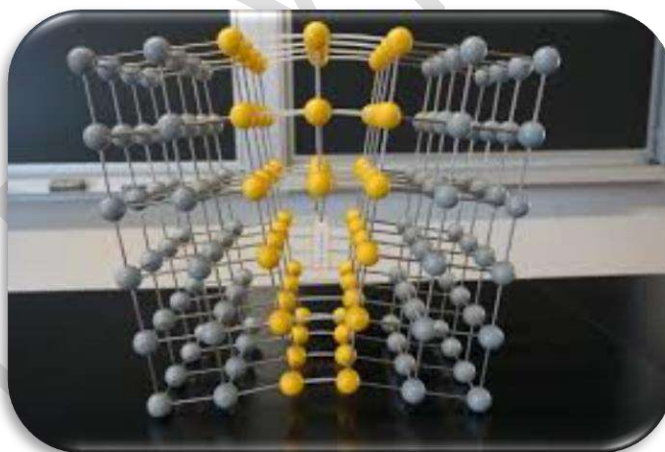


LECTURE NOTES
ON
ENGINEERING MATERIAL



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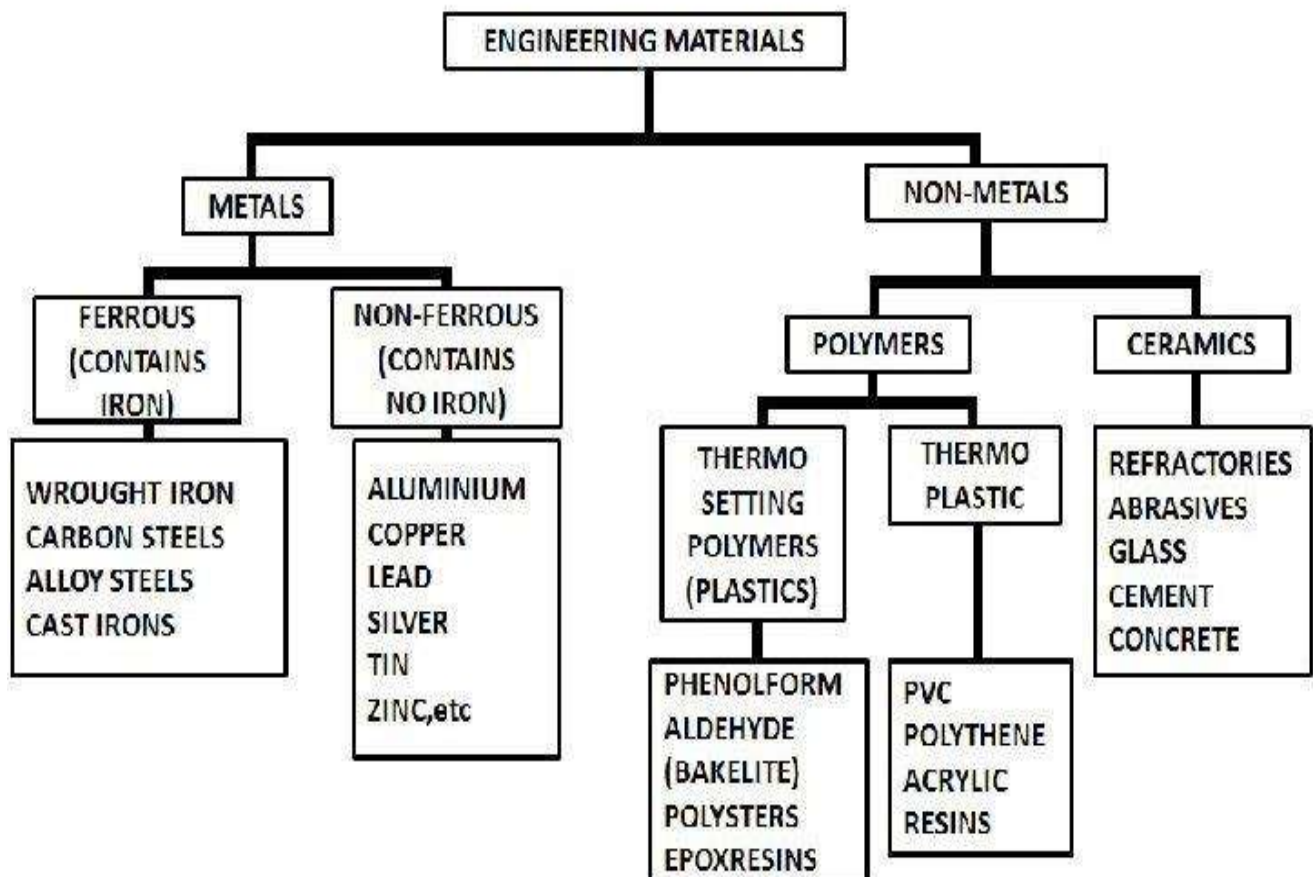
Chapter-1

Engineering materials and their properties

Introduction:

- In the current scientific and technology era, material science and engineering are extremely important. To suit the needs of the plant and the individual, various types of materials are utilized in industry, housing, agriculture, transportation, etc.
- In general, the term "material science" refers to the area of applied science that focuses primarily on the inter-disciplinary research of materials for practical applications and the investigation of the relationship between the structure and properties of materials.
- A design engineer needs to be knowledgeable about how manufacturing procedures and heat treatment affect material qualities.

Classification of Materials



Metallic Material:

- Metallic materials are those made of one or more metal elements, such as iron, copper, aluminum, nickel-free titanium.
- They are having high thermal and electrical conductivity. At room temperature, the majority of metals are comparatively robust and ductile. They are opaque. I.e. light cannot pass through them.
- Metals also possess the following properties: hardness. Strength, ductility, brittleness, mechanical ability, welds ability, cast ability, formability, stiffness, etc.

Non Metallic Materials**1. Polymer**

- Polymers commonly called Plastics consist of long molecular chains containing many repeated units of monomers.
- Examples are, Polyethylene, nylon PVC etc.
- They are poor conductor of heat and electricity and poor reflectors of light generally, characterized by low density, strength and stiffness.

2. Ceramics

- Ceramics are complex compounds composed of metallic and non- metallic elements.
- Examples- alumina, silicon carbide, silicon nitride.
- They have high temperature strength and low thermal conductivity.

3. Composites

- Composite materials are a combination of two or more distinct materials that are joined together mechanically or metallurgical.
- The composites possess properties such as strength, stiffness, high temperature performance, corrosion resistance and hardness.
- Examples- Fiber glass.

4. Semi-Conductor:

- Semiconductors have electrical properties that are intermediate between the electrical conductors & insulators. Semiconductors 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.
- Semi conducting material are basically are used of manufacturing of different electrical & electronics components.
- Ex. - Silicon, Germanium, Gallium, arsenide.

Physical Properties:

- Physical properties are employed to describe the response of a material to imposed stimuli under conditions in which external forces are not concerned.
- Physical properties include.

1. Dimensions,
2. Appearance,
3. Color
4. Density
5. Melting Point
6. Porosity
7. Structure

1. Dimensions

- Dimensions of a material imply its size (length, breadth, width, diameter, etc.) and shape (square, circular, channel, angle section, etc.).

2. Appearance

- Metals themselves have got different appearances e.g., aluminum is a silvery white metal whereas copper appears brownish red.
- Appearance includes lusture, colour and finish of a material. Lusture is the ability of a material to reflect light when finely polished. It is the brightness of a surface.

3. Colour

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

4. Density

- The density is the weight of unit volume of a material expressed in metric units.
- Density depends to some extent on the
 - a) Purity of material
 - b) Pour volume
 - c) Treatment, the material has received.
- Density helps differentiating between light and heavy metals even if they have same shape and any outer protective coating.

5. Melting point

Melting point of a material is that temperature at which the solid metals change into molten state. One metal can be distinguished from the other on the basis of its melting point.

6. Porosity

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

7. Structure

- It means geometric relationships of material components.
- It also implies the arrangement of internal components of matter(electron structure, crystal structure, and micro structure)

Mechanical Properties:**Strength**

- It is the ability of a material to resist the externally applied forces without breaking or yielding. The internal resistance offered by a part to an externally applied force is called stress.

Stiffness

- It is the ability of a material to resist deformation under stress. The modulus of elasticity is the measure of stiffness.

Elasticity

- It is the property of a material to regain its original shape after deformation when the external forces are removed. This property is desirable for materials used in tools and machines. It may be noted that steel is more elastic than rubber.

Plasticity

- It is property of a material which retains the deformation produced under load permanently. This property of the material is necessary for forgings, in stamping images on coins and in ornamental work.

Ductility: -

- It is a property of a material enabling it to be drawn into wire with the application of a tensile force. The ductile material commonly used in engineering practice are mild steel, copper, aluminum, nickel, zinc, tin, and lead. Ductile materials have good tensile strength, but having poor compressive strength.

Brittleness: -

- It is the property of breaking of a material with little permanent deformation under tensile load. Cast iron is a brittle material. Brittle materials are good in compression but not good in tension.

Malleability: -

- This property permits the material to undergo hammered or rolled into any desirable shape under compression without rupture.

Toughness:-

- It is the property of a material to resist fracture due to high impact loads like hammer blows.

Hardness: -

- It is a property of a material by virtue of which it gives resistance to wear, scratching, deformation and machinability etc. It also means the ability of a metal to cut another metal.

Machinability: -

- It is the property of a material with which a material can be cut / machined easily.

Resilience: -

- It is the property of a material which enables it to store large energy within elastic limit, when the material is subjected to shock or impact loading. This property is very essential in designing springs for different engineering application.

Chemical Properties:

- A study of chemical properties of materials is necessary because most of engineering materials when they come in contact with other substances, with which they can react, tend to suffer from chemical deterioration.
- The chemical properties describe the combining Toxicity, corrosion characteristics, reactivity, solubility, etc. of a substance.
- Some of the chemical properties are
 1. Corrosion resistance
 2. Chemical composition
 3. Acidity or alkalinity

Corrosion

- It is the deterioration of a material by chemical reaction with its environment.
- Corrosion degrades material properties and reduces economic value of the material.
- Corrosion attacks metals as well as non-metals. Corrosion of concrete by sulphates in soils is a common problem.

Toxicity

- It is the measure of a material's ability to damage or disrupt the metabolism of living tissue. The dose makes the poison.

Chemical resistance

- A material's ability to withstand degradation from acids, solvents, water, or oxygen (corrosion is a special process)

Thermal Properties:**Specific heat**

- The efficiency of a material in absorbing heat. High specific heat means a material heats fast and cools down fast. By definition, the specific heat of a material is the energy required to raise the temperature of 1 g of that material by 1 °C.

Thermal conductivity

- Thermal conductivity is the rate at which heat flows through a material. It depends on the flow of both electrons and phonons.

