SIDDANT SING BABU

ENGINEERING MATERIAL

(1) Crystal system

(2) Defects in materials

(3) Heat Treatment

(4) Non - Ferrous Materials

(5) Bearing Materials

(6) Metals

ENGINEERING MATERIALS

Crystal Structure → This structure describe the regularity and type of atomic arrangment, within a crystal.

Crystal System

(1) crystaline solid → A crystaline solid is a solid in which the constituent molecules and atoms are, arranged in a systematic pattern. these are made up from large no. of crystals.

(2) Amorphous solid → in material such as glass which are not crystaline called Amorphous. the internal structure is not in regular pattern.

Crystallography

The structure implies the arrangment and diposition of atom within a crystal.

Bravious lattice

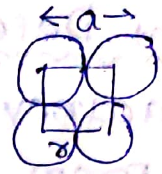
These are seven types of bravious lattice. every material block of the same unit is made up from bravious latice.

crystal system	Relation of parameter	interface angles	examples
(1) Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Au, Cu, Al, Fe
(2) Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	TiO_2, Sn, SnO_2
(3) orthogonal	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	$BaSO_4$, $MgSO_4$
(4) hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$	SiO_2, Zn, AgCl, graphi
(5) Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	$CaSO_4$, SiO_2, $CaCO_3$
(6) Monoclinic	$a \neq b \neq c$	$\alpha = \beta = 90^\circ \neq \gamma$	$FeSO_4$, $CaSO_4$, $NaSO_4$
(7) Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	$CuSO_4$, K_2CrO_4

Atomic Packing Factor:

$$A.P.F = \frac{\text{volume of atom in a unit cell}}{\text{volume of unit cell}}$$

(1) Simple cubic structure → There is one atom at each corner and this atom is shared by unit cell.



no. of atom $= \frac{1}{8} \times 8 = 1$

here $a = 2r$

$$A.P.F = \frac{1 \times \frac{4}{3}\pi r^3}{a^3}$$

$= 0.5$

co-ordination number of simple cubic crystal is 6.

(2) Body centred cubic structure → other materials having the B.C.C are Mo, V, Mn, Ta, Nb,

Total no. of atom $= \frac{1}{8} \times 8 + 1$

$= 2$

$$A.P.F = \frac{2 \times \frac{4}{3}\pi r^3}{a^3} = 0.68$$

$4r = a\sqrt{3}$

co-ordination number of B.C.C is 8.

(3) Face Centred cubic crystal → Along with one atom at each corner. there is an atom on each face.

Total no. of atom $= \frac{1}{8} \times 8 + \frac{1}{2} \times 6$

$= 1 + 3 = 4$

$$A.P.F = \frac{4 \times \frac{4}{3}\pi r^3}{a^3}$$

$4r = a\sqrt{2}$

$= 0.74$

co-ordination number of F.C.C is 12. The examples of F.C.C are Cu, Al, Pb, Au etc.

(4) Hexagonal close-packed → The atomic packing factor is same as FCC is 0.74. having co-ordination number of 12. It is found in metal like Be, Mg, Cd, Zn etc.

Defects in the Materials

(1) Point Defect

(1) Vacancy defect → It appears due to missing of atom from the lattice.

(2) Interstitial defect → When foreign atom occupies the interstitial site, the defect is called.

(3) Substitutional defect → If regular atom is replaced by another foreign atom.

(4) Frenkel defect → When atom in the lattice point goes and occupies the interstitial void of other atom.

(5) Schottky defect → In the combination of cation and anion if there is a vacancy defect.

(2) Surface Defects

(i) grain boundary defect → The bond length is more at the grain boundary due to orientation mismatch can easily be broken. Thus finer grain structure, lower will be corrosion resistance.

(ii) Tilt boundary defect → When orientation mismatch at the grain boundries is called.

(iii) Twin boundary defect → When orientation on one side form mirror image of oppsite side, such defect is called.

(iv) Stacking Fault → When the grain boundries are parallel to each other with slight disturbance of bonds in a very region, such grain boundary are called stacking fault.

