Engineering material and their properties

1.1 Material classification into ferrous and non ferrous Category and alloys.
1.2 Properties of materials: physical, chemical and mechanical
1.3 Performance requirements
1.4 Material reliability and safety

Corrosion - potentiodynamic polarisation
Electro impedance spectroscopy

Ferrous material

'Ferro' means 'iron'. The material consist of iron are called ferrous materials. The atomic number of iron is 26. It is a d-block element in the periodic table. There are different types of ferro materials like vanadium steel, stainless steel, high strength steel and spring steel. Except these, light weight ferro materials are also considered under this category like aluminium based ferromaterial, silicon based ferro materials and alloys, high entropy alloy (HEA) etc.

Non-ferrous materials

Those materials or alloys which don't contain ferro or iron called non-ferrous alloys. These are Be (berillium) based, Al (aluminium) based and Ti (titanium) based alloys. These materials have low density and low mechanical properties compared to the iron based materials and alloys.

Special properties of non-ferrous alloys

- High corrosion resistance
- High electrical conductivity
- High thermal conductivity

The major disadvantages of these alloys have energy requirment for the extraction from the ores.

Ex: One ton aluminium need 75,000 kWh for processing from ore to primary material. This is five times the making need of steel. But the aluminium scraps are needed only 5% of this energy to prepare primary materials.

Properties of materials

Physical properties:- These are the standard properties related both the chemistry of the materials.

I. **State:-** The materials can be in solid, liquid or gaseous states. There are many facts hidden within each state.

II **Density:-** The mass of the material per unit volume called density

$$Density = \frac{Mass}{Volume}$$

There are high and low density materials. The density of iron is 7.86 g/cm^3. The density of titanium is 4.5 g/cm^3. The high density materials have heavy engineering applications. The low density materials are used in aerospace industries, domestic appliances, biomaterials or manufacturing of

III **Magnetism:-** Magnetism is one among the crucial properties. These are utilized in versatile fields like electric field applications, magnetic field applications, characterization techniques, advance technology like hyperloop and supper conductivity in supper computers. All the magnetic materials have positive susceptibility. According to the magnetic properties magnetic materials are three types

1. Diamagnetic material
2. Paramagnetic material
3. Ferromagnetic material.

The diamagnetic materials have negative susceptibility but para and ferromagnetic materials have +ve susceptibility. The para and ferro materials are +vely magnetized along the direction of magnetic field but the diamagnetic materials are magnetized opposite direction of the magnetic field. Iron, Nickel and Cobalt are magnetic materials of high susceptibility.

Solubility:- The mixing of materials with other materials is called solubility. The extent of solubility is different for different materials. The solvent are also different. There are solid solution (Brass, bronze), liquid solution (syrup) and gas solution (air). The materials and alloys are generally digested in acids (strong acids). The polymers are dissolved in organic solvent (acetone, bronze, toluene) and other elements or components are dissolving in polar solvent like water.

Viscosity:- The resistance provided by the materials to flow is called viscosity. The viscosity is temperature dependence. It increases with increase in temperature.

Mechanical properties

The mechanical properties of materials (metals or alloys) are strength, ductility, creep strength, fatigue and fracture. The strength are compressive strength, tensile strength, shear strength, yield strength.

1. Strength:- It is resistance offered by the materials when subjected to external loading. So stronger the material, greater load it can withstand.

The maximum ~~that~~ stress that any material will withstand before destruction is called its ultimate strength.

ii Elasticity:- The elasticity of a material is its power of coming back to its original position after deformation when the stress of the solid removed. Elasticity is the tensile property of the material. Greater the stress of material can endure without taking up some permanent set is called elastic point.

iii Stiffness:- The resistance of the material to the deflection is called stiffness or rigidity. Steel is more stiffer than aluminium. Stiffness is measured by young's modulus of elasticity. Higher value of young's modulus, stiffer the material.

iv. Plasticity:- The plasticity of the material is its ability to undergo some degree of permanent deformation without any failure. Plastic deformation will take place only after the elastic range has been exceeded. Plasticity is an important property and widely in several mechanical process like forming, shaping, extruding and any other hot and cold working process. In general plastic deformation increases with increasing temp. and is a favourable property of material for secondary forming process.

Due to this properties various metals can be transformed into different products of required shape and size. The conversion into desired shape and size is affected either by the application of pressure, heat or both.

v Ductility:- Ductility of a material enables it to draw out into thin wire on application of the load. Mild steel is a ductile material. The wire of gold, silver, copper, aluminium etc. are drawn by extrusion or by pulling through a hole in a die due to ductile property. The ductility decreases with increase of temperature.

The percent of elongation and the reduction in area in tension is often used as empirical measure of ductility.

VI Malleability:- Malleability of material is its ability to be flattened into thin sheets without cracking by hot or cold working. Aluminium, copper, tin, lead, steel etc. are malleable metals.

Lead can be readily rolled and hammered into thin sheets but cannot be drawn into wire. Ductility is a tensile property, whereas malleability is a compressive property. Malleability increases with increase in temperature.

VII Brittleness:- The brittleness of material is the property of breaking without much permanent distortion. There are many materials, which break or fail before much distortion take place. Such materials are brittle e.g. glass, cast iron.

Therefore, a non-ductile material is said to be a brittle material. Usually the tensile strength of brittle material is only a fraction of their compressive strength. A brittle material should not be considered as lacking in strength. It only shows the lack of plasticity. On stress-strain diagram these materials don't have yield point strength and value of E is small.

