Lecture Notes

on

Engineering Material

(Th.3)

3rd Semester, Mechanical Engg.

Prepared by

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ENGINEERING MATERIALS

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CLASS-01

INTRODUCTION

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WHAT WE ARE GOING TO COVER IN ENGG. MATERIALS….?

1.0 Engineering materials and their properties
- 1.1 Material classification into ferrous and non ferrous category and alloys
- 1.2 Properties of Materials: Physical , Chemical and Mechanical
- 1.3 Performance requirements
- 1.4 Material reliability and safety

2.0 Ferrous Materials and alloys
- 2.1 Characteristics and application of ferrous materials
- 2.2 Classification, composition and application of low carbon steel, medium carbon steel and High carbon steel
- 2.3 Alloy steel: Low alloy steel, high alloy steel, tool steel and stainless steel
- 2.4 Tool steel: Effect of various alloying elements such as Cr, Mn, Ni, V, Mo,

3.0 Iron – Carbon system
- 3.1 Concept of phase diagram and cooling curves
- 3.2 Features of Iron-Carbon diagram with salient micro-constituents of Iron and Steel

WHAT WE ARE GOING TO COVER IN ENGG. MATERIALS….?

4.0 Crystal imperfections

- 4.1 Crystal defines, classification of crystals, ideal crystal and crystal imperfections
- 4.2 Classification of imperfection: Point defects, line defects, surface defects and volume defects
- 4.3 Types and causes of point defects: Vacancies, Interstitials and impurities
- 4.4 Types and causes of line defects: Edge dislocation and screw dislocation
- 4.5 Effect of imperfection on material properties
- 4.6 Deformation by slip and twinning
- 4.7 Effect of deformation on material properties

5.0 Heat Treatment

- 5.1 Purpose of Heat treatment
- 5.2 Process of heat treatment: Annealing, normalizing, hardening, tampering, stress relieving measures
- 5.3 Surface hardening: Carburizing and Nitriding
- 5.4 Effect of heat treatment on properties of steel
- 5.5 Hardenability of steel

WHAT WE ARE GOING TO COVER IN ENGG. MATERIALS….?

6.0 Non-ferrous alloys

- 6.1 Aluminum alloys: Composition, property and usage of Duralmin, y- alloy.
- 6.2 Copper alloys: Composition, property and usage of Copper-Aluminum, Copper-Tin, Babbit , Phosperous bronze, brass, Copper- Nickel
- 6.3 Predominating elements of lead alloys, Zinc alloys and Nickel alloys
- 6.4 Low alloy materials like P-91, P-22 for power plants and other high temperature services. High alloy materials like stainless steel grades of duplex, super duplex materials etc.

7.0 Bearing Material

- 7.1 Classification, composition, properties and uses of Copper base, Tin Base, Lead base, Cadmium base bearing materials

WHAT WE ARE GOING TO COVER IN ENGG. MATERIALS….?

8.0 Spring materials

- 8.1 Classification, composition, properties and uses of Iron-base and Copper base spring material

9.0 Polymers

- 9.1 Properties and application of thermosetting and thermoplastic polymers
- 9.2 Properties of elastomers

10.0 Composites and Ceramics

- 10.1 Classification, composition, properties and uses of particulate based and fiber reinforced composites
- 10.2 Classification and uses of ceramics

Sl. No.	Author	Title of the book	Publisher
01	O P Khanna	A Textbook of Material Science and Metallurgy	Dhantpat Rai
02	R K Rajput	Engineering materials and Metallurgy	S.Chand
03	S K Hazra choudhry	Material science & process	Imdian Book Distrubuting

THANK YOU

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CHAPTER-01:
ENGINEERING MATERIALS AND THEIR PROPERTIES

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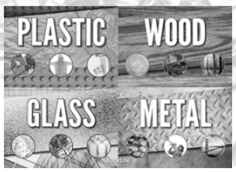
WHY ENGG. MATERIALS….?

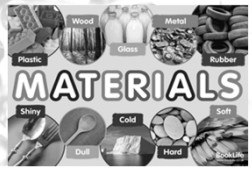
- Engineering materials always continue to play a significant role in the current and upcoming future world.
- The relevant factors that will influence this are economic/cost, environmental requirements, development trends, depletion of traditional materials, advances in research and market drives, etc.
- The importance of engineering materials is in every aspect of life, therefore, need to be over emphasized.
- We ourselves are materials and so also is everything around us; to stop talking of and working with materials is to foreclose the essence of life existence.
- So a bright future is that of even more sophisticated, better and cost effective materials. Materials Science, Technology and Engineering of Materials has the capability of solving problems in different sectors of life & the economy.
- Therefore smart nations are quickly creating areas for themselves by developing materials of both comparative and competitive advantage as required.

WHAT IS MATERIAL/ENGG. MATERIALS ….?

- It is a substance consisting matter.
- Out of this matter any required thing can be made.
- **Materials** that are used as raw **material** for any sort of construction or manufacturing in an organized way of **engineering** application are known as **Engineering Materials**.
- All the materials that one sees around, which can be cut, bent, moulded or shaped to form a engineering structure are called engineering materials..

e.g., stones, wood, iron, aluminium, plastic and cement to name a few..

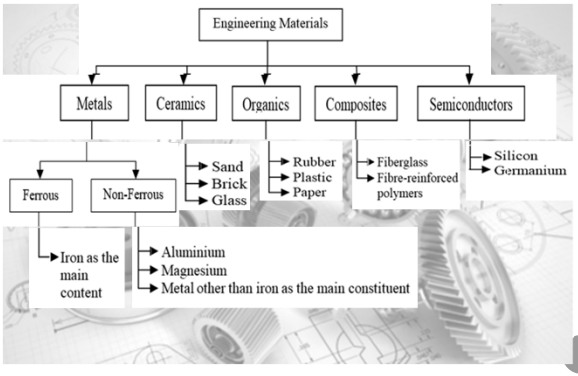




WHAT IS MATERIAL SCIENCE….?

- It deals with the physical and chemical properties of the internal structure of materials.
- Material science investigates the inter-relationships between the material structure and their properties.
- It enhances the inter-disciplinary study between the engineering materials and their practical applications.
- This science includes study of all the materials.

CLASSIFICATION OF ENGINEERING MATERIALS



PROPERTIES OF MATERIALS

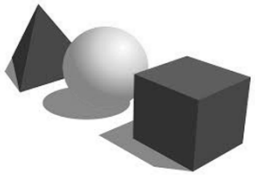
Physical Properties:

These are the properties described in the field of physics. This is in a view to describe a material under different conditions in which external forces are not considered. Some of the properties are listed below.

- ***Dimensions*** *– It implies a material's shape and size*

Size: such as length, breadth, width, diameter etc.

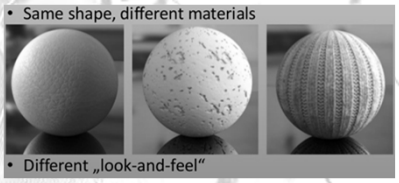
Shape: of different sections such as square, circular, I, channel, angle etc.



PROPERTIES OF MATERIALS

Appearance -

- A material's appearance depends upon its luxture, color and finish. In a simpler way line marks on the surface.
- The ability of a material to reflect light when polished finely is known as luxture. In general it is the brightness of a surface.
- E.g. Cast Iron has a sandy structure, Wrought Iron shows red scaly whereas Mild Steel as a smooth surface finish with bluish black surface.



PROPERTIES OF MATERIALS

Colour -

- It is that aspect of appearance of a material that depends on the spectral composition of the light reaching the retina of the eyes, and on the light's temperal and spatial distribution.
- The material's color depends upon the wavelength of the light that the material can absorb.

Material	Colour
Aluminium (Al)	White
Copper (Cu)	Reddish
Iron (Fe)	Grey
Zinc (Zn)	Bluish White

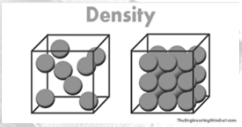
PROPERTIES OF MATERIALS

Density -

- The weight of unit volume of a material is known as density.
- The density of a substance depends on its purity, pore volume and the treatment received by it.
- Even-though the materials have same shape, density helps in differentiating light and heavy materials.

Melting Point -

- The temperature at which the material changes from solid state to liquid state is referred to melting point of the material.
- Materials can be distinguished from one another on the basis of their melting point.