Melting point

- The temperature at which liquid begins to form as a material is heated. Not all materials have distinct melting points, and many materials have phase transition temperatures in which crystal structure changes.

Electrical Properties:**Conductivity**

- A measure of how easily a material allows electrical current to flow through. Metals like copper, aluminum and iron have much higher electrical conductivities than ceramics, plastics, glass and rubber.

Resistivity

- It is the reciprocal of electrical conductivity; a measure of a material's resistance to the flow of electric current. Resistivity is an important concept in semiconductors; depends on electronic structure, temperature and microstructure.

Dielectric strength

- Dielectric properties describe the response of dielectric materials (poor conductors) to applied electric fields and depend on polarization of electric charges. Dielectric strength is the strength of an electric field necessary to cause significant electric flow through a dielectric material.

Factors Affecting the Selection of Materials for Engineering Application:

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

1. Properties of material
2. Environmental condition
3. Availability
4. Disposability
5. Economic factors
6. Physical attributes
7. Performance Requirement
8. Material reliability
9. Safety

Availability

- The Material should be readily available in market in large enough quantities to meet the requirement

Economic Factors

- For every application, there is limiting cost beyond which the designer cannot go. When the limit is exceeded the designer has to consider an alternative material. In cost analysis, there are two factors namely cost of material and the cost of processing the material into finished goods. It is likely that the cost of material might be low but the processing may involve costly machining operations.

Performance requirement

- The material of which a part is composed must be capable of embodying or performing a part's function without failure. For example – a component part to be used in a furnace must be of that material which can withstand high temperatures.
- While it is not always possible to assign quantitative values to these functional requirements, they must be related as precisely as possible to specified values of most closely applicable mechanical, physical, electrical or thermal properties.

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 conditions, then, it is neither stable nor reliable for those conditions.

Safety

- A material must safely perform its function; otherwise, the failure of the product made out of it may be catastrophic in air-planes and high pressure systems. As another example, materials that give off spark when struck are safety hazards in a coal mine.

Chapter-2

Ferrous Materials and Alloys

Introduction:

- Ferrous materials are those in which the main constituent is iron, although other constituents like carbon, sulphur, 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 main disadvantages of ferrous alloy are less resistance to corrosion.

Characteristics of ferrous materials:

- Ferrous materials are metals or metal alloys that contain the iron as a base material.
- Steel is a ferrous alloy, and there are a number of other alloys that contain iron.
- Ferrous metals are good conductors of heat and electricity.
- Metal alloys have high resistance to shear, torque and deformation.
- The thermal conductivity of metal is useful for containers to heat materials over a flame.

Application:

- Due to the strength and resilience of metals they are frequently used in high-rise building and bridge construction, most vehicles, many appliances, tools, pipes, non-illuminated signs and railroad tracks.
- Corrosion resistance property makes them useful in food processing plants, e.g., steel.
- Cast iron is strong but brittle, and its compressive strength is very high. So used in castings, manhole covers, engine body, machine base etc.
- Mild steel is soft, ductile and has high tensile strength. It is used in general metal products like structural, workshop, household furniture etc.
- Carbon steels are used for cutting tools due to their hardness, strength and corrosion resistance properties.

Carbon steel:

- It is an alloy of iron & carbon and it is malleable. Carbon steels are differing from cast iron.
- Carbon steels contain from 0.10% to 1.5% carbons whereas cast iron possess 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:

- **Low carbon steel or mild steel contain carbon from 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 390 N/mm^2 & a hardness of about 115 BHN (Brinell hardness number)
- Mild steel containing 0.15 to 0.20% carbons has a tensile strength of 420 MPa, is used for making camshafts, sheets and strips for fan blades, universal beams, welded tubing, forgings, draglines, etc. Mild steel containing 0.20 to 0.30% carbons has a tensile strength of 555 MPa and hardness of 140 BHN. It is used for making gears, valves, connecting rods, crankshafts, railway axles, fish plates, small forgings, etc.

Medium Carbon Steel:

- **Medium carbon steels contain carbon from 0.30 to 0.70%.**
- Steels containing 0.35 to 0.45% carbons have a tensile strength of about 750 N/mm^2 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% carbons have a tensile strength of about 1000 N/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 like crank shafts, axle, splines shafts etc.
- Steels containing 0.6 to 0.7% carbons have a tensile strength of 1230 N/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 from 0.7% to 1.5%.**
- Steels containing 0.7% to 0.8% carbon have a tensile strength of about 1400 N/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 used 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, knives, twist drills etc.
- Steels containing 1.2 to 1.3% carbons are used 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 is:

- To increase harden ability.
- To increase strength at ordinary temperature.
- To increase resistance to corrosion.
- To increase wear resistance.
- To improve toughness.
- 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: more than 5% but up to including 10%
 - (iii) High alloy steel: more than 10% alloying element.
- **Based on engineering 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.

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:

- a. Slight change of form during hardening.
- b. Little risk of cracking during hardening.
- c. Good toughness
- d. Good wear resistance
- e. Very good machinability

- f. A definite cooling rate during hardening
- g. A definite hardening temperature
- h. Resistance to de-carburization
- i. Resistance to softening on heating

Classification of Tool steel:

The Joint Industry Conference, U.S.A. has classified tool steel as follows:

Symbol	Meaning
T	High speed steel
W	Mo-High speed steel
D	High C, high Cr steel
A	Air hardening steel
O	Oil hardening steel
W	Water hardening steel
H	Hot work steel
S	Shock resistance steel

Composition of Tool Steel:

➤ W-High speed steel

T ₁	C 0.7	Cr 4	V 1	W 18	
T ₄	C 0.75	Cr 4	V 1	W (18)	Co 5
T ₆	C 0.8	Cr 4.5	V 1.5	W (20)	Co 12

➤ Mo-High speed steel

M ₁	C 0.8	Cr 4	V 1	W 1.5	Mo 8	
M ₆	C 0.8	Cr 4	V 1.5	W 4	Mo 5	Co 12

➤ High C, high Cr steel

D ₂ : C 1.5	Cr 12			Mo 1	
D ₅ : C 1.5	Cr 12			Mo 1	Co 3
D ₇ : C 2.35	Cr 12	V 4		Mo 1	

➤ Air hardening steel

A ₂ : C 1	Cr 5			Mo 1	
A ₇ : C 2.25	Cr 5.25	V 4.75	W 11	Mo 1	
A ₉ : C 0.5	Cr 5	V 1		Mo 1.4	Ni 1.5

➤ Oil hardening steel

O ₁ : C 0.9	Mn 1	Cr 0.5	W 0.5	
O ₂ : C 1.45	Si 1			Mo 0.25

➤ **Water hardening steel**

W2	C 0.6/1.4	V 0.25
W5	C 1.1	Cr 0.5

➤ **Hot work steel**

H10	C 0.4	Cr 3.25	V 0.4	Mo 2.5
H12	C 0.35	Cr 5	V 0.4	W 4 Mo 1.5

➤ **Shock resistance steel**

S1	C 0.5	Cr 1.5	W 2.5	
S2	C 0.5	Si 1		Mo 0.4
S5	C 0.55	Mn 0.8	Si 2	Mo 0.4
S7	C 0.5	Cr 3.25		Mo 1.4

Stainless Steel:

- When 11.5% or more chromium is added to iron, a fine film of chromium oxide forms spontaneously on the surfaces. The film acts as a barrier to retard further oxidation, rust or corrosion. As this steel cannot be stained easily, it is called stainless steel.
- The stainless steel basing on their micro-structure can be grouped in to three metallurgical classes such as Austenitic stainless steel, Ferritic stainless steel & Martensite stainless steel.

Austenitic Stainless Steel:**Properties:**

- 1) They possess austenitic structure at room temperature.
- 2) They possess the highest corrosion resistance of all the stainless steels.
- 3) They possess greatest strength and scale resistance at high temperature.
- 4) They retain ductility at temperature approaching absolute zero.
- 5) They are non-magnetic.

Composition:

C 0.03 to 0.25%	Mn 2 to 10%	Si 1 to 2%
Cr 16 to 26%	Ni 3.5 to 22%	

P & S Normal Mo & Ti in some cases

Uses:

- 1) Aircraft industry (Engine parts)
- 2) Chemical processing (heat exchangers)
- 3) Food processing (Kettles, tanks)
- 4) Household items (cooking utensils)
- 5) Dairy industries (milk cans)
- 6) Transportation industry (Trailers & railways cars)

Ferritic stainless steel:**Properties:**

- 1) They possess a microstructure which is primarily ferritic.
- 2) They are magnetic & have good ductility
- 3) They do not work harder to any appreciable degree.
- 4) They are more corrosion resistant than martensitic steel.
- 5) They develop their maximum softness, ductility & corrosion resistance in the annealed condition.

Composition:

C 0.08 to 0.20% Si 1% Mn 1 to 1.5% Cr 11 to 27%

Uses:

- 1) Lining for petroleum industry.
- 2) Heating elements for furnaces.
- 3) Interior decorative work.
- 4) Screws & fittings.
- 5) Oil burner parts.

Martensitic stainless steel:**Properties:**

- They possess martensitic microstructure.
- They are magnetic in all condition & possess the best thermal conductivity of the stainless types.
- Hardness, ductility & ability to hold an edge are characteristics of martensitic steels.
- They can be cold worked without difficulty, especially with low carbon content, can be machined satisfactorily.
- They have good toughness.
- They have good corrosion resistance to weather and to some chemicals.
- They are easily hot worked.

Composition:

C 0.15 to 1.2% Si 1% Mn 1% Cr 11.5 to 18%

Uses:

- Pumps & valve parts
- Rules & tapes
- Turbine buckets
- Surgical instruments, etc.

Effect of Alloying Elements:**Chromium:**

It joins with carbon to form chromium carbide, thus adds to depth hardenability with improved resistance to abrasion & wear.

Manganese:

- It contributes markedly to strength and hardness.
- It counteracts brittleness from sulphur.
- Lowers both ductility & weld ability if it is present in high percentage with high carbon content in steel.

Nickel:

- It increases toughness & resistance to impact.
- Lessens distortion in quenching.
- Lowers the critical temperatures of steel & widens the range of successful heat treatment.
- Strengthens steels.
- Renders high-chromium iron alloys austenitic.
- Does not unite with carbon.

Vanadium:

- Promotes fine grains in steel.
- Increases hardenability.
- imparts strength & toughness to heat-treated steel
- Causes marked secondary hardening.

Molybdenum:

- Promotes hardenability of steel.
- Makes steel fine grained.
- Makes steel unusually tough at various hardness levels.
- Counteracts tendency towards temper brittleness.
- Raises tensile & creep strength at high temperatures. Enhances corrosion resistance in stainless steels.
- Forms abrasion resisting particles.