VII Toughness:-

A toughness of material is its ability to withstand both plastic and elastic deformation. It is a highly desirable quality for structural and machine parts to withstand shock and variation. Mn steel, wrought iron, mild steel are tough materials.

For ex: if a load is suddenly applied to a piece of mild steel and then to a piece of glass the mild steel will absorb much more energy before failures occurs. Thus mild steel is said to be much tougher than glass.

Toughness is a measure of the amount of energy material can absorb before actual fracture or failure take place. The work or energy ...

by the material is called "modulus of toughness". Toughness is also resistance to shock loading. It is measured by a special test on impact testing machine.

Hardness:-

Hardness is closely related to strength. It is the ability of a material to resist scratching, abrasion, indentation or penetration.

It is directly proportional to the tensile strength and is measured on special hardness testing machines by measuring the resistance of the material against penetration of a indentor of special shape and material under a given load. The different scales of hardness are Brinell hardness, Rockwell hardness, Vicker's hardness etc.

Hardness of the materials does not directly related to the hardenability of the metal. Hardenability is indicative of the degree of hardness that the metal can aquire through the hardening process that is heating and quenching.

Hardenability:-

Hardenability is the degree of hardness that can be imparted to metal by process of hardening. A metal capable of being hardened throughout its structure is said to have high hardenability. The material is heated above a certain temperature and then suddenly quenched in a cold oil or water bath.

Impact Strength

It can be defined as the resistance of the material to fracture under impact loading i.e under quickly applied dynamics loads. Two standard test are normally used to determined this property i.e

1. The IZOD Impact Test.
2. The CHARPY TEST.

Resilience

Resilience is the capacity of material to absorb energy elastically. On removal of load the energy stored as in a spring.

The maximum energy which can be stored in a body upto elastic limit is called the proof resilience. The quantity gives capacity of materials to bear shocks and vibration. The strain energy stored in a material of unit volume gives proof resilience and is measured by work stretching.

Chemical properties

I. **Toxicity**:- A measures of a material's ability to damage of ~~[illegible]~~ disturb the metabolism of living tissue, may be accurate or chronic can be determined by contact inhalation, ingestion or injection.

ii. **Chemical resistance**:- A material's ability to withstand degradation from acids, solvents, water or oxygen(Corrosion is a special process) generally marked by weight change, discoloration, cracking or change in mechanical properties

iii. **Corrosion resistance**:- Corrosion is an electro-chemical process that is closely related to the activity series. An ion high on the list will replace a metal lower on the list

$Mg > Al > Zn > Cr > Fe > Sn > Ni > Cu > Ag > Au$

Corrosion is strongly independent on environmental variables

iv. **Combustibility**:- A material's ability to catch fire and burn, important for organic materials and reactive materials (specially finely divided)

V. **Passivity:-** The loss of chemical reactivity by some active metals and alloys, frequently by formation of a thin oxide surface coating.

Bio Compatibility:- The using of materials in or on the human body without eliciting a rejection response from the surrounding body tissues includes materials made of polymers, metals ceramics and composite.

Material selection and reliability

All the products are made up of materials. So the material selection for the fabrication of product is important. The materials are basically metals, polymers, adhesive and many other. The selection of right materials meets the needs of the customer and sufficiently reliable on understanding the response applied stress over time on it.

Acceptable things for material reliability:

① Supplier data sheets and reliability claims.

The design team may select materials according to their experience according to the data sheet provided by the supplier. The supplier's additional information are considered, specially shift, drift, degrade, deteriorate or corrode over time is considered. Engineering experience along with sufficient supplier characterization result may indicate there is little risk for the given application.

② Material performance

Metals / alloys

① Cavity is a pitting erosion due to liquid/air bubble collapse and resulting in a high force impact on the metal surface.

② Corrosion given the process and use environment including the presence of contaminants.

③ Cracking and crack propagation given shock, vibration, stress concentration or cyclic loading.

④ Deformation due to applied loads or stress relation after forming.

⑤ Embrittlement due to chemical interactions ... cyclic loading

(6) Fatigue most often due to cyclic loading
(7) Fracture Could be ductile fracture due to cyclic loading and shear fracture due to excessive loading or a Combination.
(8) Friction an increase or decrease in friction depending on the application due to lubricating failures, Contamination, tolerance, Surface finish changes
(9) Wear often due to abrasion in the normal Course of use for some application Causing a change in dimension over time.

Ferrous materials and alloys

The iron based materials are called ferrous materials. This include all types of iron and steel related materials. They are classified as

i. **Pig iron**:- It is the basic material from which wrought iron and steel are manufactured. It is obtained from blast furnace in crude and impure form.

ii. **Cast iron**:- It is a refined form of pig iron obtained from cupola furnace.

iii. **Wrought iron**:- It is virtually pure iron, containing large number of minute threads of slag lying parallel to each other, thereby giving the metal a fibrous appearance when broken.

iv. **Carbon steel**:- This is the carbon based steel with the composition of various percentage

a. Low carbon steel/mild steel
b. Medium carbon steel
c. High carbon steel

v. **Alloy steel** :- When some alloying elements like Ni, Cr, Mn, V, W etc. are added to the carbon steel to obtained some special properties, the produced steel is called alloy steel.

Properties of ferrous materials-

1. Durable
2. Greate tensile strength
3. Usually magnetic
4. Low resistance to corrosion
5. A silver like colour

Uses of ferrous material

① The ferrous materials are found in fcc and bcc phase. They are all crystalline. so they shows high mechanical properties and superior toughness permit them for heavy engineering application.