PROPERTIES OF MATERIALS

Electrical Conductivity:-

- A material's offering to very little resistance to the flow of electrons (electric current) through it (the wire).
- A plastic materials such as polymerized has been chosen for the insulating sheathing surrounding the wire conductor.

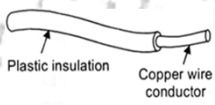


FIGURE : Electrical conductivity.

Thermal Conductivity

- This is the ability of the material to transmit heat energy by conduction.
- The bit is made from copper which is a good conductor of heat and so will allow the heat energy stored in it to and the wooden handle remains cool as it has a low thermal conductivity and resists the flow of heat energy.

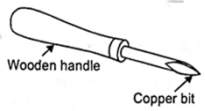


FIGURE : Thermal conductivity.

PROPERTIES OF MATERIALS

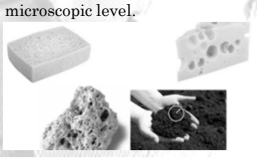
Porosity -

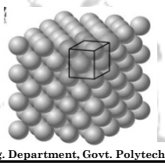
- If a material has pores within it, it is said to be porous.
- It can absorb lubricant as in case of a sintered self-lubricating bearing.

$$True\ Porosity = \frac{Total\ Pore\ Volume}{Total\ Bulk\ Volume}$$

Structure -

- The geometric relationships of material components represent structure of a material.
- It gives a detailed view in the arrangement of the internal components of matter. This may be electron structure in subatomic level / crystal structure in atomic level / microstructure in microscopic level.

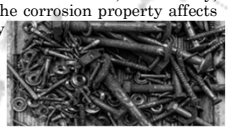




PROPERTIES OF MATERIALS

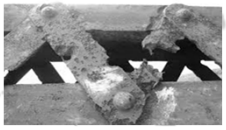
Chemical Properties:

Most of the engineering materials, when come in contact with other substances tend to suffer from chemical deterioration. This indicates the reactiveness of materials with other substances. The major chemical properties that can affect the material are corrosion, chemical composition, acidity or alkalinity etc. These properties describe the tendency of combination, corrosion characteristics, reactivity, solubilities etc. of a substance. Out of all the corrosion property affects the material most which is discussed briefly below.



Corrosion -

- It is the deterioration of a material by chemical reaction with its environment is known as corrosion.
- This results in the degradation of the material properties which leads to the reduction in economic value of the material.
- It affects metals as well as non-metals.

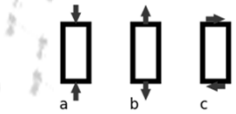


PROPERTIES OF MATERIALS

Mechanical Properties

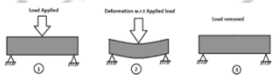
Strength:-

It is the property of a material which opposes the deformation or breakdown of material in presence of external forces or load.



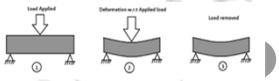
Elasticity:-

It is the ability of a material to deform under load and return to its original size and shape when the load is removed.



Plasticity:-

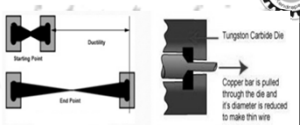
It is the state of a material which has been loaded beyond it elastic limit so as to cause the material to deform permanently.



PROPERTIES OF MATERIALS

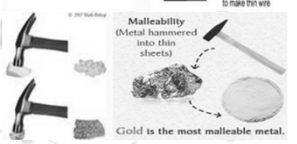
Ductility:-

- Ductility is a property of a solid material which indicates that how easily a material gets deformed under tensile stress.
- It is often categorized by the ability of material to get stretched into a wire by pulling or drawing



Malleability:-

- It is a property of solid materials which indicates that how easily a material gets deformed under compressive stress.
- It is often categorized by the ability of material to be formed in the form of a thin sheet by hammering or rolling.



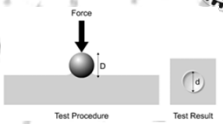
Brittleness:-

It is the property of a material that shows little or no plastic deformation before fracture when a force is applied.

PROPERTIES OF MATERIALS

Hardness:-

It is the ability of a material to withstand scratching (abrasion) or indentation by another hard body, it is an indication of the wear resistance of the material.



Toughness:-

It is the ability of a material to absorb the energy and gets plastically deformed without fracturing.

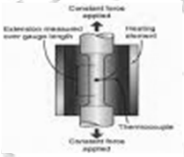
Resilience :-

It is the ability of material to absorb the energy when it is deformed elastically by applying stress and release the energy when stress is removed.

PROPERTIES OF MATERIALS

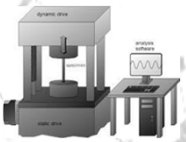
Creep:-

When a metal part when is subjected to a high constant stress at high temperature for a longer period, it will undergo a slow and permanent deformation (in the form of a crack which may further propagate towards creep failure) called creep.



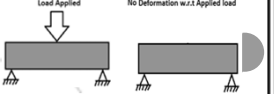
Fatigue:-

The behavior of materials under fluctuating and reversing loads (or stresses) is termed as fatigue.



Stiffness :-

It is the measure of a material's ability not to deflect under an applied load.



PROPERTIES OF MATERIALS

Performance Requirements:

- The material of which a part is composed must be capable of performing a part's function without failure. e.g. a component part to be used in a furnace must be of that material which can withstand high temperatures.
- When quantitative values can't be assigned to these functional requirements, they must be related as precisely as possible to specified values of the most closely applicable mechanical, physical, electrical or thermal properties.

Material's Reliability:

- For a given application a material must be reliable.
- Material science investigates the inter-relationships between the material structure and their properties.
- It enhances the inter-disciplinary study between the engineering materials and their practical applications.

Safety:

- A material must safely perform its function; otherwise the failure of the product made out of it may be catastrophic in air-planes & high-pressure systems.
- E.g. materials that give off sparks when struck are safety hazards in a coal mine.

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CHAPTER-02:

FERROUS MATERIALS AND ALLOYS

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FERROUS MATERIALS

Ferrous Materials :

- These materials contain **iron** which is the most important metals or alloys in the mechanical and metallurgical industries because of their extensive use.
- The ferrous materials particularly Iron is accounted for the factors like ease of availability in the earth's crust, relatively economical extraction, refining, alloying and fabrication technique.

FERROUS MATERIALS

Characteristics of Materials :

- are metals/metal alloys that contain the iron as a base material
- are good conductors of heat and electricity
- metal alloys have high resistance to shear, torque and deformation
- the thermal conductivity of metal is useful for containers to heat materials over a flame
- ferrous alloys are extremely versatile, in that they may be tailored to have a wide range of mechanical and physical properties
- the principal disadvantage of many ferrous alloys is their susceptibility to corrosion.

Applications :

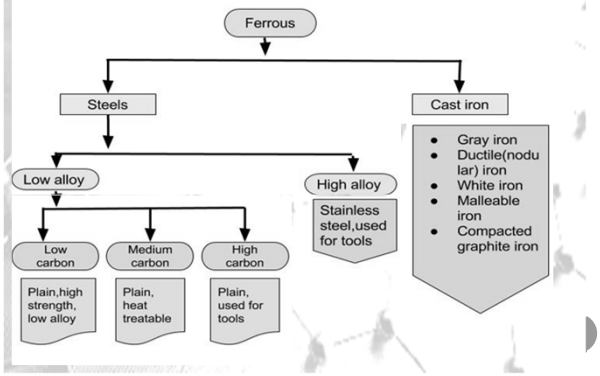
- due to strength and resilience, these are frequently used in high-rise building and bridge construction, most vehicles, many appliances, tools, pipes, railway tracks etc.
- corrosion resistance property makes them useful in food processing plants, e.g. steel.
- cast iron is brittle and strong and has high compressive strength. so used in castings if manhole covers, engine body, machine base etc.
- mild steel is soft, ductile and has high tensile strength. so used in general metal products like structural, workshop, household furniture etc.
- due to their hardness, strength and corrosion resistance properties carbon steels are used for cutting tools.