(3) Line Defects

(1) Edge dislocation → when consider that pressure is applied on 50% part of a material. once this pressure exceed beyond a certain value slipping of the atom takes place. This unit amount of plastic deformation which appears in the directi of applied load is called burger vector. There will be a boundary between slipped and unslipped region called edge dislocation. (⊥)

(2) Screw dislocation → It is formed by a shear stress that is applied to produce distortion around the atomic phase. The burger vector is parallel to dislocation line.

Types Of Bond

(1) Ionic bond → strong electrostatic force of attract bet^n cation and anion. permanent bond.

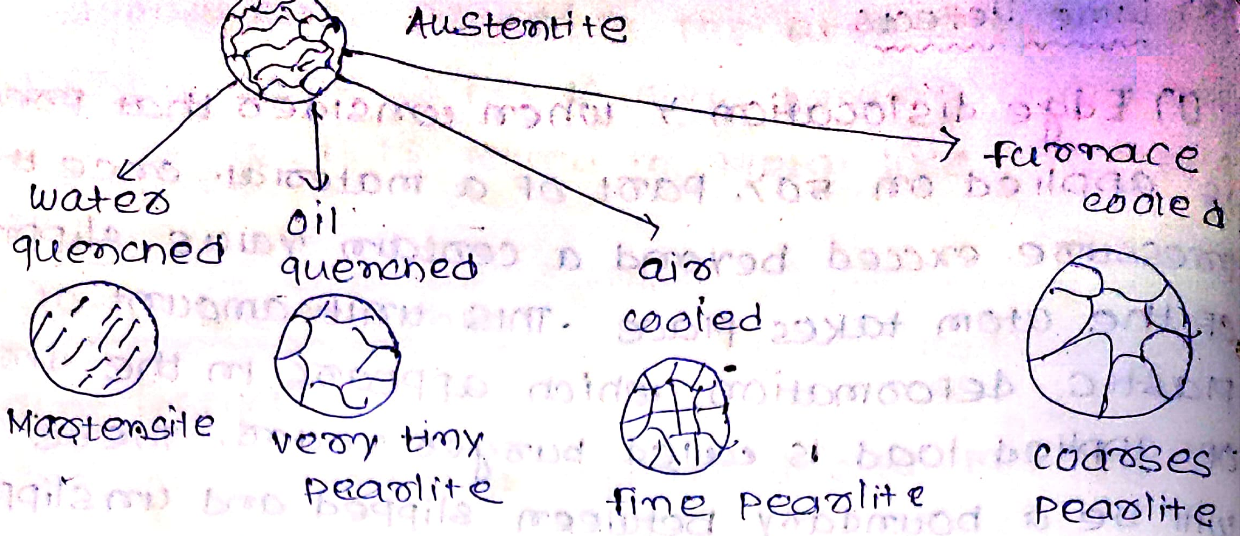
(2) Co-valent bond → shareing of one or more electron by adjecent atom.

(3) Mettalic bond → Mettalic Materials having one, two or three valance electron which will take part.

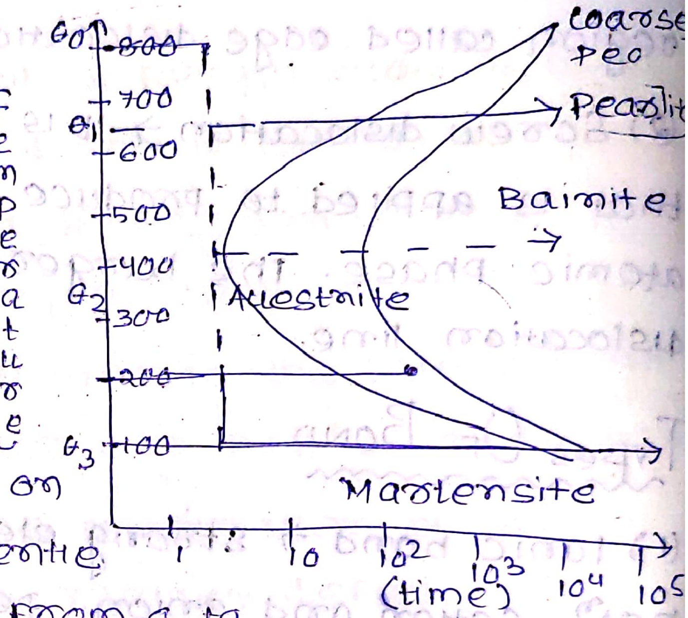
(4) vander wall bond → This is the bond that arises in the neutral atoms like innert gas this is a very weak bond.

