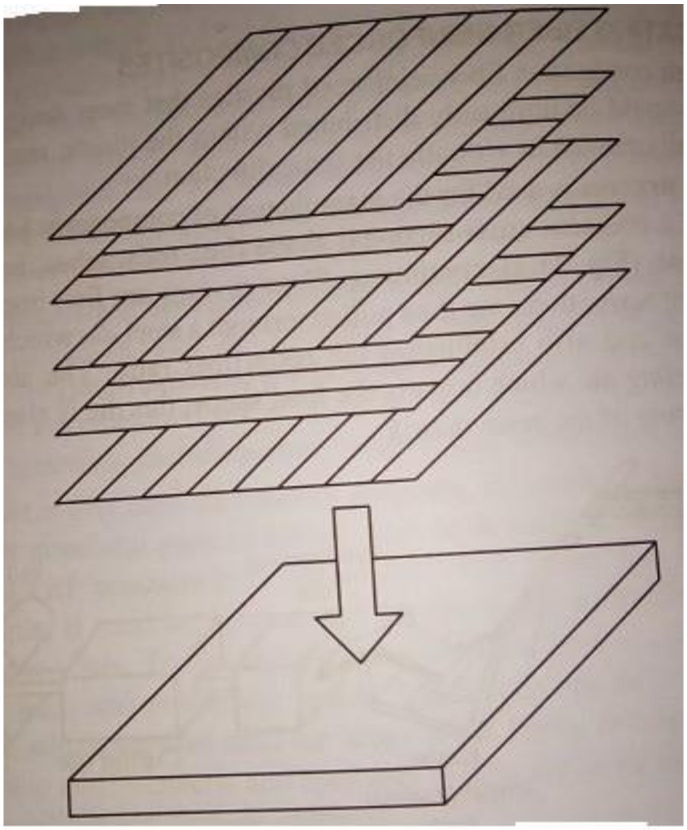
Schematic representations of (*a*) continuous and aligned, (*b*) discontinuous and aligned; and (*c*) discontinuous and randomly oriented fiber-reinforced composites

STRUCTURAL COMPOSITES:

- A structural composite is normally composed of both homogeneous and composite materials the properties of which depend not only on the properties of the constituent materials but also on the geometrical design of the various structural elements.

i) Laminar composites:

- A laminar composite is composed of two dimensional sheets that have a preferred high strength direction such as is found in wood and continuous and aligned fiber reinforced plastics.
- The layers are stacked and subsequently cemented together such that the orientation of the high strength direction varies with each successive layer.



A laminar composite

ii) Sandwich panels:

- Sandwich panels consists of two strong outer sheets , separated by a layer of less dense material, which has lower stiffness and low strength. The faces bear most of the in plane loading, and also any tram verse bending stresses.
- Typical face materials in clued aluminum alloys fiber reinforced plastics titanium steel and plywood.

- Structurally the core serves two fuctions:
    - It separates the faces and resists deformations perpendicular to the face plane.
    - It provides a certain degree of shear rigidity along plane which are perpendicular to the faces.
- Various materials and structures are utilized for cores including foamed polymers synthetic rubbers inorganic cements as well as balsa wood.
- Sandwich panels find a wide variety of applications such as roofs ,floors and walls of building and in aircraft, for wings, fuselage and tailplane skins.

Ceramic Materials:

Ceramics are inorganic, non-metallic materials that are processed to be used at high temperatures.

They are abrasive- resistant , heat resistant (refractory) and can sustain large compressive loads even at high temperature.

Classification and Uses of Ceramics:

The term ceramics is used to indicate the potter's art or articles made by the potter.

The ceramics are divided into the following three categories.

1. Clay products
2. Refractories
3. Glass

Clay products

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

Tiles are of two types

(1) Common tile
(2) Encaustic tiles

Types of common tiles

(i) Drain tiles
(ii) Floor or paving tiles
(iii) Roof tiles

Types of roof tiles

Allahabad tiles, Corrugated tiles, Flat tiles, Flemish tiles, Guna tiles, Mangalore tiles, pantiles. Refractories.

The term refractories is used to indicate substances that are able to resist high temperatures.

Classification

(i) According to chemical properties.
(ii) According to resistance to temperature.

According to chemical properties

(a) Acidic
(b) Neutral and
(c) Basic

(a) Acidic Fire clay: It is used for the manufactured of fire bricks, crucibles, hollow tiles.
Quarizite- For making the silica bricks.
Silica- Coke over and lining for glass furnaces.

(b) Neutral refractory materials
Bauxite- For tire bricks
Carbon- Lining material for furnaces
Chromite- Powerful neutral refractory material.
Forsterite- Used in furnaces for melting copper.

(c) Basic Refractory materials
Dolomite- For making refractory bricks.
Magnesia- Magnesia bricks.

According to resistance to temperature
(a) Low quality
(b) High quality

High quality - Used in modern aeroplanes, rockets, jets etc. Molyblendum, tungsten,
zirconium and their alloys are used as the refractory materials.
Cermet - Refractory material containing a combination of clay and metal.

Surface Preparation and Industrial Painting

Reasons of corrosion and surface wear.

The term corrosion is defined as an act or process of gradual wearing away of a metal due to chemical or electro-chemical reaction by its surroundings such that the metal is converted into an oxide.

The corrosion indicates the deterioration and loss of material due to chemical attack.

Following are the factors responsible for corrosion :

(i) Congested reinforcement in small concrete sections.
(ii) Excessive water-cement ratio.
(iii) Improper construction methods.
(iv) Inadequate design procedure
(v) Incompetent supervising staff or contractor.
(vi) Initially rusted reinforcement before placing concrete.
(vii) Insufficient cover to steel from the exposed concrete surfaces.
(viii) Presence of moisture in concrete.
(ix) Presence of salt.
(x) Unequal O2 distribution over the steel surfaces.

Factors influencing corrosion

(i) Blow holes, inclusions trapped gases.
(ii) Chemical nature of the metals.
(iii) Eddy electric currents.
(iv) Presence of dust, dirt.

Purpose of painting and methods of industrial pointing:

Purposes:

(i) To protect the surface from weathering effects of the atmosphere and actions by other
liquids, fames and gases.

(ii) To prevent decay of wood and corrosion in metal.

(iii) To give good appearance to the surface. The decorative effects may be created by
painting and the surface becomes hygienically good, clear, colourful and attractive.

(iv) To provide a smooth surface for easy cleaning.