② The composition of the steel decides its mechanical properties. The ultimate tensile strength of stainless steel 485-860 MPa, yield strength 172-690 MPa, elongation 12-40% and hardness 95 HRB. The ferrous materials consist of carbon, manganese, phosphorous, sulfur, silicon, chromium, nickel, molybdenum with iron. Carbon and chromium are active element for corrosion resistance. Ni used as γ-stabilizer.

③ Due to the mechanical properties of the making steel is used to make long lasting skyscrapers. They are also used for making tools, vehicle engines, pipeline, container & automobiles etc.

④ The railway tracks and various equipments are also made by steel.

⑤ Due to the magnetic properties, it is also used as magnetic materials.

Low Carbon Steel

This is the non-alloy steel because carbon is the alloying element there. Except carbon other elements in the non-alloy steel are sulphure, silicon and manganese. The low carbon steel contain carbon 0.1% ~~0.25%~~. They are pretty low cost and very well suited for bending operation. The surface hardening can be increased through carburising. The low cost and malleability low carbon steel are widely used for the making of nuts, bolts, forging and medium loaded object. They are not heat treated because the hardenability is too low to produce martensite. They are used in the form of cold roll sheet. The microstructure consist of essentially of ferrite

Mechanical properties of Low Carbon Steel

Y.S. (MPa)	T.S. (MPa)	% elongation
200-300	300-370	28-40

The excellent formability of these steels make them suitable for cold form applications such as stamping of automobile and refrigerator bodies, tin cans and corrugated sheet.

Dual phase steels:- By the development of the strength of the low carbon steel dual phase steel is formed without an appreciable loss of formability. The property of dual phase steels are

i. The absence of a discontinuous yield point.
ii. A low ratio of yield strength to tensile strength.
iii. A high work hardening rate.
iv. A high tensile strength.
v. A large uniform elongation.

Low carbon steels are annealed in the inter critical (α + γ) region of the Fe-C phase diagram and then cooled rapidly enough to convert the austenite part to lath martensite. The final microstructure consist of 15-20% of martensite islands in a fine-grained ferrite matrix. The typical mechanical properties

Y.S. (MPa)	T.S. (MPa)	% elongation
350	650	30

Medium Carbon Steel

The medium carbon steel contains 0.25% to 0.6% of carbon. The higher carbon content increases their strength and hardness compared to low carbon steel. The increase of carbon and Mn allowing tempering and quenching. The medium carbon steel is used in automotive industries to make gears, axles, shafts, bolts, nuts, screw etc. Steel ranging 0.4-0.6 of carbon are suitable for everything related to components and rails.

High Carbon Steel

The carbon percentage of high carbon steel is 0.6% to 1%. The carbon content varies according to different sources. Some have more sub groups. These are the strongest of the group, making it self able for applications, where resistance against mechanical material wear is needed. The other quality of high carbon steel is their tendency to keep a shape. This is why tool steel have lot of different applications in the field of engineering. As the downside the hardness, ductility and impact hardness are as inferior to steels with less carbon. Steels are also according to steels with less carbon. Steels overlap by use, tool steel and high carbon steels overlap. The shape keeping quality makes them useful as spring. Other use cases includes blades, rail steels, wire rope, wear resistance plates, all kind of tools etc.

Alloy steels and alloying elements

Alloy steels makes up another sub group of ferrous materials. Steel's alloying elements are chromium, nickel, silicon, copper, titanium etc. Each has either own effect on material properties

Chromium:-

1. Responsible to making standard steels
2. Above 11% of chromium make a steel corrosion resistance
3. In material a layer of chromium oxide is formed. It protects from oxidation and corrosion resistance
4. It also increases tensile strength, hardness, toughness, resistance to wear etc.

Manganese:-

1. It improves ductility, wear resistance and hardenability
2. The hardenability is done by quenching where 'Mn' has significant impact
3. It diminishes the danger of defect form during the process by making it more stable

Nickel

1. It's main purpose is to increase ductility and Corrosion resistance in combination with other elements namely Chromium.
2. When chromium contain 18% and nickel contain 8%, we get an extremly durable stainless steel.

Silicon

i. It improves strength and provide elasticity in spring
ii. It also increases the metals' magnetic property

Titanium

i. It improves the strength and corrosion resistance
ii. It limits austenite grain size

Vanadium

i. The formation of vanadium Carbides limits the grain size. This has effect on increasing a material's ductility
ii. It also increases the strength, hardness, wear and shock impact resistance. It is beta stabilizer.
iii. This material has negative impact in material properties

Molybdenum

i. Molybdenum has higher impact on steel alloys at high temperature.
ii. It improves the mechanical properties but also resistance to corrosion and acts as an amplifier for the effect of other alloying elements

Unit - 3 Iron- Carbon system

The relationship between phases in a system as a function of temperature, pressure and composition depicted in the form of maps called equilibrium relationship or equilibrium diagram or phase diagram.