Heat Treatment

Control of Material properties can also be achived without addition of other element. This is done by subjecting the material to a controlled cycle of heating or cooling. Take a example where Austentic steel above 723°C is cooled at different rates. The various Resulting structure with mechanical properties



by changing the Rate of cooling different phases can be obtained. This is easily clearout by using the (T-T-T) digram. The temperature is plotted against vertical axis and time of logarthmic scale on horizintal axis. when Austenite brought to a temperature from θ_1 to θ_0 and held at θ_1 transformation to pearlite begins. such transformation carried out at constant temperature called isothermal transformation. Below 600°C the transformation of Austinte into Baimite (Ferrite + cementite). when the isothermal transformation is decresed below 600°c the time Required for transformation decreases. The begining of transformation must carried out above 220°c. below this Ausetmite start transforming into Martensite.



(T-T-T digram)

Classification of Heat treatment

(1) First group → It comparsing of First order Annealing which is emploved to Relive the inter stress, reduce hardness. and increse the ductility It is also called stress reliving.

(2) second group / Full Annealing → This is followed by slow cooling. Full Annealing substantially changes physical and mechanical properties and Refine the grain structure.

(3) Third group → In this hardening alloys are heated above the phase transformation temperature and then rapidly cooled at room temperature. and hardening causes formation of unstable structure.

(4) Fourth group → In this tempering of hardened steel heating to a temperature below that required for phase transformation to bring in equilibrium state.

(5) Fifth group → This chemical heat treatment perform saturation of the surface of steel with a certain element by the diffusion of this element from the surrounding medium at high temperature called as case hardening.

Austempering

IF cooling rate is such that it just touches the Nose of T-T-T diagram it is called as critical cooling rate. Any rate which is greater than or equal to CCR will not produce pearlite. It is a solution of carbon or (cementite with ferrite). This phase is called as Martensite which is the hardest phase of iron. Slow cooling process produce coarses structure and fast cooling process produce fine structure. To produce Bainite the sample has to be quenched below the nose of T-T-T digram but above martensite start line (220°C). The sample is maintained at this temperature for sometime till the entire Austenite convert to Bainite called as Austempering.

Advantages → ductility, impact strength, toughes increase. Quenching cracks betn core and surface not develop.

Objective Of Heat treatment

(1) to incresе hardness, improve machinabilty, change grain size, improve electrical and magnetic properties, soften the metal.

Heat treatment Process Used In Engg Practice

(1) Annealing → It is the heating of steel into austenite temperature and then slowly cooled in the Furnace. Main objective of Annealing is to reduce hardness, improve machinabilty, Relive internal stress, refine grain size, increse ductility.

Slow cooling result in the Formation of spheroidal carbide and coarses pearlite. The cooling rate is depend upon the allooying element. It Results the Formation of Ferrite, spherodial cementite and caoarses pearlite.

(1) Full Annealing → primary objective is to reduce hardness and increase ductility. heating of steel about 50 to 70°C above the upper critical temperature For hypoeutectiod steel and above the lower critical temp For eutectiod steel. holding it at this temperature. Now slowly cooled in the Furnace where cooling varies from 30°C - 200°C per hour depending upon the composition when slowly cooling done Auestnite is decomposed into (coarases pearlite + Ferrite) → hypoeutectiod

Pearlite ⟶ eutectiod.

(2) Process Annealing → It is usually carried out to remove the effect of cold working and softeo to make it suitable for plastic deformation. It is the re-crystalization of cold worked steel by heating below critical temperature. The exact temperature

depend upon the extent of cold working, grain size composition and holding time. It produce no change in micro-structure and it is used for low carbon steel.

