LEARNING MATERIAL

SEMESTER : 3rd SEMESTER

BRANCH : MECHANICAL ENGINEERING

THEORY SUBJECT : ENGINEERING MATERIALS (TH – 3)

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ENGINEERING MATERIALS

Engineering material and their Properties :

Material classification :

(a) Metals — { Ferrous, Non-Ferrous }

(b) Ceramics, (c) Organics, (d) composites,

(e) semiconductors.

Ferrous metals and alloys :

cast iron, wrought iron and steel and alloys silicon steel, highspeed steel, spring steel etc

Non-ferrous metals and alloys :

copper, aluminium, zinc, lead etc alloys are brass, bronze, duralumin etc.

Properties of materials :

Physical Properties :

Physical Properties are employed to describe a material under conditions in which external forces are not concerned.

Physical Properties include :

(a) Dimensions, (b) Appearance, (c) colour, (d) density, (e) melting Point, (f) Porocity (g) structure etc

chemical Properties :

Most of the engineering materials, when they come in contact with other substances with which they can react, tend to suffer from chemical deteriaration.

The chemical Properties describe the combining tendencies, corrosion characteristics, reactivity, solubilities etc, of substance.

Some of the chemical properties are :

(1) corrosion resistance, (2) chemical composition,
(3) Acidity or Alkalinity.

(III) Performance Requirements :

The material of a part is composed must be capable of performing a part's function without failure. For example, a component part to be used in a furnace must be of the material which can withstand high temperatures.

While it is not always possible to assign quantitive values to this functional requirements, they must be related as precisely as possible to specified values of the most closely applicable mechanical, physical, electrical or thermal properties.

(III) Material's Reliability :

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

(IV) Safety :

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

(III) Ferrous materials and alloyes:

(i) characteristics: Ferrous metals include mild steel, carbon steel, stainless steel, cast iron and wrought iron. This metals are primarily used for their tensile strength and durability. Most ferrous metals and alloys are vulnerable to rust when exposed to the elements, wrought iron is pure that is resist oxidation. Most ferrous metals also have magnetic properties, Ferrous alloys are extremely versatile for wide range of mechanical and physical properties. The principle disadvantage of many ferrous alloyes is their susceptibility to corrosion.

(ii) Application of ferrous materials:

Ferrous metals and alloys are used in countless applications as construction materials, medical devices, tools, magnetic cores, wires and in the aerospace, military, and medical fields. Also used in a wide varity of industrial applications. Iron oxide compounds, when mixed with aluminium powder are used to create thermite reactions for welding and purification process.

(iii) classification, composition and application of low carbon steel:

Mild steel or low carbon steels may be classified as followes:

(i) Dead mild steel - C 0.05 to 0.15%.

It has a tensile strength of 390 N/mm^2 and a hardness of about 115 BHN.

Dead mild steel is used for making steel wire, sheets, rivets, screws, pipes, nail and chain.

(ii) Mild steel containing 0.15 to 0.20% carbon has a tensile strength of 420 N/mm^2 and hardness 125 BHN.

It is used for making camshafts, sheets and strips for fan blades, welded tubing, forgings, drag lines etc.

(II) Classification, composition and application of medium carbon steel :

Medium carbon steels contain carbon from 0.30 to 0.70%

(i) Steels containing 0.35 to 0.45% carbon have a tensile strength of about 750 N/mm^2.

They are used for making :

connecting rods, wires and rods, spring clips, gear shafts, key stock, shift and brake levers, small and medium forgings etc.

(ii) Steels containing 0.45 to 0.55% carbon have a tensile strength of about 1000 N/mm^2 and are used for making parts those are to be subjected to shock and heavy reversals of stress such as,

Railway coach axles, Axles, crank pins on heavy machines, spline shafts, crankshafts etc

(iii) Steels containing 0.6 to 0.7% carbon have a tensile strength of 1230 N/mm^2 and a hardness of 400–450 BHN. Such steels are used for making,

Drop forging dies, set screws, die blocks, self tapping screws, clutch discs, cushion rings, plate punches, Thrust washers etc.

(III) Classification, composition and application of ~~medium~~ high carbon steel :

High carbon steels contains carbon from 0.7 to 1.5%.

Steel containing 0.7 to 0.8% carbon have a tensile strength of about 1400 N/mm^2 and a hardness of 450 – 500 BHN. These steels are used for making :

cold chisels, pneumatic drill bits, wrenches, wheel for railway service, Jaws of vices, wire for structural work, shear blades, automatic clutch discs, hacksaws etc.

- Steel containing 0.8 to 0.9% carbon have a tensile strength of about 660 N/mm² and hardness of 500 to 600 BHN. Such steels are used for making:

Rock drills, Punches and dies, Railway rails, clutch discs, circular saws, Leaf springs, machine chisels, music wires etc.

- Steels containing 0.90 to 1.00% carbon (high carbon tool steels) have a tensile strength of 580 N/mm² and a hardness of 550-600 BHN. Such steels are used for making:

Punches and dies, springs (Leaf and coil), Pins, keys, shear blades etc.

- Steels containing 1.0 to 1.1% carbon are used for making:

Railway springs, mandrels, machine tools, taps etc.

- Steels containing 1.1 to 1.2% carbon are used for making:

Taps, Twist drills, Thread metals dies, etc.

- Steels containing 1.2 to 1.3% carbon are used for making:

Files, Reamers, Metal cutting tools etc.

