

ENGINEERING MATERIAL

material:-

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

(ii) Engineering material's are those which are design structurally develop specific property for a given application.

Material Classification:

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

(i) metals & Alloys

(ii) Non-metal

(ii) Further for engineering application metal's and alloy are classified as Ferrous and non-Ferrous.

(iii) Similarly non-metals are classified as:

- polymer
- ceramics
- organics
- composite

Semiconductor

Metals:-

- metals are composed of element's, which give up electrons to provide a metallic bond and achieve thermal or electrical conductivities.

ENGINEERING MATERIAL

material:-

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

(ii) Engineering material's are those which are design structurally develop specific property for a given application.

Material Classification:-

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

(i) metals & Alloys

(ii) Non-metal

(ii) Further for engineering application metal's and alloy are classified as Ferrous and non-Ferrous.

(iii) Similarly non-metals are classified as

- polymer
- ceramics
- organics
- composite

Semiconductor

Metals:-

- metals are composed of element's, which give up electrons to provide a metallic bond and achieve thermal or electrical conductivities.

- The metals are characterized by high thermal and electrical conductivity. Strong yet deformable under applied mechanical loads. Opaque to light.
- Metals also possess the following properties. hardness, strength, ductility, brittleness, machinability, weld ability, cast ability, formability etc.

Ferrous material:-

- (i) Ferrous metals are those in which the best constituents or main constituents is iron, although other constituents are carbon, sulphur, phosphorous manganese etc. also exists in different proportion.
- (ii) properties or characteristics of ferrous material are hardness, strength, ductility, good conductor, good conductor of heat and electricity machine ability etc.

Non-Ferrous metal's:-

- (i) Non-Ferrous metal's are those which do not contain iron constituents.
- (ii) metal's like aluminium, copper; zinc; lead tin, gold etc. and their alloy's falls under this category for metals classification.
- (iii) Non-ferrous metals possess for special character like good conductivity of heat and electricity, light weight, high resistance to corrosion etc.

Non-metal's

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

(ii) The Non-metals exists two of the three states of metal at room temperature, gases.

(Such as oxygen) Solid (Such as carbon)

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

(iv) Non-metallic element's are brittle and cannot be rolled into wires, or form into sheets.

Ceramics :-

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

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

(iii) ceramics are partly crystalline and partly amorphous.

(iv) ceramic materials are rock like or clay mineral material's.

Characteristics :-

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

Organic materials (Polymer) :-

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

(ii) The polymers composed of a large number of repeating units (small molecules) called monomers.

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

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

(v) Polymers in the form of thermoplastic (PVC, rubber, polyethylene etc) consists of molecules that have covalent bonding within each molecule. Polymer in the form of thermosets (Bakelite) consists of a network of covalent bonds.

(vi) Due to the kind of bonding, polymers are typically electrically or thermal insulators. Important characteristics :-

(i) Light weight, combustion, soft etc, poor conductor of heat and electricity, poor resistance to temperature. EX :- Polyethylene, Rubber, Fiber, PVC etc.

Composite:

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

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

Characteristics:

- (i) Strength (iv) hardness
- (ii) Stiffness (v) insulation etc.
- (iii) Corrosion

(iii) The best example have ~~electrical properties~~ that are interm. is fiber glass, a composite of glass embedded with polymer matrices.

Semi Conductor:

- Semi conductor have electrical properties that are inter-mediate between the electrical conductors & insulators.

- Semi conductors are covalent in nature.

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

For example:-

Silicon, Germanium, Gallium, arsenide.

- Semi conducting material are basically used in manufacturing of different electrical

& electronics components.

Factors affecting the selection of materials for engineering application:-

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

(i) properties of material

(ii) Environmental condition

(iii) Availability

(iv) Disposability

(v) Economic factors

(vi) physical attributes

(vii) performance & Requirement

(viii) material reliability

(ix) Safety

performance Requirement:-

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

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

Material Reliability:

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

Safety:

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

Properties of materials:

~~Mechanical prop.~~

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

Ex: ~~Strength, ductility, brittleness, creep,~~

Ex: - engineering properties of the materials are classified into different categories.

Mechanical property:

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

Ex: Strength, ductility, brittleness, creep, Fatigue. Important mechanical properties.

Electrical property:

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

EX :- Resistivity, conductivity, dielectric strength etc.

Thermal properties

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

EX :- Specific heat, thermal conductivity, melting point, thermal expansion.

Magnetic properties:

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

EX :- permeability, Hysteresis etc.

Physical property of a material:

- Physical property ~~of a~~ ^{is} employed to describe a material under condition in which external forces are not concerned.

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

(i) porosity - A material is said to be porous if it has pores within it. True porosity = $\frac{\text{Total pore volume}}{\text{Bulk volume}}$.

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

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

Chemical property -

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

- Some of the chemical properties are -

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

(2) Chemical composition

(3) Acidity

Ferrous materials

- Ferrous materials are those in which the main constituent is iron, although other 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 wide spread use of ferrous material is accounted by three factors.

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

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

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

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

Ferrous materials are -

- Pig iron
- wrought iron
- Cast iron
- Carbon Steel
- gray cast iron
- white cast iron
- malleable cast iron

Carbon steel -

- It is an alloy of iron & carbon and it is malleable.

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

- Carbon steels contain from 0.10% to

1.5% carbon where as cast iron possesses

1.8% to 4.2% carbon.

- Carbon steels can be classified as

(1) Low Carbon steel

(2) medium carbon steel

(3) High carbon steel

Low carbon steel or mild steel -

- Low carbon steel or mild steel contain carbon from 0.05% to 0.3% carbon.

steels containing 0.05 to 0.15% carbon are used for making steel wires, sheets, rivets, screws, nails, chains, etc.

- It is also known as ~~low carbon 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% carbon has a tensile strength of 420 N/mm^2 and hardness of 125 BHN. It is used for making sheets, strips for fan blades, welded turbines, forgings, cam shafts.
- mild steel containing 0.20% to 0.30% carbon has a tensile strength of 555 N/mm^2 & a hardness of 140 BHN.
- It is used for making valves, making connecting rod, crank shafts, railway axle etc.
- medium carbon steel:
 - medium carbon steels contain carbon from 0.30 to 0.70%.
 - Steels containing 0.35 to 0.45% carbon have a tensile strength of about 100 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.
 - It maintained hardness 200 to 300 BHN.

- Steels containing 0.45 to 0.55% carbon have a tensile strength of about 3000 N/mm^2 & a hardness of 300 to 400 BHN.
- They are used for making crank shafts, axle, splines shafts etc.
- Steels ~~are~~ used containing 0.6% to 0.7% carbon have a tensile strength of 1236 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 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 for leaf spring, punch & die, circular saws, machine chisels, railway

- Steels containing 0.9 to 1.0% carbon (High carbon tool steel) have a tensile strength of 580 N/mm² & a hardness of 560 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 springs etc.
- Steels containing 1.1% to 1.2% carbon are used for taps, knives, twist drills, etc.
- Steels containing 1.2 to 1.3% carbon 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 is overcome by employing alloy steel.

- Alloy steels are steel containing various alloying elements like Ni, Cr, Mn, W, Mo, V, Co, etc.
- The objectives in adding alloying element to steel is not only to improve and extend the property of plain carbon steel but also to introduce new property that are not available in plain carbon steel.

Purpose:

- The purpose of using alloying elements are.

- To increase harden ability.
- To increase strength at ordinary temperature.
- To increase resistance to corrosion.
- To increase ~~to corrosion~~ wear resistance.
- To improve toughness.
- To improve electrical and magnetic properties.

Classification:

- Alloy steels are classified as

- Low alloy steel: up to and including 5% alloying element

Chapter-2

Ferrous materials and Alloy-8

Introduction

- Ferrous materials are those in which the main constituent is ~~Fe~~ 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 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 metal 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% carbon whereas cast iron possess 1.8% to 4.2% carbon.

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 and including 10%.

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

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

→ Based on engineering application:

(i) Structural grade ~~used~~ alloy 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

- slight change of form during hardening.
- Little risk of cracking during hardening.
- Good toughness.
- Good wear resistance.
- very good machinability.
- A definite cooling rate during hardening.
- A definite hardening temperature.
- Resistance to de-carburization.
- Resistance to softening on heating.

Classification of Tool Steel:

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

<u>Symbol</u>	<u>meaning</u>
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

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 2-3.5	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
O ₃	C 0.9	Mn 1	Cr 0.5 W 0.5
O ₂	C 1.45	Si 1	Mo 0.5

→ Water hardening Steel

W ₂	C 0.6/1.4	Cr 0.5	W 0.5	V 0.25
W ₅	C 1.1			Mo 0.25
				Cr 0.5

→ Hot work steel

H10 C0.4 Cr3.25 V0.4 Mo2.5

H12 C0.35 Cr0.5 V0.4 W4 Mo1.5

→ Shock resistance steel

S1 C0.5 Cr1.5 W2.5

S2 C0.5 Si1 Mo0.4

S3 C0.55 Mn0.8 Si2 Mo0.4

S7 C0.5 Cr3.25 Mo1.4

Austenitic 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 steels.

→ The stainless steel basing on their micro-structure can be grouped into three metallurgical classes such as Austenitic stainless steel, Ferritic stainless steel & martensitic stainless steel.

Austenitic Stainless Steel:

Properties.

1) They possess austenitic structure at room temp.

- 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 temp. 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 & railway 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% Mn 1 to 1.5% Cr 11 to 27%
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 & weldability.

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

Dt = 29/7/24 Engg material

Mechanical property

* What is material.

Ans: Material is anythings which some mass and occupy volume.

* These are three types: (i) Solide

(ii) liquid

(iii) gas

* Solide: An object having three dimension like length, breath, and thickness is called as solid material.

* Solide material property:

(i) Fixed Shapped and Fined volume.

(ii) Incompressible

(iii) rigid body.

* liquid: A substance that flows freely but is of constant value having a consistency.

Ex: Water.

Property

(i) Fixed Shape.

gas: The state which is lighter weight and does not have any definite state and value.

Ex: Hydrogen, nitrogen, etc.

Property $\div$ It not fixed volume and not fixed shape.

Property of Engg. material

① Mechanical property.

② Physical property.

③ Chemical property.

Mechanical property

* The study behaviour of a material under action of force is known as mechanical property.

(i) Elasticity $\div$ It can be defined as the property of a material which is regain its original shape and size after removal the external force.

(ii) plasticity $\div$ It can be defined as the property of a material which is changed its shape permanently.

Ex $\div$ plastic

(iii) Strength $\div$ It can be defined as the property of a material which is maximum load carrying ability before failure.

(iv) Hardness $\div$ It can be defined as the property of a material which offer's resist to Indentation or scratch.

* **Ductility**:- It can be defined as the property of a material by which a material can be converted into wire form.

Ex:- Steel, gold, silver, copper.

* **Brittleness**:- It can be defined as the property of a material which is break without any significant deformation when subjected to a load.

Ex:- glass, iron, ceramics.

* **Malleability**:- It can be defined as the property of a material which is can be converted into thin layer of sheet.

* **Toughness**:- It can be defined as the property of a material by which is observed energy and deformed plastically up to fracture point without failure.

* **Creep**:- It can be defined as the property of a material which is slow and progressive deformation of material which time of constant load.

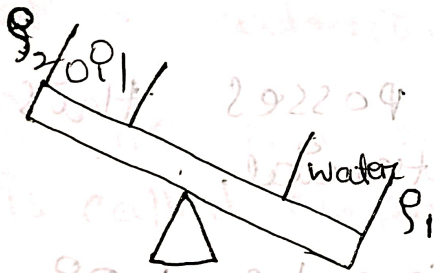
* **Fatigue**:- It can be defined as the property of a material's by which can substance million of cycling load.

Physical property

* physical property define as a characteristic of a matter that may be observed and measured without changing the chemical identity of a sample.

Physical property

(i) Density: It is defined as the mass of a given volume of a material. It is symbolically denoted by (ρ) $\rightarrow$ Rho



* Volume same

* Always water density

1000.