FERROUS MATERIALS

Applications of Ferrous Materials

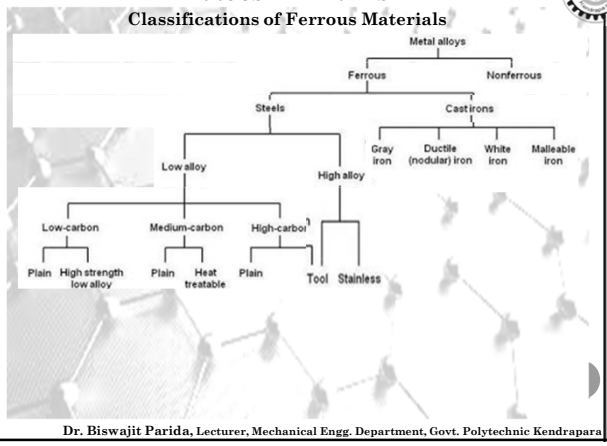
FERROUS MATERIALS

Classifications of Ferrous Materials



FERROUS MATERIALS

Classifications of Ferrous Materials



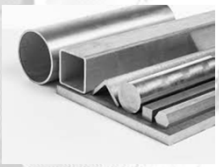
FERROUS MATERIALS

Steel:

- It is an alloy of **Iron** and **Carbon** but may contain other alloying elements.
- The carbon content is to upto **2 %** .

Cast iron:

- more carbon content than Steel i.e. **2 %** to **6.67 %**
- lowest melting point about 300 ° C lower than pure iron.
- different types are: Grey, white, nodular, malleable etc.



STEEL

Carbon Steel:

- Plain Carbon Steel is an alloy of iron and carbon with carbon content up to 1.5% although other elements such as Silicon, Manganese may be present.
- The properties of carbon steel are mainly due to its carbon content.
- Carbon Steel is classified into
  - i) Low carbon steel or Mild steel
  - ii) Medium carbon steel
  - iii) High carbon steel

i) Low carbon steel or Mild steel:

- contains carbon in the range from 0 to 0.3 %
- most abundant grade of Steel (higher produced quantity and least expensive)
- not responsive to heat treatment
- cold working needed to improve the strength
- has good weldability and machinability
- used in making steel pipe,

fan blades, gears, crankshafts, connecting rods etc.

STEEL (CONTD…)

ii) Medium carbon steel:

- contains carbon in the range from 0.3 to 0.7 %
- can be heat treated surcharge austenizing quenching and then tempering but oftenly used in tempered condition
- Chromium, Nickel, Molybdenum can be added to improve heat treating capacity
- medium carbon steels have low hardenability, higher strength but lower ductility
- used in connecting rod, gear shafts, axles, crankshafts, clutch disc, valve springs etc.



STEEL (CONTD…)

iii) High carbon steel:

- contains carbon in the range from 0.7 to 1.5 %
- high carbon content produces hardness and strength but makes least ductile
- used in hardened and tempered condition
- strong carbide formers like Cr, V, W are added as alloying elements to form carbides of these metals
- used in making cold chisels, wrenches, hack saw, circular saw, punches and dies, files, taps, twist drills etc.



STEEL (CONTD…)

Alloy steel:

- Steel is considered to be alloy steel when the maximum of the range given for the content of alloying element exceeds one or more of the following limits.

  Mn-1.65%, Si-0.6%, Cu-0.6%

- or in which a definite maximum quantity of any of the following elements is specified.

  Al, B, Cr up to 3.99%,

  Cu, Mo, Ni,Ti, W, V or any other alloying element added to obtain a desired alloying effect.

i) Low and medium alloy steel:

- In low and medium alloy steel alloying element is not exceeding 10%.

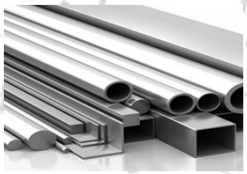
STEEL (CONTD…)

ii) High alloy steel:

- In high alloy steel, total alloying element is more than 10%.

For example: X10 Cr 18 Ni 9 S3

X- High alloy steel
10 %- 0.1 %C
Cr18 – 18 % Cr
Ni 9 – 9 % Ni
S 3 – Pickled condition.



Stainless Steel:

- When 11.5% or more chromium is added to iron, a fine film of chromium oxide forms spontaneously on the surfaces.
- The film acts as a barrier to retard further oxidation, rust or corrosion.
- As this steel cannot be stained easily, it is called stainless steel.
- The stainless steel basing on their micro-structure can be grouped in to three metallurgical classes such as Austenitic stainless steel, Ferritic stainless steel & Martensite stainless steel.
- Stainless steel differs from carbon steel by the amount of chromium present.

STAINLESS STEEL (CONTD…)

i) Austenitic Stainless Steel:

C - 0.03 to 0.25%, Mn - 2 to 10%, Si - 1 to 2%

Cr - 16 to 26%, Ni - 3.5 to 22%,

P & S Normal, Mo & Ti in some cases

Properties

- They possess austenitic structure at room temperature.
- They possess the highest corrosion resistance of all the stainless steels.
- They possess greatest strength and scale resistance at high temperature.
- They retain ductility at temperature approaching absolute zero.
- They are non-magnetic.

Uses

- Aircraft industry (Engine parts)
- Chemical processing (heat exchangers)
- Food processing (Kettles, tanks)
- Household items (cooking utensils)
- Dairy industries (milk cans)
- Transportation industry (Trailers & railways cars)

STAINLESS STEEL (CONTD…)

ii) Ferritic Stainless Steel:

C - 0.08 to 0.20%, Si - 1%, Mn - 1 to 1.5%, Cr – 11 to 27%

Properties

- They posses a microstructure which is primarily ferritic.
- They are magnetic & have good ductility
- They do not work harden to any appreciable degree.
- They are more corrosion resistant than martensitic steel.
- They develop their maximum softness, ductility & corrosion resistance in the annealed condition.

Uses

- Heating elements for furnaces.
- Interior decorative work.
- Screws & fittings.
- Oil burner parts.

STAINLESS STEEL (CONTD…)

iii) Martensitic Stainless Steel:

C - 0.15 to 1.2%, Si - 1%, Mn - 1%, Cr - 11.5 to 18%

Properties

- They posses martensitic microstructure.
- They are magnetic in all condition & possess the best thermal conductivity of the stainless types.
- Hardness, ductility & ability to hold an edge are characteristics of martensitic steels.
- They can be cold worked without difficulty, especially with low carbon content, can be machined satisfactorily.
- They have good toughness.
- They have good corrosion resistance to weather and to some chemicals.
- They are easily hot worked.

Uses

- Pumps & valve parts
- Rules & tapes
- Turbine buckets
- Surgical instruments, etc.

TOOL STEEL

- Tool steel may be defined as special steel which are used to form, cut or otherwise change the shape of a material in to finished or semi-finished product.
- Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools.
- Their suitability comes from their distinctive hardness, resistance to abrasion, their ability to hold a cutting edge, and/or their resistance to deformation at elevated temperatures.

- Tool steel is generally used in a heat-treated state.
- Many high carbon tool steels are also more resistant to corrosion due to their higher ratios of elements such as vanadium.
- With a carbon content between 0.7% and 1.5%, tool steels are manufactured under carefully controlled conditions to produce the required quality.

TOOL STEEL (CONTD…)

Properties

- Little risk of cracking during hardening.
- Good toughness
- Good wear resistance
- Very good machinability
- A definite cooling rate during hardening
- A definite hardening temperature
- Resistance to softening on heating

Classification

Symbol	Meaning
T	W-High speed steel
M	Mo-High speed steel
D	High C, high Cr steel
A	Air hardening steel
O	Oil hardening steel
W	Water hardening steel
H	Hot work steel
S	Shock resistance steel

Composition

W-High speed steel

T:	C 0.7	Cr 4	V 1	W 18	
T:	C 0.75	Cr 4	V 1	W 18	Co 5
T:	C 0.8	Cr 4.5	V 1.5	W 20	Co 12

High C, high Cr steel

D:	C 1.5	Cr 12	Mo 1	
D:	C 1.5	Cr 12	Mo 1	Co 3
D:	C 2.35	Cr 12	V 4	Mo 1

Hot work steel

H:	C 0.4	Cr 3.25	V 0.4	Mo 2.5
H:	C 0.35	Cr 5	V 0.4	W 1.5 Mo 1.5

Shock resistance steel

S:	C 0.5	Cr 1.5	W 2.5	
S:	C 0.5	Si 1	Mo 0.4	
S:	C 0.55	Mn 0.8	Si 2	Mo 0.4
S:	C 0.5	Cr 3.25	Mo 1.4	

Effect of Alloying Elements

Chromium:

It joins with carbon to form chromium carbide, thus adds to depth hardenability with improved resistance to abrasion & wear.