- Steel containing 1.3 to 1.5% carbon are used for making:

Wire drawing dies, Paper knives, metal cutting saws, Tools for turning chilled iron etc.

(III) Tool steels:

Tool and die steels may be defined as special steels which have been developed to form, cut or otherwise change the shape of a material into a finished or semi-finished product.

Properties of tool steels:

(i) Slight change of form during hardening.
(ii) Good toughness.
(iii) Good wear resistance.
(iv) Very good machinability.
(v) A definite cooling rate during hardening.
(vi) Resistance to decarburization.
(vii) Resistance to softening on heating (red hardness).

(III) Effects of various alloying elements:

chromium:

Joins with carbon to form chromium carbide, that adds to depth hardenability with improved resistance to abrasion and wear.

Manganese:

- contributes markedly to strength and hardness (but to a lesser degree than carbon).
- counteracts brittleness from sulphur.
- Lowers both ductility and weldability if it is present in high percentage with high carbon content in steel.

Nickel:

- Increase toughness and resistance to impact.
- Lessens distortion in quenching.
- Lowers the critical temperatures of steel and widens the range of successful heat treatment.

Vanadium:

- Promotes fine grains in steel.
- Increases hardenability (when dissolved)
- Imparts strength and toughness to heat-treated steel.
- causes marked secondary hardening.

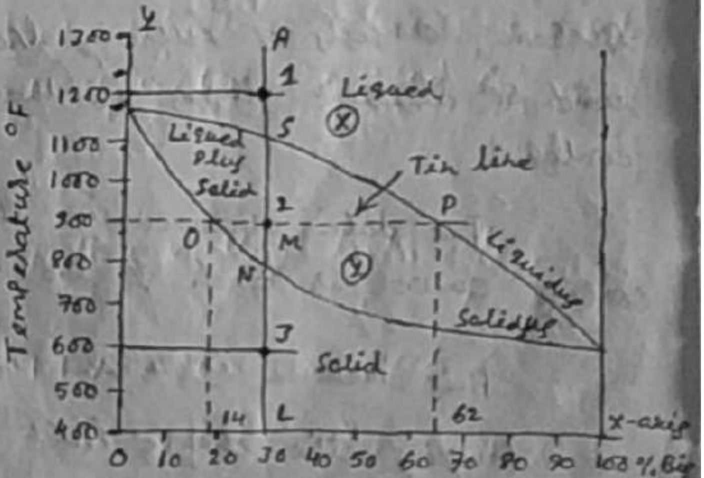
Molybdenum:

- Promotes hardenability of steel.
- makes steel fine grained.
- makes steel unusually tough at various hardness levels.
- counteracts tendency towards temper brittleness.
- Rises tensile and creep strength at high temp
- Enhances corrosion resistance in stainless steels.
- Forms abrasion resisting particles.

(III) Concept of Phase diagram:

A Phase diagram has temperature as its ordinate and (alloy) composition as abscissa from figure.

(i) Shows at a glance the phases which exist in equilibrium for any combination of temp and alloy composition. Equilibrium refers to the state of balance which exists, or which tends to be attained, between the phase in the structure of an alloy after a physical & chemical change has taken place.



Interpretation of phase diagram (Sb–Bi)

(ii) Shows the relationship between the composition, temp and structure of an alloy in series.

(iii) Provides with the knowledge of Phase composition and phase stability as a function of temp, Pressure and composition

(iv) Permits to study and control Processes such as:

Phase separation.

Solidification of metals and alloys.

Purification of materials.

The growth and doping single ~~crystal~~ crystals, and

The structural changes produced by heat treatment, casting etc.

(v) Marks liquidus (the lines or surfaces in an equilibrium diagram which indicate the temp of the beginning of solidification or the completion of melting) and solidus (the lines or surfaces in an equilibrium diagram which indicate the temp of the completion of solidification or the beginning of melting).

② Cooling curves:

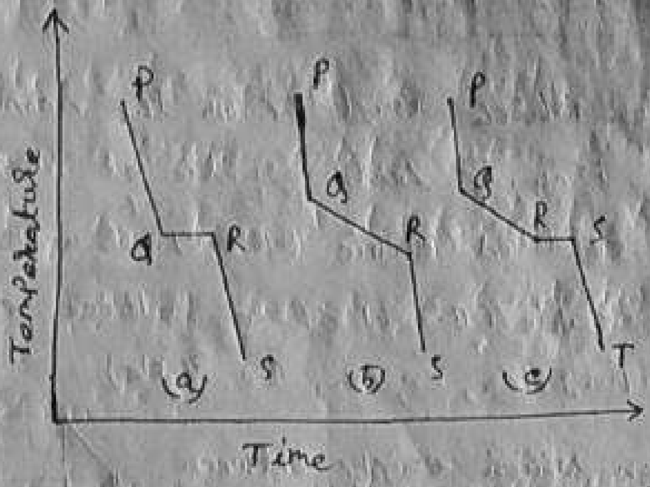
A method to determine the temperatures at which Phase changes (liquid ⇌ solid) occur in an alloy system, consists of following the temp as a function of time as different alloys in the system are very slowly cooled.

The data obtained in this manner ~~from~~ form a cooling curve for each of the alloys.

This method is useful in,

* studying the changes that occur during the solidification of alloys, and in some instances.

* determining transformations subsequent to solidification.



cooling curve for (a) Pure metal or compound
(b) Binary solid solution (c) Binary eutectic system.

(a) cooling curve of Pure metal or compound :

– Liquid metal cools from P to Q. First crystal begin to form at point Q.