(iii) Spherodise Annealing → This process is applied to high carbon steel which is diffcult to machine. It cause formation of all carbide in the steel in a form of small sphere. It consists of heating the stee near the lower critical temp, then holding it for sometime and cooling slowly at 600°C. The Rate of cooling in the furnace is 25-30°C/hr.

(iv) diffusion Annealing → This process applied to alloy steel and heavy complex castings for eliminating the chemical in homogenity within the separte crysta by diffusion. It carried out at 1000-1200°C. at 1150°C it is take place so easily. steel is heated at 1150°C then kept it for some time and followed by cooling at 800-850°C. higher temperature is selected to diffusion more and more.

(2) Normalizing

The main objective of normalizing is to Refine grain structure, improve machinability, tensile strength, to remove the strain caused by cold working process like hammering, rolling etc. To improve mechanical and electrical properties.

It is a final heat treatment process given to the system subjected to relatively high stress heating steel to a temperature 40-50°C above the line where austenite is stable. holding at that temperature for sometime and cooling in air at room temperature. This is called air quenching. Normalizing produces micro-structure consisting of ferrite and pearlite for hypo-euctiod steel and pearlite and cementite for hypereutectiod steel

It raises the tensile strength, yeid point strength the upper critical temperature of steel depends upon it's carbon contents.

Normalizing requires a heating range which is about 40° c above Annealing. Mechanical properties of steel are better than Annealing.

(3) Hardening

hardening is a process in which steel is heated to Austensite temperature held at this temperature and then quenched with water or oil. hypoeutectoid steels, are heated from 30 - 50°c above the upper critical temp while hypereu-tectoid steels are heated above the Lower C.T.

due to rapid cooling the microstructure looks like collidal solution of cementite and ferri which is known as martensite which is hard and brittle. After hardening steel must be tempered to reduce the internal stress and improves the mechanical properties.

Stages involved →

(*) heating the object at a temperature above the critical point;

(*) holding the object at this temperature for definite period

(*) quenching in a medium.

(4) Tempering

Martensite which is formed during quenching is too brittle hence can't be used in many cases. Tempering consists of heating the hardened steel to a temperature below the lower critical temperature holding it for sometim and then cooling slowly. It is the final process in heat treatment. It Refers to the secondary heating of Martensite obtained by rapid cooling of Austenite. This process hardened the steel with reduction in strength also adds toughness and ductility. higher is the tempering temperature more the Residual stress. The work is cooled slowly after tempering.

NON - Ferrous Materials

Those metals which contain a metal other than iron as the choief constituent is called non-ferro These are widely used due to →

(1) ease of Fabrication (2) Resistance to corrision (3) weight (4) electrical & thermal conductivity.

(1) Aluminimum

It is a white metal produced by the electrical process from oxide (Alumina) which is prepared from clay mineral called bauxite. It is a light metal having s.g = 0.7 and melting point 658°c. In it's pure state metal is weak and soft but mixed with other metals to form an alloys and used for blanking, Forging, drawing operation.

Aluminimum alloys →

(1) Duralium → It is an important and interesting wrought alloy.

Copper - 3.5 - 4.5 %
Manganese - 0.4 - 0.7 %
Magnesium - 0.4 - 0.7 %

Remaining is Aluminium. This alloy posses maximum tensile strength upto 400 MP

After hardening the material is allowed to work for 3 to 4 days so that it is hardened and the process is called age hardening. It is widely used for Forging, tubes, rivets, connecting rod and bars

(2) Y-alloy → It is also called copper - Aluminium alloy. having composition :

copper - 3.5 - 4.5 %
Manganese - 1.2 - 1.7 %
Nickel - 1.8 - 2.3 %

Si, iron = 0.6 % each
Remaining is Aluminium.

This alloy is also treated and hardened like duralium. The ageing process is carried out at room temperature for five days. since Y alloy has better strength than duralium at high tempⁿ it is used in air-craft, piston, crank component.