Manganese:

- It contributes markedly to strength and hardness.
- It counteracts brittleness from Sulphur.
- Lowers both ductility & weldability if it is present in high percentage with high carbon content in steel.

Nickel:

- increases toughness & resistance to impact.
- lessens distortion in quenching.
- Lowers the critical temperatures of steel & widens the range of successful heat treatment.
- strengthens steels.
- renders high-chromium iron alloys austenitic.
- does not unite with carbon..

Effect of Alloying Elements

Vanadium:

- promotes fine grains in steel.
- increases hardenability.
- imparts strength & toughness to heat-treated steel

Molybdenum:

- promotes hardenability of steel.
- makes steel fine grained.
- makes steel unusually tough at various hardness levels.
- counteracts tendency towards temper brittleness.
- raises tensile & creep strength at high temperatures.
- enhances corrosion resistance in stainless steels.
- forms abrasion resisting particles

Tungsten:

- increases hardness.
- promotes fine grains.
- resists heat.
- promotes strength at elevated temperature.

Thank You

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CHAPTER-03:

IRON – CARBON SYSTEM

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PHASE DIAGRAM

Phase: In an alloy system the components may combine (within a certain temperature range) to form two homogenous co-existing portions each having different compositions and properties and these homogenous, physically distinct portions of the system are called phases.

System: A system is a substance (or group of substances) so isolated from its surroundings that it is unaffected by these and is subjected to changes in overall composition, temperature, pressure or total volume only to the extent allowed by the investigator.

Phase Diagram

- Also known as equilibrium diagram or constitutional diagram which shows the limits of composition and temperature within which the various constituents or phases of an alloy are stable.
- Equilibrium refers to the state of balance which exists or which tends to be attained, between the phases in the structure of an alloy after a physical or chemical change has taken place.
- It shows the relationship between the composition, temperature and structure of an alloy in series.
- Provides with the knowledge of phase compositions and phase stability as a function of temperature, pressure and composition.
- permits to study and control processes such as phase separation, solidification of metals and alloys, purification of materials and the structural changes produced by heat treatment, casting etc.
- Three types such as unary or one component phase diagram, Binary or two component phase diagram and tertiary or three component phase diagram.

PHASE DIAGRAM (CONTD…)

- Iron in bcc structure, *f*cc structure, in liquid form and in gaseous state are different phases of iron.
- In one component materials a phase is stable over a range of temperature and pressure.
- A homogeneous solution of two or more components that may exists over a range of composition, temperature and pressure is considered as the same phase.

The phase rule can be started as ***f* = C - P + 2, - Gibbs phase rule**

Where, C - is number of components in the system;
P - is number of phases in equilibrium,
2 - represents temperature and pressure as independent variables,
f - is **Degree of Freedom -** It is the maximum number of variables that may be independently varied without changing the number of phases in equilibrium.

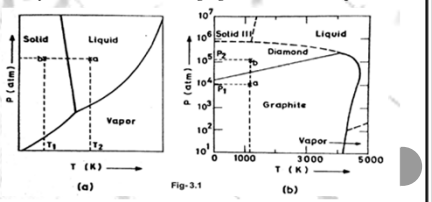


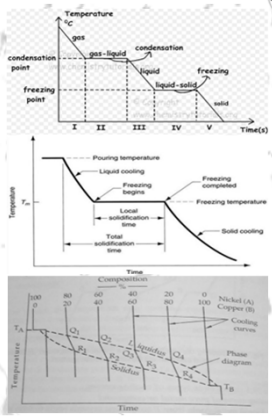
Fig-3.1

Chapter-03: Iron-C System

COOLING CURVES

- A method, to determine the temperatures at which phase changes occur in an alloy system, consists of the temperature as a function of time as different alloys in the system are very slowly cooled.
- The cooling curve is useful in studying the changes that occur during the solidification of alloys.
- In some instances determining transformations subsequent to solidification.
- Liquidus is that line above which the alloy is in liquid state and where solidification starts.
- Solidus is that line above which the alloy is in solid state and where solidification completes.

(Solid ⇄ Liquid)



Chapter-03: Iron-C System

IRON-CARBON DIAGRAM

- This diagram indicates the phase changes that occur during heating and cooling and the nature and amount of structural components that exist at any temperature.
- The diagram is constructed by plotting temperature along the y-axis and % composition of the alloy along the x-axis.
- This diagram shown ranges of temperatures and compositions within which the various phase changes are stable and also the boundary each at which the phase changes occur.
- It establishes 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.

Hypo-eutectoid Steels - 0.008 to 0.8 % C

Hyper-eutectoid Steels - 0.8 to 2 % C

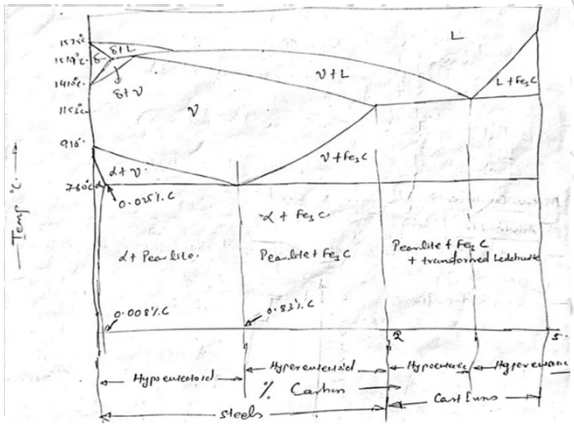
Hypo-eutectic Cast Iron - 2 to 4.3 % C

Hyper-eutectic Cast Iron - > 4.3 % C

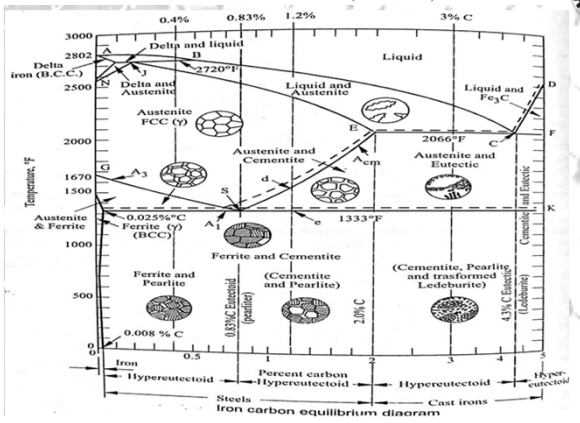
α – Ferrite – BCC structure.
γ – Austenite – FCC structure.
δ – BCC structure
L – Liquid.
Fe_3C – Cementite / Graphite.

Chapter-03: Iron-C System

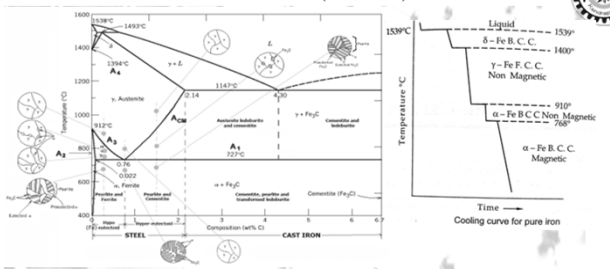
FE-C DIAGRAM (CONTD…)



IRON-CARBON DIAGRAM (CONTD…)



IRON-C DIAGRAM (CONTD…)



$$\text{Delta } (\delta) + \text{Liquid} \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \text{Austenite}$$

$$\text{Liquid} \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \underbrace{\text{Austenite} + \text{Cementite}}_{\text{Eutectic mixture (Ledeburite)}}$$

$$\text{Solid} \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \underbrace{\text{Ferrite} + \text{Cementite}}_{\text{Eutectic mixture (pearlite)}}$$

IRON-C DIAGRAM (CONTD…)

Micro-constituents of Iron and Steel

a) Austenite:

- is the solid solution of carbon and other alloying elements in Gamma (γ) iron
- can dissolve maximum 2% of carbon at 1165 °C.
- is non magnetic and soft.
- has tensile strength of 10,500 Kg/cm2, elongation of 10% in 50 mm and hardness RC 40.