– From Q to R, the melt liberates latent heat of fusion in such amounts that the temp from Q to R remains constant, untill the whole mass has entirely solidified (at point R).

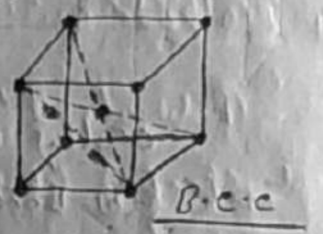
Between Q and R, the mass is partly liquid and partly solid.

– On further cooling from R to S, the solid metal cools and tends to reach room temperature.

The slopes of PQ and RS line depends upon the specific heats of liquid and solid metals respectively.

(II) Allotropic forms of pure iron :

(a) Alpha (α) iron which exists from the room temp to 910°c. The α - iron is ferromagnetic at room temp. It has a body centred cubic (B.c.c) structure. In body centred cubic (B.c.c) space lattice exists nine atoms. (Exmple: Tungsten, cr, Mn, Mo, V etc.)

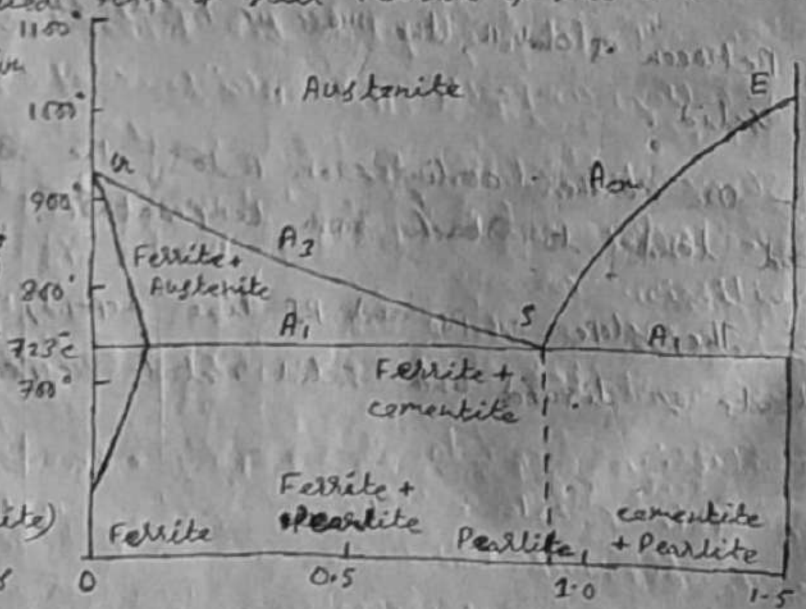


(b) Gamma (γ) iron which exists between 910°c to 1404°c. It has a face centred cubic (F.c.c) structure. It has fourteen atoms. (Exmple: Al, cu, lead, nickel, gold, Pt etc.)

(c) Delta (δ) iron which exists between 1404°c to 1539°c (melting point of pure iron). It has a B.c.c structure but has longer cube edge than B.c.c structure of α-iron.

(III) Iron carbon equilibrium diagram :

Fig shows a simplified form of steel portion of the iron - iron carbide equilibrium diagram for 0 to 1.5% carbon content variation. When a eutectoid steel (containing 0.8% carbon, composed exclusively of Pearlite) is heated a transformation in structure



occurs at point S at 723°c, Pearlite changes its constituents. Pasty cementite and ferrite go into solution to form a new stable phase called austenite. Similarly for hyper or hypo-eutectoid steel (containing more or less than 0.8% carbon), the transformation occurs when the temp

Passes the temp is extended. The transformation temp. is reflected to as the A_1 point. If the temp rises beyond this point the excess particle of cementite, by the case may be, dissolved in the austenite. Take as and is make the completion of the transformation according to the carbon content and are known as the A_3 and the A_{cm} points. Beyond this critical temperatures, pearlite and cementite are completely in solution and the steel has purely austenitic structure. The grain size of austenite increases with the temp and the [illegible] of the temp on slowly cooling towards [illegible] close.

In plain carbon steels, the structures obtained by annealing treatment followed by slow cooling are as far the equilibrium diagram, [illegible] with faster rates of cooling, equilibrium is not approached and significant differences in structure state and other modes of [illegible] -mation due to [illegible] of diffusion occur.

(III) Designation of crystal :

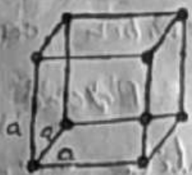
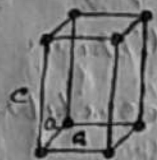
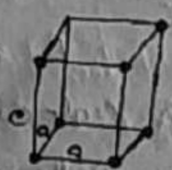
A crystal is a solid whose constituent atoms or molecules are arranged in a systematic geometric pattern.

(IV) Classification of crystals :

Crystal structures are classified according to unit cell geometry. This geometry is specied in terms of the relationship between axes lengths a, b, and c and interaxial angles α, β and γ.

There are seven different crystal systems, namely (i) cubic, (ii) Tetragonal, (iii) Hexagonal, (iv) Orthorhombic, (v) Rhombohedral, (vi) Monoclinic, (vii) Triclinic

Lattice Parmanent relationships and figures showing unit cell geometries for the seven crystal systems:

Crystal system	Axial relationship	Interaxial angles	Unit cell geometry
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$	 
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	
Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ \neq \beta$	
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	

* The cubic system for which $a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$, has the greatest degree of symmetry.

* Latest symmetry is displayed by the triclinic system, since $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma$.