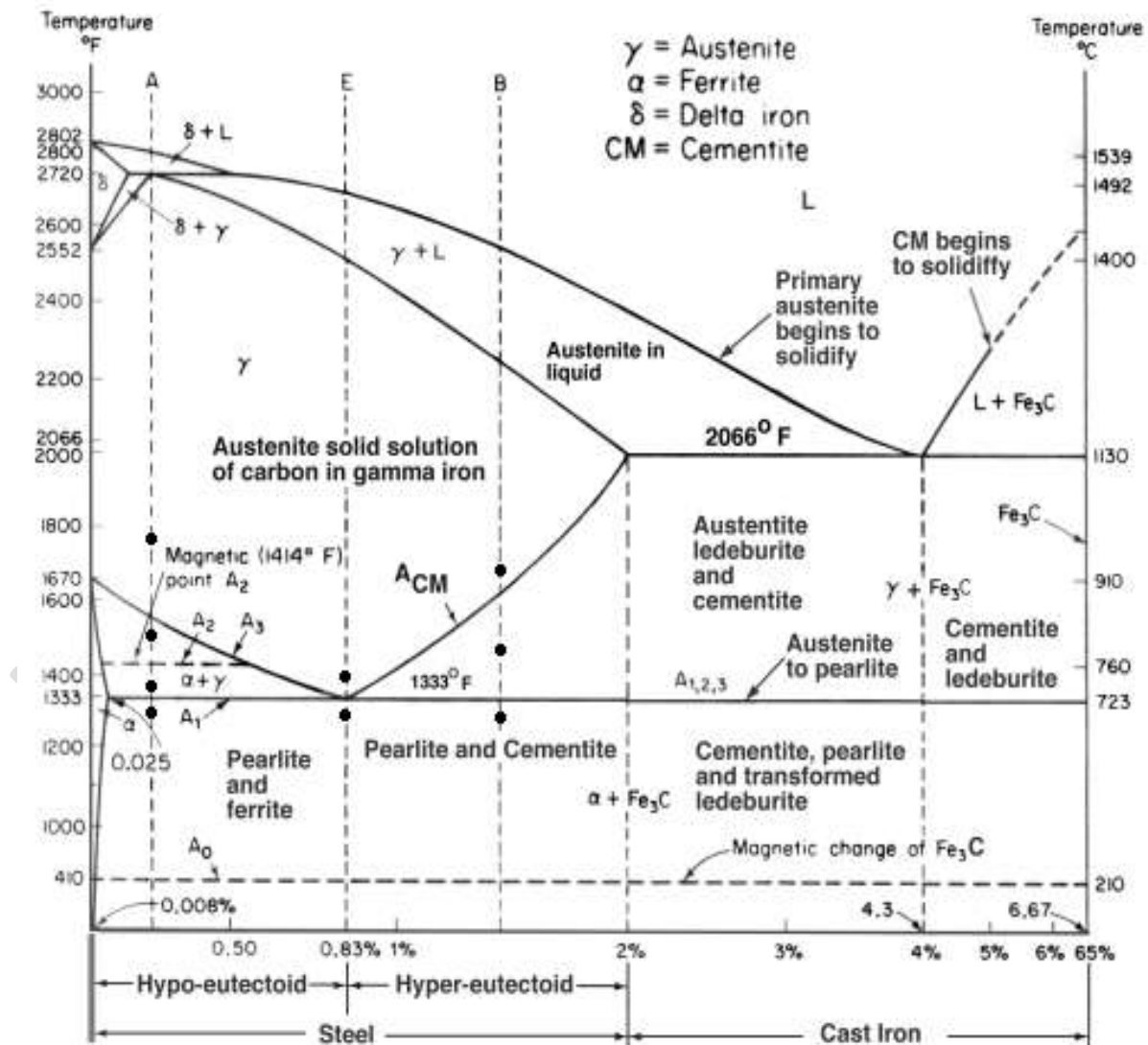
Tungsten:

- Increases hardness.
- Promotes fine grains.
- Resists heat.
- Promotes strength at elevated temperature.

Chapter-3

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.
- Iron carbon alloys are widely used in practical application because it gives mechanical properties.
- The alloying element is 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 intermetal 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.



Alpha (α) ferrite:

- Ferrite is the name given to the interstitial solid solution of carbon in α -ferrite. It has BCC crystal structure.
- The solubility of carbon in α -ferrite is 0.008% at room temperature which increases 0.025% at 723°C.
- It is the softest structure & ductile in nature that appears in iron carbon diagram. It is strongly ferromagnetic up to 768°C after which it becomes Non-Magnetic in Nature. This temperature is called Curie temperature.

Austenite or (γ) iron:

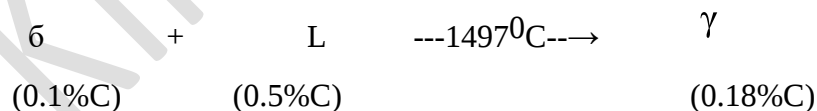
- It is the solid solution of carbon in γ -iron.
- The maximum solid solubility carbon in γ -iron is 2% at 1130°C.
- It is a soft, ductile & Non-magnetic in nature.
- It has FCC crystal structure.
- It is stable above 723°C.

 δ - Ferrite

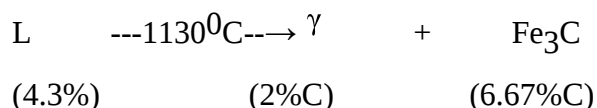
- It is an interstitial solid solution in carbon in δ - iron.
- It is stable between the temperatures 1400°C to 1539°C.
- The maximum solubility of carbon in δ -iron is 0.012% at 1497°C.
- It has BCC crystal structure.

Cementite: (Fe_3C)

- It is an intermetallic compound of iron & carbon.
- It has a fixed carbon contained that is 6.67% by weight.
- It has a complex crystal structure having 12 iron atoms & 4 carbon atoms in a unit cell that is 3:1 ratio.
- It is hard & brittle in nature & having low tensile strength.
- It is the hardest structure that appears in iron- carbon diagram.

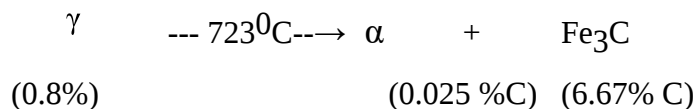
Difference Reactions occurring in iron carbon carbon equilibrium diagram.**(a) Peritectic reaction (P):**

- At temperature 1497°C liquid having composition 0.5% carbon react with δ -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):

- Liquid having composition 4.3% carbon at 1130°C 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'):



- Austenite having composition 0.8% carbon and at temp. 723°C transforms to ferrite & cementite, simultaneously having composition 0.025%C & 6.67%C respectively. This eutectoid mixture is called as **pearlite**. ($\alpha + \text{Fe}_3\text{C}$).
- 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 temperature (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.

Hypo eutectoid temp. (A_3):-

- It is the temperature at which free ferrite transforms to austenite while heating. It is the boundary between austenite and ($\gamma + \alpha$) 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.

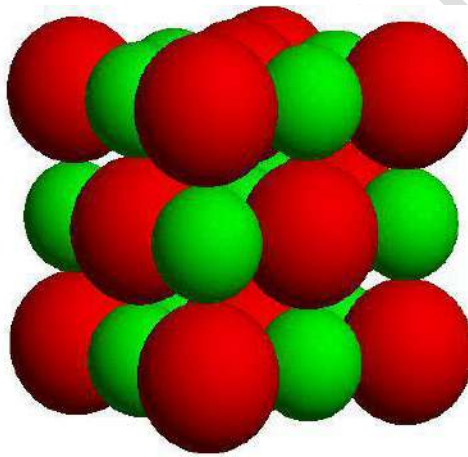
Hyper eutectoid temperature (A_{cm}): -

- It is the temperature at which free cementite transforms to austenite while heating. It is boundary between austenite and ($\gamma + \text{Fe}_3\text{C}$) 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.

Chapter-4

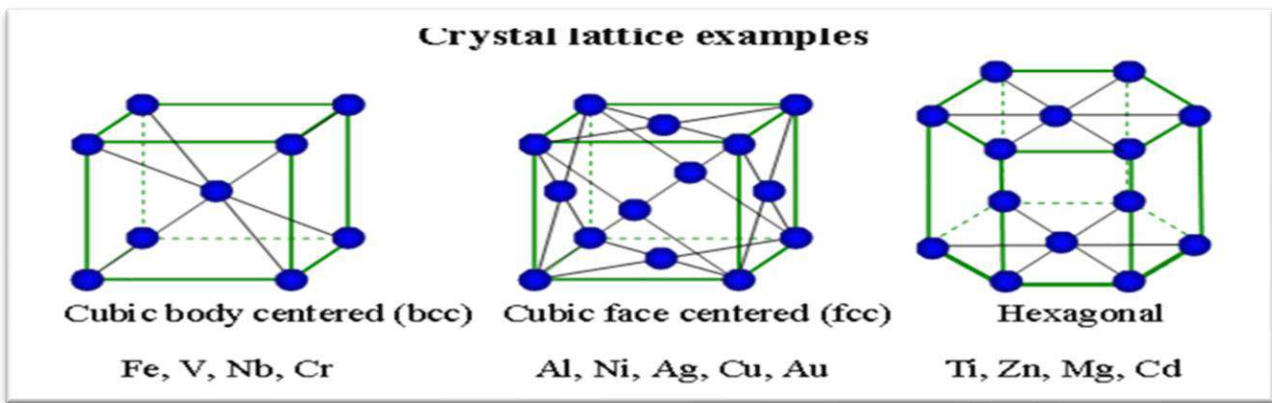
CRYSTAL IMPERFECTION

- 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 in space of identical structural units or building blocks.
- A crystal is a solid material whose constituents (such as atoms, molecules or ions) are arranged in a highly ordered microscopic structure, forming a crystal lattice that extends in all directions. All metals are crystalline, where atoms are arranged in a definite periodic order.
- The scientific study of crystals and crystal formation is known as **crystallography**. The process of crystal formation via mechanisms of crystal growth is called as **crystallization** or **solidification**.



Metal crystal structure

- The crystal system found in most elements metals are either
 - BCC (Body centered cubic)
 - FCC (Face centered cubic)
 - HCP (Hexagonal close packed)
- 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 (Hexagonal Close Packed) 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.



