LECTURE NOTES ON

ENGINEERING MATERIAL

PREPARED BY

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AUTOMOBILE ENGINEERINGDEPATMENT

VISSION:

Todevelopcompetent,disciplinedimaginativeAutomobile engineers,equipped withcorecompetencyandtechnicalskillsusefultothelearning/teachingcommunityandtheindustrialfraternity.

MISSION:

M1: Toprovidewithoperationalandtechnicalinputstogetinnovativeandresearchideasinthefieldofautomotiveengineering.

M2: Togiveinputsforhighereducationwithmanagementqualitiesforthebettermentofthesociety.

M3: Skillingwithmodernengineeringtoolsnecessarytomeetandsolveengineeringproblems.

PROGRAMEDUCATIONALOBJECTIVES

PEO1: Toprovidetechnicalskillstodiagnoseandapplytheconceptofautomotivesystem

PEO2: Topreparetodesign,fabricateandinnovateinautomobilesectortofacetheindustrialchallenges.

PEO3: Toinculcatewithgoodcommunicationskills,ethicsand entrepreneurshipskillstoplaythekeyroleinautomotiveindustry.

UNIT - 1

1. ENGINEERING MATERIALS AND THEIR PROPERTIES

1.1 MATERIAL:-

- Material is something consist of matter.
- Materials comprise a wide range of metals and non-metals and other.

1.2 MATERIAL CLASSIFICATION:-

- Normally materials are 5 type.

(A)Metals (Ferrous and Nom-ferrous)

(B)Ceramics

(C)Organic

(D)Composites

(E)Semiconductors

1.3 PROPERTIES OF MATERIALS

- **Physical Properties**
- Dimension:-
  - Dimension of a material implies it's size(breadth, width, length, dimeter) and shape (section, circular,channel,angle).
- Appearance:-
  - Different materials have different looks.
  - Some materials got specific colour and some materials got some specific porperty which make them different from others
- Density:-
  - The density is the weight of unit volume of a material.
    - Density=weight/volume
- Melting point:-
  - Melting point of a material is that temperature at which the solid metals changes into the molten state.
- Porosity:-
  - A material is said to be porous if it has pores within it.
  - Pores can absorb lubricant as in a sintered self-lubricating bearing.
    - True porosity=Total pore volume/Total volume

- **Chemical Properties:-**
- Corrosion resistance:-
    - It is the deterioration of material by chemical reaction with it's environment.
- Chemical composition
- Acidity or Alkalinity
- **Mechanical Properties:-**
- Elasticity
    - The tendency of a deformed solid to seek it's original dimensions upon withdrawing force is known as elasticity.
    - Stress=Load/Area
    - Strain=Change in dimension/Original dimension
    - Young's Modulus of Elasticity=Stress/Strain
- Plasticity
    - Plasticity is that property of a material by virtue of which it may be permanently deformed when it has been subjected to an external force great enough to exceed the elastic limits.
- Toughness
    - Toughness is the ability of the material to absorb energy during plastic deformation up to fracture.
- Resilience
    - Resilience is the capacity of a material to absorb energy when it is elastically deformed and then upon unloading, to have this energy recovered.
- Tensile Strength
    - Tensile strength is the maximum force needed to fracture the material.
- Yield Strength
    - Yield strength is that value of stress at which a material exhibits a specified deviation from proportionality of stress and strain.
    - Yield strength of a material represents the stress below which the deformation is almost entirely elastic.
- Impact Strength
    - The capacity of a material to resist shock energy before it fracture is called it's impact strength.
- Ductility
    - Ductility refers to the capacity of a material to undergo deformation under tension without rupture.
- Malleability
    - Malleability is the capacity of a material to withstand deformation under compression without rupture.

- Brittleness

    - Brittleness is defined as a tendency to fracture without appreciable deformation and is therefore the opposite of ductility
- Hardness
    - Hardness is the resistance of a material to plastic deformation.
- Fatigue
    - When subjected to repeated loads, material tends to develop a characteristic behavior which is different from under steady loads.
    - Fracture takes place under stresses whose maximum value is less than the tensile strengthof the material.
- Creep
    - Creep is the time-dependent permanent deformation that occurs under constant stress at elevated temperature.
- Wear Resistance
    - Wear is the unintentional removal of solid material from rubbing surface.

1.4 PERFORMACE REQUIREMENTS:-

- Fabrication requirements:-
    - It means that the material should be able to get shaped and joined easily.
- Service requirements:-
    - It imply that the material selected for the purpose must stand up to service demand.
- Economic requirements:-
    - It demand that the engineering part should be made with minimum overall cost.

1.5 MATERIAL RELIABILITY AND SAFETY:-

- The final product should be reliable(e.g.,should last for desired time period in a particular conditions) and safe for user(e.g., shouldn't harm the user in anyway possible)

1.6 FERROUS AND NON-FERROUS CATEGORYAND ALLOY:-

- Ferrous metals are any metal that contains iron, such as stainless steel. They are known for their tensile strength, which makes them ideal for architectural and structural uses such as the tallest skyscrapers, as well as bridges, railways and more.
- Ferrous metals are also have magnetic properties, which is why you can use magnets to pin things to your refrigerator door, although their high carbon content means that many ferrous metals are prone to rusting. The exceptions to this are stainless steel, which doesn't rust because of the chromium, and wrought iron which doesn't rust due to the high pure iron content.
- Example:-
    - Steel
    - Stainless Steel
    - Cast Iron
    - Wrought Iron

    - Carbon Steel
- Non-ferrous metals don't contain iron. They are lighter and more malleable than ferrous metals, making them ideal for applications where strength is required but weight is a consideration, such as with the aerospace industry.
- Non-ferrous metals are not magnetic but do offer good resistance to corrosion and can conduct heat and electricity. They are used in for items including industrial piping, gutters, roofing and electrical applications.
- Example:-
    - Aluminium
    - Cupper
    - Lead
    - Tin
    - Silver
    - Brass
    - Gold
    - Zinc

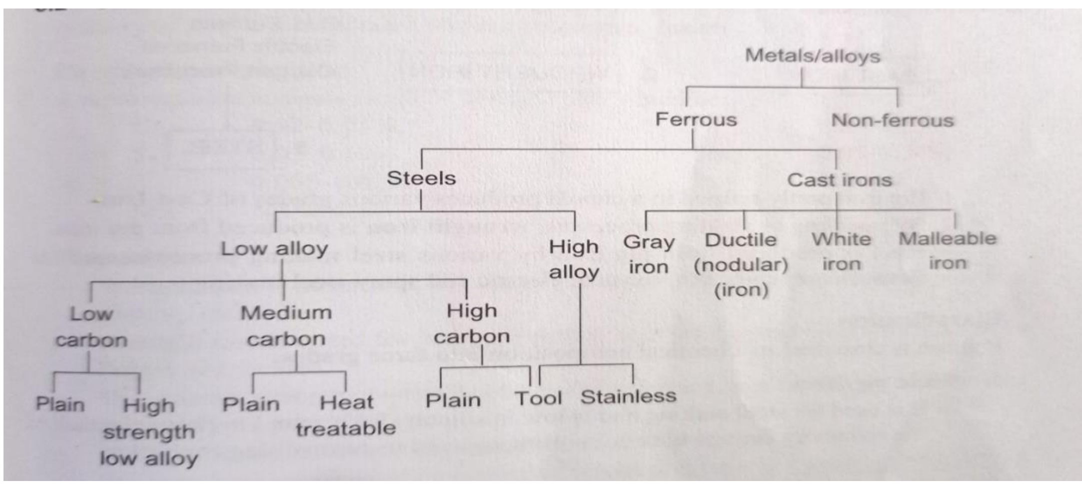
UNIT -2

2. Ferrous Materials and Alloys

Introduction:-

- Ferrous materials contain iron, and the one elements people use more than all other is Iron .
- Ferrous materials are the most important metals/alloy in the metallurgical and mechanical industries because of their very extensive use.
- Iron containing compounds exist in abundant quantities within the earth's crust.
- Metallic iron and steel alloys may be produced using relatively economical extraction, refining, alloying and fabrication technique.
- Ferrous alloys are extremely versatile in that they may be tailored to have a wide range of mechanical and physical properties.