* B.c.c and F.c.c structures belong to the cubic crystal system, where as rally within hexagonal.

(I) Ideal crystal :

In an ideal crystal the automic arrangement is perfectly regular and continuous throughout. An ideal crystal is perfect.

(II) crystal imperfections :

Real crystals as in case of welded objects are never perfect, lattice distortion and various imperfections irregularities or defects are generally present in them. There is always a discrepancy between the computed and real yield stresses not only the yield stresses, many more other physical and mechanical properties of engineering metals and alloys are effected by the imperfections in the crystals.

(III) classification of imperfections :

(1) Point defects : (a) vacancies, (b) Interstitialcies, (c) Impurities, (d) Electronic defects.

(2) Line defects : (a) Edge dislocation, (b) Screw dislocation

(3) Planar, surface, interfacial or grain boundaries defects :

(a) Grain boundaries, (b) Tilt boundaries, (c) Twin boundaries.

(4) Volume defects : such as cracks or stacking faults.

(III) Point defects :

In a crystal lattice, Point defect is one in which is completely local in its effect, a vacant lattice site.

The introduction of Point defect into a crystal ~~increases~~ increases its internal energy as compared to that of the perfect crystal.

The number of defects at equilibrium at a certain temp can be determined from eqn (i)

$$n_d = N e^{-E_d/kT}$$

Where, n_d = is the no of defects,

N = is the total no of automic sites per cubic metre or per mole.

E_d = is the energy activan necessary to form the defect

k = Boltzmann const.

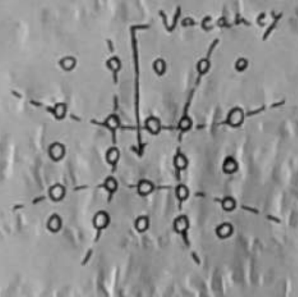
T = Absolute temp.

(IV) The Possible Point defects have been explained as under :

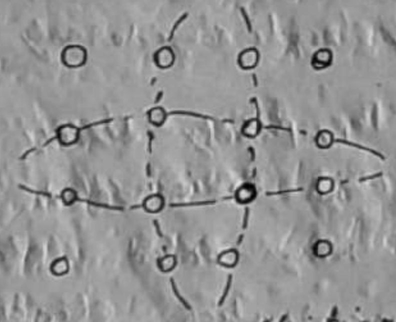
(a) Vacancies :

A vacancy or vacant site implies an unoccupied atom Position with in a crystal lattic. In other words, vacancies are simply empty atom sites. Vacancies may occur as a result of imperfect Packing during the original crystallization or they may arise from thermal vibrations of atoms at elevated temp because of individual atoms will jump out of their position of lowest energy.

Vacancies may be single, or two or more of them may condense into a di or tri-vacancy.



(a) Vacancy



(b) Interstitialcy

(b) Interstitialcies:

An interstitial defect arises when an atom occupies a definite position in the lattice that is not normally occupied in the perfect crystal.

The interstitial (atom) may be [redacted] lodge with in a crystal structure, particularly if the atomic packing factor is low.

$$\text{Automic Packing factor} = \frac{\text{Volume of atoms}}{\text{Volume of unit cell}}$$

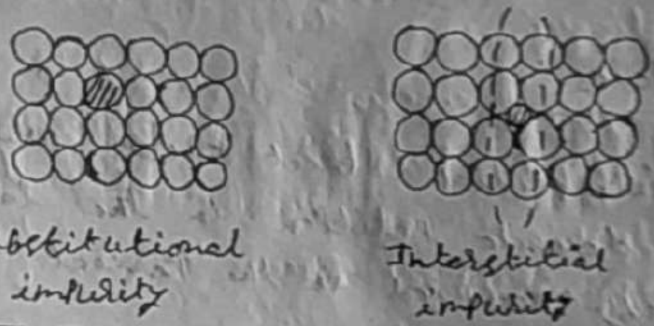
Interstitialcy produces atomic distortion because interstitial atoms tends to push the surroundings atoms further apart, unless the interstitial atom is smaller than the rest of the atoms in the crystal.

(c) Impurities:

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

Impurity (foreign) atoms are introduced into crystal structure as substitutional or interstitial atoms. Foreign atoms either occupy lattice sites from which the regular atoms are missing or they occupy positions between the atoms of the ideal crystal. Impurities may considerably distort the lattice.

Impurity defects occur in metallic, covalent and ionic solids and play a very important role in many solid state processes such as diffusion, phase transformation, electrical and thermal conductivity.



(iii) Electronic defects :

Electronic defects are the result of errors in charge distribution in solids.

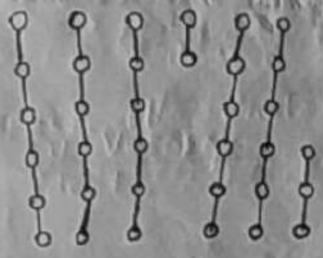
These defects are free to move in the crystal under the influence of an electrical field, thereby accounting for some electronic conductivity and their increased reactivity of certain solids.

(ii) Line defects :

The most important two dimensional or line defects is the dislocation.

Dislocation is a (line) defect in a crystal structure whereby a part plane of atoms is displaced from its symmetrically stable position in the array. It is surrounded within the structure by an extensive elastic strain field and its associated stresses.