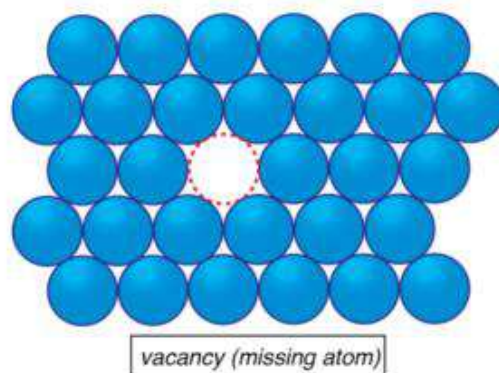
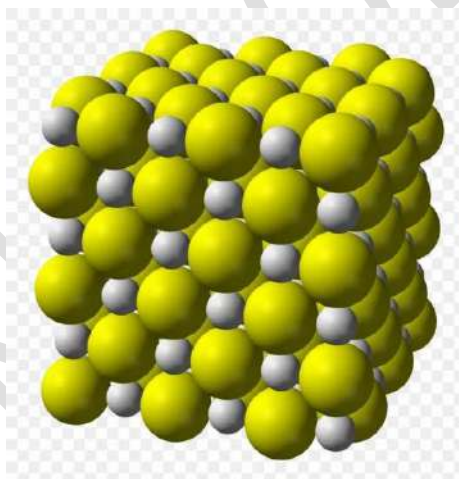
Classification of Crystals

1. Ideal crystal
2. Real crystal

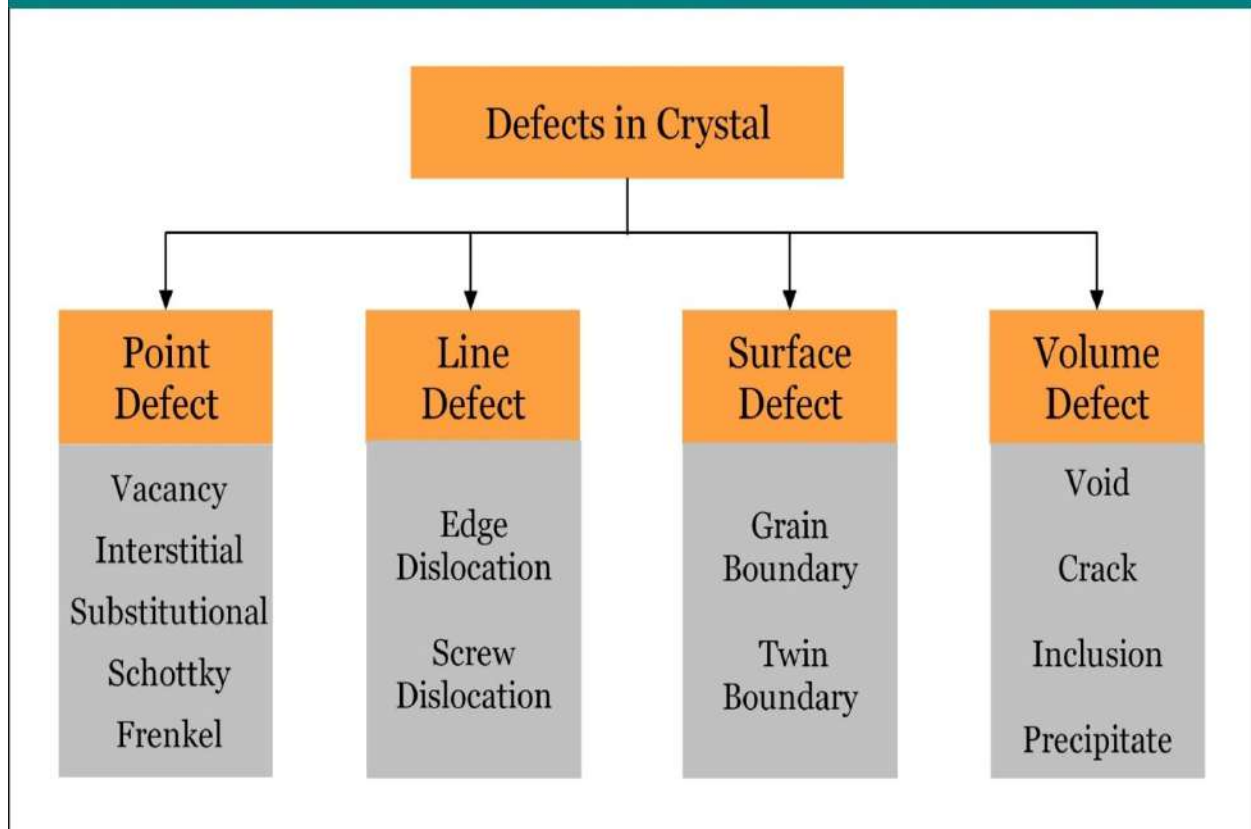
- In ideal crystal (perfect crystal) the atomic arrangement is perfectly regular and continuous thought.
- Real crystal due to some reasons the regular orientation of atoms may be disturbed at a point, along a line or in a region.

Crystal Imperfections

- Crystal defect, imperfection in the regular geometrical arrangement of the atoms in a crystalline solid.
- 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 DEFECTS IN CRYSTALLINE SOLID

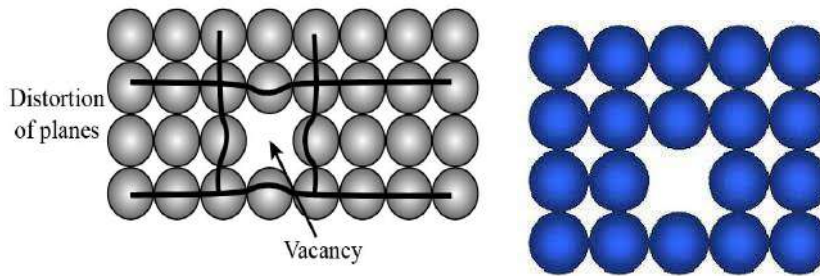


Point Defect:

- A point defect occurs when one or more atoms of a crystalline solid leave their original lattice site and/or foreign atoms occupy the interstitial position of the crystal.
- So there exist three possibilities by which point defect may occur, as provided below:
 1. One or more original atoms of the crystal are missing from their corresponding lattice site.
 2. One or more original atoms are shifted from the original lattice site to the interstitial position in same crystal.
 3. One or more foreign atoms occupied the interstitial position of the crystalline solid.
 4. One or more foreign atoms replaced the original atom of the crystal and subsequently occupied the interstitial position.

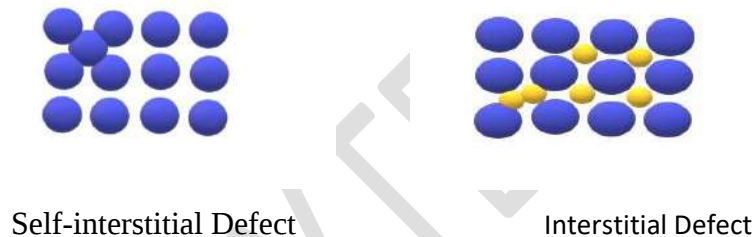
Vacancy:

- A vacancy is produced when an atom is missing from its original lattice site. So vacancy creates an empty lattice site as depicted below. Like other point defects, vacancy is also a zero-dimensional defect.
- The number of vacancies present within a crystalline solid depends exponentially with temperature, thus with increase in temperature of solid, number of vacancies also increases.



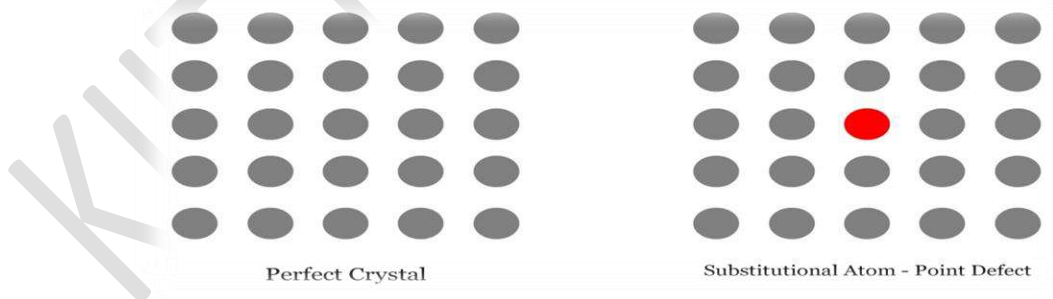
Interstitial

- An interstitial defect occurs when an atom takes the interstitial position of the lattice structure. This interstitial atom may be of the same crystal or of a foreign material.
- **Self-Interstitial Defect**—occurs when atom of the same crystalline solid occupies the interstitial position leaving its original lattice site.
- **Interstitial Defect**—occurs when a foreign atom occupies the interstitial position.



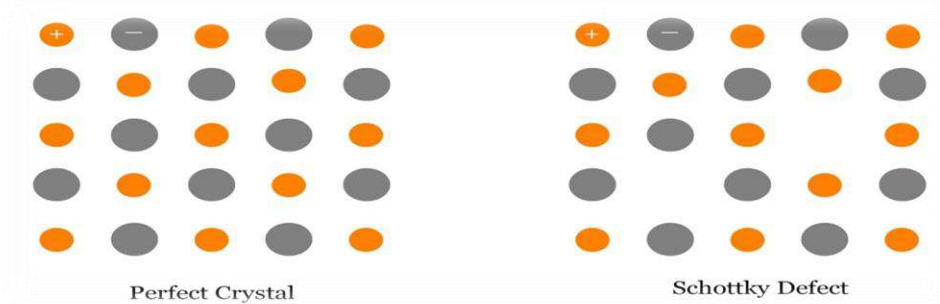
Substitutional:

- Substitutional Defect occurs when the original atom in the lattice site of a crystalline solid is replaced by a different type of atom.
- The foreign atom may be of same size or different (either larger or smaller). Depending on the size of the substituted foreign atom, the neighboring atoms may remain either in tension or in compression.



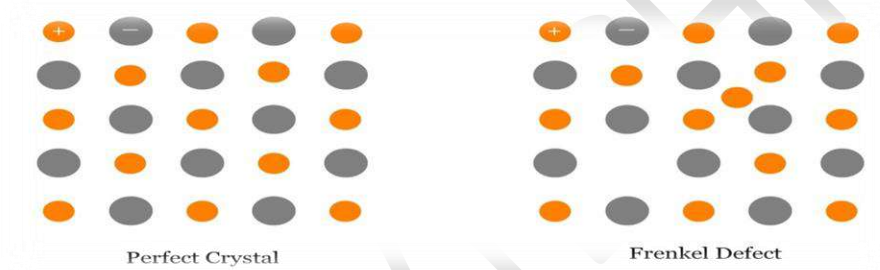
Schottky Defect – Point Defect in Ionic Crystal (Ceramic)

- ☐ Schottky defect occurs when oppositely charged atoms (cation and anion) leave their corresponding lattice sites and create a pair of Vacancy Defects.
- ☐ So, one Schottky defect leads to the formation of two vacancies.