Classification:-



Composition and Application of different steel:-

Steel is an alloy of iron and carbon. Carbon steel can be classified as

i. Low carbon steel
ii. Medium carbon steel
iii. High carbon steel

Low carbon steel(Mild steel):-

Mild steels may be classified as follows

- Dead mild steel(C 0.05-0.15%)

It is used for making steel wire, sheet and chain
It has tensile strength of 390 N/mm^2 and hardness of about 115 BHN

- Low mild steel(C 0.15-0.2%)
  It is used for camshaft, welding tube
  It has a tensile strength of 420 N/mm^2 and hardness of about 125 BHN
- Mild steel(C 0.2-0.3%)
  It is used for valves, gears, connecting rod
  It has a tensile strength of 555 N/mm^2 and hardness of about 140BHN

Medium carbon steel:-

- Steel containing carbon from 0.35 to 0.45%
  - They are used for key stock, wires and rods
  - They have a tensile strength of about 750 N/mm^2
- Steel containing carbon from 0.45 to 0.55%
  - They are used for axle, crankshaft
  - They have a tensile strength of 1000 N/mm^2
- Steel containing carbon from 0.6 to 0.7%
  - They are used for clutch disc, valve spring
  - They have a tensile strength of 1230 N/mm^2

High carbon steel:-

- Steel containing carbon from 0.7 to 0.8%
  - It is used for jaws for vises, cold chisel
  - It has a tensile strength of 1400 N/mm^2
- Steel containing carbon from 0.8 to 0.9%
  - It is used for Leaf spring, clutch discs
  - It has a tensile strength of 660 N/mm^2
- Steel containing carbon 0.9 to 1%
  - It is used for Pins, keys
  - It has a tensile strength of 580 N/mm^2
- Steel containing carbon 1 to 1.1%
  - It is used for Railway spring machine tool
- Steel containing carbon 1.1 to 1.2%
  - It is used for knives, twist drill
- Steel containing carbon 1.2 to 1.3%
  - It is used for files, metal cutting tools
- Steel containing carbon 1.3 to 1.5%
  - It is used for wire drawing dies, paper knives

Alloy Steel:-

- Steel is considered to be alloy steel when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits;
    - Mn = 1.65%
    - Si = 0.6%
    - Cu = 0.6%
- Given below is the composition of typical alloy steel

C=0.2-0.4%	Mn=0.3-1%
Si=0.3-0.6%	Ni=0.4-0.7%
Cr=0.4-0.6%	Mo=0.15-0.3%

Advantages and disadvantages of alloy steel

Advantages that may be attained	**Disadvantages that may be encountered**
Greater hardenability	Cost
Less distortion and cracking	Special handling
Greater stress relief at given hardness	Tendency toward austenite retention
Less grain growth	Temper brittleness in certain grades
Higher elastic ratio and endurance strength	
Greater high temperature strength	
Better machinability at high hardness	
Greater ductility at high strength	

Tool steel:-

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

Properties:-

i. Slightly change of form during hardening
ii. Little risk of cracking during hardening
iii. Good toughness
iv. Good wear resistance
v. Very good machinability
vi. A definite cooling rate during hardening
vii. A definite hardening temperature
viii. A good degree of through hardening
ix. Resistance to decarburization
x. Resistance to softening on heating

Composition:-

1. **W-High speed steels (T)**
   - $T_1 \rightarrow$ C 0.7, Cr 4, V 1, W 18
   - $T_4 \rightarrow$ C 0.75, Cr 4, V 1, W 18, Co 5
   - $T_6 \rightarrow$ C 0.8, Cr 4.5, V 1.5 W 20, Co 12
2. **Mo-High speed steels (M)**
   - $M_1 \rightarrow$ C 0.8, Cr 4, V 1 W 1.5, Mo 8
   - $M_6 \rightarrow$ C 0.8, Cr 4, V 1.5, W 4, Mo 5, Co 12
3. **High C, high Cr steels (D)**
   - $D_2 \rightarrow$ C 1.5, Cr 12, Mo 1,
   - $D_5 \rightarrow$ C 1.5, Cr 12, Mo 1, Co 3
   - $D_7 \rightarrow$ C 2.35, Cr 12, V 4, Mo 1
4. **Air hardening steels (A)**
   - $A_2 \rightarrow$ C 1, Cr 5, Mo 1
   - $A_7 \rightarrow$ C 2.25, Cr 5.25, V 4.75 W 1, Mo 1
   - $A_9 \rightarrow$ C 0.5, Cr 5, Ni 1.5, V 1, Mo 1.4
5. **Oil hardening steels (O)**
   - $O_1 \rightarrow$ C 0.9, Mn 1, Cr 0.5, W 0.5
   - $O_6 \rightarrow$ C 1.45, Si 1, Mo 0.25
6. **Water hardening steels (W)**
   - $W_2 \rightarrow$ C 0.6/1.4, V 0.25
   - $W_5 \rightarrow$ C 1.1, Cr 0.5
7. **Hot work steel (H)**
   - $H_{10} \rightarrow$ C 0.4, Cr 3.25, V 0.4, Mo 2.5
   - $H_{12} \rightarrow$ C 0.35, Cr 5, V 0.4, W 1.5, Mo 1.5
8. **Shock resisting steel (S)**
   - $S_1 \rightarrow$ C 0.5, Cr 1.5, W 2.5
   - $S_2 \rightarrow$ C 0.5, Si 1, Mo 0.5
   - $S_5 \rightarrow$ C 0.55, Mn 0.8, Si 2, Mo 0.4
   - $S_7 \rightarrow$ C 0.5, Cr 3.25, Mo 1.4

Stainless steel:-

- When 11.5% or more chromium is added to iron, a film of chromium oxide forms spontaneously on the surface exposed to air. The film acts as a barrier to retard further oxidation, rust or corrosion.
- As the steel cannot be stained easily, it is called stainless steel.
- All stainless steel can be grouped into 3 classes;
  1. Austenitic
  2. Ferritic
  3. Martensitic

Austenitic:-

Composition:-

C=0.03 to 0.25% Mn=2 to 10%

Si=1 to 2%   Cr=16 to 26%

Ni=3.5 to 22%

- They possess the highest corrosion resistance of all the stainless steel
- They possess the greatest strength and scale resistance at high temperature
- They are non-magnetic so that they can be easily identified with a magnet
- They may uses in Aircraft industry, Food processing, Dairy industry