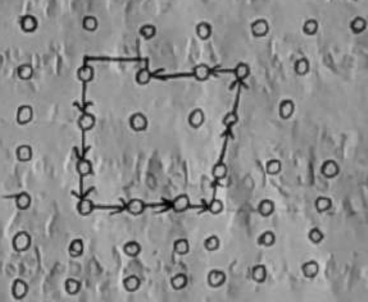
The dislocation is responsible for the phenomenon of slip by which most metals deform plastically.



A dislocation

(III) Edge dislocation :

(a-1)



(a-2)

Edge dislocation

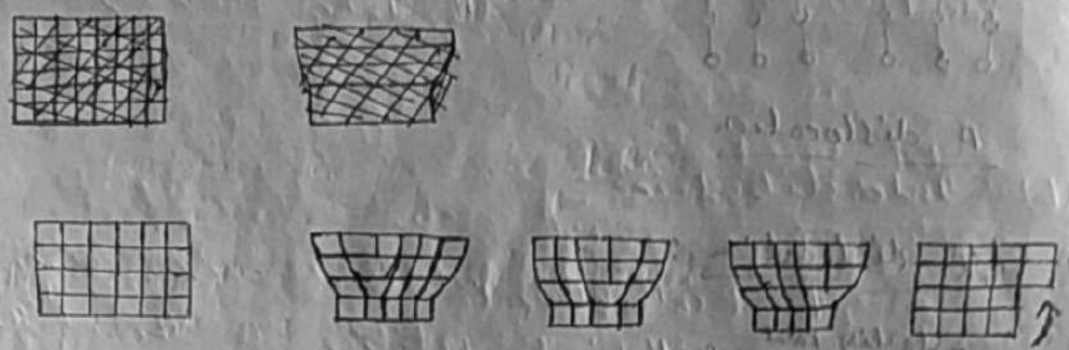
Burger's vector marks the magnitude and direction of the strain component of dislocation

An edge dislocation lies perpendicular to its Burger's vector (a-2).

An edge dislocation moves (in its slip plane) in the direction of the Burger's vector (slip dislocation)

An edge dislocation involves an extra row of atoms, either above (positive sign) or below (negative sign) the slip plane. The presence of this extra row means that adjacent atoms are displaced elastically, and consequently from both sides elastic forces are exerted on the dislocation.

The edge dislocation is particularly useful in explaining slip in plastic flow during mechanical working.



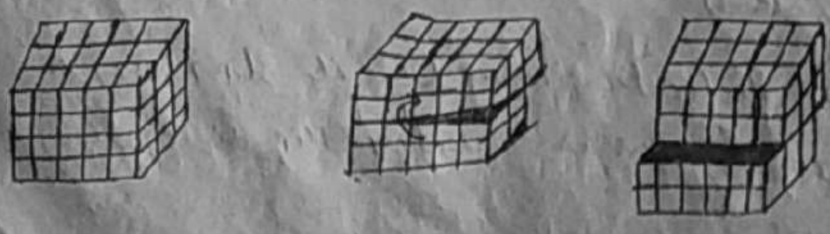
Slip caused by the movement of edge dislocation

(iii) Screw dislocation:

A screw dislocation lies parallel to its Burger's vector.

In the screw dislocation, the distortion follows a helical or screw path and both right ~~and~~ hand and left hand senses are possible.

Screw dislocation is especially useful in explaining crystal growth as well as slip in plastic deformation.



Mechanism of screw dislocation

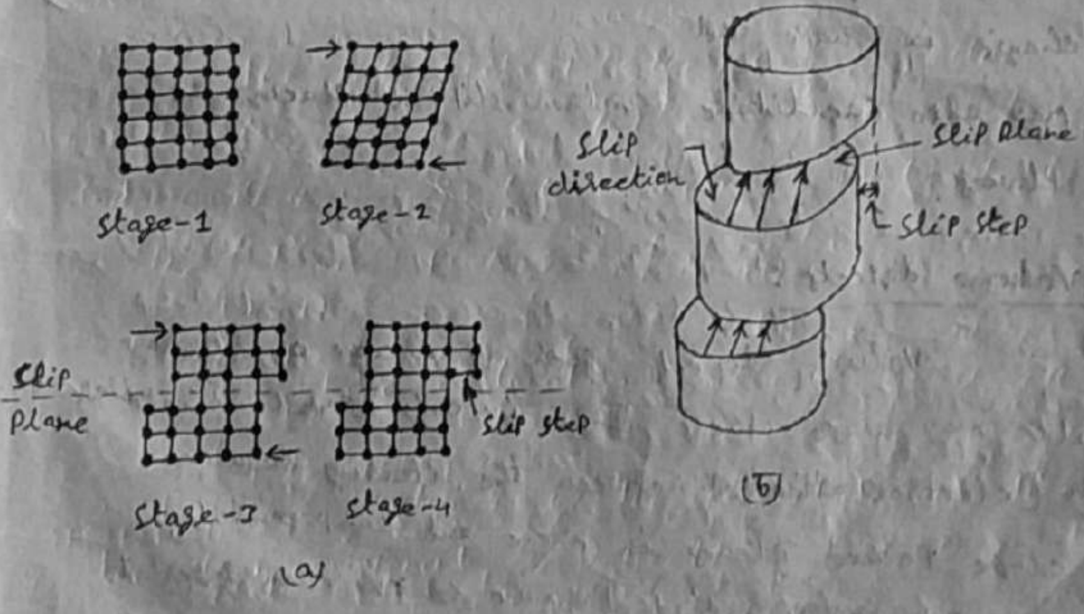
(III) Surface defects :

Surface imperfections may include, grain boundaries, tilt boundaries, twin boundaries, stacking faults, ferromagnetic domain walls, coherent and incoherent participate interfaces.