* Mercury density = 13600

$$\text{density}(\rho) = \frac{W}{V}$$

$$= \frac{\text{mass}}{\text{volume}} = \frac{\text{kg}}{\text{m}^3}$$

$$W_1 = \rho_1 V$$

$$W_2 = \rho_2 V$$

(ii) Specific volume: It can be defined as the ratio of volume occupied per unit mass it is. Symbolically denoted (v) (small)

$$v = \frac{\text{Volume}}{\text{mass}} = \frac{\text{m}^3}{\text{kg}}$$

* Specific gravity: It is the ratio of density of the fluid to the density of standard fluid. It is symbolically denoted by (sg) (Specific gravity)

$$sg = \frac{\text{density of fluid}}{\text{density of standard fluid}}$$

* Porosity: (i) It is the property of a material which allows the material to absorb fluid.

Fluid: * Which can flow is called fluid.
* Fluid composition.

(ii) The material which possesses this property is called porous material.

* Thermal Conductivity: It can be defined as the property of a material which allows the heat to pass through it.

Ex: Iron, gold, Copper, Steel.

* Electrical Conductivity: It can be defined as the property of a material which allows the current to pass through it.

Ex: Iron is the heavy electrical conductivity material.

* The material which possesses this property is called electrical conductor.

* magnetic property: (i) It can be define as the property of a material by which it is attracted towards a magnet.

Ex: Copper, nickel, iron.

(ii) The material which posses this property is called magnetic material.

* Compressibility: It can be defined as a property of a material by which we easily compressed.

* Enpanssibility: It can be defined as a property of a material to get enpanted.

(ii) The material which posses this property is called expandable material.

* Refractoriness: It can be defined as the property of a material to with stand at high temperature.

Ex: Sylicat, Alumina, tungsten

Chemical property: chemical properties are material characteristic that relate to the structure of a material and its formation from the elements.

* Chemical Composition: Chemical composition is material effect the property of a engg material very much. Ex: Steel.

chemical composition of steel

= Ferrous, Chromium
nickel

Brass = Copper, nickel.

Bronze = Copper (90%), nickel
(10%)

* Atomic bonding: Atomic bonding represent how atom are bonding to each other to form the material.

(i) Many properties such as melting point, boiling point, thermal conductivity, and electrical conductivity of material are governed atomic bonding of material. hence proved understand the properties of material.

Corrosion resistance

* It is the ability of a material to resist the ~~oxylation~~ oxidation in atmospheric condition.

* Generally pure metal such as iron, copper, Aluminium etc. get corroded slowly in atmosphere to avoid the corrosion of those metal in pure form.

* Therefore we are use those metal ~~than~~ in the form of alloys such as stainless steel, brass, bronze, silver etc.

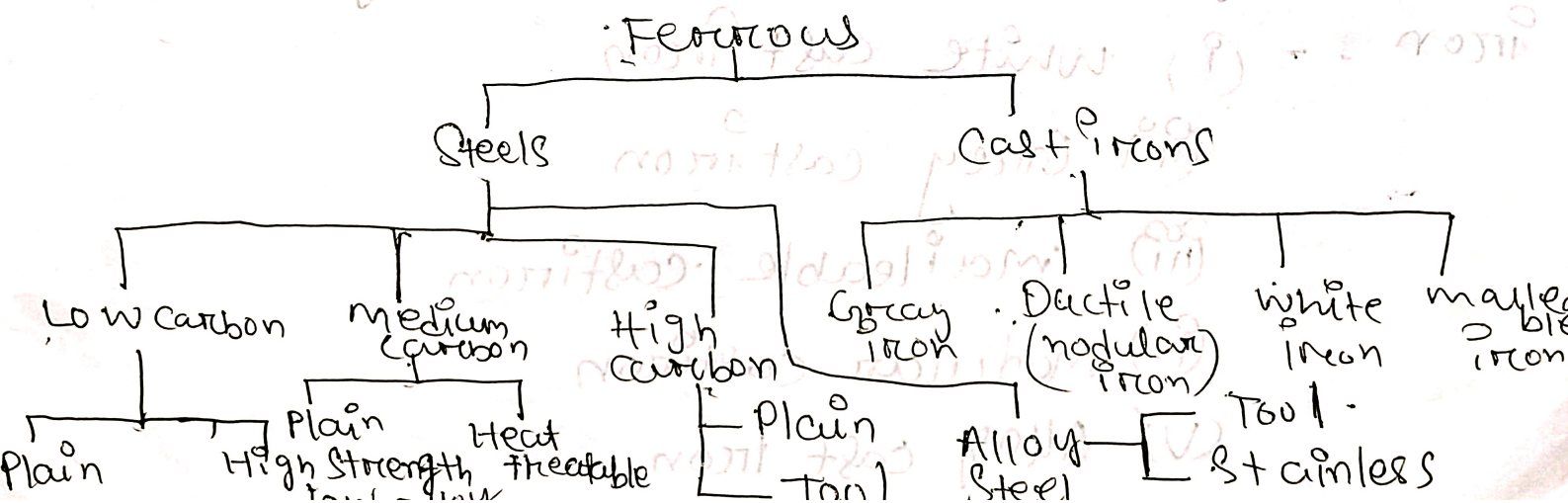
* painting and coating are also method of corrosion resistance.

Acidity or Alkaline

- * A material is acidic or alkaline is decided by the pH value of the material. pH value of a material varies from 0-14.
- => pH value of 7 is considered to be neutral.
- => Ordinary water is having pH value of 7
- => The material which are having pH value below 7 are called acidic and the material which are greater than 7 are called alkaline.
- => Acidity or Alkalinity of material indicates that how they react with other material.

Classification of Ferrous materials 2nd Chapter

* A taxonomic classification for the various materials is presented.



Ferrous:- The Ferrous material which contains iron as their prime constituent

Cast iron:- Cast iron are basically alloy of iron and carbon
(2%) (6.66%)

⇒ The ductility of cast iron is very low and it cannot be rolled or drawn.

⇒ Corrosion resistance is very good.

⇒ High carbon content tends to make the cast iron very brittle.

Classification of cast iron

* Best method of classification of cast iron, based on structure and appearance of fracture.

* Following are the different types of cast iron.

* Following are the different types of cast iron.

(i) white cast iron

(ii) grey cast iron

(iii) malleable cast iron

(iv) nodular cast iron

(v) Alloy cast iron

(i) White cast iron : A cast iron structure is very hard and it posses high wear resistance because of the presence of large amount of iron carbon.

* A white cast iron containt 2.9% carbon 1.15% Silicon 0.6% manganese, 0.15% ~~phosphorus~~ and 0.5% Sulphure.
 Phosphorus.

* White cast iron is obtained by ~~the~~ rapid cooling of ~~white~~ iron.

Properties of white cast iron

(i) very hard and brittle

(ii) un machinable and cannot be welded.

(iii) Not suitable for structural work.

Application of white cast iron

(i) For wear resistance surface

(ii) ~~the~~ Roller for crusher.

(iii) ~~the~~ Railway track block

Dt: 2/9/24

New Notes

104 201

Material: It defined as anything which contain's some matter.

Engg material → These are the material which are having ~~engr~~ engg application.

Types of materials -

① Ferrous material :- iron

② Nonferrous material.

③ Alloy's

④ Ceramics

⑤ Composites

⑥ Organic

⑦ Semiconductor

Ferrous material: these are the material which contain's iron in it.

* It is generally taken due to easy availability, cheap method of extraction and due to high strength.

Non ferrous material: * It does not contain any iron element's.

ex: copper, aluminium, zinc, etc generally used for higher electrical conductivity and light weight.

←

Alloy $\div$ Ferrous material

Steel
(less carbon percentage)

cast iron
(high carbon percentage)

lower alloy higher alloy

white Cast iron malleable Cast iron

Alloy $\div$ It is the mixing of ^{more than} one or more elements when one of the elements is metal. Ex: Brass.

• (Copper + zinc), Bronze (Copper + tin), duralumin (Aluminium + copper), Steel (Iron + carbon)

* White gold (Gold + Silver).

* Red gold (Gold + Copper)

* Alloy are generally use for lower melting point and increase tensile strength.

* Used for making automobile parts, house hold product, aircraft parts and jewellery

④ Ceramics $\div$ These are the elements which are donate electron to get higher electrical conductivity and metallic bond.

* These are the oxides, Nitrides, carbides of different materials may be metals or Non metals.

* Used for hardness, brittleness, resistance to higher temp. or corrosion. Ex: glass, sand, bricks, cements, concretes, refractoric, abrasives, Plaston, Silicon Carbides, tungsten carbide.

Composites: It is produced by mixing without dissolving with each other. ex: fiber glass, plywood, Engineered Bamboo.

* The ~~ply~~ Plywood is used for ~~starch~~ Structural material.

Purpose Used as Flooring material.

* It is the combination of glass fiber with polymer used for making automobile parts.

* Organic materials: These are the polymers having carbon compounds. ex: rubber, plastic, paper, wood, ~~adhesive~~ adhesives, paints, textile, etc.

* Generally used due to ductility but it is generally combustible.

* Semiconductor: These are having conductivity property in between conductors and insulators. ex: Silicon, germanium, Gallium etc.

* Generally used for micro processing, integrated circuit (IC), solar cells, laser diodes etc.

Physical Properties

① Dimensions

② Appearance

③ Colour

④ Density

⑤ Melting Point

⑥ Porosity

⑦ Structure.

physical properties: These are the property of any material when there is no involvement of ~~any~~ external force.

① Dimension: It includes size and shape.

* Size means length, breadth, height and diameter

* Shape means the circular, square, I, and triangle shape

② Appearance: It includes lustres and finish

* ~~Aluminium~~ Aluminium $\rightarrow$ white, copper $\rightarrow$ brownish red
Wrought iron $\rightarrow$ red scaly, mild steel $\rightarrow$ smooth finish

③ colour $\rightarrow$ It depends upon the spectrum of light and temporal and spatial distribution

$\downarrow$ Time $\downarrow$ Space
Cu - Reddish, Iron - Gray, lead - soft ~~grey~~ grey

④ Density: It is defined as the ratio between weight per volume.

$$\text{Density} = \frac{\text{weight}}{\text{volume}}$$

* Aluminium $\rightarrow$ 2.5 to 2.7

* lead $\rightarrow$ 11.3 gm/cc

* Iron $\rightarrow$ 7.5 gm/cc

⑤ melting point: It is the temp. at which solid metal changes into liquid state.

Al - white $\rightarrow$ (660°C)

~~Cu - Reddish~~

Iron - Grey $\rightarrow$ 1539°C

Lead - Soft Grey $\rightarrow$ 327°C

⑥ Porosity: It is the property into which the material having pores to the surface.

⑦ Structure: These are the relationship of internal components of the materials.

* Electron Structure is based of ~~Sub~~ atomic particle.

* Crystal Structure is based on atomic arrangement.

DT: 14/9/24

Mechanical properties

* These are the property of material with relation to external applied force.

* The diff types are

① Elasticity: It is the property due to which ~~deformation~~ deformation occurs during loading and it disappears at the time of unloading.

* generally depends upon stress, strain & Young's modulus of elasticity.

② Plasticity: It is the property due to which there is permanent deformation in the material. Different engg operation requires the property of plasticity.

③ Toughness: It is the ability of material to absorb energy during plastic deformation.

out fracture.

④ Resilience: It is the property of material to absorb energy during deformation and the same energy can be again recovered during unloading.

⑤ Tensile Strength: It is the measurement of strength and ductility.

* This property gives us ultimate or final tensile strength required for fracture.

⑥ Yield Strength: It is the property of a material which is such that the elongation suddenly increases.

⑦ It gives the stress value with which the material is elastic.

⑧ Impact Strength: It is the ability of material to resist shock load before fracture.

* It is dependent upon temp and rate of loading.

⑨ Ductility: It is the material capacity to produce deformation with the action of loading (tensile) without failure or fracture.

⑩ Malleability: It is the strength of material under compression without failure.

⑪ Brittleness: It is the property of a material which tends to fracture without sufficient deformation.

⑫ Hardness: It is the resistance of the material against plastic deformation by indentation. Ex: diamond.

⑫ Fatigue: It is the property due to which material behavior changes under fluctuating or repeated load. It initiates a crack and then the material's fails.