Austenite

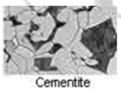
b) Ferrite:

- is BCC Iron phase with very limited solubility of maximum 0.025 % carbon at 740 °C.
- It is the softest structure on the Fe-C equilibrium diagram.
- Tensile strength of 2,800 Kg/cm2, elongation of 40% in 50 mm, hardness less than RB90.


Ferrite

c) Cementite:

- otherwise known as iron carbide (Fe_3C) and contains 6.67 % of carbon by weight
- is a hard and brittle compound of low tensile strength (approximately 350 Kg/cm2) but high compressive strength.
- is the hardest structure in the Fe-C diagram and having orthorhombic crystal structure


Cementite

IRON-C DIAGRAM (CONTD…)

d) Pearlite :
- is the product of austenite decomposition by an eutectoid reaction and consists of a ferrite and cementite.
- is an eutectoid mixture containing 0.8 % of C and is formed at 723 ºC.
- it has an elongation of 20% in 50 mm and RC 20.

e) Ledeburite :
- is the eutectic mixture of austenite and cementite and contains for 4.3 % of carbon
- it is formed at about 1130 ºC

f) Bainite:
- is a decomposition product of austenite, consisting of an aggregate of ferrite and carbide.
- it is an isothermal transformation product and cannot be produced by continuous cooling.

g) Martensite:
- is a solid solution of carbon in α-iron and has a body centered tetragonal lattice structure.
- is a product of quenching and possesses an acicular cooler or needle like structure.

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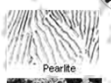

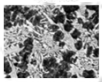


THANK YOU

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CHAPTER-04:

CRYSTAL IMPERFECTIONS

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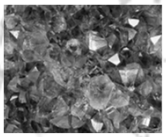
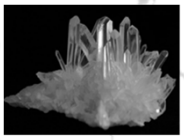
CRYSTALLOGRAPHY

Crystallography :
is that branch of science in which internal structure of crystals, their properties external or internal symmetries of crystals are studied.

Crystal:

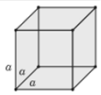
- Is a solid whose constituent atoms or molecules are arranged in a systematic geometric pattern.
- A perfect crystal is constructed by the infinite regular repitation in space of identical structural units or building blocks.
- the symmetry is an important characteristics of most of the crystals, e.g. cube and octahedrons are simple forms of the crystal.
- the **structure** implies the arrangement and deposition of the atoms within a crystal.
- the atoms arrange themselves in distinct pattern in space called a **space lattice**.
- the **unit cell** is the smallest group of atoms possessing the symmetry of the crystal.
- the layers of atoms or the planes along which atoms are arranged are known as **atomic or crystallographic planes**.



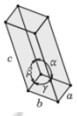


CLASSIFICATION OF CRYSTAL

On the basis of periodic arrangement of atoms, crystals are grouped into seven systems.

Crystal System	*Axial Relationships*	*Interaxial Angles*	*Unit Cell Geometry*
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90°$	
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90°, \gamma = 120°$	
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$	

CLASSIFICATION OF CRYSTAL (CONTD…)

Crystal System	*Axial Relationships*	*Interaxial Angles*	*Unit Cell Geometry*
Rhombohedral (Trigonal)	$a = b = c$	$\alpha = \beta = \gamma \neq 90°$	
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$	
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90° \neq \beta$	
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$	

CLASSIFICATION OF CRYSTAL (CONTD…)

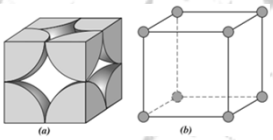
In the present context only cubic and hexagonal crystal structures are considered as most of the metals and alloys belong to these two systems.

In general four types of Crystal structures are used

i) Simple Cubic structure (SC):

A simple cubic unit cell has one atom each at all the corners.

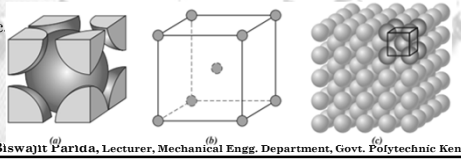
Ex:- Polonium



ii) Body Centred Cubic structure (BCC):

A BCC unit cell has one atom in the centre of the cube and one atom each at all the corners.

Ex:- Cr, V, Mo, Mn etc

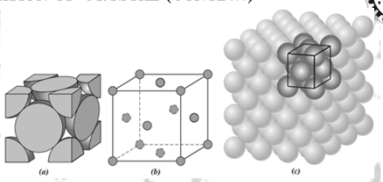


CLASSIFICATION OF CRYSTAL (CONTD…)

iii) Face Centred Cubic structure (FCC):

A FCC cube has an atom at each corner of the cube and in addition one atom are the intersection of the diagonals of each of the six faces of the cube.

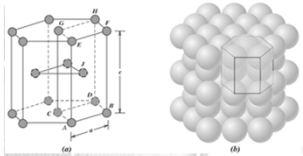
Ex:- Cu, Al, Ni, Co etc.



iv) Hexagonal Close Packed structure (HCP):

HCP structure has one atom at each corner of hexagon one atom at the centre of the two hexagonal faces one atom at the centre of the line connecting the perpendiculars in case of three rhombus.

Ex:- Cd, Be, Mg, Zn etc.

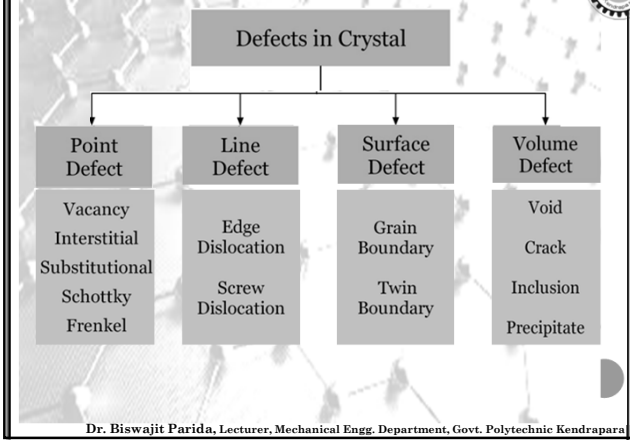


Ideal Crystals :- In an ideal crystal the atomic arrangement is perfectly regular and continuous throughout and it is perfect.

CRYSTAL IMPERFECTIONS

- Real crystals are never perfect, lattice distortion and various imperfections, irregularities or defects are generally present in them
- All crystals are not composed of identical atoms or identical sites throughout a regularly repeating 3D lattice.
- Because of these defects, there is always a discrepancy between the computed and real yield stresses.
- Imperfections or defects are used to describe any deviation from an orderly periodic array of atoms and influence the characteristics like mechanical strength, electrical properties and chemical reactions.

CRYSTAL IMPERFECTIONS (CONTD…)



CRYSTAL IMPERFECTIONS (CONTD…)

1) Point Defects:

- In a crystal lattice, point defects is one which is completely local in its effect i.e. a vacant lattice site
- The introduction of point defect into a crystal increases its internal energy as compared to that of the perfect crystal.

a) Vacancies:

- A vacancy or vacant site implies an on occupied atom position within a crystal lattice.
- It is simply empty atom sites.
- It exist in a certain proportion in a crystal in thermal equilibrium, leading to an increase in the randomness of the structure.

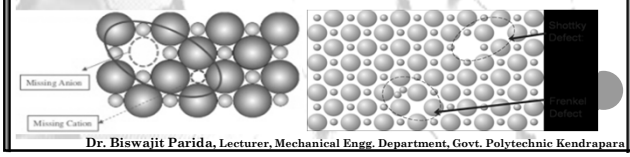
CRYSTAL IMPERFECTIONS (CONTD…)

- 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, because as thermal energy is increased there is a higher probability that individual atoms will jump out of their position of lower energy.
- The number of vacancies at equilibrium present in a crystal at a given temperature can be determined by the 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.