(IV) Deformation by slip :

Slip is that mechanism of deformation wherein one part of the crystal moves, glides or slips over another part along certain planes known as slip planes.

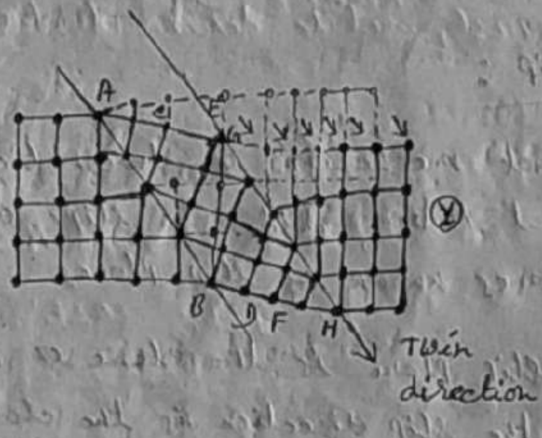
Generally slip plane is the plane of greatest atomic density and the slip direction is the closest packed direction with in the slip plane. Slip starts on the set along which there is the maximum shear stress. The results of slip in a polycrystalline mass of metal may be observed under a microscope.



Deformation by slip

(III) Deformation by twinning:

The twinned region seperates or devides the crystal into two regions, X and Y from fig. oriented in such a way that one forms a mirror image of the other relative to the twin plane between them.



Twinning in an f.c.c. lattice

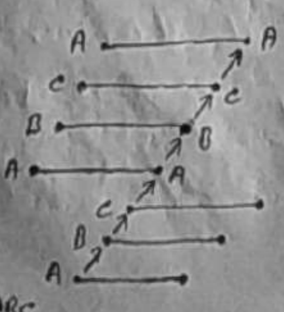
The twinned section may participate in deformation in two ways:

(i) The twinning itself may accomplish an extensive change in shape and

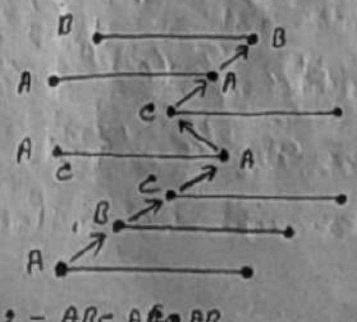
(ii) may also facilitate further slip by placing the planes.

(IV) Volume defects:

Volume defects such as cracks or stacking faults may arise where there is only small dissimilar-ity (electrostatically) between the stacking sequences of close packed planes in f.c.c and h.c.p metals, ABC ABC and AB AB AB. It is possible for one atom layer to be out of sequence relative to the atoms of the layers above and below giving a mistake (defect), ABC AC AB



1 - ABCABC



2 - ABC ABCAB

Stacking fault are more frequently found in deformed metals and annealed metals.

(VII) Effect of imperfections on metal Properties :

(i) Flow and fracture characteristics.

(ii) crystal growth.

(iii) Electrical Properties including semi-conducting behaviour.

(iv) Diffusion mechanism.

(v) creep characteristics of real metals and alloys.

(vi) Annealing and Precipitation.

(vii) Oxidation and corrosion.

(viii) Yield strength, fracture strength, Plasticity, thermal conductivity, dielectric strength, etc.

(I) Effect of deformation on material Properties :

(i) Growth accident

(ii) Thermal stress

(iii) External stresses causing plastic flow

(iv) phase transformations

(v) Segregation of solute atoms causing mismatches etc.

(III) Purpose of heat treatment : *HEAT TREATMENT*

(i) cause relief of internal stresses developed during cold working, welding, casting, forging etc.

(ii) Harden and strengthen metal

(iii) Improve machinability.

(iv) change grain size.

(v) soften metals for further (cold) working ~~process~~ as wire drawing or cold rolling.

(vi) Improve ductility and toughness.

(vii) Increase heat, wear and corrosion resistance of materials.

(viii) Improve electrical and magnetic properties.

(ix) Homogenise the structure to remove coring or segregation.

(x) Spheroidise tiny particles, such as those of Fe_3C in steel by diffusion.

(III) Process of heat treatment:

(i) Annealing:

It is one of the most important process of heat treatment of steel. Following are four types of annealing:

(a) Full annealing:

The purpose of full annealing is to soften the metal, to refine the grain structure, to relieve the stresses and to improve trapped gases in the metal. The process consists of heating the steel 30°c - 50°c above the upper critical temperature for hypo-eutectoid steel and by the same temp above the lower critical temp for hyper eutectoid steels. It is held at this temp for sometime and then cooled slowly in the furnace.

(b) Process annealing:

It is also known as low temp annealing or sub-critical annealing. This process is used for relieving the internal stresses previously set up in the metal and for increasing the machinability of the steel. In this process, steel is heated to a temperature below or close to the lower critical temp (generally 550 - 650°c) held at this temperature for sometime and then cooled slowly.

(c) Spheroidise anneling (Spheroidising) :

It is applied to high carbon tool steels which are difficult to machine. The operation consists of heating the steel to a temp slightly above the lower critical temp (730–770°c) for sometime and then cooled slowly to a temp of 600°c. The spherodising improves the machinability of steels, but lowers the hardness and tensile strength.