Phase rule

The Gibbs phase rule can be stated as

$$F = C - P + 2$$

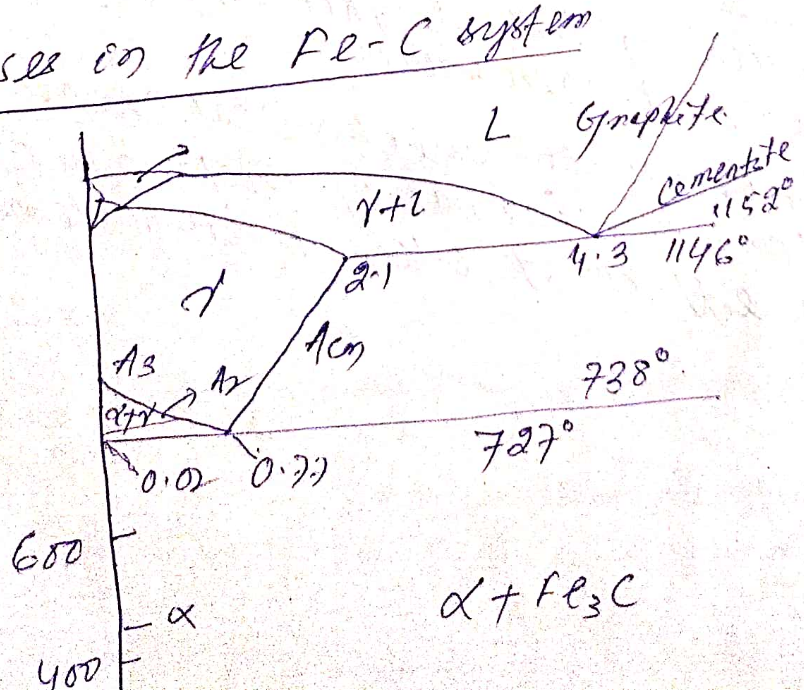
where F is the degree of freedom
C is the number of components
P is the number of phases in the system

Phase:- ① Seggregation of state of matter like solid, liquid and gas. liquid has only one phase like gas. But solid has multiple phases.

Components:- The components refer to the independent chemical species that constitute an alloy

Degrees of freedom:-
The degrees of freedom refer to the number of independent variables associated with the system.

Phases in the Fe-C system



α - Ferrite is an interstitial solid solution of Carbon in BCC iron. It is stable over the temperature range from -273°C to 912°C.

Austenite (γ) is an interstitial solid solution of carbon in FCC iron. It is stable from 912 to 1394°C.

δ - ferrite (BCC) is stable from 1394 to 1539°C the melting point of iron. The maximum solubility of Carbon here is 0.09 wt%.

Cementite is an intermetallic compound with formula Fe_3C. The atomic percent of Carbon in Cementite is 25 and the weight percent is 6.67.

Crystal imperfections

The imperfection in the regular pattern of the crystal is called crystal imperfection.

The crystal imperfections are following types

(i) Vacancy
(ii) Interstitialcy
(iii) Interstitial impurity
(iv) Substitutional impurity

Unit cell:- A unit cell is an arrangement of atoms and molecules that it has minimum volume and its repeated arrangement in all the three co-ordinate directions form the crystal.

The crystal systems are of

(1) **Cubic system:-** The three co-ordinate axes of unit cell are of equal axial lengths. They are inclined to each other at angle of 90°.

$$a = b = c, \ \alpha = \beta = \gamma = 90$$

(2) **Tetragonal system:-** In this crystal system two axes of unit cells are equal lengths.

$$a = b \neq c, \ \alpha = \beta = \gamma = 90°$$

(3) **Orthorhombic system:-**

In this crystal system, the axes have different lengths but they are right angle to each other.

$$a \neq b \neq c, \ \alpha = \beta = \gamma = 90°$$

(4) Rhombohedral system:-

The axes are of in lengths but not mutually perpendicular to each other.

$a = b = c, \; \alpha = \beta = \gamma \neq 90^\circ$ and $< 120^\circ$

(5) Monoclinic system:-

The three axes could be of any length but one axis is perpendicular to the other two which are inclined among themselves at any angle except 90°

$a \neq b \neq c, \; \alpha = \gamma = 90^\circ, \; \beta > 90^\circ$ or $\beta < 90^\circ$

(6) Triclinic system

The tree ~~lengths~~ axes are of any length and inclined to each other in any angle, none of which is right angle.

$a \neq b \neq c, \; \alpha \neq \beta \neq \gamma \neq 90^\circ$

(7) Hexagonal system

Two axes are equal lengths and third is longer or shorter than other two.

$a = b \neq c, \; \alpha = \beta = 90^\circ, \; \gamma = 120^\circ$

Classification of Imperfections

The imperfections are following types

(1) Point defect:-

The defect raised due to the replace of the atom or molecule from its position is called point defect.

(2) Line defect:-

The line defects are scratches. The line defects are displaced from the atoms or molecules displaced from the raw in regular pattern is called line defect.

3. Surface defect:-

The irregularities on the material surface due to the irregular position of the particles causes surface defects

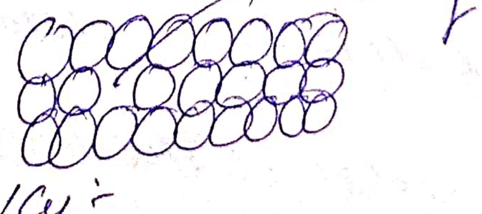
4. Volume defect

The deviation of the regular volume of the matter or object by the deviation or irregular arrangement of the atoms causes volume defect.

Types and Causes of point defects

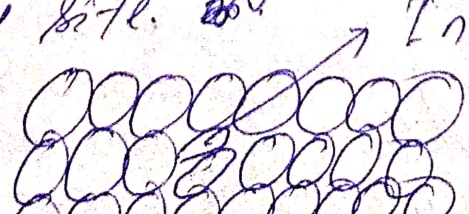
The point like regions of distortion in the crystal causes point defects
The point defects are
(I) Vacancy (II) Interstitialcy
(III) Interstitial impurity
(IV) Substitutional impurity.