⑬ Creep: It is the permanent deformation which takes place as per time under higher temperature conditions.

⑭ Wear resistance: It is the property due to which the material's fails because of wear.

It is of two types: (A) Adhesive wear

(B) Abrasive wear

(A) Adhesive wear: It is the material failure which occurs when two materials are continuously in contact with each other.

(B) Abrasive wear: It is the wear which occurs when any hard external material enters in between the materials in contact.

Chemical property: These are the properties which occur due to the reactivity and solubility of the material.

① Corrosion Resistance: It is the property due to which the material reacts with the environment chemically.

* The corrosion occurs both the metal or non metal.

② Chemical composition:- It is the arrangement and different types of atom in the molecule of the material's.

* Generally there are three type of compounds

(i) Ionic

(ii) covalent

(iii) organic

* Ionic compounds are having charged particle

* The covalent compound share electrons.

* organic compounds contain carbon atom's bonding with hydrogen atom.

③ Acidity or Alkalinity:- These are determined by the pH value of material.

when the pH value of the material is below 7. acidic material.

when the pH value of the material is above 7. Alkaline material.

w:

acidic material have higher concentration of H^+ ions which.

Performance

- * It means the ability of material to perform the function for which it is made.
- * The material must perform's as for their mechanical, physical and chemical requirement.

Material Reliability

- * The reliability means the material must have the probability to be stable during its life period's without failure/fracture.
- * It helps in considering for proper functioning of the material.

Safety

- * The material must not fail, before its life span.
- * It is associated with the safety of human's.
- * So material's must be safe as for requirement.

25/9/2024

Ferrous materials

Characteristics :-

- ① High tensile strength
- ② Good magnetic properties
- ③ Durable
- ④ Silver like appearance.
- ⑤ Low corrosion resistance
- ⑥ Recyclable.
- ⑦ Good conductor of electricity.
- ⑧ Higher melting point
- ⑨ Hard
- ⑩ Heavy and dense

Advantages of ferrous material

- ① The method of extraction, fabrication, alloying are economical
- ② available in large quantity
- ③ Having higher mechanical and physical properties.

Limitation of ferrous material

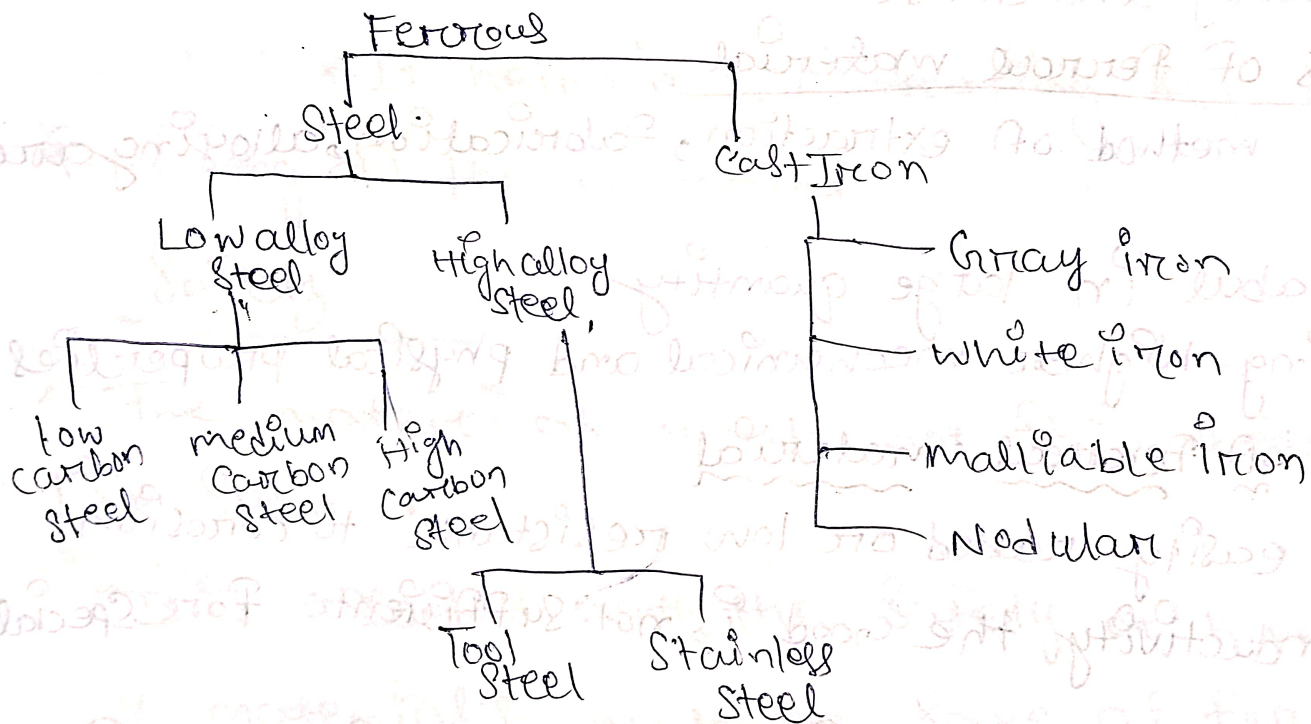
- ① Can be easily rusted or low resistance to corrosion.
- ② The conductivity the good is not sufficient for special use.
- ③ Due to heavy weight it can't be manufacture into light wear application.

Application of ferrous material

- ① Used for construction and transportation for application in ship building railway track etc.

- ② Manufacturing factors like...
- ③ Engineering area for making of diesel, petrol, etc. due to high tensile strength.
- ④ used in aerospace applications like rocket motors, missile systems, aircraft parts etc.
- ⑤ Electrical application use in motor due to magnetic properties.
- ⑥ medical devices for diff surgical instruments and medical components;

Classification



- ① Pig iron
- ② wrought iron
- ③ Grey iron
- ④ white iron
- ⑤ malleable iron
- ⑥ Nodular iron

Pig Iron

- * It is generally obtained from the blast furnaces and then it is sand cast into pig shape element ~~de~~
- * Here the (Carbon $\approx 4\%$, Si $\approx 3\%$, Mn $\approx 1\%$, P $\approx 1\%$, S $\approx 2\%$ Rest $\approx$ Iron) It is generally use for as raw material for all iron and steel products. It is refined in couple up furnace to get cast iron.
- * When puddling furnace is used we get wrought iron to obtain steel ~~be~~ bessemer furnace or open hearth, and Electric furnace is use.

Wrought Iron

- * It is the mechanical mixture of pure iron and Silicate slag (C $\approx 0.03\%$, Si $\approx 0.1\%$, S $\approx 0.02\%$, Mn $\approx 0.02\%$, P $\approx 0.25\%$, Silicate slag $\approx 1.5\%$; Rest $\approx$ Iron)
- * The wrought iron has been never cast but diff shape are made by hammering, forging etc the wrought iron is highly ductile, easily forge and welded, high resistance to corrosion, High resistance to Fatig, By old working the ultimate strength is increase, Higher tensile strength in longitudinal direction due to distribution of Silicate Slag.
- * The slag distribution is like the shape of ribbon

Application

- * Building construction for underground pipe line, electric conduit etc.
- * Public work like bridge railing, drainage line

- * Industrial (concentric tube, alkalic pipe lined etc)
- * Railroad and merain (Used for ~~air~~ making air brake pipe, tanker hitting coils, deck plating)
- * Other application (coal handling equipments, ~~rolling~~ ^{coil} tower scrap pump piping etc)

~~Gray~~ Gray Iron

Characteristic

- * It is an alloy of iron, carbon and silicon
- * When it is broken then we can see gray colour hence it is so named.
- * It can be easily cast. the diff percentage are (C - 3.5%, Si - 1.8%, Mn - 1%, P - 0.15%, S - 0.1%, Rest - iron)
- * It contains graphite flakes in iron matrix
- * It has ~~high~~ ^{low} melting point, it can be giving shape of thin sections, higher machinability ~~for~~ ^{than} steel, higher vibration damping capacity, load ductility and impact strength, high compressive strength
- * Low cost with rigidity

Application

- * Structure of machine tool
- * Underground water pipe & engine
- * Manhole cover
- * Piston rings
- * Electric motor frames.

★ Rolling mill's parts.

(White cast Iron / mottled)

- ★ When broken it shows bright, white colour hence so named.
- ★ It has more percentage of carbides and very hard and brittle.
- ★ Higher abrasive wear resistance can be casted easily.
- ★ $C - 3.6\%$, $Si - 2\%$, $Mn = 0.08\%$, $P - 0.18\%$, $S - 0.12\%$, Rest Iron)

Application

- ★ Generally use to produce malleable iron castings.
- ★ Used in manufacturing which required higher abrasion resistance material.
- ★ It is also used where hardness is of main importance.

Malleable cast iron

- ★ It is obtained from the white cast iron through control process.
- ★ The malleable cast iron make contain ferrite or pearlite matrix.
- ★ It has higher yield strength, higher Young's modulus, good wear resistance, higher vibration damping capacity. Cost is low to medium.
- ★ It is so named because we can use into any shape by hammering or rolling.

Application

- ★ Rail road, conveyor chain, crankshaft part, ~~and~~ automobile parts, agricultural parts, gear case.

Modular Cast Iron

- ★ Hence the graphite has rounded shape or nodules so it is called as modular cast iron.
- ★ It is also called as ductile cast iron.
- ★ It has good machinability.
- ★ The damping capacity is less than cast iron.
- ★ Excellent on higher wear resistance.

Application $C = 4\%$, $Si = 2\%$, $Mn = 0.8\%$, $S = 0.2\%$, $P = 0.01\%$

- ★ Parts of engine parts.
- ★ Pipes, pump and compressor, Paper industry components, earth moving machine & valve.

DT: 27/9/2024

Steel:

Plain carbon steel / Low carbon steel: It is the alloy of iron with carbon percentage having 0.10 up to 1.5. If the carbon percentage is increased @ 1.8 to 4.2% mild steel or low carbon steel it generally classify as

Billow Low Carbon Steel

① Dead mild steel: ($C = 0.05\%$ to 0.15%) It is used for making steel wire pipe fits etc. the tensile strength is 390 N/mm^2 . Hardness = 115 BHN;

② ^{medium} mild steel: ($C = 0.15\%$ to 0.2%) The tensile strength is 420 N/mm^2 , Hardness = 125 BHN, It is used for making camshaft, fits, forging etc.

③ Mild Steel: (C = 0.2% to 0.3%) It has tensile strength = 555 N/mm², Hardness = 140 BHN. used for making valves, gears, connecting rods, railway axle etc.

Steel:

Medium carbon Steel: (C = 0.3% to 0.7%) The ~~the~~ medium carbon steel has 3 subgroups (i) Lower medium carbon steel

① Lower medium carbon steel (C = 0.35% to 0.45%)
Tensile strength = 800 N/mm² & It is used for making gear shaft, crank liver, wire etc.

② Medium carbon steel (C = 0.45% to 0.55%) TS = 1000 N/mm² used for making parts like spline shafts, crank pin, axle etc.

③ Upper medium carbon steel (C = 0.55% to 0.7%) TS = 1250, It is used for making die block, clutch disc, set screw, valve spring, etc.

High carbon steel (C = 0.7 to 1.5) It has also diff types as follow:
① carbon steel containing (0.7% to 0.8%) It is use for making cold chisel, hacksaw, pneumatic drill bit, wrenches.

② containing (0.8% to 0.9%) -> It is used for making railway rail, Rock drill, punch, Particular saw etc.

③ containing (0.9% to 1.1%) -> It is used for making Springs, key, pin etc.

④ containing (1% to 1.1%) -> It is used for making machine tools, railway spring

③ containing (1.1% to 1.2%) $\div$ It is used for making

Twist drill, Tap, Die etc.

④ containing (1.2% to 1.3%) $\div$ It is used for making Reamers, metal cutting tool

⑤ containing (1.3% to 1.5%) $\div$ It is used for making tools for chilled iron, die (wire drawing), ~~metal~~ metal cutting saw.