(d) Diffusion annealing (Homogenization) :

This process is mainly used for ingots and large castings. After diffusion annealing, the castings undergo full annealing to improve their properties or to refine grain structure. The process consists of heating the steel to a high temp (1100–1200°c). It is held at this temp for 8 to 20 hours and then cooled to 800°c – 850°c inside the furnace for a period of about 6 to 8 hours. It is further cooled in the air to room temperature.

(III) Normalising :

The process of normalising consists of heating the steel 30°c–50°c above its upper critical temp for hypo-eutectoid steels or Acm line for hyper eutectoid steels. It is held at this temp for about fifteen minutes and then allowed to cool down in steel air. The process of normalising is frequently applied to castings and forgings etc.

It is done for the following purposes :

(a) To refine the grain structure of the steel to improve machinability, tensile strength and structure of weld.

(b) To remove strain caused by cold working process.

(c) to remove dislocations caused in the internal structure of the steel due to hot working.

(d) To improve certain mechanical and electrical properties.

(II) Hardening:

The Process of hardening consists of heating the metal to a temperature of 30°-50°c above its upper critical Point for hypo-utectoid steels and by the same temp above the lower critical temp for hyper eutectoid steel. It is held at this temp for a considerable time and then quenched (cooled suddenly) in a suitable cooling medium.

The main objects of hardening are:

(a) To increase the hardness of the metal so that it can resist wear.

(b) To enable it to cut other metals, to make it suitable for cutting tools.

(III) Surface hardening or case hardening:

In many engineering applications, it is desirable that a steel being used should have a hardened surface to resist wear and tear. It should have soft and tough interior or core so that it is able to absorb any shocks etc. This type of treatment is applied to gears, ball bearings, railway wheels etc. The various surface hardening Processes are below;

(a) carburising, (b) cyaniding (c) Nitriding (d) Induction hardening (e) flame hardending

(IV) carburizing:

carburizing is a method of introducing carbon into solid iron-base alloys such as low carbon steels in order to Produce a hard case (surface). carburizing is also called cementation. carburizing increases the carbon content of the steel surface by a process of absorption and diffusion.

Process: Low carbon steel (about 0.20% carbon or lower) is heated at 870° to 925°c in contact with gaseous, solid or liquid carbon containing substances for several hours.

The high carbon steel surface (thus obtained) is hardened by quenching from above the A_1 temp.

(III) Nitriding:

Nitriding accompanies the introduction of nitrogen into the surface of certain types of steels (containing Al and cr) by heating it and holding it at a suitable temperature in contact with partially dissociated ammonia or other suitable medium.

This process produces a hard case without quenching or any further heat treatment.

Process: Before being nitrited, the components are heat treated to produce the required properties in the core.

(i) Oil quenching from between 850 and 900°c followed by tempering at between 600 and 700°c.

(ii) Rough machining followed by a stabilizing anneal at 550°c for five hours to remove internal stresses.

(iii) Finish maching followed by nitriding.

(III) Non ferrous alloys :

(1) Brass :

Brasses contain zinc as the Principle alloying element.

Brasses are subdivided into three groups,

(i) Cu - Zn alloyes,

(ii) Cu - Pb - Zn alloys or leaded brasses and

(iii) Cu - Zn - Sn alloys or tin brasses.

Brass has high resistance to corrosion and is easily machinable. It also acts as good bearing material.

Zinc in the brass increases ductility alongwith strength.

Brass Possesses greater strength than copper, however it has a lower thermal and electrical conductivity.

Types of Brasses;

(i) Gilding metal (5% to 15% Zn balance Cu)

(ii) Cartridge brass (70% Cu and 30% Zn)

(iii) Admiralty brass (Cu 71%, Zn 28% and Sn %)

(iv) Aluminium brass (76% Cu, 22% Zn and 2% Al)

(v) Basis brass (61.5 - 64% Cu and remainder Zn)

(vi) Muntz or yellow metal (60% Cu and 40% Zn)

(vii) Leaded 60 : 40 brass (lead 0.5 to 3.5% and rest Cu-Zn)

(viii) Naval brass (Cu 60%, Zn 39.25% and Sn 75%.)

(ix) Admiralty brass (71% Cu, 28% Zn and 1% Sn).

(11) Copper - Nickel alloys :

Bronze is a broad term defining an alloy of copper and elements other than nickel or zinc.

Example: Leaded Phosphor bronze contains 87% cu, 7.5% Sn, 2.0% (max) Zn, 3.5% Pb, 0.3% (min) P and 1% (max) Ni

In sand cast condition, it has a tensile strength of 190 - 250 N/mm^2 and % elongation is 3-12.

This material is satisfactory for many bearing applications.

(12) Nickel and its alloys :

The usual commercial grade of wrought nickel ('A' nickel) normally contains 99% nickel + upto 0.4% cobalt.

commercially pure nickel is almost as hard as a low carbon steel.

Wrough nickel is amenable to most of the fabrication processes used for mild steel. It can be forged, rolled, bent, extruded, punched, deep drawn, machined, polished and buffed.

Properties:

(1) It has a hard lustrous white metal

(2) Possesses good corrosion and oxidation resistance.

(3) It has high tensile strength and can be easily formed hot or cold.

(4) can take up high polish.

(5) can be fabricated using processes similar for mild steel.

(6) It is ferromagnetic at ordinary and low temp but becomes paramagnetic at elevated temp.

uses:

(i) For corrosion protection of iron and steel parts and Zn base die castings used in the automotive field

(ii) In the chemical, soap, caustic and industries for the construction of evaporators, tanks heating coils, tubular condensers etc.

(iii) In the incandescent lamp and radio industries

(iv) As permanent magnets.