1. Vacancy:- A vacancy is an atomic site from which the atom is missing causes vacancy



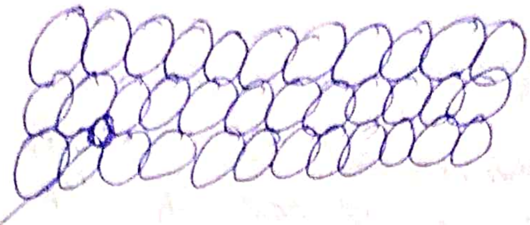
ii. Interstitialcy:-

An interstitialcy refers to an atom displaced from a regular site into an interstitial site.



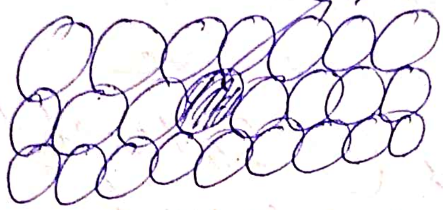
(iii) Interestitial impurity

An interestitial impurity is a small atom occupying an interestitial void space between parent atoms of the crystal.



(iv) Substitutional impurity

A substitutional impurity is an impurity atom that has substituted for one of the parent atoms on a regular atomic site.



Dislocation:-

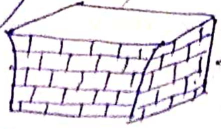
The line imperfections are known as dislocation. The geometry of dislocations can be understood with reference to the two limiting straight line types

The line defects or dislocation are

1. The edge dislocation
2. The screw dislocation.

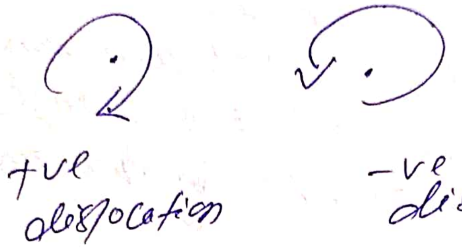
Edge dislocation:- An edge dislocation extending from the front to the back face of the crystal. It distored the region all along the region of the edge of an incomplete plane in the crystal. The atoms above the edge in compression whereas those just below are in extension.

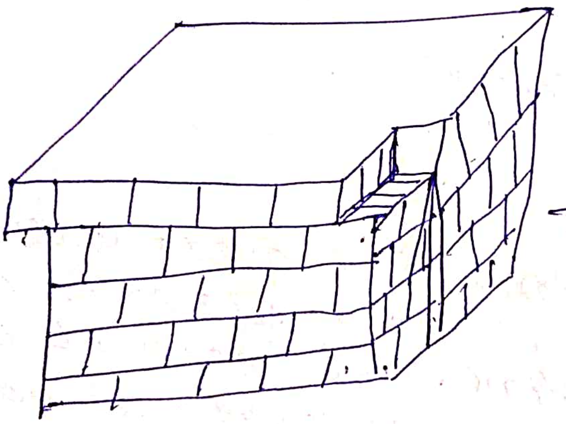
The edge dislocation is characterized by Burgers vector.



Screw dislocation

A screw dislocation extending from the right to the left side face of the crystal. It is characterized by a shear strain. The Burgers vector is parallel to the screw dislocation. The positive and negative dislocations are denoted by





Effect of imperfection on material properties

1. Dislocations are present in crystal due to the accidents during the growth of the crystal. The dislocation density in an annealed range from 10^6 to 10^{10} mm^{-3}. Perfect crystals are free from dislocation can be grown.

2. Dislocation plays an important role in the plastic deformation of metals and alloys. The thin perfect crystals that are totally free from dislocation known as whiskers possess very high strength.

3. The presence of dislocation makes crystal

The strengthening crystalline materials against this inherent weakness increase the resistance to dislocation motion.

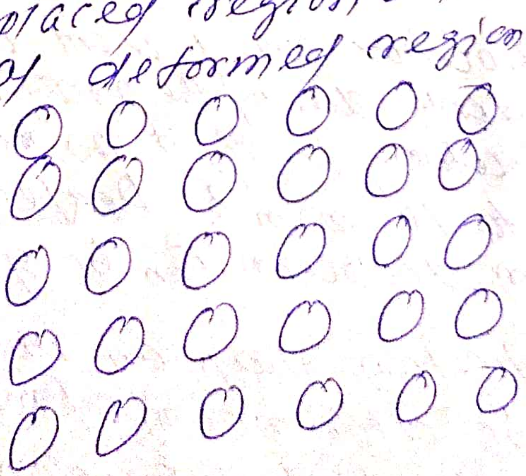
Deformation by slip and twinning

Plastic deformation permanently changes the shape and dimension of a metal. X-ray analysis of a deformed metal shows that during plastic deformation there is no change in the crystal structure or the lattice parameters. Only the number of imperfection increase. The microscopic change of shape and dimension can be brought about without any change in the unit cell dimension shows by two processes

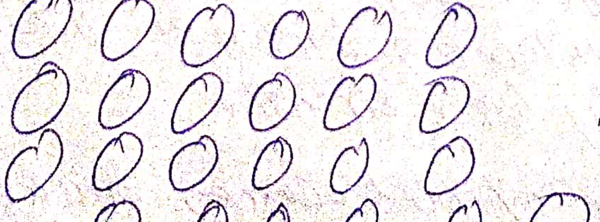
1. slip
2. Twinning

Slip:-

In slip atoms move over a number of interatomic distances related to their initial positions. The magnitude of the each step in displacement is one full interatomic distance. The orientation of the displaced region is the same as the original deformed region.