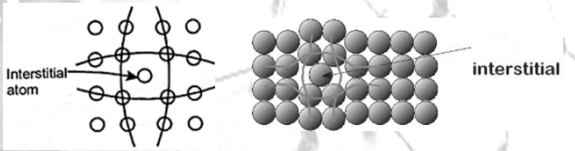
- Schottky defect is closely related to vacancies and is formed when an atom or an ion is removed from a normal lattice site and replaced in an average position on the surface of the Crystal



CRYSTAL IMPERFECTIONS (CONTD…)

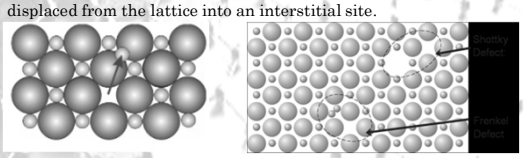
b) Interstitialcies:

- It arises when an atom occupies a definite position in the lattice that is not normally occupied in the perfect crystal.
- In interstitialcies, atoms occupy positions between the atoms of the ideal crystal.
- The interstitial atom may be lodged within a crystal structure if the atomic power factor is low.
- Interstitialcy produces atomic distortion because interstitial atom tends to push the surrounding atoms further apart unless the interstitial atom is smaller than the rest of the atoms in the crystal.



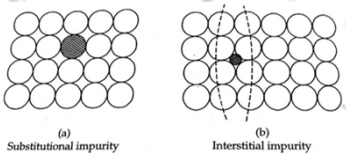
CRYSTAL IMPERFECTIONS (CONTD…)

- A similar type of defect namely **Frankel defect** occurs when an ion displaced from the lattice into an interstitial site.



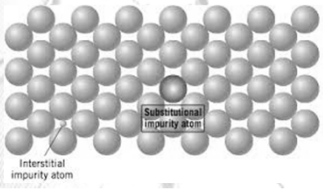
c) Impurities:

- It give rise to compositional defects.
- Impurities may be small particles embedded in the structure, or foreign atoms in the lattice.



CRYSTAL IMPERFECTIONS (CONTD…)

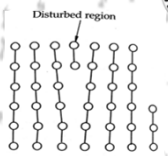
- Foreign atoms generally have atomic radii and electronic structures differing from those of the host atoms and therefore act as centres of distortion.
- Impurity atoms are introduced into crystal structure as substitutional or interstitial atoms i.e foreign atoms either occupy lattice sites from which the regular atoms are missing or they occupy positions between the atoms of the ideal crystal.
- 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 and electrical and thermal conductivity.



CRYSTAL IMPERFECTIONS (CONTD…)

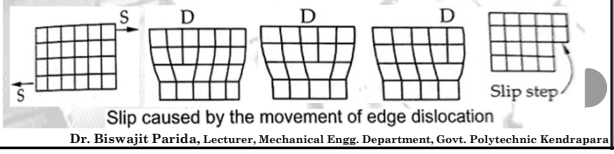
2) Line Defects:

- The most important line defect is dislocation and may be defined as a disturbed region between two substantially perfect parts of a crystal.
- Dislocation is a defect in a crystal structure where by a part plane of atoms is displaced from its symmetrically stable position in the array.



a) Edge Dislocation:

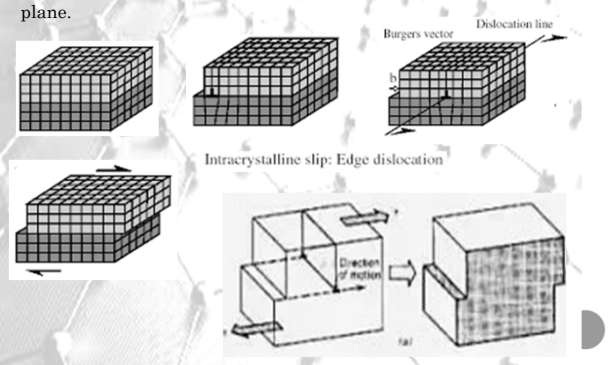
- Burger's vector, marks the magnitude & direction of the strain component of dislocation.
- Burgers vector, named after Dutch physicist Jan Burgers, is a vector, that represents the magnitude and direction of the lattice distortion resulting from a dislocation in a crystal lattice.
- The edge dislocation lies perpendicular to its Burger's vector.



Slip caused by the movement of edge dislocation

CRYSTAL IMPERFECTIONS (CONTD…)

- It moves in the direction of the Burger's vector i.e. slip direction.
- It involves an extra row of atoms either above or below the slip plane.

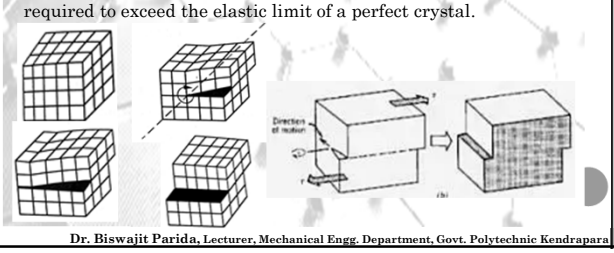


Intracrystalline slip: Edge dislocation

CRYSTAL IMPERFECTIONS (CONTD…)

b) Screw Dislocation:

- It lies parallel to its Burger's vector.
- A screw dislocation moves in a direction perpendicular to the Burgers vector (slip direction).
- The distortion follows a helical or screw path and both right hand and left hand senses are possible.
- The forces 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.



CRYSTAL IMPERFECTIONS (CONTD…)

Effect of Imperfections on Material Properties:

The imperfections acount for

- flow and fracture characteristics
- crystal growth
- electrical properties
- diffusion mechanism
- creep characteristics of real metals and alloys
- annealing and precipitation
- oxidation and corrosion
- Yield strength, fracture strength, plasticity, thermal conductivity etc.

The study of Crystal imperfections has two main purposes

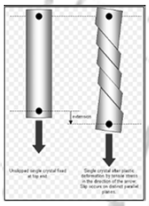
- A better understanding of them and how they affect metal properties.
- Exploration of possibilities of minimising or eliminating these defects

CRYSTAL IMPERFECTIONS (CONTD…)

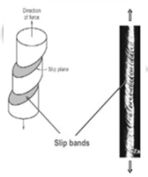
Deformation by Slip and Twinning

a) Slip:-

- Metals deform plastically by slip.
- Slipping is facilitated in the presence of dislocation.
- **Slip** is defined as the process or mechanism by which a large displacement of one part of the crystal relative to another along particular crystallographic planes takes place.
- There may be one or more slip planes and one or more slip directions in each crystal.
- Slip begins when the shearing stress acting along the slip planes in the direction of slip exceeds a certain value known as **Critical Slip Planes** are planes of high atomic densities while the direction of slip along these planes is always the direction of highest atomic density.



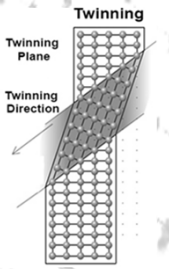
Slip in a Single Crystal

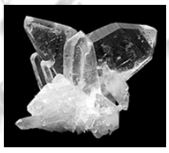


CRYSTAL IMPERFECTIONS (CONTD…)

b) Twinning:

- It gives rise to plastic deformation in crystals.
- It may be called as a special case of slip movement.
- In twinning, instead of whole blocks of atoms moving different distances along the slipping planes, each plane of atoms concerned moves a definite distance.
- The total movement at any point relative to the twinning plane is proportional to the distance from this plane.
- In BCC and HCP it occurs frequently.

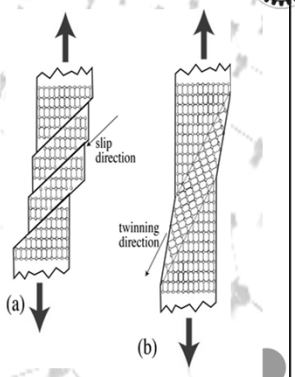




CRYSTAL IMPERFECTIONS (CONTD…)

Effect of Deformations on Material Properties

- The mechanical properties are greatly affected by deformation i.e plastic deformation.
- The deformation process like rolling, forging, extrusion, drawing.
- Strain hardening takes place, so hardness changes.
- Elasticity changes, cracking takes place, grain growth takes place.
- Residual stress are produce in cold working



THANK YOU

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CHAPTER-05:

HEAT TREATMENT

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HEAT TREATMENT

Purpose of Heat Treatment:

Heat treatment process in carried out in order to-

- Cause relief of internal stresses developed during cold working
- Harden and strengthen metals
- Improve machinability
- Change in grain size
- Improve ductility and toughness
- Increased heat, wear and corrosion resistance of materials
- Improve electrical and magnetic properties

HEAT TREATMENT (CONTD…)

Heat Treatment:

An operation or combination of operations involving heating and cooling of a metal/alloy in solid state to obtain desirable conditions and properties.