(v) As thermocouple material

(vi) In electronic and low-current electrical applications.

(III) Lead [redacted] and its alloys:

Lead is the oldest of the commonly used metals and the softest of the heavy metals. When it is cast or cut, it is a lustrous silvery colour to begin with. After some times, the surface turns a dull bluish grey due to oxidation. Lead is a poisonous and should not be brought into contact with food. Lead has a F.C.C crystal structure

(III) Properties of lead:

(1) It has a low melting point of 327°C and density is 11.34 kg/cm^3.

(2) It is very resistance to corrosion against most acids, but not against aqua regia (HCl-HNO_3 mix)

(4) Its strength, hardness and electricity are least, tensile strength 15 N/mm^2, extensibility upto 60%.

(5) Lead can be easily soldered, welded and cast. It can be spread over other metal surfaces.

(6) It has heavy weight, high density, softness, melteability, lubricating properties, high coefficient of expansion, low electrical conductivity.

(II) Uses and applications of lead :

(1) manufacture of storage batteries.

(2) As an alloying element to improve the machining machinibility of bronzes, brasses and free steels.

(3) Tank lining at corrosion protection.

(4) Pipe and drainage fittings.

(5) Bearing metals

(6) Lead compounds in paints

(7) Low melting solders.

(8) Radiation protection (From X-rays)

(III) Lead alloys :

Bearing metals are lead and tin alloys for friction bearings. When antimony is added, they are known as babit metals.

With about 9% tin, 15% Antimony, 1% cu and 0.5% cadmium posses good antifriction characteristics, thermal condn and wearing in charactoristics. This alloy is applied to a bearing body of steel, cast steel, or cast iron.

(III) Nickel Alloys :

(a) Nickel iron alloys :

Invar is the trademark for an iron-nickel alloy containing 40-50% nickel and is characterized by an extremly low coefficient of thermal expansion. Invar is used for making precision instruments, measuring tapes, weights etc.

(b) Nickel copper alloys :

The major nickel based alloy with copper is monel which normally contains 66% Ni, 31.5% Cu, 1.35% Fe, 0.9% Mn, plus residuals.

Properties : Monel has a brighter apperance than nickel, is stronger and tougher than mild steel, has excellent resistance to atmospheric and sea-water corrosion.

Uses : Monel is used in architectural and marine applications where appearance and corrosion resistance is important and in specialized equipment used by the food, pharmaceutical, paper, oil and chemical industries.

Constantan, another alloy of nickel and copper contains 45% Ni and 55% Cu.

Properties :

Highest electrical conductivity.

Lowest temp coefficient of resistance.

Uses :

Electrical resistors

Thermocouples

[illegible]

(c) Ni - cu - Zn alloys (Nickel - silver) :

Nickel-copper-zinc alloys through known as nickel-silver, do not contain silver and in actually they are brasses with sufficient nickel added to give a silvery white colour, improved corrosion resistance and high strength.

Nickel-silver are used in Jewellery also construction materials for many musical, drafting and scientific instruments and are also used for marine and architectural applications.

(d) Nickel-chromium alloys :

It content 80% Ni, 14% Cr, 6% Fe alloy (Inconel) with many modifications resists progressive oxidation below 1093°c and is used in applications such as furnace chambers, salt pots, aircraft exhaust manifolds and high temp springs, milk industries and in many chemical industries because of its excellent corrosion resistance.

(e) Nickel - molybdenum alloys :

Nickel-molybdenum alloys such as Hastelloy A, Hastelloy c and Hastelloy D posses very good resistance to corrosion.

(III) Zinc and Zinc base alloys :

characteristics :

(i) Relatively low melting point, 419.5°c (die casting),
(ii) Good resistance to atmospheric corrosion.
(iii) Solubility in copper (brass).
(iv) Inherent ductility and malleability.

(II) Application of Zn :

(i) Stamping.

(ii) Die castings.

(iii) Anodes for electro-galvanising.

(iv) Coating on steel (to protect it).

(v) making different alloys (brass).

(vi) Fabricated (and rolled) shapes.

(vii) Shells for dry batteries.

(viii) Engravers plates.

(ix) Wire for metallizing.

(II) Composition (%) :

(i) Rolled Zinc : Pb - 0.05 to 0.12 (max),
Fe - 0.0012 (max)
Cd - (0.005) (max)
Cu - (0.65 to 1.25)
Reminder - Zn.

(ii) High grade slab Zinc : Pb - 0.07, Fe - 0.02, Cd - 0.07
Zn Reminder.

(iii) Selected grade slab Zinc : Pb - 0.8%, Fe - 0.04, Cd - 0.75
1.25 Reminder.

(III) Bearing material :

classification, uses :

Bearing support moving parts, such as shafts and spindles, of a machine or mechanism.

Bearing may be classed as,

i) Rolling contact (ball and roller) bearings,

(ii) Plain bearings.

(I) Copper based alloys:

Bronze covers a large number of copper alloys with varying percentages of Sn, Zn, and Pb.

Bronze is one of the oldest known bearing materials.

Types:

(i) is easily worked.

(ii) has good corrosion resistance.

(iii) is reasonably hard.

Composition of bearing bronze:

Cu - 80%, Sn - 10%, Pb - 10%.

(II) Tin bronze:

Tin bronze (10 to 14% tin remainder copper) is used in the machine and engine industry for bearing bushes made from thin-walled drawn tubes.

They are employed for making bearing required to resist heavier pressures such as in railways.