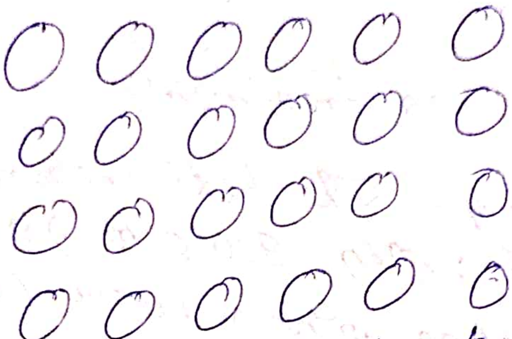
Pattern before slip



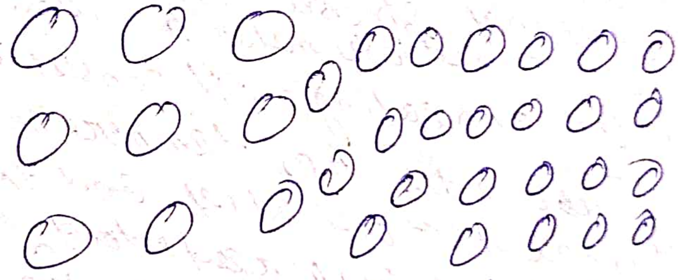
pattern after slip

Twinning:-

In twinning each atom moves by only a fraction of an interatomic distance relative to its neighbours. The orientation of the twinned region is different from the untwined region. Slip is operative mechanism of plastic deformation at high temperature and lower strain rates, where as twinning is operative at lower temperatures and higher strain rate



pattern before twinning



pattern after twinning.

Effect of deformation on material properties:-

① The stress required to slip in a perfect ideal crystal can be estimated. It is in the range of G/6 to G/30, where G is the shear modulus of crystal. The large difference in the yield stresses arises from the presence of dislocations in the real crystal

② The material free from dislocation (whiskers) possess high strength

③ Slip usually starts from sources within the crystal. A typical source is the Frank-Read source which

Heat treatment

The heat treatment of the materials various various characteristics of the materials like establish different phases with mechanical properties. The phase transformation in various temperature. The heat treatment process is applicable both ferrous and non-ferrous alloys.

Process of heat treatment:-

Annealing:- The heat treatment of iron (steel) within 900°C to 725°C is called annealing with various carbon percentage.

The purpose of annealing is to reduce the hardness, facilitate machining and to relieve internal stresses. It is a subcritical treatment provided to the metals to soften them during mechanical processing.

I. **Full annealing:-** It consist of heating the steel above the AC_3 temperature in the case of hypoeutectoid steel and the ACL temperature in case of hypereutectoid steels. The steel is then cooled very slowly (in the furnace) at the rate of a few tens of degrees per hour. The austenite transforms to coarse pearlite within 50°C of the eutectoid temperature.

II. **Spheroidizing anneal:-** It is heating to just below AC_1 or thermal cycling in a narrow temperature interval around A_1. The cementite lamellae in pearlite colonies tend to spheroidize (become sphere) and thereby reduce their surface area with prolonged anneal, the spheroidized particles coarsen, becoming fewer in number and more widely spread.

iii Recrystallization anneal

The recrystallization anneal is done at subcritical temperature in the range of 600 - 650°C. The cold worked ferrite recrystallizes during this anneal.

IV Stress-relief anneal:-

It is a subcritical treatment given to hypoeutectoid steel up to 0.3% C. The temperature used is up to 600°C. Recovery process occurs without recrystallization. The residual stresses due to cold working or matching are removed by this treatment

V Process anneal:-

It is a subcritical treatment given to metals to soften them during mechanical processing. It may or may not involve full crystallization of the cold work metal.

Normalizing:-

Normalizing consists of heating the steel above the A_{c3} temperature for hypoeutectoid compositions and between A_{c1} and A_{cm} temperature for hypereutectoid composition. This is followed by cooling in still air. Fine pearlite and proeutectoid ferrite result from this treatment and Normalizing is done for refining the grain structure and for improving the mechanical properties. The hardness and strength obtained after normalizing are higher than those obtained after annealing

This process is applied to casting and forgings. In casting, normalizing is essential to eliminate the dendritic structure

Patenting:-

This is a special heat treatment process adopted for wire products of medium carbon content. The wire from the austenitizing temperature is passed through a molten lead bath maintained at 500°C.

Quenching and tempering

Tempering is almost always necessary to remove the residual stresses and to reduce the brittleness of martensite. The actual tempering temperature chosen depends on the final properties desired

Quenching of a steel is done from the austenitic range to produce martensite. The cooling rate for the steel to get full hardening. Hypoeutectoid steels are heated above the A_{C3} temperature to ensure full austenization and to avoid the soft ferrite in the final microstructure

Surface hardening

The surface of the steel is made hard and wear resistance but the core remains soft and tough. Such improvement of the material is called surface hardening. 2.
In steel with more than 0.35% C, the surface can be preferentially hardened by a heat treatment

1. Induction hardening :- An alternating current of high frequency passes through an induction coil enclosing the steel part to be heat treated. The heating time is usually a few seconds immediately after heating, water jets are activated to quench the surface. Martensite is produced at the surface, making it hard and wear resistance. The microstructure of the core remains unaltered. This is suitable for mass production of articles of uniform cross-section. ii.