Stainless steel:

* It is prepared by adding more than 11.5% of Chromium than fine ~~filled~~ ^{film} of chromium oxide on the surface. This coating prevents ~~for~~ further corrosion.

* It is having 3 number of metallurgical type as per their micro-structure

① Austenitic

② Ferritic

③ Martensitic

Austenitic ~~st~~ Stainless Steel: C $\div$ 0.03% to 0.25%, Mn = 2 to 10%, Cr = 16 to 26%, Si = 1 to 2%, Ni = 3.5 to 22%.

* It possesses highest corrosion resistance, highest tensile strength, resistance against high temp ^(corrosion) maintaining ductility approximately at Absolute temp. 0°K .

It has austenitic structure at room temp. It is generally used in making air craft engine parts, milk can, heat exchanger, tank in food industry and cooking items.

dt: 30/9/2024

② Ferritic Stainless Steel

(C = 0.2% → Si = 1%, Mn = 1.5%, Cr = 11 to 27%.

generally during heat treatment this type of steel is not hardened. It is magnetic, ductile, most corrosion resistant between all ~~the~~ regressive type. It generally use for furnaces heating elements, oil burner parts, interior decoration, screw, etc.

③ Martensitic Stainless Steel

* (C = 0.2% → Si = 1%, Mn = 1%, Cr = 18%.)

* It is generally attains higher hardness under heat treatment. It has best thermal conductivity, good ductility. It can be cold ~~work~~ worked easily, ~~and~~ has good toughness, good corrosion resistance against diff chemicals. It is used for making pump parts, turbine parts, diff surgical instrument.

Alloy Steel

① Low alloy Steel

* generally diff elements are added to get alloy steel like, Mn, Si, Cu, Mo, Ni, etc.

Advantages of alloy steel

- * hardenability increases low cracking.
- * Higher strength at higher temperature
- * High ductility.
- * High strength, high machinability.

Limitation of alloy steel

- * High cost, careful handling.
- * The brittleness increases in some cases.

Purpose

* Increase in corrosion resistance.

* Higher strength

* Higher ductility

* Higher wear resistance

* Improve toughness

* Greater strength

* Higher machinability.

Effect of alloying elements:-

① Nickel: * Increases toughness, reduction in distortion

* Improve strength.

② Chromium: By adding chromium it increases depth hardenability, wear resistance, abrasion resistance.

③ Molybdenum: Increases hardenability.

* Also increases tensile & creep strength.

* Increases corrosion resistance.

* Also increases toughness.

④ Vanadium: It increases hardenability with completely dissolved.

* Improve strength, also improve toughness to heat treated steel.

⑤ Manganese: Increases strength also increases hard ness, reduces brittleness. With contact in

~~Sulphur~~ Sulphur:

Low alloy steel: When the alloy element is generally less than 5% then it is called as low alloy steel.

* The diff types of low alloy steel are:

① Nickel steel: ($C = 0.35\%$, $Ni = 3.5\%$)

* It increases strength without reducing ductility.

* It is generally used to cylinder to store liquid gases generally under low temp conditions. * Used for making turbine blades, highly stressed nut and bolts etc.

② Chrome - Nickel steel

($C = 0.35\%$, $Ni = 1.25\%$, $Cr = 0.6\%$)

* Generally it has low cost. It increases toughness & ductility due to nickel. It also increases hardenability and wear resistance due to chromium making cranks, gear, aircraft parts.

Molybdenum steel

($C = 0.35\%$, $Mo = 0.76\%$)

* It increases the elastic limit without reducing ductility, also increases strength and hot hardness. used for making coil spring, gear, pressure vessel.

③ Chrome - molybdenum steel

($C = 0.35\%$, $Cr = 0.16\%$, $Mo = 0.36\%$)

* It increases hardness, highest corrosion resistance, higher tensile strength, used for making ball bearing, springs, electrical parts.

DI: 18/10/2024

Non-Ferrous Alloys:

① Copper alloy: It is generally used in order to improve corrosion resistance, to increase electrical conductivity and reduce weight.

* Copper: Copper has higher electrical conductivity and thermal conductivity, higher corrosion resistance. Higher resistance against fatigue, good machine ability, more ductile and malleable.

* Copper alloy: (a) Copper with Zn (Brass): Brass has generally higher resistance against corrosion, higher strength against copper, easily machinable, the addition of zinc both ductility and strength.

Diff types of brass: (i) Briding metal (Zinc 5-15%, Rest Cu).

It has more hardness and more strength after cold work, it is generally supplied in the form of sheet and has in between red and brass yellow, it is generally used for making coin, medals, for jewelry and decorative purpose.

(ii) Cartridge Brass: (Zn=30%, Cu=70%) : It has higher tensile strength greater than 300 N/mm², it also has more hardness under cold condition and it needs to be annealed, used for spring, for making cartridge case, shell case, also for diff

door furniture and case of electric ~~key~~ cable.

(iii) Admiralty Brass: (Cu=71%, Zn=28%, Sn=1%) : The Sn is added to improve resistance against corrosion, it has higher strength - generally use for making diff parts of marine condensers and tubes.

(iv) Aluminium Brass: (Cu=76%, Zn=22%, Al=2%) : It also has higher corrosion resistance as a coating is formed when having contact with sea water. Use for making diff parts of ships.

(v) Basic Brass (Cu=64%, Zinc=36%) : It has more malleability and ductility. It is also having lower cost generally used for making ~~diff~~ and water.

(vi) Muntz metal or yellow metal: (Cu=60%, Zn=40%) : It is generally made under hot working conditions. It has higher ductility, higher malleability, easy to work. Use for making condenser tubes, valves, stems, etc, the alloy metal is generally use after brazing alloy for steel.

(vii) Leaded 60:40 Brass: (~~Cu~~ Lead=3%, Rest Cu ^{Zn}) : It increases the machinability and it also does not reduce the tensile strength, use for making keys, gear, valve parts, pipe unions.

(viii) Naval Brass: (Cu=60%, Zn=39.25%, Sn=0.75%) : It improved resistance against corrosion also improved strength generally use for making valve stem, and propeller shaft.

(ix) Babbitt metal: (Cu=2%, Sn=89%, Antimony=9%) : It has low wear resistance but higher corrosion

resistance and reduced friction. generally used in bearings lining and the other name is also bearing metals. the colour is white.

* Copper - Aluminium Alloy (Aluminium Bronze)

Cu = 88 to 91%, Al = 8%, Sn = 0.5% to 1% $\Rightarrow$ Composition

Properties: Higher mechanical properties, good resistance to corrosion, low thermal conductivity, good plasticity.

Application

* Generally used for making wires, also used for diff. fittings, used for base metal in case of plumbing.

Application Use

* Die casting, ..
* used for hot stamping, used for automobile appl.

* generally use making wire also use for electrical fitting and also use for base metal in case of plumbing.

Bronze: Cu-based alloy

* When tin is added with copper then the alloy formed is called as Bronze.

* generally the maximum percentage of tin is 20% because after that the diff. required properties decreases.

* The most useable bronze has 8 to 11%.

Different types of Bronze

① Phosphor Bronze: ~~generally~~ it contains 3 types of phosphorous bronze (a) Standard phosphor bronze

② For gear

③ Lead ~~phosphor~~ Phosphor bronze

④ Standard Phosphor bronze: Cu = 90%, P = 0.5%, Sn = 9.5%

⑤ For gear: (Cu = 88, Sn = 11.85, P = 0.15)

⑥ Lead phosphor Bronze: ~~(Cu = 87, Sn = 7.5, Zn = 1.7, P = 0.3, Pb = 3.5)~~

* The phosphor bronze as phosphor need which improves the strength and hardness with reduction in ductility, ~~generally~~ higher resistance to corrosion.

* use for making parts of pump, gear, valve, spring etc.

⑦ Silicon Bronze

(Si = 1 to 4%, Mn = 1%, Cu = 95) it has higher toughness, higher strength, higher corrosion resistance

Uses: use for making bearing, boiler parts and machine parts.

Dt: 23/10/2024

Aluminium Alloy

* Copper is added with aluminium in order to increase both hardness & strength. Silicon is added in order to improve further hardness. Manganese is also added in order to improve more strength.

(i) Duralumin: (Al = 94%, Cu = 4%, Mg = 0.5%, Mn = 0.5%, Si = 0.5%, Fe = 0.5%)

Properties: (i) High tensile strength
(ii) High electrical conductivity
(iii) The hardness increases at room temp
(iv) Melting Point 650°C

Uses / Application: (i) Common use making cables
(ii) Use for making parts of aeroplane
Also use for making surgical instruments, making nut and bolts, rivets etc.

(ii) Y-alloy: (Al = 92.5%, Cu = 4%, Ni = 2%, Mg = 1.5%)

Properties: (i) More strength than aluminium
(ii) More hardness for high temp
(iii) Easy to hot work

Uses: (i) Used for making crank case, for making die casting, for making piston head

* Lead alloy: The diff alloys are as follows (bearing hard lead (Sb = 13%, Cu = 1.5%, Ni = 0.3%, As = 1.5, Pb = 83.5%))

It has higher hardness and higher strength normally used for making bearing, liners, soldering application.

(iii) Antimony lead (Sb = 0.2 to 0.3%, Pb = 99.7%)

* It increases the hardness generally use for making drainage pipes.

(iii) Lead-tin alloy: (Tin = 25%, Pb = 75%)
Properties

* High resistance against corrosion.
* Use for coating of iron sheet

(iv) Nickel alloy:

* The diff alloys are as follows (i) Nickel Iron Alloy

(i) Nickel Iron Alloy (50% Ni, Rest Iron) $\rightarrow$ Invar

* It improves the thermal properties and is very less thermal expansion lower coefficient of expansion.
* Generally use making for measuring tubes & weight

(ii) El Invar (50% Ni, Cr = 12%, Fe = 38%)

* It increases the modulus of elasticity and also has low coefficient of expansion and generally use for making diff high precision equipment

(iii) Nickel copper Alloy (monel)

* It is generally called as (monel) metal.

Composition: (Ni = 66%, Cu = 31.5%, Fe = 1.35%, Mg = 1%)

Properties: (i) Higher resistance against corrosion.

(ii) More toughness, more strength. low resistance to alkaline

Uses: (i) Use in architecture and maritime application also used for making diff equipment for medicine, chemical industry etc.

K-monel $\rightarrow$ age-hardening

R-monel $\rightarrow$ Free machining

H-monel $\rightarrow$ Hard-casting

③ Constantan (45% Ni, 55% Cu)

Property: (i) High electrical ~~resistivity~~ resistivity, low coefficient of resistance ~~of~~ against temp. etc.

Uses

* used in electrical resistors, thermal couple.

④ Nickel-chromium Alloy (80% Ni, Cr-14%, Fe-6%)

* generally called as Enkel and when iron is removed it is called as chromel

* It generally improves the strength, highest resistance against corrosion etc.

* use in case of making ~~the~~ heater elements, also used for high temp resistance material and also used in milk industry.

⑤ Nickel-molybdenum alloy (Hastelloy)

(Ni = 54% to 57%, molybdenum = 17% to 20%, Fe = 5% to 20%)

* It improve higher resistance against corrosion

* High strength, High ductility.

* generally use in chemical plants for making valve, pump, vessel, storage tanks etc.

⑥ Super alloy

* It may contain diff alloying element like Chromium, Iron, Cobalt, molybdenum, aluminium etc.

* In Super alloy the strength is very high can have very high resistance to fatigue can have highest resistance against corrosion, sufficiently high strength to mass ratio

* generally use for making large blades, large blades in case of steam, oxidizing ~~at~~ atmosphere and with highest tough ness - ~~generally~~

* generally used in aircraft part, large turbine parts, nuclear reactor, petrochemical etc.

Composition

(Ni = 25%, Cr = 16%, molybdenum = 6%, Rest - Iron (Fe))

(Ni = 78%, Cr = 20%, Rest - Iron (Fe) - Fe = 2%)

Brass alloy

* It has the following type of alloy is called as Zinc based die casting alloy

Composition

(Cu = 0.1%, Al = 3.5 to 4.3%, Zn = 95.6%)

Properties: (i) It has higher ductility, more strength

* generally used for making diff automobile parts, and carburetor part, radiator parts, and also for making die casting

* Lead (Pb) increases corrosion resistance, Cadmium increases hardness, Copper improve ductility, Inj. Improves resistance against creep etc.