Ferritic:-

Composition:-

C=0.08 to 0.2%   Si=1%

Mn=1 to 1.5%   Cr=11 to 27%

- It has low carbon to chromium ratio which eliminates the effects of thermal transformation and prevents hardening by heat treatment
- These steels are magnetic and good ductile
- These steels developed their maximum softness, ductility and corrosion resistance in the annealed condition
- These are uses in Lining for petroleum industry, Interior decorative work, Oil burner parts

Martensitic:-

Composition:-

C=0.15 to 1.2%   Si=1%

Mn=1%   Cr=15 to 18%

- Because of higher carbon to chromium ratio, these are the only types hardenable by heat treatment
- These steel are magnetic and possess the best thermal conductivity of the stainless types
- Hardness, ductility and ability to hold an edge are characteristic of martensitic steel
- These type of steel uses in pumps and valve parts, Turbine bucket

Tool steel: Effect of various alloying elements

Carbon: Carbon content in steel affects

- Hardness
- Tensile strength
- Machinability
- Melting point.

Nickel: Nickel

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

- Strengthens steels
- Renders high-chromium iron alloys austenitic
- Does not unite with carbon.

Chromium: Chromium

- Joins with carbon to form chromium carbide, thus adds to depth hardenability with unproved resistance to abrasion and wear,

Silicon: Silicon

- Improves oxidation resistance
- Strengthens low alloy steels
- Acts as a deoxidizer.

Titanium: Titanium

- Prevents localized depletion of chromium in stainless steels during long heating
- Prevents formation of austenite in high chromium steels
- Reduces martensitic hardness and hardenability in medium chromium steels.

Molybdenum: Molybdenum

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

Vanadium: Vanadium

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

Tungsten: Tungsten

- Increases hardness (and also red-hardness)
- Promotes fine grain
- Resists heat
- Promotes strength at elevated temperatures.

Manganese: 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.

Copper: Copper (0.2 to 0.5%) added to steel
— Increases resistance to atmospheric corrosion
— Acts as a strengthening agent.

Boron: Boron
— Increases hardenability or depth to which steel will harden when quenched.

Aluminium: Aluminium
— Acts as a deoxidizer
— Produces fine austenitic grain size
— If present in an amount of about 1%, it helps promoting nitriding.

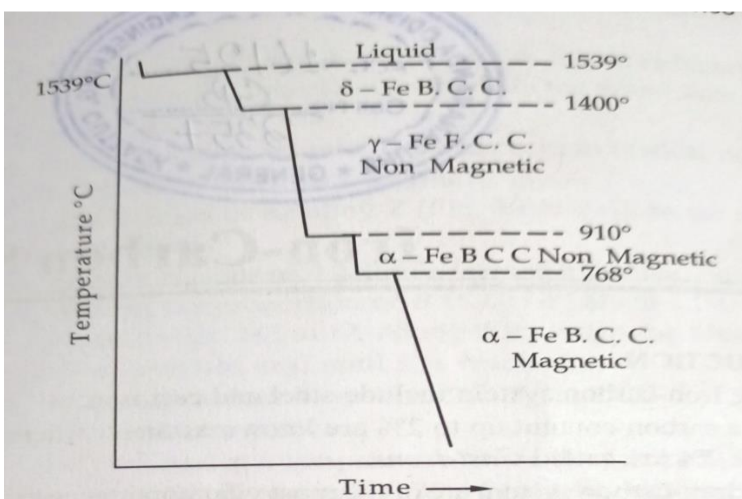
Cobalt: Cobalt
— Contributes to red-hardness by hardening ferrite
— Improves mechanical properties such as tensile strengths, fatigue strength and hardness
— Refines the graphite and pearlite
— Is a mild stabilizer of carbides
— Improves heat resistance
— Retards the transformation of austenite and thus increases hardenability and freedom from cracking and distortion.

Vanadium: Vanadium (0.15 to 0.5%)
— Is a powerful carbide former
— Stabilizes cementite and improves the structure of the chill.

UNIT – 3

Introduction

- Alloys of Iron-Carbon system include steel and cast iron
- Alloys with a carbon content up to 2% are known as steels whereas those having carbon above 2% are called cast irons
- The iron carbon system provides the most prominent example of heat treatment and property alteration based on polymorphic transformation and eutectoid decomposition
- The primary constituent of iron carbon system is the metal iron



- Iron is a relatively soft and ductile metal
- Iron has a melting point of 1539°C

- Iron is a allotropic metal, which means that it exists in more than one type of lattice structure depending upon temperature
- In normal room temperature state, iron is B.C.C. in lattice arrangement, whereas at 908°C it changes to F.C.C. and then at 1403°C back to B.C.C.
- One another change occurs at about 770°C (called the curie point) at which the room temperature magnetic property of iron disappear and becomes non magnetic
- Iron is molten above 1539°C. It solidifies in the B.C.C. Delta form
- On further cooling at 1400°C, a phase change occurs and it take Gamma F.C.C. nonmagnetic form
- On further cooling at 910°C another phase change occurs and it change to Alpha B.C.C nonmagnetic
- Finally at 768°C it again change to magnetic Alpha B.C.C.

Micro-Constituents of Iron and Steel

- When steel is heated above the austenitic temperature and is allowed to cool under different conditions, the austenite in steel transforms into a variety of micro-constituents
- Various micro-constituents are:-
    - Austenite
        - Austenite is the solid solution of carbon and other alloying elements in Gamma iron
        - Austenite can dissolved maximum 2% carbon at 2066°F
        - It has tensile strength of 10500 Kg/cm^2
        - It is non-magnetic and soft
    - Ferrite
        - The maximum solubility is 0.025% carbon at 1333°F and it dissolves only 0.008% carbon at room temperature
        - It is the softest structure that appears on the Fe-C equilibrium diagram
        - Tensile strength is 2800kg/cm^2

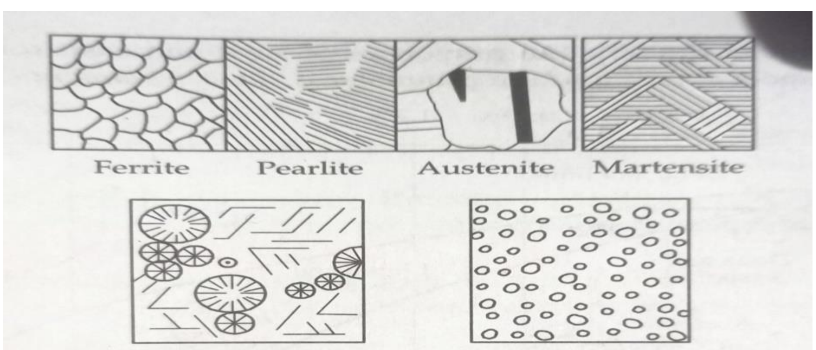


Fig. 40.3

    - Cementite
        - It contain 6.67% of carbon by weight

- It is the hardest structure in Fe-C equilibrium diagram. It's crystal structure is orthorhombic
- Tensile strength is 350 kg/cm^2