2. Flame hardening :- For large work pieces, such as mill rolls, large gears and complicated cross-sections, induction heating is not easy to apply. In such cases flame hardening is done by means of oxyacetylene torch. Heating should be done rapidly by the torch and the surface quenched before appreciable heat transfer to the core occurs. iii

3. LASER hardening :- A LASER beam can be used for surface hardening. As LASER beam are of high intensity, a lens is used to reduce the intensity by producing defocused spot of size ranging from 0.5 to 25 mm. Proper control of energy input is needed to avoid melting. LASER hardening has the advantage of precise control over the area to be hardened, an ability to harden reentrant surface, very high speed of hardening and no separate quenching step. The disadvantage is that the hardening is shallower than in induction and flame hardening. iv

4. Carburizing

Carburizing is the most widely used method of surface hardening. Here the surface layer of a low carbon steel ($C \leq 0.25\%$) is enriched with carbon upto 0.8 - 1.0%. The source of carbon may be a solid medium, a liquid or a gas. In all cases the carbon enters the steel at the surface and diffuses into the steel as a function of time at an elevated temperature. Carburizing is done at 920 - 950°C. Carburizing is always done in the austenitic state.

I. Pack Carburizing

The articles to be Carburized are packed in a box embedding them in a powdery mixture of 85% charcol and 15% of energizers such as $BaCO_3$

$$BaCO_3 \rightarrow BaO + CO_2$$
$$CO_2 + C \rightarrow 2CO$$
$$2CO + Fe \rightarrow Fe(C) + CO_2$$

Typical Carburizing times are 6-8 times

II. Selective Carburization:-

The Copper is electroplated to a thickness of ~0.05 mm in regions where Carburization is not desired or a refractory paste of fireclay mixed with asbestos can be applied. Control of temperature and penetration depth is less in pack carburizing as compared to liquid and gas carburizing.

III Gas Carburizing:-

The gas carburizing proceeds with a mixture consisting of 5-15% methane (or propane) in a neutral Carrier gas is used. The methane decompose according to the following reaction

$$CH_4 + Fe \rightarrow 2H_2 + Fe(C)$$

IV Liquid Carburizing

It is an outgrowth of cyaniding process discussed below. A typical bath composition is 8% NaCN, 82% $BaCl_2$ and 10% NaCl. The following reactions take place

$$BaCl_2 + 2NaCN \rightarrow Ba(CN)_2 + 2NaCl$$
$$Ba(CN)_2 + Fe \longrightarrow Fe(C) + BaCN_2$$

Cyaniding

Cyaniding is done in a liquid bath of NaCN, with the concentration varying between 30 and 97%. Both Carbon and nitrogen enter the steel

$$2NaCN + O_2 \rightarrow 2NaCNO$$
$$3NaCNO + \rightarrow NaCN + Na_2CO_3 + C + 2N$$

Nitriding

In contrast to the processes described, nitriding is carried out in the ferrite region. No phase changes occures in nitriding. The part to be nitrided should posses the required core properties prior to nitriding

$$2NH_3 \longrightarrow 2N + 3H_2$$

The solubility of nitrogen in ferrite is small. most of the nitrogen that enters the steel forms hard nitrides (Fe_2N). A typical nitriding steel contains alloying element of 1% Al, 1.5% Cr and 0.2% Mo. The temperature of nitriding is 500 - 590°C. The time for a case depth of 0.02mm is about 2hrs. An extremely hard case is produced with hardness in the range of 1000 - 2000 VPN.

Non-ferrous alloy

Alluminium alloys:-

The aluminium alloys are considered one among the light alloys. They have some special characteristics like high corrosion resistance, high electrical conductivity, high thermal conductivity. But they have large requirement for energy for production.

Composition of aluminium alloys:-

The alloys consist of copper, manganese, silicon, magnesium, zinc along with aluminium.

Properties of aluminium alloys

1. Light weight
2. High corrosion resistance
3. High electrical conductivity
4. High thermal conducting
5. Impenetrability to oxygen, moisture and micro-organisms

Uses

1. Pure aluminium is used in electrical industries, packaging industry and for chemical process equipment and for architectural purpose.
2. Al-Mn and Al-Mn-Mg alloys are used for beverage cans, cooking utensils, buildings and roofing sheets
3. Al-Si alloys are used as welding and brazing electrodes
4. Al-Cu alloy, $CuAl_2$ and associated plates are used to fabricate sheets, plates and extrusion for structural purpose and forgings for air craft structure

Copper alloys

Among the common metals Copper is the best Conductor of heat and electricity, next only to the noble metals silver and gold. The common impurity in copper, oxygen, is virtually insoluble

I. Cu-Al → Aluminium bronze
Cu-Sn → phosphor bronze
Cu-Si → Silicon bronze

In Cu-Sn solubility of Tin (Sn) in copper is about 17% at 520°C and decreases continuously cooling to the room temperature

In Cu-Si solubility of Si is 5.3% at 852°C and decreases with decreasing temp.

The solubility of aluminium is 9.5% in aluminium bronze at 500°C

II. Brass.

The brasses are alloys of Copper and Zinc. The Cu-Zn phase diagram indicates the formation of α & α+β phase with heat treatment

The solution of 20% Zn form reddish in colour and above 20% the colour will be yellow.

70/30 brass → Cartridge brass
Cu Zn

70%/29%/1% brass → Admiralty brass
Cu Zn Sn

76% Cu / 22% Zn / 2% Al → Aluminium brass

60% Cu / 40% Zn → Muntz metal

60% Cu / 39% Zn / 1% Sn → Naval brass

Babbit

The white metal consist of ~~a soft matrix in which~~ either lead based or tin based. A typical lead based consist of 10% Pb, 10% Sb, 10% Sn. The tin based babit is 90% Sn, 5% Sb and 5% Cu.