Dt: 25/10/2024

Bearing metal ÷ This is used to take the external loads which are applied on rotating elements like shafts, spindles etc.

Diff property of Bearing materials:

- (i) Low coefficient of friction
- (ii) Higher wear resistance
- (iii) High compressive strength
- (iv) High strength against fatigue
- (v) Able to bear shock load.
- (vi) Higher thermal conductivity to give out the heat of friction.
- (vii) High strength against higher temp
- (viii) Resistance against corrosion.
- (ix) Easy to fabricate.
- (x) Should not seize

* Types of bearing material

* cadmium base alloy: The percentage of cadmium is 90%, Mn = 2%, Sn = 8%.

Properties

- * High compressive strength
- * more hardness
- * Low coefficient of friction
- * High fatigue strength
- * High resistance against wear

Uses

* use in diff automobile parts and aircraft parts etc.

Cu-based alloy (Bronze)

* Bearing for railway, also a heavy weight engine

Dt: 1/11/2024

Spring material

* These are the material which have higher capacity to absorb energy, generally upon removal of external load they come back to their original shape & condition.

* These material also have higher resistance against internal stress

* This is two types: ① Iron based
② Copper based

Iron based

① The most common spring material is steel. The spring steel has good elastic limits, higher fatigue strength, higher creep strength. generally it is used for making helical spring, leaf spring etc.

② Steel piano wire (C-1%, Mn-0.5%, Fe-98.5%)

* It has higher fatigue strength and generally used for small size helical spring

③ Hard drawn spring wire (C-0.5%, Mn-1%, Fe-98.5%)

* It has also higher stress absorbing capacity and also used for making different automobile applications.

③ Oil-hardened Spring Steel (C-0.8%, Mn-0.9%, Fe-98.3%)

It has more strength and used in weighing machine.

④ Cr-vanadium spring steel (C-0.5%, Mn-1%, Cr-0.9%, V-0.1%, Fe-98.5%)

It has also sufficiently higher resistance and generally use in, automobile valve, railway springs.

⑤ Stainless Steel (Cr-18%, Ni-8%, C-0.1%, Fe-73.9%)

It is having generally higher resistance against corrosion and use in valve springs.

⑥ Copper based Spring material

This material have higher electrical conductivity & also high resistance against corrosion. It has the following types.

① Phosphor Bronze (Cu-92%, Sn-8%)

Higher strength and used in making electrical switch, electrical relay.

② Brass (Cu-67%, Zn-33%)

Higher electrical conductivity & used for making electrical contact.

③ Nickel silver (Cu-56%, Ni-18%, Zn-26%)

Generally use for making higher quality contact & switch due to higher electrical conductivity and higher strength.

④ Beryllium copper (Cu-98%, Be-2%)

Good resistance to corrosion higher electrical conductivity used for making switch, relay.

DT-4/11/2024

Ceramics ÷ (Greek word Keramos) → meaning

- Burnt stuff

Definition:- It is define as a phase of combination of compounds of diff metallic & non-metallic elements which are generally heat treated.

Types of ceramics

① As for diff function

① Abrasives (Alumina)

② Pure - oxide ceramics (Al_2O_3 , MgO)

③ Fire - clay products (Bricks, tiles)

④ Inorganic glasses (Glasses)

⑤ cementing materials (cement)

⑥ Rocks (Sandstone, Granite)

⑦ Minerals (Quartz)

⑧ Refractories (Silica Bricks)

② As for diff structure

① Crystalline type (MgO, Al_2O_3)

② Non-crystalline type (Glasses)

③ Glass-bonded ceramics (Fire-clay, inglass)

④ Cement (Cement)

③ As for diff type of product

① Bricks

- ⑥ cements
- ⑦ Abrasive
- ⑧ Glass
- ⑨ Insulator
- ⑩ Refractories
- ⑪ porcelain
- ⑫ minerals ores.

Properties

- ① Strong, dense & hard
- ② Higher resistance against diff type of chemicals.
- ③ Higher compressive strength.
- ④ Good properties against creep.
- ⑤ easily available
- ⑥ low cost
- ⑦ Higher thermal insulation capacity.
- ⑧ Higher fusion temperature.

Application

- ① Used as white ware (olden ceramics)
- ② Generally used for making diff. Insulators, used as components of diff chemical reactors, crucibles in chemical industries, burner, burner tip, nozzles, heater supports in heat resistance uses.
- ③ Advanced ceramics: these are the generally nitrides, oxides, borides, or diff compound with hardness & heat resistance used in furnaces as refractories, insulators, and glass semiconductor for electrical application. also used in nuclear power

Plant as fuel container, parts of motor etc, also used in opticals application like window glass.

Advanced ceramics: These are the generally silicon, ^{Carbon} ZnO, use for making of ceramic plate, cutting tools energy storage devices, packing electronic product etc.

dt = 26/11/2024

Composites: Composite is defined as the combination of two dissimilar material in order to get a new material with new or improve properties. It has mainly consists of two types of composites.

(i) polymers

Classification

(i) Particle Reinforced

① Large particles

② Dispersed strengthened

(ii) Fibre reinforced

① Continuous (aligned)

② Discontinuous (short)

Matrix

* The matrix are those base material which are present in higher percentage.

Reinforcement

* The smaller percentage material which change in other property is called as reinforcement.

Composite

* The matrix and reinforcement must have covalent bond between them. It may be due to chemical reaction or mechanical bonding between them etc.

① Particle reinforced: large particle composite

★ Concrete: It is the mixture of cement, sand, stone, ballast, & water. When mixed properly we get a permanent harden unit called as concrete.

Cement is the main binding material, the ballast is the coarse aggregate and sand is called as smooth aggregate.

★ The concrete is having higher strength in compression but weak in tension.

★ Cement: It is the main binding material generally portland cement is use for normal work. but when there is time limits then special quick hardening cement is use. The cement should satisfy the diff. conditions like it must bind the diff. aggregates/element properly and will give sufficient strength.

★ Sand: it has grain's / particle of silica oxide and generally prepared from sand stone; can be collected as natural sand from river bed, artificially can be made by crushing of stone gravel. generally sea sand is not used because it has to be washed well to remove salt.

★ Property of Sand: The sand particle must be sharp, angular, chemically inert, free from impurities like clay and other chemical or organic matter, must be strong, hard, durable.

★ Function of Sand: The sand generally fills of the gaps or voids between coarse aggregates, it must allow water to pass through it to become easily harden and must be cheap.

★ Coarse aggregate: These are the grown, broken stone, broken bricks, granite pieces etc. the coarse aggregates help in increasing the wear resistance, more crossing strength etc.

Properties: must be hard, cheap, free from any chemical coating, angular in shape, durable, higher resistance etc.

Function: It generally gives more stability and durability to concrete, it makes the concrete more hard, increases crossing strength, generally cheap.

Water: It is generally use for mixing setting and hardening it also increases strength, durability sufficient water must be used as for suitable chemical reactions.

Function: It wet's the gravels, spreads the cement over fine particle also asked as lubricant for the surface of different particle which increases the strength & durability. it also chemically combine diff elements.

(RCC) Reinforced cement concrete

★ The concrete is weak in tension hence it is reinforced to increase its tensile strength. the reinforcement material must have high tensile strength, cheap high modulus of elasticity etc. the reinforcement material are generally steel.

* The steel reinforcement properties 1: Round steel bars, 2: Flat bars are also used for pipes.

Properties of R.C.C

* There must be no internal stress between the elements of R.C.C; the cement coating protects the corrosion of steel bars.

* The concrete generally transmits the tensile stress to the grouted steel bar.

Advantages of R.C.C

1. Does not decay quickly, fire resistant, economical, low maintenance cost; no effect of moisture etc.

Limitations

* More heavy; skilled work persons are required, high initial cost.

Uses

* use in slab, beam, column, pile structure, road making.

Dispersion's Strength Composite

* generally metal alloy's are strengthened by dispersion of hard fine particles of metallic, non-metallic or oxides. The strength is maintained at high temp as there is generally no chemical reaction between matrix & dispersed particle.

* The thorium (Th) the dispersed particle with nickel which increases the strength of thorium dispersed nickel at high temp.

Fiber reinforced composite

* These composites use low density fiber material. The strength depends upon the concentration, distribution, and orientation of a fiber. The diff examples are whiskers.

Whiskers: It has very thin crystals with higher length to diameter ratio, free from flaws. It generally provides high tensile strength of 21 GN/m^2 . It is generally costly to manufacture. It includes aluminium oxide, silicon carbide & graphite. The boron & carbon crystal are used in polymer products.

Fibers: These are having small diameter & polycrystalline in nature, used for general application where strength is required.

Wires

* It is having larger diameter than fiber generally contains tungsten, steel etc used in radial tires.

* The matrix (resin) provides the binding strength gives protection against surface damage to individual fiber and also it separates the fibers in order to prevent transmission of brittle cracks in fibers.

* The other important fiber composites are hybrid composite, carbon carbon composite, polymer matrix composites.

DT = 01/11/2021

Polymer

It is composed of large no of small molecule called as monomers the method of combining of monomers are called as Polymerization.

Types of Polymers

① Thermoplastic

② Thermosetting

① Thermoplastic - These are the materials which are generally the combination of long chain or slightly branched molecules which are combined with weak force called as van der Waals' Force.

These type of low melting temperature but can be reused.

Ex: polythene, polyvinyl chloride, polypropylene, polytetrafluoroethylene, polystyrene.

② Thermosetting - These are generally having cross-linked and after softening it cannot regain its shape.

Ex: Bakelite, Amine formaldehyde, Polyester etc.

Thermoplastic example

① Polythene or polyethylene - These are generally obtained by ~~high~~ ^{low pressure} process and can be up liquid or solid state.

Properties

* Wax like appearance

* Chemically resistance

* Moisture resistance

* Lite ~~water~~ wear, low cost

Uses

* For packaging

* Water proof material

* Insulation for cable

* Use for fan casing.

* For making pipes etc.

P.V.C Polyvinylchloride

* It is generally obtained from addition polymerization of vinyl chlorides.

Properties

* More wear & tear resistance.

* Higher dimensional stability.

* Acid, alkali & water resistance.

* Resistance to sunlight, can maintain little higher temperature.

Uses

* For casting, For ruffling, cable jacket, For wear insulation, rain water resistance good etc.

③ Polypropylene (P.P)

* It is obtained by additional polymerization process of propylene.

Properties

* More chemical resistance, good fatigue strength, high flexibility etc.

Uses

* Electrical insulators, vacuum cleaners, parts, vacuum flase, pipes, automobile parts, hair dryer, refrigerator.

④ Teflon or polytetrafluoroethylene

* It is produced by additional polymerization of tetrafluoroethylene.

Properties

* Chemically inert, non flammable, good electrical insulator, low coefficient of friction, high creep resistance.

Uses

* Anti-corrosive, pipes, gaskets, electrical parts, laboratory

-ry equipment, bearing, non stick coating.

⑤ Poly Styrene

★ It is also called by addition polymerization of styrene

Properties

★ transparent, higher water resistance, hard, good electrical properties, high resistance to corrosion etc.

Uses

★ Lense, ~~head~~ reador parts, refrigerator's cabinet parts, food container, water jugs etc.

Thermosetting example

① Phenol formaldehyde (PF)

★ It is produce by condensation polymerisation process of phenol & formaldehyde.

Properties

★ strong, rigid, dimensionally stable, resistance to heat, chemicals etc.

Uses

★ laboratory seats, parts, vacuum cleaner parts, electrical parts, handle etc.

② Amine formaldehyde

★ It is produce by condensation of urea & melamine or urea melamine formaldehyde.

Properties

★ Higher resistance against moisture, chemical, heat, better electrical properties.

Uses

★ paint, adhesive, switch, surface coating, glue for plywood etc.

★ produce by condensation polymerisation of malic acid & glycol

Properties

★ High resistance against ~~chem~~ heat & chemicals, high compressive strength.

Uses

★ safety helmets, automobile parts, paints, fiber boat etc.