- Ledeburite
  - Ledeburite is the eutectic mixture of austenite and cementite
  - It contains 4.3% carbon
  - It is formed at about 1130^o C

- Pearlite
  - Pearlite is an eutectoid mixture generate by austenite decomposition
  - It contains 0.8% carbon
  - It formed at 723^o C
- Bainite
  - Bainite is produced by Aiistempering
  - It formed below the temperature of pearlite and above the temperature of martensite
  - If bainite is formed in the upper part of the temperature range it's appearance is feathery and it is called Feathery Bainite
  - If it is formed in lower part of the temperature range it's known as Acicular Bainite
- Martensite
  - Martensite is an interstitial supersaturated solid solution of carbon in Alpha iron and has a body centered tetragonal lattice
  - Martensite possess an acicular or needle-like structure
- Troostite
  - Troostite is a mixture of ferrite and cementite
  - It is produced on tempering mastensite below approximately 450^{o}C
- Sorbite
  - It is the microstructure consisting of ferrite and finely divided cementite
  - It produced on tempering martensite above approximately 450^{o}C

Iron-Carbon Diagram

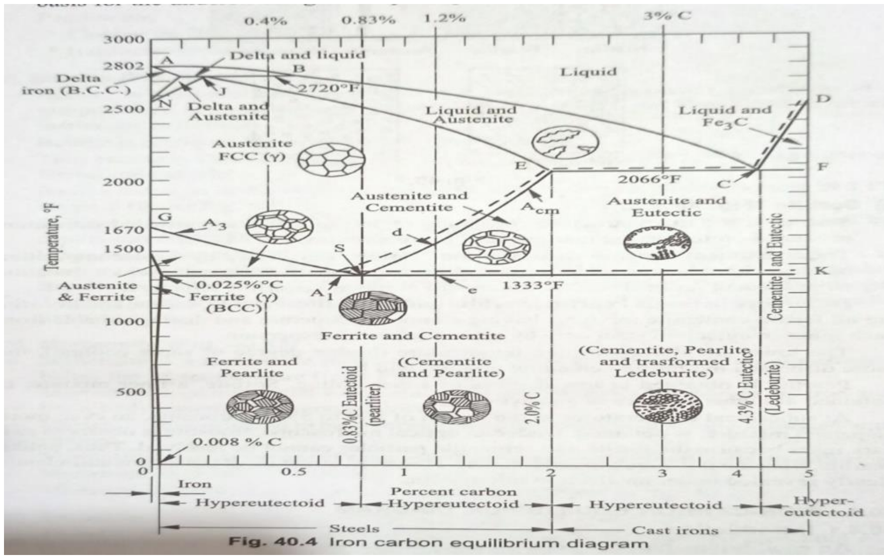


Fig. 40.4 Iron carbon equilibrium diagram

- Iron-Carbon diagram indicates the phase changes that occur during heating and cooling and the nature and amount of the structural component that exist at any temperature
- It establish a correlation between the microstructure and properties of steel and cast iron and provides a basis for the understanding of the principles of heat treatment
- This diagram has a peritectic point "J" , an eutectoid point "S" , eutectic point "C"
- Peritectic equation
    - Delta+ Liquid = Austensite
- Eutectic equation
    - Liqiud = Austenite + Cementite
- Eutectoid equation
    - Solid = Ferrite + Cementite

UNIT-4

Introduction:

- A crystal is a solid composed of atoms, ions, or molecules arranged in a pattern which is repetitive in three dimensions.
- In an ideal crystal the atomic arrangement is perfectly regular and continuous throughout. An ideal crystal is perfect.
- But real crystals are as in cast or welded objects are never perfect; lattice distortion and various imperfections, irregularities or defects are generally present in them.
- All defects and imperfections in crystals can be conveniently classed under four main divisions, namely:
    - Point Defects
        - Vacancies
        - Interstitialcies
        - Impurities

        - Electronic defects
    - Line Defects
        - Edge dislocation
        - Screw dislocation
    - Surface Defects
        - Grain boundaries
        - Tilt boundaries
        - Twin boundaries
    - Volume Defects

Point Defects:

- In a crystal lattice, point defect is one which is completely local in its effect, e.g. a vacant lattice site
- The number of defects at equilibrium at a certain temperature can be determined from equation

$$n_d = Ne^{-E_d/kT}$$

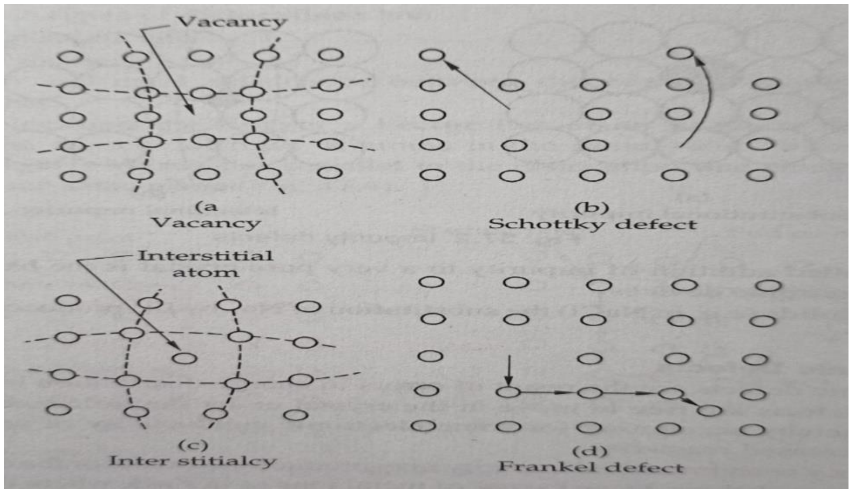
where, n_d is the number of defects.
N is the total number of atomic sites per cubic metre or per mole.
E_d is the energy of activation necessary to form the defect.
k is the Boltzmann constant, and
T is the absolute temperature.
The possible point defects have been explained as under:

Vacancies:

- A vacancy implies an unoccupied atom position within a crystal lattice. In other word, 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 temperatures
- Schottky defect is closely related to vacancies an is formed when an atom or an ion is removed from a normal lattice site and replaced in an average position on the surface of the crystal

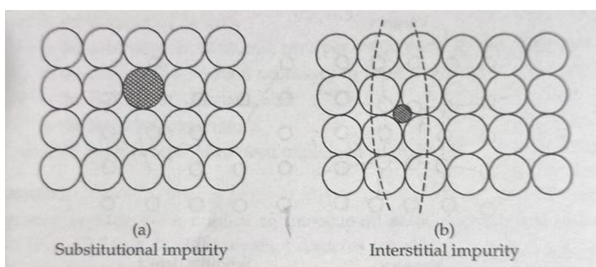
Interstitialcies:

- An interstitial defect arises when an atom occupied a definite petition in the lattice that is not normally occupied in the perfect lattice
- The interstitial atom maybe either a normal atom or a foreign atom
- Frankel defect closely related to interstitialcies. An displaced from the lattice into an interstitial site is called a Frankel defect



Impurities:

- Impurities give rise to compositional defects
- Foreign atoms generally have atomic radii and electronic structure differing from those of the host atoms and therefore act as center of distortion
- Impurity atoms are introduced into crystal structure as a substitutional or interstitial atoms