Classification:

- Annealing
- Normalising
- Hardening
- Tempering
- Stress Relieving measures

HEAT TREATMENT (CONTD…)

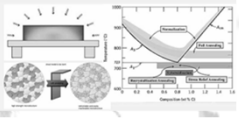
a) Annealing

is the process of heating a metal which is in a distorted structural state, to a temperature which will remove the instability or distortion and then cooling it (usually at a slower rate) so that the room temperature structure is stable and strain free.

Purpose

- Inducing a completely stable structure
- Reducing hardness
- Refining and homogenizing the structure
- Improving machinability
- Removing gases and residual stresses
- Improving mechanical, physical, electrical and magnetic properties

All About types of Annealing??



HEAT TREATMENT (CONTD…)

b) Normalising:

It consists in heating Steel to about 40 to 50 ° C above its upper critical temperature and if necessary, holding it at that temperature for a short time and then cooling in still air at room temperature and compared to underlying the rate of cooling is more rapid.

Purpose

- produces a uniform structure
- refines grain size of the Steel
- reduces internal stresses
- improves structures in welds
- produces a harder and stronger steel than annealing

HEAT TREATMENT (CONTD…)

c) Hardening:

In this process Steel with sufficient Carbon (0.35 to 0.7 %), is heated 30º to 50 ° above the critical temperature line, is held at that temperature from 15 to 30 minutes per 25 mm of cross-section, is cooled rapidly or quenched in a suitable medium (water, oil etc.) to produce desired rate of cooling.

Hardening followed by tempering-

- Hardens Steel to resist wear
- Enables Steel to cut other metals
- Improve strength, toughness and ductility

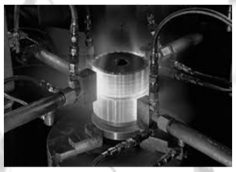
HEAT TREATMENT (CONTD…)

d) Tempering:

It is the process of heating hardened Steel below lower critical temperature, holding it at that temperature for 3 to 5 minutes for each mm of thickness or diameter and cooling it (in water, oil or air) either rapidly or slowly.

Purpose

- Relieve residual stresses
- Improve ductility and toughness
- Reduce hardness and increase % elongation



HEAT TREATMENT (CONTD…)

e) Stress Relieving measures:

- It essentially eliminates stresses produced by, casting, quenching, machining, cold working, welding etc.
- It applies equally well to ferrous and non ferrous metals
- It is often desirable when a casting is liable to change dimensions to a harmful degree during machining or use
- Thermal stress relieving requires heating the casting to a temperature at which relaxation of the residual stress is brought about by plastic deformation corresponding to the elastic strain.

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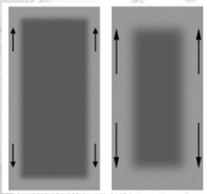


HEAT TREATMENT (CONTD…)

Stages of Heat Treatment process:

1. Heating a metal/alloy to definite temperature.
2. Holding at that temperature for a sufficient period to allow necessary changes to occur
3. Cooling at a rate necessary to obtain the desired properties associated with changes in the nature, form, size and distribution of micro-constituents.

Surface Hardening:

- In order to process considerable strength to withstand forces acting on them and to withstand wear on their surface, the parts must be made of tough materials and provided with a hard surface by introducing carbon or nitrogen on its surface with core remaining soft.
- Surface hardening or case-hardening provides us a hard and wear resistant surfaces.
- Close tolerance in machining parts and tough-core can be obtained combined with a higher fatigue limit and high mechanical properties in core.

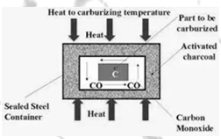
SURFACE HARDENING (CONTD…)

Types:

a) Carburising **b)** Nitriding
c) Cyaniding **d)** Carbonitriding
e) Induction Hardening **f)** Flame Hardening.

Carburising :

- It is a method of introducing carbon into solid iron-base alloys such as a low carbon steels in order to produce a hard surface and also called cementation.
- It increases the carbon content of the steel surface by a process of absorption and diffusion
- The low carbon steel is heated at 870 ºC to 925 ºC in contact with gaseous, solid or liquid carbon containing substances for several hours.



SURFACE HARDENING (CONTD…)

Characteristics :
- case depth is about 0.05 inch
- hardness after heat treatment is RC 65
- causes negligible change in dimensions
- distorsion may occur

Types or Methods :
- **Pack carburizing** employing solid carburizing medium
- **Gas carburizing** employing suitable hydrocarbon gases
- **Liquid carburizing** employing fused bath of carburizing salts such as calcium cyanide, sodium or potassium cyanide. The baths are operated at 815.85 °C to 898.85 °C to produce a case depth of 0.5 mm in 90 minutes

$2Na_2CO_3 + SiC - Na_2SiO_3 + Na_2O + 2CO + C.$

Uses :
- Gears, camshafts, bearings etc



SURFACE HARDENING (CONTD…)

b) Nitriding :
- It companies 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
- it is provided by placing the article in Ammonia vapour at a temperature between 450 °C to 550 °C for 40 hours

Characteristics :
- case depth is about 0.381 mm
- extreme hardness of about Vickers 1100
- growth of 0.025 to 0.05 mm occurs during nitriding
- Case has improved corrosion resistance

Uses:
- Aircraft engine parts, valve seats, gears, aero crankshafts, gauges, bushing, crankpin etc

SURFACE HARDENING (CONTD…)

Advantages:
- very high surface hardness
- minimum distortion or cracking
- good corrosion and wear resistance
- good fatigue resistance
- no machining is required after nitriding
- process is Economical for large number of parts

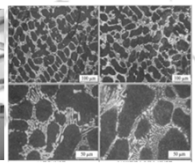
Disadvantages:
- long cycle times (40 to 100 hours)
- brittle case
- only special alloy Steels can be treated


HEAT TREATMENT (CONTD…)

Effect of heat treatment on properties of steel:

- HSS has greater hardness In The heat treated condition
- is able to resist softening or relatively high working temperatures
- heat treatment of stainless steel is carried to restore ductility
- for relieving stresses resulted from welding
- to improve strength by hardening or tempering
- rapid cooling of ferritic stainless steel generally improve its impact properties
- light sections may be air cooled, however to minimise distortion
- tempering in martensitic stainless steel results in marked changes in hardness, microstructure and mechanical properties
- higer tempering temperature reduces hardness, yield strength and tensile strength but increases elongation and impact strength





HEAT TREATMENT (CONTD…)

Hardenability of Steel:

Hardness is a measure of resistance to plastic deformation usually by indentation

Hardenability is the ease with which hardness may be attained in the depth direction of an object

or

It may also be stated as the ability of steel to become uniformly had or to harden in depth direction

or

It is defined as the property of a steel to be hardened by quenching and determined the depth and distribution of hardness throughout a section obtained by quenching

Factors affecting hardenability:

- Composition of steel (Alloying elements, carbon content etc) and method of manufacture
- Grain size and homogeneity of steel
- The quenching media and the method of quenching
- Section of the steel
- The presence of undissolved carbides and non-metallic inclusion before quenching

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CHAPTER-06:

NON-FERROUS ALLOYS

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NON-FERROUS ALLOYS

Aluminium Alloys

Aluminium

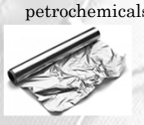
Aluminium is a silvery white metal and possesses the following characteristics

- is a light metal with the density about one third of steel
- very good conductor of electricity
- higher resistance to corrosion
- is a good conductor of heat
- each very ductile and nonmagnetic
- melting point of pure Aluminium is about 650 °C

ALUMINIUM ALLOYS (CONTD….)

Uses

- Transportation industry - structural framework, engine parts, hardware, doors, window frames, tanks, furnishing and fittings
- Overhead conductors and heat exchanger parts
- In food industry for food preparation equipments, storage containers, bakery equipment
- Cryogenic applications
- In heavy duty structures such as travelling cranes, hoists, bridges etc
- in process industries to handle organic chemicals, petrochemicals, drugs etc



ALUMINIUM ALLOYS (CONTD….)

Duralumin:

Cu - 3.5 to 4.5%, Mn – 0.4 to 0.7%, Fe or Si - < 0.7%

Mg – 0.4 to 0.7%, Al - Balance

Properties

The maximum properties are developed as a result of heat treatment and age hardening which can be worked readily about 500 °C after quenching ages over a period of 4 to 5 days. It's tensile strength increases from 1.55 to 1.86 ton/cm2, yield point from 1.04 to 2.3 to 5 ton/cm2 and hardness from 65 brinnel to 95 brinnel.