(3) Magnalium → It is made by melting of Aluminium with 2 to 10 % Magnesium in a vaccum and then cooling it on the vaccum at a pressure of 100 to 200 kPa. It contains 1.75 % of copper. due to it's light weight it is used in air crafts.

(4) hindalium → Aluminium + Magnesium with small quantity of chromium. untensil Manufacturing.

(2) Copper

Most widely used non-ferrous material which is soft, malliable, ductile having s.g = 8.9 and melting point of 1083°C. The tensile strength varies from 150 to 400 Mpa under different condition. It is a good conductor of electricity so widely used in cables, electrical machines and home appliances.

Copper alloys →

(1) Brass (copper + zinc) →

copper - 50 %, zinc - 50 %, by adding small quan of lead it's propeties can be changed. They can be easily fabricated like electroplating, spinning peration.

(2) Bronze (copper + tin) →

Cu - 75 to 95% tin - 5 to 25%. This material is comparatively hard, wear resistance, and can be shaped into wires, rods etc.

(a) phosphor bronze → when bronze contained phosphorus then it is called phosphor bronze. phosphorus increases strength, ductility, Tensile strength varies from 215 MPa to 280 MPa. It can be forged, rolled etc.

Cu - 87-90%, tin - 9 to 10%, P - 0.1 - 3%

(b) Silicon bronze → Cu - 96%, Si - 3%, Mg/zin - 1%. It is used in boilers, tanks, stoves, etc.

(c) Berylium bronze → Cu - 97.75, Be - 2.25% high yeild strength, high Fatigue, It is used in bearing metals.

(d) Manganese bronze → Cu - 60%, zinc - 35%, Mg - 5% used in bushes, Plungers, feed pump etc.

(e) Aluminium bronze → (Cu + Aluminium). The aluminium bronze with 6-8% Al has valuable cold working properties, these are widely used for gears, propellers, air pump etc.

(3) Solder (Lead + tin)

(i) soft solder → It is based on lead and tin melt between 180°C to 250°C. It has two parts tin and 1 parts lead. for special purpose pure tin must be used.

(ii) Brazing solder → These are high zinc brasses melt around 850°C - 900°C.

(iii) silver solder → alloy of silver with (Cu + Zn) They have 64% of Cu and 43% silver. melting range 725 / 750°C

(iv) White metal → These are usually either tin base or lead base. The former being babbit metals. Tin base alloys are more powerful than that of lead alloys.

(4) GUN METAL

(copper + tin + zinc)
(88% 10% 2%)

It may be forged at 600°C. This metal is very strong and resistant to corrosion.

(5) Lead

It is a bluish grey metal having s.g = 11.36 and melting point of 326°C. It is so soft that it can be cut with a knief. Lead base alloys employed with cheap and corrosion material.

(6) Tin

brightly shining white metal, it is soft, malleable and ductile. It can be rolled into very thin sheets used for making important alloys. A tin base alloy contains 88% tin, 8% Atimmony, 4% cupper is called babbit metal.

Bearing Materials

(i) copper-base alloys.
(ii) Lead-base alloys (iii) Tin-base alloy
(iv) cadmium base alloys → cd-95%, silver-5%

The selection of Bearing Material involves bearing pressure, Rubbing speed, temperature.

Properties of bearing material includes → low μ, sufficient melting point, economical in cost, high thermal conductivity, withstand bearing pressure, good wearing qualites, good casting qualities.

Zinc-base Alloys

Most of the die-castings are produced from zinc base alloys which can be casted very easily at low temperature. The alloying elements are Al, Cu and Mg.

Al - 4.1%, Cu - 0.1%, Mg - 0.04%, Remaining is zinc

Aluminum improves the mechanical properties and reduce tendency of zinc to dissolve iron. It is used in Automobile industry, Radios, Refrigeration

Nickel-base Alloys

This are widely used in the Engineering and industry for their high mechanical strength

(i) Monel metal → Ni - 68%, Cu - 29%, 3% - iron, mg, Si, C, $S_g = 8.87$, $m_t = 1360°C$. It is used in propellers, pump fittings.