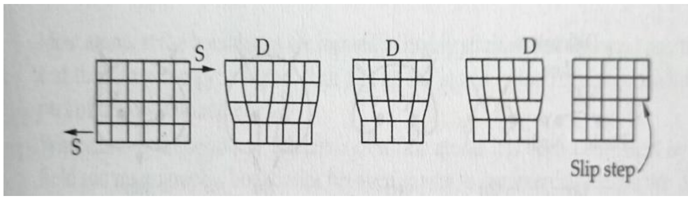


Line Defects:

- The most important 2 dimensional defect is dislocation
- A dislocation may be defined as a disturbed region between two substantially perfect parts of a crystal
- Two type of line defects are Edge dislocation and Screw dislocation
- The main difference between them is that In edge dislocation the Burger's vector lies in same plane in right angle whereas in screw dislocation the Burger's vector lies parallel in same plane

Edge Dislocation:

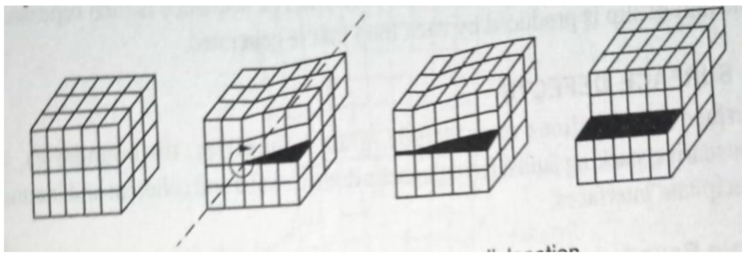
- An edge dislocation lies perpendicular to it's Burger vector



- Edge dislocation is particularly useful in explaining slip in plastic flow during mechanical working

Screw Dislocation:

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



- The force required to form and move a screw dislocation, although probably somewhat greater than those required to initiate an edge dislocation, are markedly less than those required to exceed the elastic limit of a perfect crystal
- Dislocation arises in crystals as a result of
    - Growth accident
    - Thermal stress
    - External stress causing plastic flow
    - Phase transformation
    - Segregation of solute atoms causing mismatch

UNIT – 5

Definition:-

- Heat treatment may be define as an combination of operation involving heating and cooling of a metal/alloy in solid state to obtain desirable condition(i.e. relieved stresses) and properties (i.e. better machinability, improved ductility, homogeneous structure etc)

Classification of heat-treatment processes:-

1. Annealing
    a. Stress-relief annealing
    b. Process annealing
    c. Spheroidising
    d. Full annealing
2. Normalizing
3. Hardening
4. Tempering
5. Martempering
6. Austempering
7. Maraging

Purpose of heat treatment:-

1. Cause relief of internal stresses developed during cold working, welding, casting, forging etc
2. Harden and strengthen metals
3. Improve machinability
4. Change grain size
5. Soften metal for further working as in wire drawing or cold rolling
6. Improve ductility and toughness
7. Increase heat, wear and corrosion resistance of material
8. Improve electrical and magnetic properties
9. Homogenise the structure; to remove coring or segregation
10. Spheroidize tiny particle such as those of Fe_2C in steel by diffusion

Annealing:-

- Annealing is the process of heating a metal which is in a metastable state, to a temperature which will remove the instability or distortion and then cooling is so that the room temperature structure is stable and strain free

Purpose:-

1. Including a completely stable structure

2. Refining and homogenizing the structure
3. Reducing hardness
4. Improving machinability
5. Improving cold working, characteristics for facilitating further cold work
6. Producing desired microstructure
7. Removing residual stresses
8. Removing gases
9. Improving mechanical, physical, electrical and magnetic properties

- In case of ferrous alloy annealing known as full annealing and in case of non-ferrous alloy annealing known as to soften the alloy
- If any process of annealing has a sole purpose to reduce stress, then it known as stress relief

Stress Relief:-

- It relieves stresses produced by casting, quenching, machining, cold working, welding
- Stress relief is often desirable when a casting is liable to change dimensions to a harmful degree during machining or use

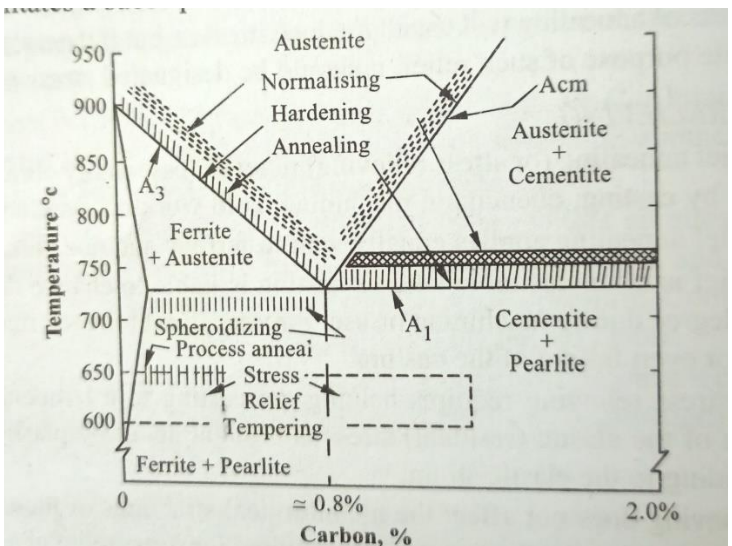


Fig. 43.1 Heat treating temperatures for carbon steels

Normalizing:-

- Normalizing consists in heating steel to about 40-50ºC above it's upper critical temperature and if necessary holding it at that temperature for a short time and then cooling in still air at room temperature
- Normalizing produces microstructures consisting of ferrite and pearlite for hypoeutectoid steel

Purpose:-

1. Produces a uniform structure

2. Refines the grain size of steel, which may have been unduly coarsened at the forging or rolling temperature
3. May achieve the required strength and ductility in a steel that is too soft and ductile for machining
4. Reduces internal stresses
5. Improves structures in welds
6. Produces a harder and stronger steel than full annealing
7. Eliminates the carbide network at the grain boundaries of hypereutectoid steel

Hardening:-

- Hardening is that heat treatment of steel which increase it's hardness by quenching
- The hardening of steel requires the formation of martensite
- In steel, the maximum % increase of hardness by quenching is obtained if they contain between 0.35 and 0.6% carbon

Purpose

1. Hardens steel to resist wear
2. Enable steel to cut other metals
3. Improves strength, toughness and ductility
4. Develops best combination of strength and notch-ductility

Tempering:-

- Tempering produces structure martensite and retained austenite
- It requires
    - Heating hardened steel below the lower critical temperature
    - Holding it at that temperature for 3 to 5 minutes for each mm of thickness
    - Cooling the steel either rapidly or slowly except in case of steels susceptible to temper brittleness

Purpose:-

1. Relieve residual stresses
2. Improve ductility
3. Improve toughness
4. Reduce hardness
5. Increase % elongation

Surface Hardening:-

- Numerous industrial applications such as cams, gears require a hard wear resistant surface called the case and a relatively soft, tough and shock resistant inside, called the core