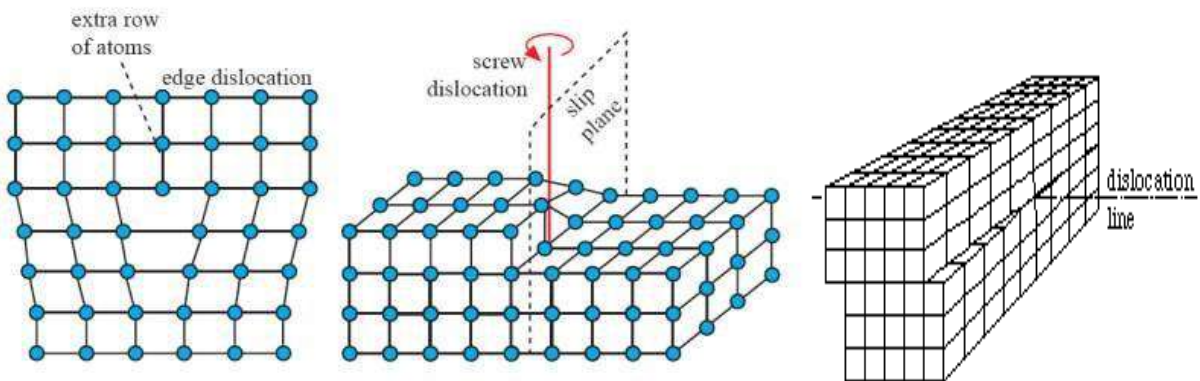
Frenkel Defect – Point Defect in Ionic Crystal (Ceramic)

- ❑ Frenkel Defect is one type of Point Defect; in fact, it is a combination of both Vacancy and Interstitial type of point defects.
- ❑ Basically, a Frenkel Defect is occurs when an atom (better to say ion, especially cation) leaves its original lattice site and occupies an interstitial position on the same crystal.

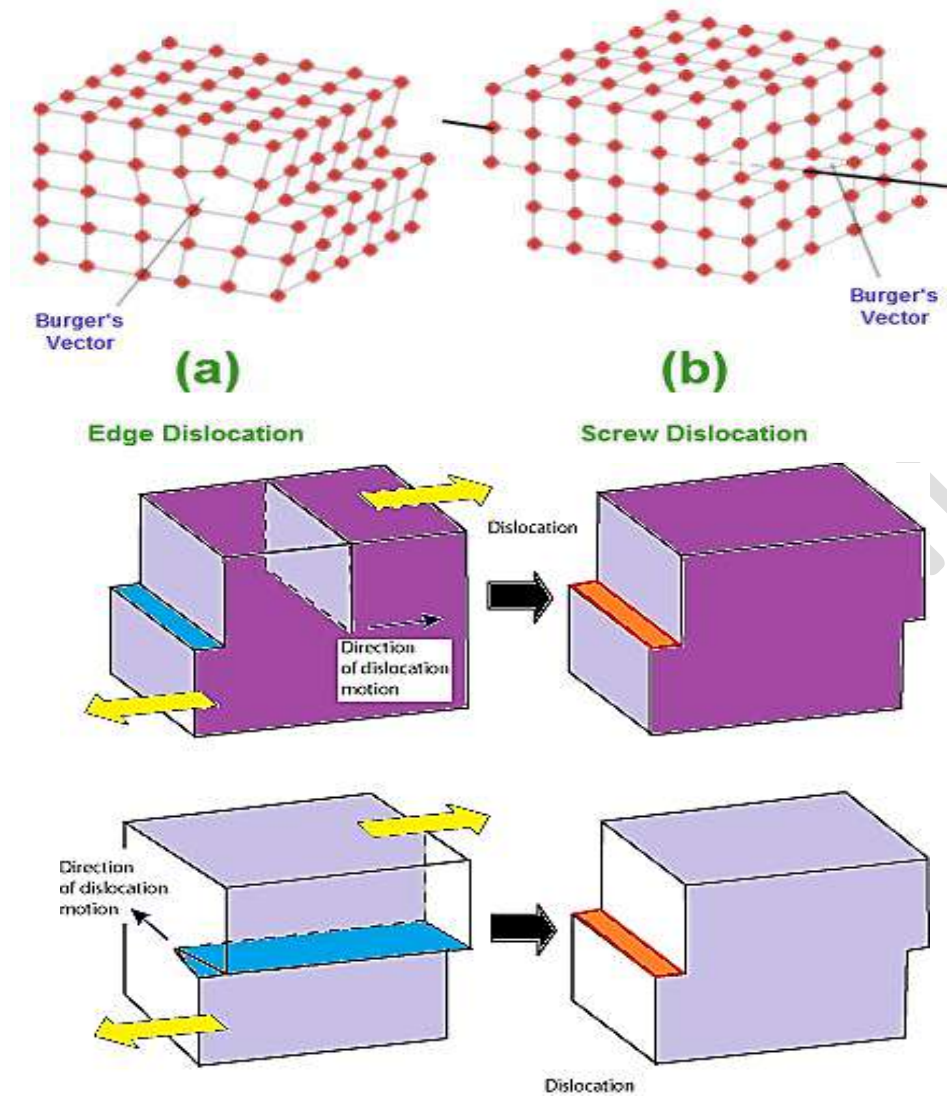


Line Defect or Dislocation

- 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.
- Line defects can weaken or strengthen solids.
- Dislocations are generated and move when a stress is applied.



- When defect in a crystal occurs due to absence of extra half plane of atoms or presence of half plane of atoms then this type of line defect is called Edge dislocation or Edge imperfection.
- Screw dislocation can be formed in a crystal structure by applying upward and downward shear stress to regions of a perfect crystal which have been separated by a cutting plane.



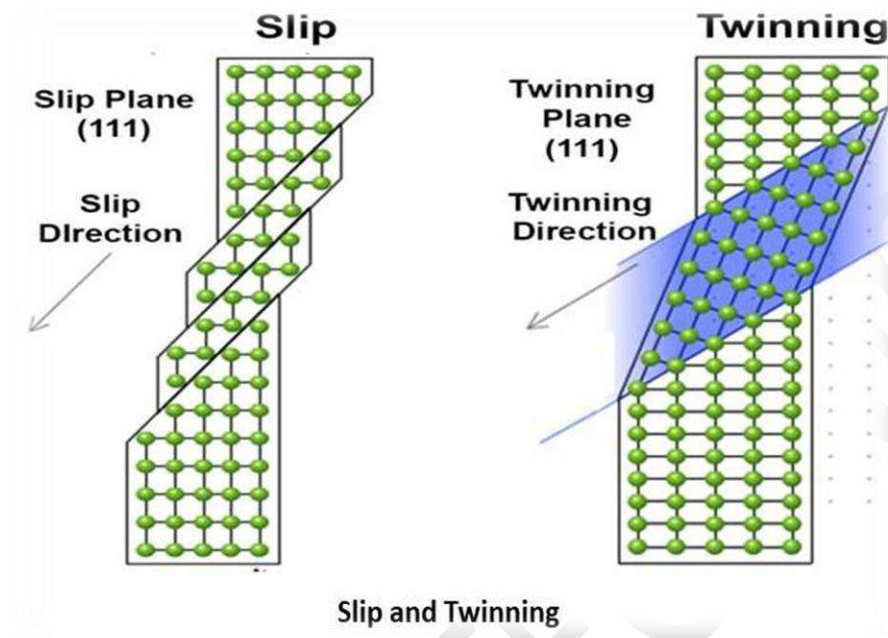
Effect of Imperfection on Material Properties

- It affects or influences 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, besides this, other metallurgical phenomena, such as **oxidation, corrosion, yield strength, creep, fatigue and fractures** are governed by imperfections.
- 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 these properties are further **improved by heat treatment**.

Deformation by slip and twinning:

- **Deformation by Slip**- The usual methods of plastic deformation in metal are by sliding of blocks of the crystal over one another along definite crystallographic plane called slip planes. Slip occurs when the shear strain exceeds a critical value.

- **Deformation by Twinning**- Twinning is the mechanism by which metal deforms plastically and it results a portion of crystal takes of an orientation that is related to the orientation of the rest of the untwined crystal lattice in a geometrical.



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 stresses are produce in cold working.

Chapter-5

HEAT TREATMENT

1. Define Heat Treatment?

- Heat treatment is the process of using heat at various, staged levels to change the physical properties (microstructure) of a material; most often metals.

Or

- It may be defined as heating and cooling operations applied to metals and alloys in solid state so as to obtain the desired properties.

2. Purpose of Heat Treatment?

- To improve machinability.
- To improve ductility and toughness.
- To increase the wear and corrosion resistance.
- To soften the metal.
- Refinement of grain size.
- To increase the chemical uniformity.
- To achieve electrical and magnetic properties.
- Relieving internal stresses

3. Process of heat treatment

- Annealing
- Normalizing
- Hardening
- Tempering

4. Define Annealing?

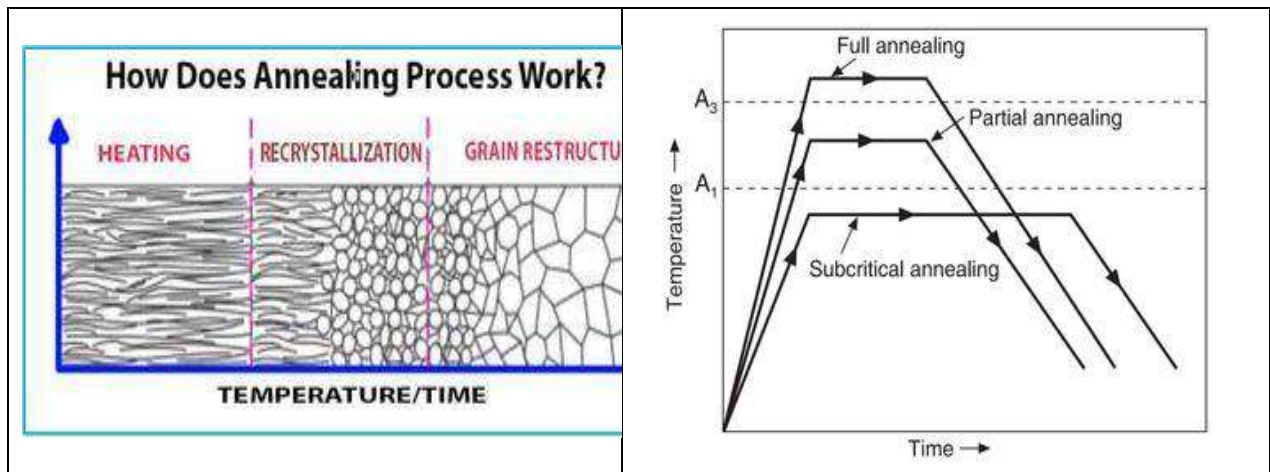
- Annealing is the process involving heating above recrystallization temperature, holding at this temperature for some time and then slow cooling.

Or

- Annealing**, treatment of a metal or alloy by heating to a predetermined temperature, holding for a certain time, and then cooling to room temperature to improve ductility and reduce brittleness.