(ii) Iconel → Ni - 80%, Ch - 14%, iron - 6%, $S_g = 8.55$, $m_t = 1395°C$ used in making springs, manifold, air-craft engines.

(iii) Nichrome → Ni - 65%, Ch - 15%, iron - 20%, used in electrical wires, Furance

(iv) Nimonic → Ni - 80%, Ch - 20%, gas turbines.

Metals

Metals are the element which gives up electron to form mettalic bond and conduct electricity. When two or more pure metals melted together to form a new metal whose propeties are different known as alloy. Metal posses various propeties like plasticity, strength, hardness, thermal and electrical conductivity, Toughness, malleability, ductility.

Hardness testing →

(a) Vickers diamond pyramid test → This method uses a square based diamond pyramid to make an indentation in the surface of metal.

$$V.P.H.\ Number = \frac{Applied\ load}{Area\ and\ impression}$$

(b) Rockwell test → here either a steel ball or a diamond cone is used as indentor. The hardness value shown on a dial..

(c) Brinell test → here a hardnes stell ballis Force into the speciman under test by means of suitable standrad load. The diameter of the ball can be measured using a microscope.

$$H = \frac{Applied\ load}{Area\ of\ impression} = \frac{P}{\frac{1}{2}\pi D\left[D-\sqrt{(D^2-d^2)}\right]}$$

(d) shore scleroscope test → in this test an indentor weighting 25g is contained in a glass tube and allowed to Fall Freely down this tube height 250 mm The rebound of the indentor can be measured from graduation.

NON-metals → commonly adopted non-mettalic materials is called non-metal. ex - rubber, leather

(2) Ceramics

ceramics are the compounds of mettalic and non-mettalic elements. Most of them are oxides eg. silica, Al_2O_3, MgO, garnet, etc. There structure may be crystaline or glassy. It includes all the product made from clay, bricks, tiles etc.

bcz of the smallness indentation component with a polished surface finish vicker test is accurate upto a hardness number of 500.

(1) Amorphous ceramic → lead glass, soda glass, borocilicate glass used in lenses, insulators

(2) Crystaline ceramic → hard Engg Materials used in abrasive and cutting tool material

(3) Bonded ceramic → indivisual crystals bonded together by a matrix and large no. of clay produce used in Furnace lining, insculators etc.

(4) Cements → used for investment casting, mould, cladding, furance lining

Cermets

To get the material of high melting point, strength rigidity at high temperature and shock resistance we have to combine metal and ceramics in suitable combination by power metallgy method. If a materi of considerable rigidity at high temperature is required then we have to increse the ceramic contents

Cements generally have suitabilty in lamp filam, air-craft engines, gas-turbine, rocket engine, drilling, bearing parts etc. cermets tool material which consists of extremly hard abrasion resistant particle held together by strong bonding material. The most widely used are titanium or tungsten carbide.

Organic Materials

These materials are directly derived from carbon. They usually consists of carbon chemically combined with hydrogen, oxygen or non-mettalic subtaince. Plastics and synthetic rubber are called polymer becuse they formed. due to polymerization

Plastics → PVC, PTFE, Polythene

fibers → nylon, leather, natural or synthetic rubber

NON-Mettalic Materials:

(1) Plastics → These are synthetic Material which are moulded into shape under pressure with or without application of heat.

Thermosetting Plastics → which are formed into shape under heat and pressure and result in a permanently hard product. It's formed by chemical change the examples are Bakelite, Plaskon etc.

Thermoplastic → which do not become hard under the application of heat and pressure They Remain soft at elivated temperature. examples are Polythene, P.V.C etc.

manufacturing of Aeroplane and Automobile Parts, making safety glasses, pillar, bearing etc.

Source of Plastic are →

Natural → available in nature, natural resin, casein etc.

Synthetic resin → Artifical, urea, Formaldehyde

Formation of Plastics →

Polymerization: It is defined as the process of formation of high molecular weight hydrocarb from low hydrocarbon under excessive temperat

condensation: It is the formation of high molecular weight compounds from lower ones by combination or elimination of molecules.

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