- Both these requirements may be met by employing a low carbon steel with suitable core properties and then adding Carbon, Nitrogen or both to the surface of the steel part in order to provide a hardened case of a definite depth
- These treatments are known as case hardening

Purpose

1. Improve corrosion, heat or wear resistant
2. Rebuild worn or undersized parts
3. Serve as an ornamental finish
4. Lengthen the useful life of a part manufactured from a low cost material having surface characteristics unsuited for a given installation

Carburizing:-

- Carburizing is a method of intruding, carbon into solid iron-base alloys such as low carbon steels in order to produce a hard case
- Low carbon steel is heated at 870 925^{o}C in contact with gaseous, solid or liquid carbon containing substances for several hours

Characteristics

1. Case depth is about 0.05 inch
2. Hardness after heat treatment is Re 65
3. Carburizing causes negligible change in dimensions
4. Distortion may occur during heat treatment

- There are three general methods of carburizing, depending upon the form of the carburizing medium, namely
    - Pack Carburizing
    - Gas Carburizing
    - Liquid Carburizing

Nitriding:-

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

Characteristics

1. Case depth is about 0.381mm
2. Extreme hardness
3. Growth of 0.025-0.050mm occurs during nitriding
4. Case has improved corrosion resistance

Advantages	Disadvantages
Very high surface hardness of the order of 1150 VPN may be obtained	Long cycle times (40 to 100 hrs)
Since nitride parts are not quenched, this minimizes distortion	The brittle case
Good fatigue resistance	Only special alloy steels can be satisfactorily treated
Good corrosion and wear resistance	High cost of the nitriding process
Whereas in a carburized part, hardness begins to fall at about 200ºC, a nitride part retains hardness up to 500ºC	Technical control required
No machining is required after nitriding	If a nitride component is accidentally overheated, the surface hardness will be lost completely and the component must be nitride again
Some complex parts which are not carburized satisfactorily, can be nitride without difficulty	
The process is economical when large number of parts are to be treated	

Effect of heat treatment on properties of steel:-

- When steel with a medium to high carbon content is subjected to heat treatment, it can be hardened
- Annealing changes a metal's properties by altering and realigning the grain structure using heat, making the metal softer and more ductile
- When heating the metal to a point higher than that of the annealing process and allowing it to air cool, the grain structure stresses can be removed. Normalizing steel gives the structure more stability and the metal can be prepared for other processes
- Steel can be made more malleable by "tempering" it. This involves heating the metal to a predetermined temperature which depends on the level of malleability required
- Quenching refers to the rapid cooling of hot metal using oil or water. This sets the steel, making it hard but brittle

Hardenability of steel:-

- The hardenability is defined as the ability of the steel to partially transform from austenite to martensite at a given depth below the end surface, when cooled under a given condition
- In the absence of adequate hardenability of steel even the most drastic quench is incapable of producing martensite in a steel bar of a given size.

UNIT-6

INTRODUCTION:

- Aluminium is a silvery white metal.
- It is a light metal, with a density about a third that of a steel.
- Aluminium is a very good conductor of electricity
- It has a higher resistance to corrosion than many other metals.
- It is also a good conductor of heat
- It is very ductile
- It is non-magnetic
- Melting point of aluminium is 650^0C

ALUMINIUM ALLOYS:

- Although pure aluminium is not particularly strong, it forms high strength alloys in conjunction with other metals such as Cu, Cr, Ni, Zn, Mo, Si and Mg
- They are malleable and ductile
- Aluminium and its alloys can be
    - Cast
    - Forged
    - Welded
    - Extruded
    - Rolled

Use of Aluminium Alloy:

- Transportation industry
- Overhead conductors and heat exchanger parts
- Food industry
- Architectural
- As heavy duty structures such as dragline booms, travelling cranes, hoists, conveyor supports, bridges etc

CLASSIFICATION:

- Aluminium alloys can be classified as follows
    - Wrought alloys
        - 4.4 Cu, 0.6 Mn, 1.5 Mg, balance Al
        - 0.12 Cu, 1.2 Mn, balance Al
        - 2.5 Mg, 0.25 Cr, balance Al
        - 0.6 Si, 0.27 Cu, 1.0 Mg, 0.2 Cr, balance Al
    - Cast alloys
        - 12 Si, balance Al

        - 4 Cu, 3 Si, rest Al
        - 4.5 Cu, 5.5 Si, rest Al
        - 3.8 Mg, 1.8 Zn, rest Al
    - Heat treatable alloys
        - 3.9-5.0 Cu, 0.2-0.8 Mg,0.5-1.0 Si, 0.3-1.2 Mn, rest Al
        - 0.5-1.2 Mg, 0.7-1.3 Si, 0.4-1.0 Mn, rest Al
        - 0.4-0.9 Mg, 0.3-0.7 Si, rest Al
    - Non heat treatable alloys
        - 0.8-1.5 Mn, rest Al
        - 1.7-2.4 Mg, rest Al
        - 10-13 Si, rest Al
        - 5.0-5.5 Mg, 0.6-1.0 Mn, 0.05-0.2 Cr, rest Al

Duralumin:

- It contains:
    - Cu 3.5-4.5 %
    - Mn 0.4-0.7 %
    - Mg 0.4-0.7 %
    - Al Balance
- It possesses:
    - High machinability
    - High tensile strength after heat treatment
    - Strength as high as steel but has only about one third of its weight
    - Excellent casting and forging properties
- Uses of Duralumin:
    - Aircraft and automobile parts
    - As bar, sheet, tubes and rivets
    - As light structure and extruded section

Y Alloy:

- Y alloy is a nickel containing aluminium alloy.
- It contained:
    - Cu 4.0 %
    - Mn 1.5 %
    - Ni 2.0 %
    - Al Balance
- Uses of Y alloy:
    - Piston
    - Forging components which require high strength at very high temperature

COPPER ALLOY:

- Copper possesses following properties
  - Excellent resistance to corrosion
  - Non-magnetic properties
  - It is ductile and malleable
  - High thermal and electrical conductivity
  - High resistance to fatigue
  - Very good machinability
- Copper used for following
  - Electrical parts
  - Heat exchanger
  - Household utensils
- Copper alloys may be classified as
  - High copper alloy
  - Brass
  - Bronze
  - Copper-Nickel
  - Leaded copper
  - Special alloy
  - Copper-Nickel-Zinc

BRASS:

- Brass contain zinc as principle alloying element
- It subdivided into three groups
  - Cu-Zn
  - Cu-Pb-Zn
  - Cu-Zn-Sn
- Zinc in the brass increase ductility along with strength
- Brass possesses greater strength than copper, however, it has a Lower thermal and electrical conductivity

BRONZE:

- Bronze is basically an alloy of copper and tin
- It possesses superior mechanical properties and corrosion resistance than brass
- It is comparatively hard and it resist surface wear
- These are subdivided into three group
  - Phosphor Bronze
  - Aluminium Bronze
  - Silicon Bronze

PHOSPHOR BRONZE:

- The most important copper-tin alloys are those which have been deoxidized with phosphorus during the refining process and hence are known as phosphor bronze
- Existence of phosphorus increase hardness and strength of the alloy, in exchange of ductility
- A phosphor bronze containing approximately 4 % each of tin, lead and zinc has excellent free cutting characteristics
- Standard Phosphor bronze contain
  - Cu 90%
  - Sn 10%
  - P 0.5%
- In sand cast condition it has a tensile strength of 220-280 N/mm^2 and %elongation 3-8%
- In general phosphor bronze
  - Has high strength and toughness
  - Is resistance to corrosion
  - Has good load bearing capacity
  - Has low coefficient of friction
- Phosphor bronze is used for
  - Bearing application
  - Making pump parts, lining, springs, diaphragms, gears, clutch discs, bellows

LEAD ALLOY:

- Lead alloy containing 8% to 10% Pb are used as bearing, cable sheaths, accumulation plates
- Lead glass refracts light strongly
- Bearing metals are lead and tin alloys for friction bearings. When antimony is added, they are known as babbit metals
- Lead-tin alloy containing 10 to 25% tin and rest lead is used as metallic coating for sheet iron for manufacturing containers

NICKEL ALLOYS:

- Various nickel alloys are:
  - Nickel-iron alloy
  - Nickel-copper alloy
  - Nickel-chromium alloy
  - Nickel-molybdenum alloy
  - Super alloy
- Invar is one of the nickel-iron alloy containing 40-50% nickel is characterized by an extremely low coefficient of thermal expansion
- Monel which is a nickel-copper alloy has a brighter appearance than nickel, is stronger and tougher than mild steel

- Super alloys are atleast five times as strong as steel. They withstand enormous strain and exhibit remarkable resistance to fatigue

ZINC ALLOY:

- It has slightly low melting point
- It has good resistance to corrosion
- It is soluble in copper
- It inherent ductility and malleability

P-22 AND P-91:

- P-22 contain:
  - C 0.05-0.15%
  - Mn 0.3-0.6%
  - P 0.025%
  - S 0.025%
  - Si 0.5%
  - Cr 1.9-2.6%
  - Mo 0.8-1%
- P-22 has
  - Yield strength 30ksi
  - Tensile strength 60ksi
  - Elongation 30%
- P-91 contain:
  - C 0.08-0.12%
  - Mn 0.3-0.6%
  - P 0.02%
  - S 0.01%
  - Si 0.2-0.5%
  - Cr 8-9%
  - Mo 0.85-1%
- P-91 has
  - Yield strength 60ksi
  - Tensile strength 85ksi
  - Elongation 20%

DUPLEX AND SUPER DUPLEX STAINLESS STEEL:

Duplex stainless steel	Super duplex stainless steel
It has around 22% chromium	It has around 25% chromium
It has pitting resistance equivalent number of 22 to 45	It has pitting resistance equivalent number of 38 to 45

UNIT-7

INTRODUCTION:

- Bearing support moving parts, such as shafts and spindles, of a machine or mechanism
- It may be classified as
  - Rolling contact bearing
  - Plain bearing
- Rolling contact bearings are almost invariable made of steel that can be hardened after machining

PROPERTIES:

- A bearing material should:
  - Possess low coefficient of friction
  - Provide hard, wear resistant surface with tough core
  - Have high compressive and fatigue strength
  - Be able to bear shocks and vibration
  - Possess high thermal conductivity
  - Possess resistance to corrosion
  - Possess anti-seizure characteristics
  - Have be cheap and easily available

TYPES OF BEARING MATERIAL:

- They are
  - Copper based alloy
  - Lead based alloy
  - Tin based alloy
  - Cadmium based alloy

Copper based alloy:

- Bronze is one of the oldest known bearing material
- Typical composition of bronze bearing are
  - Cu 80%
  - Sn 10%
  - Pb 10%
- Bronze
  - Is easily worked
  - Has good corrosion resistance
  - Is reasonably hard

- Copper based bearing used in machine and engine industry for bearing bushes made from thin walled drawn tube
- These are employed for making bearing required to resist heavier pressures such as in railway

Lead based alloy:

- Lead based alloy contain 80% of lead and 1-10% of tin
- Composition:
    - Pb 75%
    - Sb 15%
    - Sn 10%
- Lead based alloy are softer and brittle than the tin based alloy
- It is cheaper
- It possess good corrosion resistance and good conformability to journal
- Lead based alloys are suitable for light and medium loads
- It is used in rail roads and speed

Tin based alloy:

- Tin based alloy contain 80% of tin and little or no copper
- Composition:
    - Sn 88%
    - Sb 8%
    - Cu 4%
- Tin based alloys have low coefficient of friction as compared to copper based alloy
- These alloy possess good ability to embed dirt and very good seizure resistance
- Tin base alloys are preferred for higher loads and speed
- These are used in high speed engines, steam turbines

Cadmium based alloy:

- Composition:
    - Cd 95%
    - Ni 2%
    - Ag 1%
    - Cu 1.25%
    - Zn 0.75%
- These alloys are not popular because of high price
- These bearing possess greater compressive strength
- It also possess:
    - Low coefficient of friction
    - High fatigue strength
    - Low wear
    - Good seizure resistance

- High load carrying capacity
- Fair ability to embed dirt
- Poor corrosion resistance

- These alloys are tired in automobile sector and aircraft industry and good results were obtained

UNIT-8

INTRODUCTION:

- Spring store mechanical energy. Therefore the spring material remains under high tension stress
- In ideal spring the deviation from the rest position is directly proportional to the load it carries, even for high loads. After the load is removed, no matter after a long time, the ideal spring returns to its original position

TYPES:

- These are some commonly used spring material:
    - Iron based spring material
    - Copper based spring material
    - Nickel based spring material
    - Special spring material

Iron based spring material:

- Steel is usually the best choice as spring material
- A good steel spring possesses high
    - Modulus of elasticity
    - Elastic limit
    - Fatigue strength
    - Creep strength
    - Notch toughness
- Steel is used for making
    - Helical spring
    - Plate spring
    - Leaf spring
    - Torsional spring
    - Cone spring
- Steel piano wire
    - Composition:
        - C 0.7-1.0%
        - Fe 98.5%
        - Mn 0.3-0.6%
    - Uses:
        - Small sized helical spring
- Cr-V spring steel
    - Composition:
        - C 0.5%

        - Mn 0.8-1.1%
        - Cr 0.2-0.9%
        - V 0.07-0.12%
        - Fe 97.8%
    - Uses:
        - Engine
        - Railway carriages
        - Automotive valves
- Stainless steel:
    - Composition:
        - Cr 18%
        - Ni 8%
        - C 0.1-0.2%
        - Fe 73.8%
    - Uses:
        - Valve springs in flow meters

Copper based spring material:

- They possess
    - High electrical conductivity
    - Good resistance to corrosion
    - Lack of magnetic properties
- Phosphor bronze:
    - Composition:
        - Cu 92%
        - Sn 8%
    - Uses:
        - High quality springs for switches, relays, contacts
- Brass:
    - Composition:
        - Cu 67%
        - Zn 33%
    - Uses:
        - Switches and contacts
- Nickel silver:
    - Composition:
        - Cu 56%
        - Ni 18%
        - Zn 25%
    - Uses:
        - Better switches and contacts than brass