Propose of Annealing

- Improve or restore ductility and toughness.
- Enhance machinability.
- Eliminate chemical non-uniformity.
- Refine grain size.
- Reduce the gaseous contents in steel



5. Define Normalizing?

- Normalizing is a process of heating steel to about 40-500C above upper critical temperature, holding for proper time and then cooling in still air or slightly agitated air to room temperature.

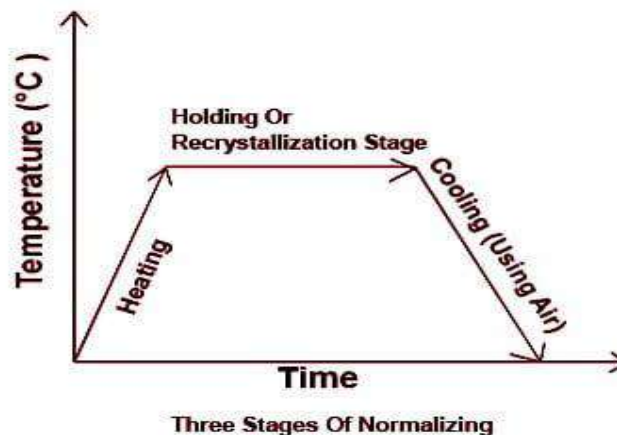
Or

Normalizing is defined as a heat treatment process where a material is heated to a pre-decided elevated temperature, hold at that temperature for a certain period of time (usually 10-20 minutes), and then allowed to cool freely in the air to reach room temperature.

- After normalizing, the metal gets back its ductility and the hardness is reduced.

6. Purpose of Normalizing

- To remove structural irregularities or impurities and defects from the metal.
- To improve ductility that has been lost in some metal processing.
- To reduce the hardness that has been increased by mechanical or thermal hardening processes.
- To increase the toughness of the metal.
- To relieve internal stresses.
- To get an improvement in machinability.



7. Define Hardening?

- Hardening consists of heating to hardening temperature, holding at that temperature, 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.

8. Define Tempering?

- The process which consists of heating hardened steel below the lower critical temperature, followed by cooling in air or at any other desired rate, is known as tempering.
- This treatment lowers hardness strength and wears resistance of the hardened steel marginally. The higher the tempering temperature, the more is the restored ductility and toughens the steel.
- A proper tempering treatment result is optimum combination of mechanical properties. Elastic properties are affected by this. Hardening followed by tempering will improve elasticity.

9. Purpose of tempering?

- To reduce hardness and brittleness
- To increase ductility and toughness
- To relieve quenching stresses
- To achieve strength

10. Surface Hardening?

- **Surface hardening**, treatment of steel by heat or mechanical means to increase the hardness of the outer surface while the core remains relatively soft.
- The combination of a hard surface and a soft interior is greatly valued in modern engineering because it can withstand very high stress and fatigue, a property that is required in such items as gears and anti-friction bearings.
- Surface-hardened steel is also valued for its low cost and superior flexibility in manufacturing.
- The various processes of surface hardening are
 1. Carburizing
 2. Nitriding
 3. Cyaniding
 4. Induction hardening
 5. Carbonitriding
 6. Flame hardening.

11. Carburizing

- Carburizing is a process by which the carbon content of the steel is increased; this is the most widely used case hardening process.

- It is the process of producing a hard surface on low carbon steel parts which contain carbon from 0.1% to 0.25% carbon.
- There are three methods of carburizing such as
 - (a) Pack or solid carburizing
 - (b) Gas carburizing
 - (c) Liquid carburizing.
- This process is extensively used for machine parts including (cams, gears, piston pins, pump shaft, rotor blade).

12. Nitriding?

- The introduction of nitrogen into the outer surface of steel parts in order to give an extremely hard, wear resisting surface is called Nitriding.
- This process is more effective for special alloy steel containing Al, Cr, W, Mo, etc.
- It is used for various auto motives, airplane and diesel engine parts like cylinders, sleeves, liners etc.

13. 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.
- The main factors affecting hardenability are:
 - (a) Alloying elements
 - (b) Carbon content
 - (c) Grain size of steel
 - (d) The homogeneity of starting steel
 - (e) Homogeneity obtained in the austenite before quenching by increasing carbon content, hardness can be increased.

CHAPTER-6

NON - FERROUS ALLOYS

Pure Aluminum

Aluminum is a silvery white metal and it poses the following characteristics:-

- It is a thin metal.
- It is a very good conductor of heat and electricity.
- Aluminum is more resistant to corrosion.
- It is non-magnetic in nature.
- It is soft and ductile.
- Aluminum and its alloys can be cast, forged, welded, extruded, and rolled, among other things.

Uses:

- Industry transformation.
- The structural framework.
- engine parts, doors, window frames, decorative components of automobile parts, boat parts, refrigeration, food preparation equipment, storage containers, wires, tubes, pipes, etc.

Aluminum Alloys:

- Aluminum forms a wide range of alloys with alloying elements like copper, manganese, silicon, magnesium, zinc, titanium etc.
- The most commonly used aluminum alloys are Duralumin and Y-alloy

Duralumin

- It is one of the oldest and most well-known aluminum alloys, widely used for aircraft parts.
- Its composition is 3.5–4.5% copper, 0.4-0.7% manganese, and 0.4% silicon and sometimes contains 0.4–0.7% magnesium and less than 0.5% iron. It developed maximum properties as a result of heat treatment and age hardening, which can be worked readily at about 5000 °C and after quenching ages over a period of 4 to 5 days.
- Its tensile strength increased from 1.55-1.86 ton/cm² yield point from 1.04-2.325 t/cm² and its hardness from 65 to 95 brinell. used for highly stressed structural components, aircraft and automobile parts such as front axle, levers, bonnets, connecting rods, chassis, ship girders, air screws, spares, clips, fittings, levers, and so on. Also used for surgical and orthopedics work for non-magnetic and other instrument parts.

Y-alloys

- Y-alloys are some of the best alloys in this group.
- It is a low-cost alloy that retains its strength and hardness at high temperatures. Its percentage composition is 4% copper, 1.5% magnesium, and 2% nickel. Silicon, magnesium, and nickel are all 0.6%. At the cost and heat treated, its ultimate strength is 2.12tons/cm², but after heat treatment, it shows strength of 3.1tons/cm². The ultimate strength of heat-treated forged alloys is 3.565–4.185 tons/cm², the elongation is 17–22%,

and the Brinell hardness is 100–105. It is extensively used for pistons, cylinder heads, and crankcases of internal combustion engines.

Copper alloys

Copper- Aluminum alloys

- Aluminum gets hardened and strengthened by the addition of copper. The most extensively used alloys for castings are those containing 4, 5, 7, 10 and 12% of copper and with ultimate strength ranging from 1.12 – 4.185 t/cm². It is employed in industry for light casting requiring greater strength and hardness than ordinary aluminum.

Copper-Tin

- These bearing alloys containing greater proportion of tin with copper and antimony and known as white metals. Another alloys of this type having composition of 86% tin, 10.5% antimony, 3.5% copper has a tensile strength of 0.996 t/cm², elongation 7.1% with brinell hardness of 33.3 and compressive yield point of 4.3.
- It is used in main bearings of motors and Aero-engines.

Babbot

- It is a general white metal alloy with soft lead and tin base metals, covering a range of alloys having similar characteristics but varying composition. Its actual composition is 82.3% tin, 3.9% copper, and 7.1% antimony.
- A cheaper Babbot metal used for bearings subjected to moderate pressure has a composition of 59.54% tin, 2.25 to 3.75% copper, 9.5 to 11.5% antimony, 26% lead, 0.08% iron, 0.08% bismuth.
- They are used as liners in bronze or steel backing and are prepared for higher speed, excellent embed ability, conformability, and ability to deform plastically. They are used in IC engine bearings and general machinery purpose bearings.

Phosphorous bronze

- The phosphorous bronzes are the alloys of copper and tin with 0.1 to 1.5% phosphorous. Phosphorous is added both to deoxidize the tin oxide and develop the structure and general properties of the metal.
- In the form of casting, phosphorous bronze gives an ultimate strength about of 18 tons/cm² with an elongation of 4% and a brinell hardness number of 80-100. It is used for heavy compressive loads and is used for gear wheels and slide valves.
- Phosphorous bronze in wrought alloy form containing 10% tin and 0.1–0.35% phosphorous has a tensile strength of 3.72 t/cm², Bhn 100–130. It has good corrosion resistance to sea water and is used for springs and turbine blades.

Brass

- These are the alloys of copper and zinc, with varying percentages of the two metals. If a small amount of one or more metals are added, they provide more specific properties like colour, strength, ductility, and machinability.
- α = brasses-36% zinc and 64% cu.

- α β = brasses—40 to 44% zn and 64 to 55% cu.
- α (Brasses have high tensile strength and ductility, making them ideal for the production of sheets, strips, tubes, wires, and other similar products) and are α β (used for hot pressings, stampings)

Lead alloy

- The tin is replaced by lead base alloys and contains 10 – 15% antimony, 15% Cu, 20% Tin and 60% Lead. These alloys are cheaper than tin base alloys, but not strong and do not possess the lead carrying capacity strength decreases with increasing in temperature. An alloy containing 80% lead, 15% antimony and 5% tin or 20% antimony generally used for long bearings with medium loads.

Zinc alloy

- These alloys used in the form of tooling plate and easy and speed of fabrication. Brasses – Alloys of Cu and Zn.

Nickel alloy

- Nickel is one of the most important metals which is used as a pure metal and alloyed with other elements.
 1. Nickel copper, nickel copper silicon alloys.
 2. Nickel copper tin, sometimes with lead.
 3. Nickel chromium- with iron or cobalt.
 4. Nickel molybdenum-also with chromium.
 5. Nickel silicon.
 6. Nickel manganese,
 7. Nickel aluminum.

Low alloying elements

- Which possess slowly cooled micro structures, similar to those of plain carbon steel in the same condition namely pearlite, pearlite plus ferrite. These low alloys also known as pearlite alloy steel.

High Alloying Elements

- Which possess slowly cooled micro structure, consisting either of Martensite, austenite or ferrite plus carbide particle. It is more than 8% in the case of steels.

Chapter-7

BEARING MATERIAL

- Bearing supports moving parts such as shafts, spindles of a machine or mechanism. The main purpose of bearings is to prevent direct metal-to-metal contact between two elements that are in relative motion. This prevents friction, heat generation and ultimately, the wear and tear of parts. It also reduces energy consumption as sliding motion is replaced with low-friction rolling.
- Bearing may be classified as
 - (i) Rolling contact bearing
 - (ii) Plain bearing or Flat bearing.