Difference between thermosetting & thermoplastic.

Thermoplastic

(i) combination of linear polymers.

(ii) less strong & softer

(iii) can be repeatedly softend by heat & hardened by cooling.

(iv) cannot be used at higher temperature

(v) generally supplied granular structure

(vi) can feed complicated mould.

(vii) can recycle again

(viii) It is economical

Thermosetting

(i) cross linking of polymers

(ii) more strong & harder.

(iii) once hardened generally do not soften under heat.

(iv) can be used at higher temperature

(v) supplied with polymerised form.

(vi) ~~can~~ difficult to feed complicated mould.

(vii) can't recycle again

(viii) less economical.

Elastomer (Rubber)

⇒ It is a polymer material with hydrocarbons with large and reversible amount of elastic deformation. As per ASTM (American Society for testing & measurement) Elastomer is the polymer which can be stretched elongated two times its original length & again return to original length by releasing load.

Properties

(i) Resilience & Hysteresis :- Resilience measures the storing energy capacity and is the ratio of output energy to the input energy. As there is always friction so the loss of energy as frictional heat is called as Hysteresis. So, both are inversely related.

(ii) Hardness :- property which is measured by means of durometer. With increase in hardness the elongation decreases. As the tensile increases, when hardness increases in durometer.

(iii) Tensile Strength :- It gives the overall performance of the elastomer & it is also used to measure the life span of elastomer. i.e. with increase in time tensile strength decreases.

(iv) Compression set :- It is the % of distortion remain after removal of compressive load.

It depends upon temp. loading.

(v) Tear Resistance :-

* Generally it is defined as the resistance against tear. The rubber has generally tear resistance it also has sudden failure if the object has cuts in it.

(vi) Abraction Resistance :- Hard TART and elastomer has lower value of A.R.

(vii) Deterioration Resistance :-

* It is the change occurs due to oxidation and also depends upon sunlight ozone etc.

First of all hardness ↓ with cracking which is generally used as per the environment of hydrocarbon fluids like oil, gasoline etc. It is the swelling capacity of the elastomer in the oil atmosphere.

Crystals Imperfections Chapter-4

Crystals :- It is the group of diff. atom which are generally arranged in a particular order. The crystalline material may be single crystal or polycrystalline.

Unit cell :- When small atoms are arranged in a systematic order to form a block. It is called as unit cell.

Lattice point :- When atoms are replaced by points then it is called as lattice point.

Lattice array :- When these lattice points are arranged in a 3-dimensional structure then it is called as lattice array.

Space lattice :- It is the 3-dimensional structure which is octane by links of combination of diff. lattice array.

* Lattice spacing (Interatomic spacing)

⇒ The distance betⁿ the lattice points is called as lattice spacing or interatomic spacing.

⇒ Crystal structure (metals)

* There are three types of structure

(i) Body centered cubic (BCC) :-



① FCC (Face centered cubic) :



② HCP (Hexagonal close packed) :



③ BCC : In this case the atoms are placed at each corner of the cube & one atom at the center. $(8+1) = 9$ atoms. Generally its structure found in Sodium, malleable iron etc.

④ FCC : where atoms are located at each corner and also at the centre of each face $(8+6) = 14$ atoms. Ex: Gold, Silver, Cu, Al, Lead.

⑤ HCP : It has atoms at each corner one atom at center of each of the faces (top & bottom) & 3 atoms for each pair of opposite faces. (17 atoms) Ex: Mg, Lithium, beryllium, Zn.

Imperfection in crystals:-

① Ideal or perfect crystals :-

* It is the crystal which is having no (0) defects. but it is practically impossible.

② Actual crystal :- These are the

* These are the crystal which is having has some defect in it. Practical every crystal is actual crystal with some defects which can be minimized.

Types of crystal defects

① Point defect or zero dimensional defects.

① vacancy defects

② Schottky imperfection.

① Interstitial defects.

② Compositional defects

i) Substitutional defects

ii) Interstitial defects.

③ Electronic defects.

② Line defect or one dimensional defects

① edge dislocation

② screw dislocation

③ Surface or plane defects or two dimensional defects

i) Grain boundaries

ii) tilt boundaries

iii) Twin boundaries

iv) Stacking fault.

④ volume defects or three dimensional defects.

① point defects

* It is the defect with point like character the dimension of size is of one to two atomic diameters.

=> These defects having presence in a localized area and it generally reduces the free energy or energy of the crystal.

=> The point defects are generally created due to following facts.

i) By thermal fluctuations.

ii) Due to quenching (quick cooling).

=> Due to quenching from high temp.

(iii) Due to Severe deformation of crystal lattice. After some time the original crystal structure can be maintain but it contains large no of defects.

(iv) By the external collision of atoms with high energy particles.

(v) The high energy particles displaces the atoms & defects is formed. It is generally depends upon the nature of the crystal, energy of the bombarding particle here independent of temp.

Dt: 18/11/2024

Point defects (Types)

① a vacancy defect

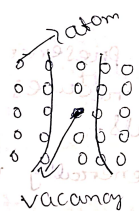
② Schottky defect

③ Interstitials

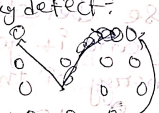
④ Impurities

⑤ Electronic defects

① a vacancy



② Schottky defect



It is the absent atom in the crystal lattice. These vacancy can occur due to diff. process like sintering, creep, annealing, oxidation process etc.

* These vacancy in the crystal generally occur due to improper packing during crystallization. It may also be made from the thermal vibrations at higher temp.

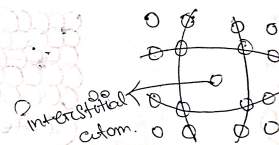
* The surrounding atom tends to close together which makes the destruction of the crystal lattice.

Schottky defect:

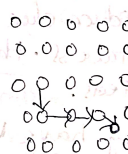
* This type of defects is formed the atoms or ions moves from their normal position & replaced on the crystal surface. It generally occurs in case of compound & displaced in pairs.

③ Interstitials

③ Interstitials



③ Frenkel defect



* Interstitial defects: It happens when an atom occupies a position in between the crystal lattice of the perfect crystal. It may be a normal atom or a foreign atom. It generally happens when the atomic packing factor is low.

atomic packing structure = volume of unit cell

* It produces distortion in atom because the interstitial atom either produces compressive strength (larger size) or tensile strength (smaller size)

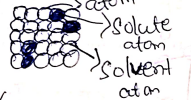
Frankel defect: It happens when the atom ^{with} in the crystal is displaced to new position between atom. this defect's require more energy.

* No. of vacancy defect are more than no. of interstitial defects.

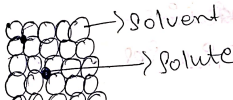
Dt: 25/11/2024

Impurities

(a) Substitutional (b) Interstitial



(Substitutional)



(Interstitial)

Impurities

* These defects are produce due to the impurities atom during crystallization process. the other name is also called compositional defects.

* The impurities may have variable atomic structure & radius from the original atom. It is divided into 2 type ① Substitutional. ② Interstitial.

(a) Here the impurities atom replaces the vacant parent atom for example! When Zinc is used as substitutional atom in the copper

disturb structure then we obtained brass.

⑥ In this case generally small atom occupies the space between two larger atoms. for example: Carbon atom are placed in the interstitial position of Iron atom to give the product known as steel

Electronic defect:

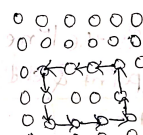
* These are the defects due to which the conductivity & other properties are improved the impurity may be vacancy or interstitial. the electronic defect's are due to error in charge distribution (positive or negative charge) Ex: transistor & PN Junction.

Dt: 26/11/2024

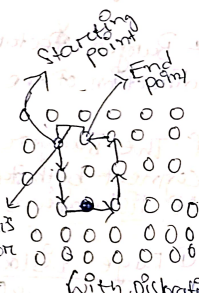
Line defects:



(Dislocation)



(No Dislocation)



(With Dislocation)

Line defect on dislocation.

Types: ① Edge dislocation

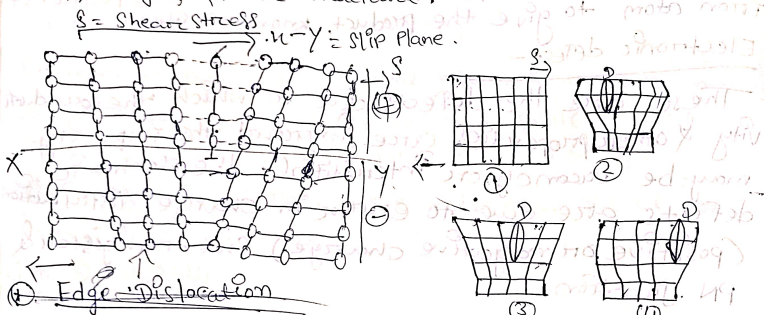
② Screw dislocation

Line defect: It is also called as two dimensional defect or dislocation the dislocation is defined as the disturbed area between the perfect ~~parent~~ crystal.

* In case of dislocation a group of atoms is displaced from the stable position.

* The dislocation is the region which separates the slipped & unslipped area.

* The dislocation generally causes slip, strain hardening, creep, fatigue, & brittle fracture.



* Burger Vector gives the magnitude & direction of the strain component of.

* The Burger vector is the line which connect both starting point & end point in case of dislocations in atom.

① Edge Dislocation
 * This dislocation is perpendicular to the burger vector. both the edge dislocation moves parallel to the direction to the burger vector or slip direction.

* When edge dislocation has row of atoms above the slip plane. then it is called a positive dislocation with positive sign.

* The positive dislocation moves towards right side due to the shear force. When the dislocation is due to row of atom below the slip plane. then it is called

as negative dislocation generally moved towards the left.

* The slip step is formed due to the movement of edge dislocation.

Screw dislocation

* Here the dislocation is positioned parallel to the burger vector.

* The screw dislocation moves perpendicular to the burger vector. It is so named because the ~~modification~~ moves through helical or screw parts.

* The speed of motion of screw dislocation is lower.

* It is generally used to explain both crystal growth & plastic deformation.

- * Dislocation is produced in the crystal due to:
- ① Accidental growth
 - ② Thermal stress
 - ③ Outside stress
 - ④ Phase change
 - ⑤ Segregation/mismatch.

Edge Dislocation	Screw dislocation
(i) It is produced due to addition or removal of extra row of atom. (ii) There is no compressive & shear stresses are present. (iii) The disturbance is along the edge. (iv) It is perpendicular to the burger vector. (v) It moves parallel to the burger vector. (vi) It can glide & climb.	(i) It is generally produced during the crystal growth. (ii) Only shear stress is present. (iii) The disturbance is generally in two planes with 90° to each other. (iv) It is parallel to the burger vector. (v) It moves perpendicular to the burger vector. (vi) It can only glide.

DT: 7/12/2024

Surface defects

Idea about Cooling curves & phase Diagram or Equilibrium Diagram

Alloy

Components, Phases, Structural constituents.

Phase Diagram

Definition:- It is the diagram which shows the diff phases in equilibrium under diff temp & alloy composition.

Important & objective (aim)

- ① It gives idea about diff phases under diff temp & for diff composition of component.
- ② It also gives idea about structure composition & temp.
- ③ It also shows the relationship between phase stability as a function of temp, composition, & pressure.
- ④ It allows us to study & control about phase separation, solidification, recrystallization, growth & doping of crystal & also structural changes due to heat treatment.

- ⑤ Shows the liquidus & solidus line or surfaces.
- * Liquidus:- It is the line or surface which shows the completion of melting & beginning of solidification.
- * Solidus:- It is the line or surface it shows the temp of completion of solidification & ~~completion~~ beginning of melting.

* System:- It is a substance which is a combination of solid, liquid & gases including metal & non metal in any combination & is separated from its surrounding.

A The system, is classified as for the no. of components. The component is the one of the variables available within the system.