UNIT-9

Introduction:-

- A polymer is a large molecule or macromolecule which essentially is a combination of many smaller units of molecule
- Normally we can get two types of polymer such as naturally occurring polymers and synthetic organic polymer
- Characteristics:-
    - Low density
    - Good corrosion resistance
    - Low coefficient of friction
    - Poor tensile strength
    - Poor temperature resistance
    - Low mechanical resistance
    - Can be produced with close dimensional tolerance
    - Excellent surface finish can be obtained
- Classification:-
    - Thermoplasts
    - Thermosets

Thermoplast:-

- It soften when heated and harden when cooled
- So it can be remolded
- On molecular level, as the temperature is raised, secondary bonding forces are diminished so that the relative movement of adjacent chains is facilitated when a stress is applied
- Irreversible degradation results when the temperature of a molten thermoplastic polymer is raised to a point at which molecular vibrations become violent enough to break the primary covalent bonds
- Properties:-
    - Low melting point
    - Soft
    - Ductile
    - Economical
- Example:-
    - Polyvinyl chloride(plastic wall and floor tile)
    - Polystyrene(fluorescent light reflector)
    - Polymethyl methacrylate(plastic lences)

Thermoset:-

- It soft during their first heating and become permanently hard when cooled
- So it cannot be remolded
- If heated to excessive temperature, the polymer degradation takes place
- Properties:-
  - Harder
  - Brittle
  - Better dimensional stability
  - High temperature resistance
- Example:-
  - Bakelite
  - Vulcanized Rubber
  - Polyester

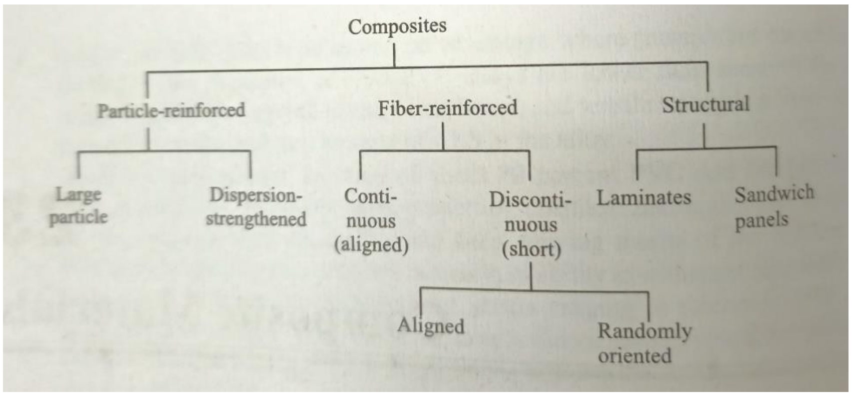
Elastomer:-

- An elastomer is a polymeric material that may experience large and reversible elastic deformation
- These are commonly known as rubber
- Characteristics:-
  - Non-crystalline
  - Non-conductor of electricity and heat
  - High resistance to chemical and corrosion
  - Low softening temperature
- Properties:-
  - Hardness
  - High Tensile strength
  - Low Tear resistance
  - High resilience
  - Resistance to abrasion
  - Resistance to friction
- Types of elastomer
  - Natural rubber
  - Styrene butadiene rubber
  - Chloroprene
  - Isobutylene-Isoprene
  - Isoprene
  - Polyacrylate
  - Nitrile butadiene
  - Polybutadiene

UNIT-10

Composite:-

- Composite materials are produced by combining two dissimilar materials into a new material that may be better suited for a particular application than either of the original material alone
- Example:-fiberglass, reinforced plastic
- Classification:-



Particle reinforced composites:-

- The dispersed phase for particle reinforced composites is equiaxed

Large particle composites:-

- In this type of composite, particle interaction cannot be treated at atomic or molecular level
- Examples:-polymeric materials with fillers, concrete
- The particles should be approximately the same dimension in all directions and should be small and evenly distributed. So that the mechanical properties are enhanced with increasing particulate content
- Both elastomers and plastics are frequently reinforced with various particulate materials. Example :- Carbon black
- These type of composite contain enhanced tensile strength, toughness, tear and abrasion resistance

Dispersion strengthened composites:-

- In this type of composite, particle interaction treated at molecular level
- Examples:-thoria dispersed nickel and sintered aluminium powder
- These type of composites are very hard in nature

Fiber reinforced composites:-

- The most important composites are those in which the dispersed phase is in form of a fiber

- Basic characteristics of these composites are specific strength and specific modulus
- Some critical fiber length is necessary for effective strengthening and stiffening of the composite material

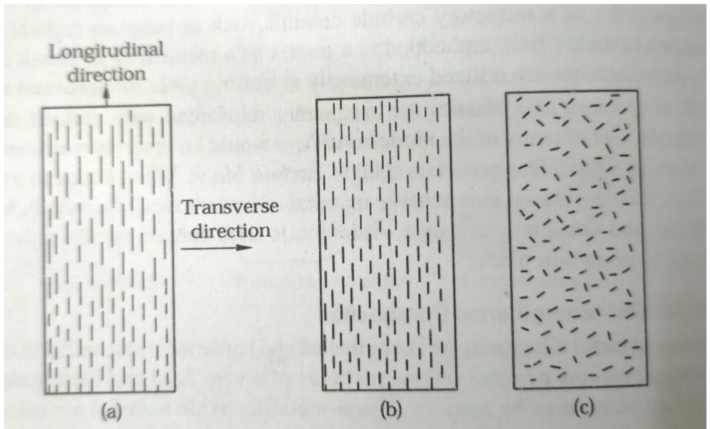
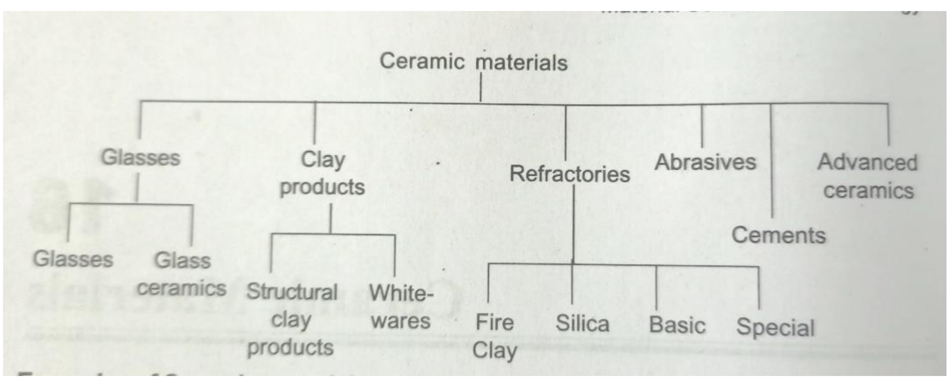


Fig. 23.2 Schematic representations of (*a*) continuous and aligned, (*b*) discontinuous and aligned; and (*c*) discontinuous and randomly oriented fiber-reinforced composites

Ceramics:-

- Ceramics are inorganic, non-metallic materials that are processed and used at high temperatures
- They are brittle materials that withstand compression but do not hold up well under tension
- They are abrasive resistant, heat resistant
- Ceramics are chemically inert
- Types of ceramics



- Uses:-
  - Brick and concrete saws
  - Used for sand paper
  - Used for cleaning aircraft engine parts
  - Used as a refractory material
  - Floor sanding machines