Properties:

- Bearing material should have low coefficient of friction.
- Provide good wear resistance.
- Ability to withstand bearing pressure.
- High compressive strength.
- Fatigue strength.
- 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.
- Have non corrosive properties.
- 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

Composition & uses of different type of bearing material

Name	Composition (Wt. %)	Uses
Tin Based Babbitt	85Sn,10Sb,5Cu	High speed bearing bushes in steam and gas turbine, electric motor, blower, pumps etc.
Lead Based Babbitt	80Pb-12Sb-8Sn	Railway Wagon bearing
Cadmium Based	95cd-5ag& small amount of iridium	Medium loaded bearing subjected to high temperature
Copper Based	80Cu-10Pb-10Si	Heavy duty bearing.

Lead Based Alloys:**Composition:**

Lead (Pb) - 80%
 Tin (Sn) - 8%
 Antimony (Sb) - 12%

Properties:

- Lead based alloys are softer and brittle.
- Lead based alloys are chipper than tin base alloy.
- Lead base alloys are suitable for light & medium loads.
- Lead base alloys find application in manufacturing collapsible, automobile industries, rail road construction etc.

Tin Base Alloy:**Composition**

Tin (Sn) = 85%
 Antimony (Sb) = 10%
 Copper (Cu) = 5%

Properties:

- Tin base alloy low coefficient of friction.
- Tin base alloys are preferred for heavier load.
- A tin base alloy poses good resistance to corrosion.
- Tin base alloys are costly and find application in steam turbines high speed engine generators etc.

Cadmium Based Alloys:

Cadmium based alloys bearing are not very popular because high price of cadmium. This bearing alloy poses greater compressing strength than tin base alloys.

Composition:

Cd	98	98	98.5	94.75
Ni	2			3
Ag		1	1	1.50
Cu		1	0.5	
In				0.75

Properties:

- Low coefficient of friction.
- High fatigue strength
- High load carrying capacity
- Low wear poor corrosion resistance.

Chapter- 8

SPRING MATERIAL

Introduction:

- A spring is an elastic object that stores mechanical energy and releases it when the opposing force is removed.
- **Spring is defined** as an elastic machine element that deflects under the action of the load and returns to its original shape when the load is removed.
- Springs are elastic bodies (generally metal) that can be twisted, pulled, or stretched by some force. They can return to their original shape when the force is released. In other words it is also termed as a resilient member.
- It can take any shape and form depending upon the application.
- 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.

Application of spring:

- **To absorb shocks and vibrations.** – Used in Vehicle suspension springs, Railway buffer springs, Buffer springs in elevators, Vibration mounts for machinery.
- **To store energy** – Used in springs used in clocks, toys. Movie-cameras, circuit breakers, and starters.
- **To measure force** – Used in springs used in weighing balance and engine indicators.
- **To control Motion** – Used in the cam and follower mechanism, spring is used to maintain contact between two elements.
- **To apply force** – Used in in engine valve mechanism, spring is used to return the rocker arm to its normal position when the disturbing force is removed. The spring used in the clutch provides the required force to engage the clutch.

Characteristics of spring:

- It should possess high modulus of elasticity.
- It should have high elastic limit
- It should have high fatigue strength
- It should have high creep strength
- It should have high notch toughness
- It should have good resistance to corrosion
- It should have high electrical conductivity

Types of springs:

- a. Helical springs
- b. Conical and volute springs.
- c. Torsion springs.

- d. Laminated or leaf springs
- e. Disc or Belleville springs.
- f. Special purpose springs



Spring Material

- Most springs are made with iron- based alloy (high-carbon spring steels, alloy spring steels, stainless spring steels), copper base spring alloys and nickel base spring alloys.
- The commonly employed spring materials are
 - (i) Copper based spring material
 - (ii) Iron based spring material
 - (iii) Nickel based spring material

Iron- based spring material

- **High Carbon Spring Steel** – (C 0.7-1.0, Mn 0.3-0.6 & remaining Fe) these spring steels are the most commonly used of all spring materials because they are the least expensive, are easily worked, and are readily available. They are not suitable for springs operating at high or low temperature or for shock or impact loading.
- **Alloy Spring Steel** – EN-45 (C 0.5, Mn 1.0, Cr 0.2-0.9, V 0.12 & remaining Fe), EN-60 (C 0.5-0.75, Mn 0.6-1.2 & remaining Fe). These spring steels are used for conditions of high stress, and shock or impact loadings. They can withstand a wider temperature variation than high carbon spring steel and are available in either the annealed or pre-tempered conditions.
- **Stainless Spring Steel** – (Cr 18, Ni 8, C 0.1-0.2 & remaining Fe) the use of stainless spring steels has increased and there are compositions available that may be used for temperatures up to 288°C. They are all corrosion resistant but only the stainless 18-8 compositions should be used at sub-zero temperatures. They are suitable for valve springs.

Copper Base Spring Alloys

- Copper base alloys are more expensive than high carbon and alloy steels spring material. However they are frequently used in electrical components because of their good electrical properties and resistance to corrosion. They are suitable to use in sub-zero temperatures.
 - a. Brasses (Cu 67, Zn 33): Switch control, electrical application.
 - b. Nickel Silver (Cu 56, Ni 18, Zn 18): Electrical relays.

- c. Pb Bronze (Cu92, Sn8, Pb 0.1): Bushes.
- d. Beryllium Copper (Cu98, Be2.0): Relays and Bushes

Nickel Base Spring Alloys

- Nickel base alloys are corrosion resistant, and they can withstand a wide temperature fluctuation. The material is suitable to use in precise instruments because of their non-magnetic characteristic, but they also pose a high electrical resistance and therefore should not be used as an electrical conductor.
 - i) Monels (Ni68, Cu27 & remaining Fe and Mn)
 - ii) Inconel's (Ni76, Cr16 & Fe8)
 - iii) Chromels (Ni80, Cr20)
 - iv) iv) Nichrome (Ni60, Cr16 & Fe24)
 - v) Elinvar (Ni36, Cr12 & rest Fe)
 - vi) Invar (Ni35, Fe65)

CHAPTER-09

POLYMER

1. Define Polymer?

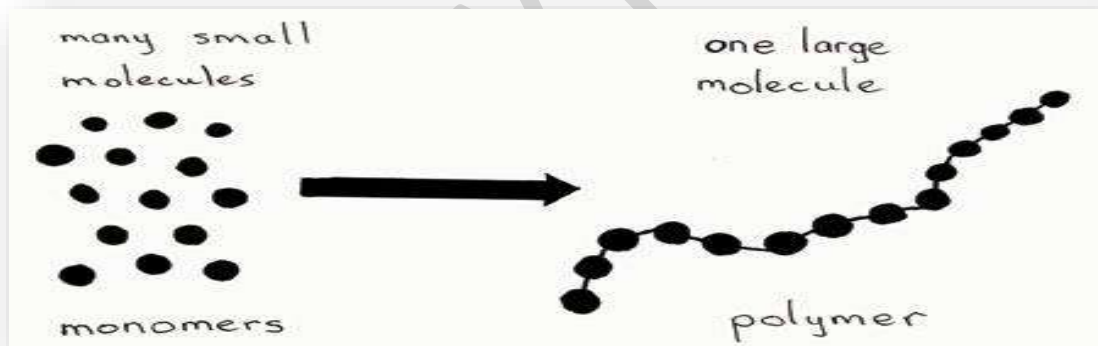
- **Polymer** is any of a class of natural or synthetic substances composed of very large molecules, called macromolecules that are multiples of simpler chemical units called "monomers."
- A polymer is a large molecule or a macromolecule which essentially is a combination of many subunits. Polymers can be found all around us.
- Examples of polymers are:
(i) Wood (ii) Starch (iii) Resin (iv) PVC (v) Polyethylene (vi) Epoxy

2. Define Polymerization?

- Monomers are to be combined to form polymers by the process known as **polymerization**. 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.

3. Define Monomer?

- The simplest substance consisting of one primary chemical is known as the **monomer**. The polymer molecule is also called a **macromolecule**.



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

4. Explain Characteristics of polymer?

- Good corrosion resistance
 - Low coefficient of friction
 - Good mold-ability
 - Excellent surface finish
 - Poor tensile strength
 - Poor temperature resistance
 - Low mechanical properties
 - Can be produced transparent and in different colors.
- The classification of plastics can be made by considering various aspects and for the purpose of discussion, they can be classified according to their

1. Behaviour with respect to heating.
2. Structure and
3. Physical and chemical properties.

Behaviour with respect to heating

According to this classification the plastics are divided into two groups:

- (i) Thermo-Plastic
- (ii) Thermo-Setting

- The above classification is based on the inherent characteristics of each group. These two groups can further be divided into several distinct sub-divisions. These sub-divisions are based on the raw materials from which plastics are prepared. It is interesting to note that each of above group contains several hundred different products and with the advance of plastic industry, the number of sub-divisions under each category is constantly increasing.

Thermoplastic polymer

- The thermo-plastic or heat nonconvertible group is the general term applied to the plastics which become soft when heated and hard when cooled. The process of softening and hardening may be repeated for an indefinite time. Provided the temperature during heat is not so high as to cause chemical decomposition. It is thus possible to shape and reshape these plastics by means of heat and pressure. One important advantage of this variety of plastics is that the scrap obtained from old and worn-out articles can be effectively used again.

PVC (Poly Vinyl Chloride)

The polymers are produced by polymerizing vinyl compound.

- a. It is relatively low in cost.
- b. It offers good toughness strength & abrasion resistance.
- c. It is self-extinguishing with low moisture absorption.
- d. They have good electrical insulation property
- e. They are widely used to manufacture, rain coats, hand bags, tubes, pipes etc.

Poly Ethylene

- These polymers are produced by polymerization ethylene molecules.

Properties

- It is light and odorless. It offers chemical resistance & don't absorb moistures.
- It is an excellent electrical insulator.

Uses

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

Polystyrene

- 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

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

Thermosetting polymer

- These polymers become soft during their 1st heating & become permanently hard when cooled. They don't soften upon subsequent heating. 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.
- Thermo sets are generally hardened stronger & more brittle. Some commercially available thermo sets are:

Phenol

- Phenolic or phenols are produced by the poly condensation of phenol and thermal dehyde.
- It offers excellent strength, resistance to heat.
- It shows chemical resistance property & relatively low on cost.
- They are widely used for making electric iron handles, fan motor, switch covers etc.

Melamine

- These polymers are produced by the co polymerization of melamine's and formal dehyde.
- They have excellent tensile strength.
- It is the hardest plastic known & dimensional stability
- It offers low moisture absorption & Flame resistance.
- It is moderate in cost.

Uses

- Melamine are used for plastic crockery, automobile parts etc.

Epoxy

These polymers are produced by the condensation of epochlorhydrin & Dioxy diphenyle propane.

- They have excellent adhesive property.
- It offers chemical resistance & low moisture absorption.
- It offers good toughness and electrical insulation property.
- It is relatively expensive.
- They are widely used for bonding the material together such as wood, plastic, metal etc.
- They are also used the manufacturing of high voltage, insulating material, laminates, varnish.