- * The diff type of systems are :-
- ① unary system. (1 component)
 - ② Binary system (2 components)
 - ③ Tertiary system (3 components)
 - ④ Quaternary system (4 components)

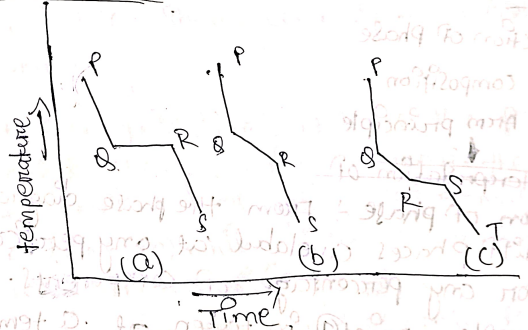
Phase

* When diff components are mixed in the alloy to produce different homogeneous parts with diff composition & property.

Structural constituents

* When the phases are combined in diff known way there are called as structural constituent.

Cooling Curve



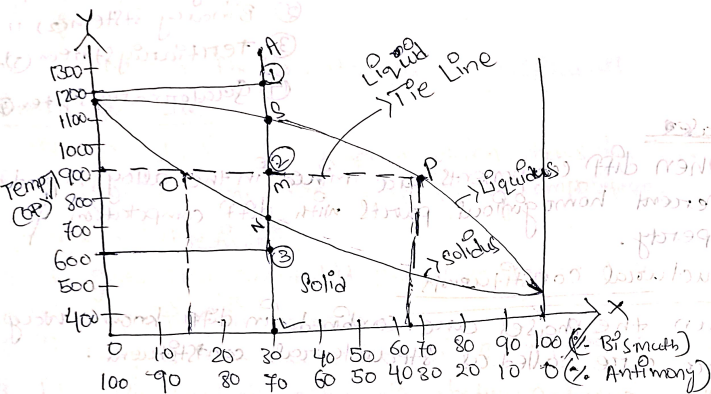
(a) Pure metal or compound.

(b) Binary solid solution.

(c) Binary eutectic system.

DT: 11/12/24

Interpretation of Phase diagram



3 rules

- ① Prediction of phase
- ② Phase composition
- ③ Lever Arm principle

The Interpretation of

① Prediction of phase :- From the phase diagram we can know the diff phases available at any particular temp. For any percentage of components.

For example :- point (0) is taken at a temp of 1200° Fahrenheit.

② Phase composition :- The point (0) along a vertical line touched the percentage line at point (A) with 30% Bismuth & 70% Antimony. It cuts the liquidus line at point (S) & solidus line point (N).

Suppose at the temp of 900° F we draw a horizontal line to cut the solidus line at point (O) & the line (L) at point (M) or point (2).

* The point 1 shows it is having only 1 phase that is liquid with 30% Bismuth & 70% Antimony at 1200° F temperature.

* At the point (2) which is having same composition but with temp of 900° F it has 2 phases that is liquid & solid.

* At the point (3) with same composition with 600° F temp it has 1 phase that is solid or solid solution.

③ Phase composition :- Draw a horizontal line extended from the line (O2) up to the point (P) cutting liquidus line.

* The line having point (P) shows composition of 60% Bismuth & 40% Antimony.

* The point (O) shows composition of 30% Bismuth & 70% Antimony.

③ Lever Arm principle :- It shows the proportion of diff phases at any particular temp. The intersection of the vertical line (AL) & isothermal line (OP) gives the point (m) which is the fulcrum of the system with lever arms (Om, mp).

* The multiplication of amount of phase present with relative length of lever arm must be balanced with each other. This is called as lever rule. The isothermal line (Omp) is called as Tie line, because it connects the diff phase composition in equilibrium at particular temp.

* It can be expressed mathematically

$$\textcircled{1} \text{ Amount of solid phase} = \frac{MP}{OP} \times 100 = \frac{(62-30)}{(62-14)} \times 100 = 66\frac{2}{3}\%$$

$$\textcircled{2} \text{ Amount of liquid phase} = \frac{OM}{OP} \times 100 = \frac{(30-14)}{(62-14)} \times 100 = 33\frac{1}{3}\%$$

Gibb's phase Rule

$$P + F = C + 2$$

$$P + F = C + 1$$

→ At constant pressure

* This rule shows relationship between no. of degrees of freedom, F = No. of degrees of freedom or no. of physical variables.

P = No. of phases.

C = No. of components.

* At constant pressure it is change into the modified rule as $P + F = C + 1$ or $F = C + 1 - P$

* It shows that the no. of phases can't exceed the addition of no. of component + 1

Other Rules of geometry are made for the Phase diagram

* They are $\textcircled{1}$: Single phase areas are always separated by 2 phase areas.

$\textcircled{2}$ 2-phase area is always at constant temperature etc.

Different types of Equilibrium on Phase diagram

* one type is where 2 metal was completely solid sol. in both liquid & solid phase.

* ex: Nickel, Copper, Antimony, Bismuth etc.

Eutectic System

* Liquid $\xrightarrow{\text{cooling}}$ Solid (1) + Solid (2)
 $\xrightarrow{\text{Heating}}$

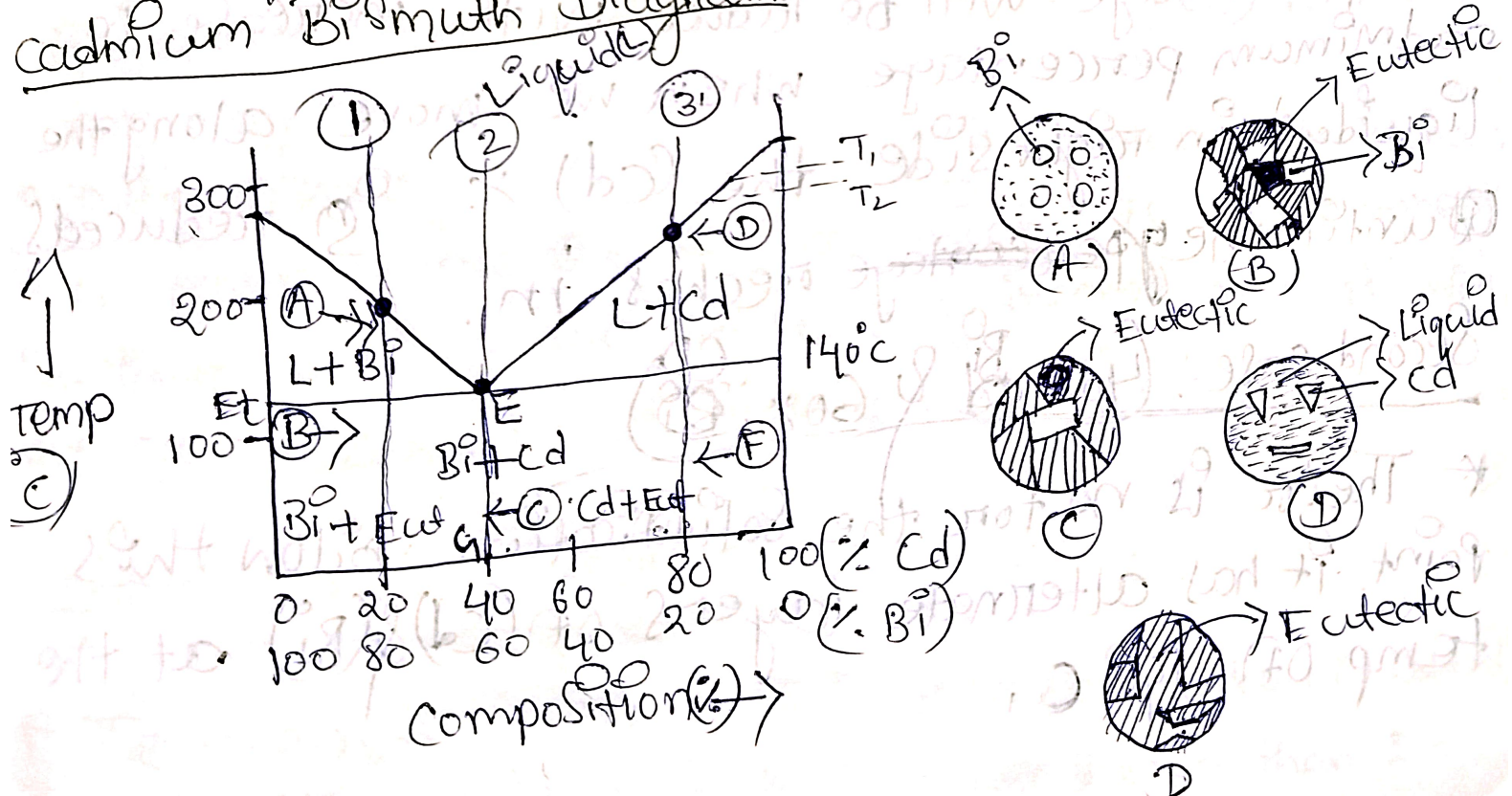
* Here the liquid solution ~~when~~ when cooled is converted into 2 solids without any paste type phase. This system at a temp called as Eutectic temp which is lower freezing point than any of its ~~comp~~ components.

* The eutectic point is the point with eutectic temp & eutectic composition. The eutectic composition is the composition at which it ~~freezes~~ ^{temp} ~~lower~~ ^{temp} ~~components~~ as their components.

Case - 1

* Two metal was completely solid sol. in the liquid state & completely insoluble in solid state.

Cadmium Bismuth Diagram



Line - 3 (80% Cd or 20% Bi)

By cooling along the line 3 when reached point t_1 than solidification of cadmium starts then as the percentage of cadmium is reduced so the liquid solution became reaches in Bismuth. Then at the lower temp t_2 more amount of cadmium is deposited.

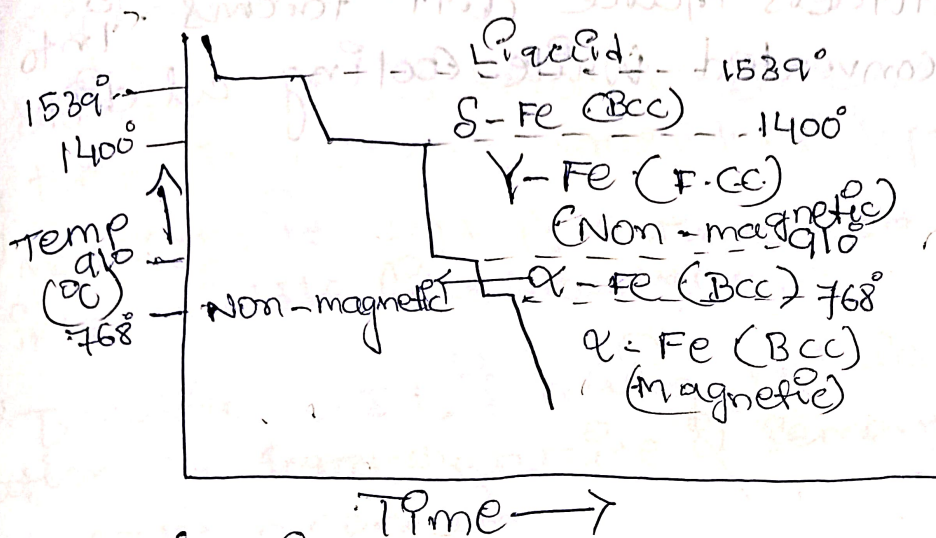
* At lower temp t_2 more amount of cadmium deposited as solid which increases Bismuth percentage in liquid. It continues along the line until the Eutectic temp of 140°C where Cadmium percentage is 40% & Bismuth percentage 60%.

* For the first composition (1) 20% (Cd) & 80% (Bi) it cuts in reverse of first case here at the temp on the liquidus line Bi will solidify first enhanced its percentage will be reduce with increase in cadmium percentage when we move along the liquidus in right side the (Cd) % is reduced until the ~~percentage~~ reaches in.

Second case: (40% Bi & 60% Cd)

* There is no for the solidification below this point it has alternate layers of (Cd) & (Bi) at the temp of 140°C .

DT: 16/12/24



(Cooling curve for pure Iron)

* The melting point of Iron is 1539°C . Iron is called an allotropic metal because it has more than 1 lattice structure like (FCC, BCC) according to diff temp.

* When Iron is cooled between 1539 to 1400°C it is solidified into δ -Iron (BCC).

* Again cooling 1400 to 910°C the phase change occurs & the atom then self into γ -Iron (Fe) (FCC) which is non-magnetic.