Bearing material:-

The properties required for bearings are

1. The friction between the bearing and rotating part should be as small as possible.
2. The wear of the contacting metals should be as low as possible.
3. The bearing must capable of withstanding pressure that arise from misalignment.
4. It must contain a relatively low melting component which will soften or melt and prevent seizure.

There are different types of bearing materials

1. Lead based :- 80% Pb, 10% Sb and 10% Sn
2. Tin based :- 90% Sn, 5% Sb and 5% Cu

Spring materials

The spring steel have carbon contents in the range of 0.5 - 0.65%. They are quenched and tempered to high level of yield strength. A spring must possess a high resilience. It must capable of storing a large of elastic energy. so that it can spring back without permanently deforming. The quantity σ_y/Y should be maximized for this purpose. The youngs modulus Y being a structure-intensive property a large increase in the yield strength is the key to achieve a high resilience. The tempering is done to give a yield strength of about 1500 MPa.

The alloying elements in a spring steel have several functions. They increase the hardenability so that martensite is obtained without resorting to drastic quenching. The presence of silicon in the 55 Si 2Mn90 spring steel serves the additional purpose of retarding softening during tempering. So that residual stresses are relieved without much loss in hardness and strength. Vanadium in the 50CrV23 steel prevents grain coarsening austenitizing and improves the toughness of the steel.

Polymers

The polymers are the compounds prepared by the various organic and inorganic materials.

The polythene is a polymer prepared by the polymerisation of ethene.

$$CH_2 = CH_2 \xrightarrow{\text{polymerisation}} (-CH_2-CH_2-)$$

polymer

The other polymers are teflone, PLA, PLLA, PGA, POG, PEU etc.

Properties of polymer

① The polymers are light weight.

② The thermoplastic polymers are used as the insulator for insulation.

③ The thermosetting plastics are used for the fabrication of different objects for moulding process.

The polymers have versatile uses.

① The polymers like natural and synthetics are used as fabrics.

② The electrical equipments and wires are coated with polymers for insulation.

③ The body of the car, buses are made from the polymers for their anti corrosion properties.

④ The polymers are also used as biomaterials for traumatic applications.

⑤ The elastomers like natural and synthetic rubbers are used to make tyres of the vehicles and dolls.

Elastomers

The polymers which shows high elasticity called elastomers. The synthetic and natural rubbers are good elastomers.

The elastomers are prepared by the pulverisation of the natural gum of the rubber plant or prepared in the laboratory by various synthetic material. The elastomers have multipurpose uses. They used as containers, compressible objects like tyres and dolls along with game equipment like tennis ball, football and fabrics.

Composites and Ceramic

Composites

The Composites are the compound which are formed by Compaction or reinforcement of different materials with each other according to the required characteristics.

If the particle size of the Constituent elements in the Composites are in micro range, they are called microcomposite and if in the nano range they are called nano composite.

According to the constituent elements the Composites are (i) metal based (ii) Ceramic based and (iii) polymer based.

The Composites have various uses like medical, fabrication of different Circuit elements, aircraft body and many more.

Ceramics

The ceramics are non metalic or metal oxide based Compounds. The ceramics have high brittle and stiff property but they have low mechanical properties. Due to the anticorrosion quality the ceramics are used for various purpose like architect, medical application and many more. The ceramics are biocompatible materials. So they are widely used as biomaterials. CaP (Calcium phosphate), HA (hydroxyapetite), clay are basically ceramics. The bioglass (B... are currently used used as biomat...

Biophysics

Biophysics is an interdisciplinary science that applies approaches and methods traditionally used in physics to study biological phenomena. Biophysics covers all the scales of biological organization, from molecular to organismic and population. Biophysical research shares significant overlap with biochemistry, molecular biology, physical chemistry, physiology, nanotechnology, bioengineering, computational biology, biomechanics, developmental biology and systems biology.

Biological organization:-

Biological organization is a hierarchy of complex biological structure and systems that defines life using a reductionist approach. The hierarchy extends from atoms to biospheres. The higher level scheme is referred to as an ecological organization or as the field, hierarchical ecology.

BO of life is a fundamental premise of numerous areas of scientific research, particularly in the medical science.

BO : Levels

- Acellular and pre-cellular level → Atoms, molecules, Biomolecular complex
- Sub cellular level → Organelle
- Cellular level → Cell
- Supper cellular level → Tissue, organ, organ system
- Ecological levels → Organ, organ system, organism, population, community, Ecosystem, Biome, Biosphere

Biochemistry:- Biological chemistry is the study of chemical processes with and relating to the living organisms. Sub discipline both biology and chemistry

Bio chemistry

- Structural biology
- Enzymology
- Metabolism.

Molecular biology

Molecular biology is the branch of biology that seeks to understand the molecular basis of biological activity in an between cells including biomolecular synthesis

Physical chemistry

Physical chemistry is the study of macroscopic and microscopic phenomenon in chemical system in terms of the principles, practice and concept of physics such as motion, energy, force, time, thermodynamics, quantum chemistry, statistical mechanics, analytical dynamics and chemical equilibria.

Important relationship:-

① Intermolecular forces that act upon the physical properties of materials (plasticity, tensile strength, surface tension in liquids)

② Reaction kinetics on the rate of ~~surface tension~~ reaction