Properties of Plastics

- **Appearance** : Transparent
- **Chemical resistance**: The plastics offer great resistance to moisture, chemicals and solvents, excellent corrosion resistance.
- Dimensional stability.

- **Ductility:** The plastic lacks ductility. Hence its members may fail without warning.
- **Durability:** The plastics are quite durable, if they possess sufficient surface hardness.
- **Electric insulation:** They are far superior to ordinary electric insulators.
- **Finishing:** Any surface treatment may be given to the plastics.
- **Fire resistance:** All plastics are combustible.
- **Fixing:** Can be easily fixed in position.
- **Humidity:** PVC plastics offer great resistance to the moisture.
- **Maintenance:** It is easy to maintain plastic surfaces. They do not require any protective coat of paints.
- **Melting point:** Most of the plastics have low melting point and MP of some plastics is only about 50°C.
- **Optical property:** Several types of plastics are transparent and translucent.
- **Recycling:** It does not give a serious problem to pollution as generated by a host of other industries. The plastics used for soft drink bottle, milk and juice bottles, bread bags, syrup bottles, coffee cups, plastic utensils etc can be conveniently recycled into carpets, detergent bottles, drainage pipes, fencings, handrails, grocery bags, car battery cases pencil holders, benches, picnic tables, roadside posts etc.
- **Sound absorption:** The acoustical boards are prepared by impregnating fiber-glasses with phenolic resins. This material has absorption co-efficient of about 0.67.
- **Strength:** The tensile members are generally made of plastics as their strength to weight ratio in tension very nearly approaches to that of metals.
- **Thermal property:** The thermal conductivity of plastics is low and it can be compared with that of wood.
- **Weather resistance:** Certain plastics are seriously affected by sun light, but other plastic can resist weather which is prepared from phenolic resins.
- **Weight:** The plastics, whether thermo-plastic or thermo-setting have low specific gravity being 1.30 to 1.40.

Applications of Plastic:

The typical use of plastics in building is as follows:

1. Bath and sink units.
2. Cistern ball floats.
3. Corrugated and plain sheets.
4. Decorative laminates and moldings.
5. Electrical conduits.
6. Electrical insulators.
7. Floor tiles.
8. Foams for thermal insulation.
9. Joint less flooring.
10. Lighting fixtures.
11. Overhead water tanks.
12. Paints and varnishes.
13. Pipes to carry cold water.

14. Roof lights.
15. Safety glass.
16. Wall tiles.

Elastomer:

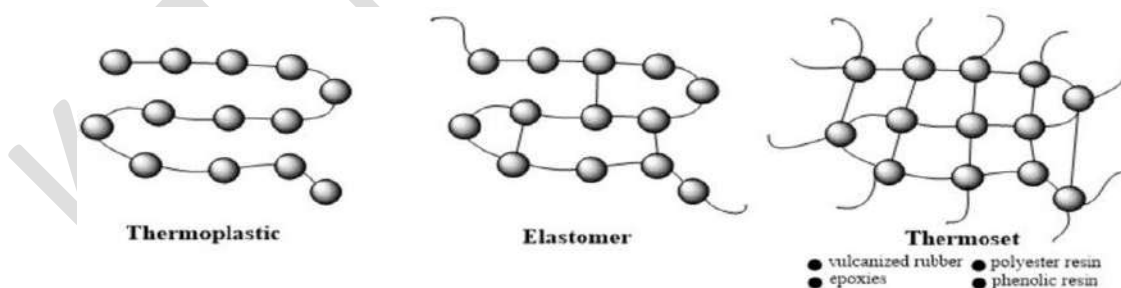
- Elastomers commonly referred to as rubber are hydrocarbon & polymeric materials, Similar in structure like plastic.
- An elastomer is a type of polymer having the specific characteristic feature of elasticity. Elasticity is the ability of an object or a material to resume its normal shape after being stretched or compressed. Elastomers are rubber-like material and are usually amorphous polymers (there is no ordered structure).
- **Elastomer**, any rubbery material composed of long chain like molecules, or polymers, that are capable of recovering their original shape after being stretched to great extents—hence the name **elastomer**, from “**elastic polymer**.”
- 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:

- They are non-crystalline in structure. They are non-conductors of electricity.
- They are high resistance to chemical & corrosion.
- They have relatively low softened temperature.

Properties of elastomer:

- High resilience or energy storing capacity.
- Good tensile strength.
- Excellent abrasion resistance & oil resistance.
- Good compression strength & hardness.



Differentiate between Thermosetting and Thermoplastic polymer

Thermoplastic Polymer	Thermosetting polymer
1. These are formed by addition Polymerization.	1. These are formed by condensation Polymerization.
2. They are linear or slightly branch long chain polymers.	2. They are cross linked or heavily branched.

3. They can be easily soften on heating and hardened on cooling.	3. It cannot be softened on heating.
4. They have low molecular weight.	4. They have high molecular weight.
5. They are soft, weak, brittle.	5. They are strong, hard and more brittle
6. They can be softened, reshaped and reused.	6. They cannot be softened and reshaped again and again.
7. They are held together by Van der Waal forces of attraction.	7. They are held together by strong hydrogen bonds.
8. They can be remolded into desired shapes.	8. They cannot be remolded.
9. Monomers used here do not have more than two reaction sites.	9. Monomers used here have more than two reaction sites.
10.Examples: polythene, polystyrene, polyvinyl, etc.	10. Examples: Bakelite, urea-formaldehyde resins, etc.

Difference between Elastomers and Polymer:

Property	Elastomers	Polymer
Definition	It is a polymer with very weak intermolecular forces and Viscoelasticity. Thus, they are famously known as elastic polymers.	It is a macromolecule or large molecule made up of clusters of sub-units.
Physical property	They inherit the unique property of elasticity.	They inherit diverse properties based on the category.
Morphology	They are amorphous structure.	They vary from crystalline form to amorphous form.
Flexibility	They are elastic in nature. They are capable of configuring the right distribution of applied pressure to retain their original size and shape.	They are mostly brittle/ hard/rigid in nature except for elastomers. Application of force can result in permanent deformation.

Probable Questions:

2. Define polymer and state its types.
3. Define elastomer.
4. Differentiate between thermosetting and thermoplastic polymer.
5. Explain the properties and uses of elastomer.
6. Write the properties and application of thermosetting polymers.
7. Write the properties and application of thermoplastic polymers.

Chapter-10

COMPOSITES AND CERAMICS

CERAMICS

- **Ceramics** materials are complex chemical compound composed of both metallic & non-metallic elements are bonded together primarily by ionic or co-valent bond.
- A **Ceramic** is an inorganic non-metallic solid made up of either metal or non-metal compounds that have been shaped and then hardened by heating to high temperatures. In general, they are hard, corrosion-resistant and brittle.
- Ceramics are all around us. This category of materials includes things like tile, bricks, plates, glass, and toilets.
- Ceramics can be found in products like watches (quartz tuning forks-the time keeping devices in watches), snow skis (piezoelectric-ceramics that stress when a voltage is applied to them), automobiles (sparkplugs and ceramic engine parts found in racecars), and phone lines.
- They can also be found on space shuttles, appliances (enamel coatings), and airplanes (nose cones).
- Depending on their method of formation, ceramics can be dense or lightweight. Typically, they will demonstrate excellent strength and hardness properties; however, they are often brittle in nature.
- Ceramics can also be formed to serve as electrically conductive materials, objects allowing electricity to pass through their mass, or insulators, materials preventing the flow of electricity. Some ceramics, like superconductors, also display magnetic properties.
- Ceramics are generally made by taking mixtures of clay, earthen elements, powders, and water and shaping them into desired forms. Once the ceramic has been shaped, it is fired in a high temperature oven known as a kiln. Often, ceramics are covered in decorative, waterproof, paint-like substances known as glazes.
- They are good electrical & thermal insulator due to the absence of conducting electrons. They have relatively high melting temperature good chemical stability & corrosion resistance.

Ceramics may be classified as:

1. Glasses
 - I. Glass
 - II. Glass ceramics
2. Clay product
 - I. Structural clay product
 - II. White wares
3. Refractories
 - I. Fire clay
 - II. Silica
 - III. Basic
 - IV. Special
4. Abrasive
5. Cements

6. Advanced ceramics

USES

- Ceramics materials are used in glass product.
- It is used for making bricks, tiles grain pipes.
- It is used in dinner wear, sanitary wear.
- It is used as cement plaster etc.
- Porcelain enamels & refractory coating for metal.
- Ceramics used in refractory for high temperature used.

COMPOSITE

- The material which is produced by combining of two dissimilar materials into a new material that may be better suited for a particular application than the original material is called composite.
- The base material which is present in large amount is called matrix, the material is sometimes known as reinforcing phase.

CLASSIFICATION OF COMPOSITE MATERIAL:-

Composite are classified

1. Partial reinforced
 - i. Large partial
 - ii. Distortion strength thread
 2. Fiber reinforced
 - i. Continues
 - ii. Discontinues
 - a) Aligned
 - b) Randomly oriented
 3. Structural
 - i. Laminates
 - ii. Sandwiches plane
- The general properties which can be improved by manufacturing composite material including strength, stiffness, corrosion resistance, wear resistance, thermal insulation, and fatigue.

PARTIAL REINFORCED COMPOSITE

- Partial reinforced composite are made by dispersing partial of varying size and shape of one material in matrix on another material.
- The operation may be carried out by adding partial to a liquid matrix material, which later solidified or may be pressed (By the powder process).
- In such composite the matrix as well as partial share the load

EX: - Cements, metal ceramic compound.

Used in cutting tools, used in dams, buildings etc....

- As the volume fraction of the dispersed partial increases, mechanical properties improve and reaching on optimum value and then begin to fall.
- At higher volume fraction of the dispersed the brittle ceramic partial come closer to each other there by continues brittle phase is form to which promotes permutated failure.

FIBRE REINFORCED COOMPOSITE

- Fibre reinforced components involves three components normally filaments or polymer matrix and bending agent.
- The glasses and metallic fibre commonly employed for this for this purpose.
- Fibre in composite provides stiffness and also density of the components where metal matrix is used.
- Matrix provided toughness to the composite material and it binds the fibre together
EX: - Glass reinforced plastic
- The fiber reinforced composite possess superior properties like: higher yield strength, fracture strength and fatigue.
- To obtain composite having the maximum strength and elastic modulus .it is essential that there should be maximum number of fibre per unit volume so that each fibre shears the load acting.
- For preparing a fiber reinforced composite. It is essential that
 - i. The fiber should be at room temperature and posses' good strength at elevated temperature.
 - ii. The fibre and matrix should be chemically balanced with each other and no considerable reaction takes place between them.