* Cooling below 910°C to 768°C due to another phase change it is converted into α -Fe (BCC) which is non-magnetic. Further cooling the α -Fe only becomes magnetic without any change in structure.

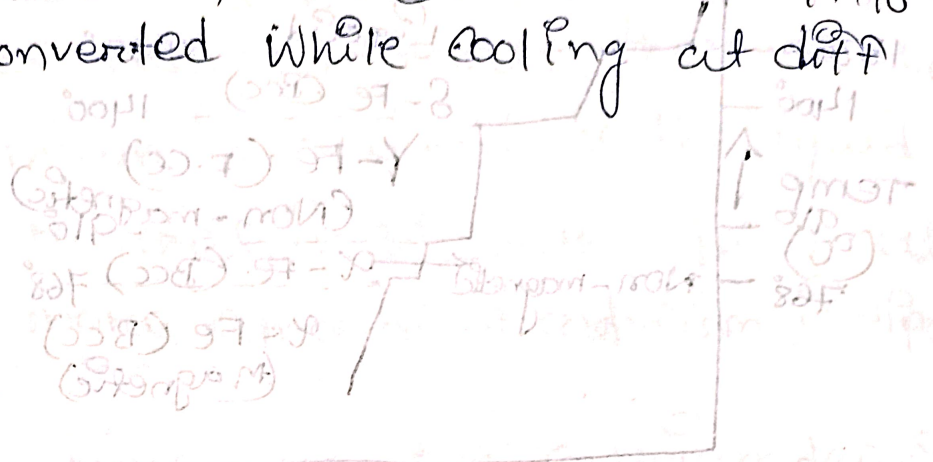
Iron Carbon diagram

* The main constituent is Iron when carbon is added up to 2% with Iron & again when greater than 2% .

Micro-Constituents of Iron & Steel.

* The micro constituents have diff forms. Into which steel is converted while cooling at diff rates.

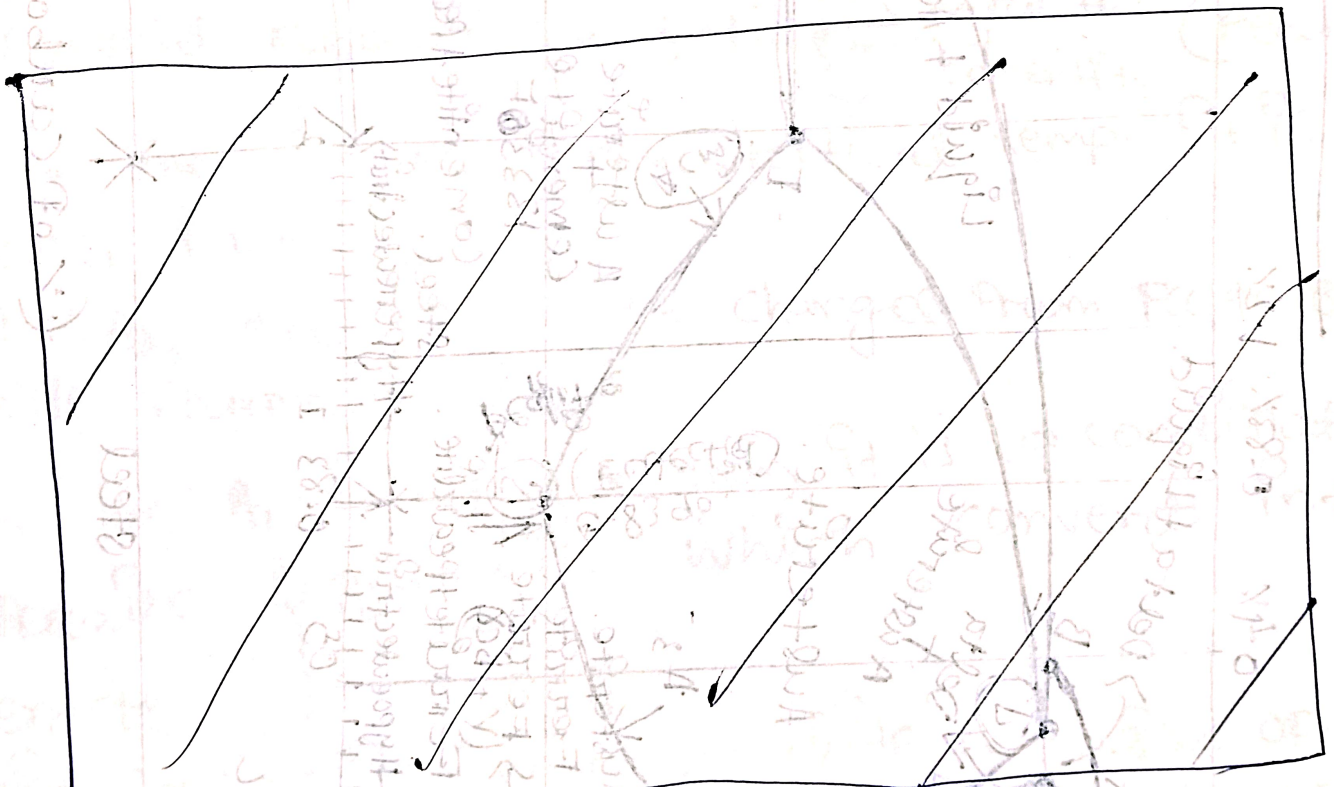
- ① Austenite
- ② Ferrite
- ③ Cementite
- ④ Ledeburite
- ⑤ Pearlite
- ⑥ Bainite
- ⑦ Martensite
- ⑧ Troostite
- ⑨ Sorbite



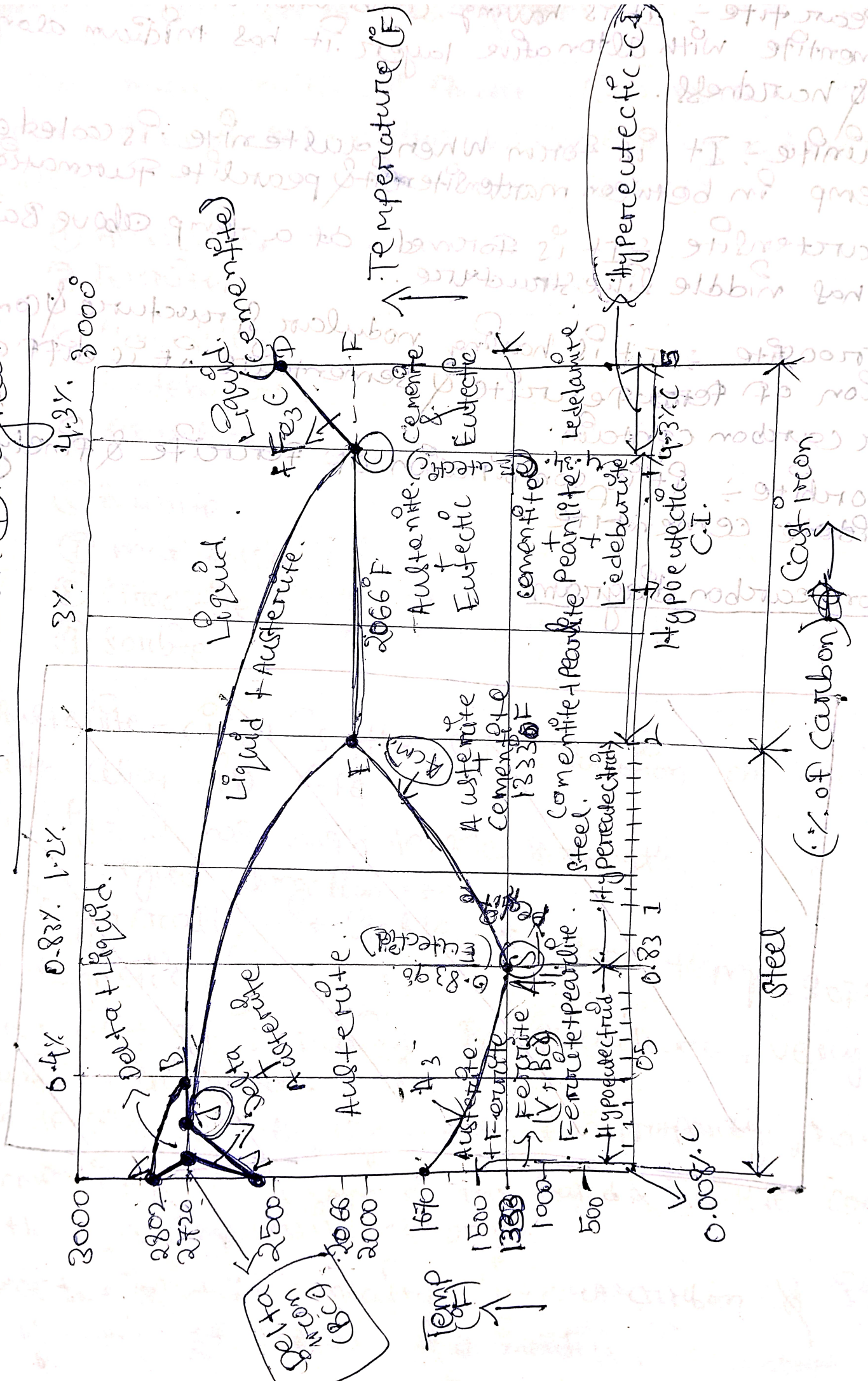
- ① Austenite: (i) It is the solid solution of carbon with alloy in γ -Fe.
Property: It has high tensile strength, good elongation etc.
* It is generally not stable at room temp, soft, non magnetic.
- ② Ferrite: It is having BCC structure, very less solubility for carbon.
High tensile strength, higher elongation property, hardness.
- ③ Cementite: It is one of the hard & brittle compounds with high compressive strength.
- ④ Ledeburite: It contains 4.3% of carbon & is a combination of Austenite & Cementite.

- ⑤ Pearlite $\div$ It is having combination of Ferrite & cementite with alternative layers. It has medium strength & hardness.
- ⑥ Bainite $\div$ It is formed when austenite is cooled at a temp in between martensite & pearlite formation.
- ⑦ Martensite $\div$ It is formed at a temp above Bainite & it has needle like structure.
- ⑧ Troostite $\div$ It is having nodular structure & combination of Ferrite & cementite. It is diff as for carbon content.
- ⑨ Sorbite $\div$ It is combination of Ferrite & finely divided cementite.

Iron-carbon diagram.



Iron - Carbon Diagram



* The Iron-carbon diagram is very important due to its higher industrial application.

* Up to 0.83% of carbon it is called as hypoeutectic. From ~~4.3%~~ 4.3% of carbon it is called as hypereutectic cast iron. More than 4.3% of carbon it is called hypoeutectic cast iron.

* This diagram has peritectic point, T point, eutectic point & point S the eutectoid point.

* The peritectic reaction is $\delta + \text{liquid} \rightarrow \text{Austenite}$.

* The eutectic reaction is $\text{liquid} \xrightarrow{\text{cooling}} \text{Austenite} + \text{Cementite (Ledeburite)}$
 $\text{liquid} \xrightarrow{\text{heating}} \text{Austenite} + \text{Cementite}$

* Eutectoid reaction is $\text{Solid} \xrightarrow{\text{cooling}} \text{Ferrite} + \text{Cementite (Pearlite)}$
 $\text{Solid} \xrightarrow{\text{heating}} \text{Ferrite} + \text{Cementite}$

* Above the line A_3 upper critical temp. $\gamma + \text{Fe}$ is in austenite form.

* Below A_3 the structure changes from FCC to BCC & Ferrite formation starts.

* When the A_1 is reached then it is a combination of Ferrite & Austenite which converts into Cementite.

* Again cooling it forms pearlite at 0.83% of carbon. Up to ~~point~~ 0.83% of carbon it is Ferrite + pearlite. After 0.83% it is pearlite + cementite.

* When carbon percentage is around 3% then it is of cast iron type at temp around 2066°F it is.

Combination of austenite & cementite; Further cooling produces leadburrite.

* Cast iron of between 2 to 4.3 carbon below 1333°F contain cementite, pearlite & leadburrite.