Characteristics

- 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

ALUMINIUM ALLOYS (CONTD….)

Uses

- aircraft and Automobile parts
- as bars, sheets, tubes and rivets
- as light structures and extruded sections
- also used for surgical and orthopaedic works for non magnetic and other instrument parts

ALUMINIUM ALLOYS (CONTD….)

Y-Alloys:

Cu - 4%, Mn – 0.6%, Si - 0.6%

Mg - 1.5%, Ni – 2%, Al – Balance

- is a Nickel containing aluminium alloy
- Are high strength alloy which retains its strength and hardness at high temperature
- in the cast and heat treated form its ultimate strength is 2.12 to tons/cm2
- heat treated forged alloys give an ultimate strength of 3.565 to 4.185 ton/cm2, an elongation of 17 to 22 % and Brinell hardness of 100 to 105.
- resistant to corrosion and fatigue
- withstands relatively high temperature
- can be heat treated and age hardened

Uses

It is extensively used for pistons, cylinder heads and crank case of internal combustion engine

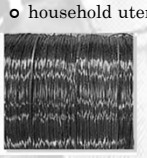
COPPER ALLOYS

Copper

- excellent resistance to corrosion
- non magnetic properties
- ductile and malleable, so easy to work
- moderate to high hardness and strength
- high thermal and electrical conductivity
- resistance to fatigue, abrasion & corrosion
- very good machinability

Uses

- used in electrical parts and heat exchangers
- scew machine products
- household utensils



COPPER ALLOYS (CONTD....)

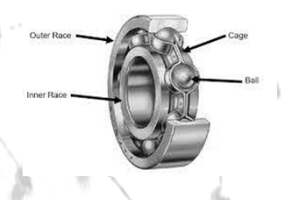
Copper-Aluminium Alloy

- Aluminium gets hardened and strengthened by the addition of copper.
- The most extensively used alloys for castings are those containing 4,5,7,10 and 12% of copper and with ultimate strength ranging from 1.12 – 4.185 t/cm2.
- It is employed in industry for light casting requiring greater strength and hardness than ordinary aluminium.
- It is used for automobile piston, crank cases, cylinder heads, connecting rods.

COPPER ALLOYS (CONTD....)

Copper-Tin Alloy

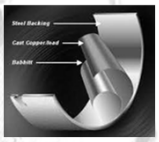
- These bearing alloys containing greater proportion of tin with copper and antimony and known as white metals.
- Another alloys of this type having composition of 86% tin, 10.5% antimony, 3.5% copper has a tensile strength of 0.996 t/cm2, elongation 7.1% with Brinell hardness of 33.3 and compressive yield point of 4.3.
- It is used in main bearings of motors and aero-engines



COPPER ALLOYS (CONTD….)

Babbit Metal

- It is a general white metal alloy with soft lead and tin base metals covering a range of alloy having similar characteristics varying composition.
- Its actual composition is 82.3% tin, 3.9% copper, 7.1% antimony.
- A cheaper babbit metal used for bearings subjected to moderate pressure has composition as 59.54% tin, 2.25 to 3.75% copper, 9.5 to 11.5% antimony, 26% lead, 0.08% iron, 0.08% bismuth.
- They are use as liners in bronze or steel backing and are prepared for higher speed, excellent embedability, conformability, ability to deform plastically used in IC engine bearing, general machinery purpose bearings



NON – FERROUS ALLOYS (CONTD….)

Phosphorous Bronze

- The phosphorous bronzes are the alloys of copper and tin with 0.1 to 1.5% phosphorous.
- In the form of casting phosphorous bronze gives and ultimate strength of about 18 t/cm**2** with elongation of 4%, Brinell hardness number 80-100.
- It is used for heavy compressive loads and is used for gear wheels and slide values.
- Phosphorous bronze in wrought alloy form containing 10% tin, 0.1 – 0.35% phosphorous has a tensile strength 3.72 t/cm2, BHN 100 – 130.
- It has good corrosion resistance to sea water and is used for spring and turbine blades.
- has high strength and toughness
- has low coefficient of friction


Uses

- for bearing application
- making pump parts, lining, springs, gears, clutch disc, turbine blades etc.

NON – FERROUS ALLOYS (CONTD….)

Brass

- it contains zinc as the principal alloying element
- α - brasses- 36% zinc and 64% Cu - are used for hot pressings, stampings
- αß – brasses – 40 to 44% zn and 64 to 55% Cu - are used for hot pressings, stampings.
- Has high resistance to corrosion and easily machinable
- it also acts as a good bearing material
- Zinc in brass increases ductility along with strength
- has a lower thermal and electrical conductivity
- used in Caps of electric lamp balls, door furnitures
- For making coins, medals, tokens etc




NON – FERROUS ALLOYS (CONTD….)

Copper-Nickel

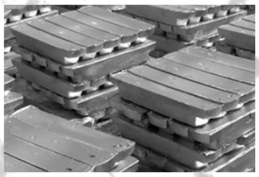
- Nickel forms with Copper in varying properties a large number of alloys.
- The addition of even a small amount of nickel to copper has a marked effect upon its mechanical properties and increase its corrosion resistance.
- Cupro-Nickel has a nickel content between 10 – 30% has remarkable drawing properties with tensile strength of 6.2 t/cm2 used for sheaths or envelopes of rifle bullet.
- A 70/30 Cupro-Nickel used for condenser tubes produced by extrusion process. 8 t/cm2 elastic limit, 5.9 t/cm2 ultimate strength, BHN 140.



NON – FERROUS ALLOYS (CONTD….)

Lead Alloys

- lead alloy containing 8 to 10 percentage Pb are used as bearing (anti-friction)metals, accumulation plates
- Antimony makes the alloy hard
- Bearing metals are lead-tin alloy for friction bearing
- Lead with about 9 % Sn, 15 % Sb, 1 % Cu and 0.5 % Cd possesses good antifriction characteristics, thermal conductivity and wearing characteristics. The alloy is applied to a bearing body of Steel, cast steel or cast iron
- Lead-tin alloy containing 10 to 25% Tin and rest Lead is used as metallic coating for sheet iron for manufacturing containers

NON – FERROUS ALLOYS (CONTD….)

Zinc Alloys

- Pb stimulates intercrystalline corrosion in Zn alloy die casting
- Cd exerts an important hardening effect and raises the recrystallization temperature and it can absorb considerable amounts of work hardness during cold rolling or drawing
- Copper-Zinc alloy are more ductile and easier to roll
- Magnesium when added in the presence of Copper increases resistance to Creep
- Zinc base die casting alloys find applications as hardware items, including automobile hardware i.e. radiator grill, door, handle etc.



NON – FERROUS ALLOYS (CONTD….)

Nickel Alloys

- **Invar** is an Iron-Nickel alloy containing 40-50 % Nickel and is characterized by an extremely low coefficient of thermal expansion
- It is used for making Precision instruments, measuring tapes, weights etc
- 12% Cr addition produces an alloy, **Elinvar** with a considerable temperature range as well as fairly low coefficient of expansion
- Nickel based alloy with Copper is **Monel**, contains 66% Ni, 31.5% Cu, 1.35% Fe, 0.9% Mn and reciduals
- Is stronger and tougher than mild steel has excellent resistance to atmospheric and sea water corrosion
- Used in architectural and marine applications, in specialised equipment used by food, pharmaceutical, paper, oil and chemical industries



NON – FERROUS ALLOYS (CONTD….)

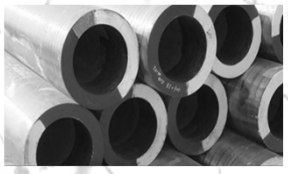
Nickel Alloys

- Nickel-Chromium alloy (80% Ni, 14% Cr, 6% Fe) called **Inconel** has excellent corrosion resistance
- used as furnace chambers, salt pots, aircraft exhaust manifolds and high-temperature springs
- **Nickel-Molybdenum** alloy (57% Ni, 20% Mo 20% Fe) has high strength and ductility, possesses very good resistance to corrosion.
- used in chemical industry for storage tanks and for material handling and transportation


NON – FERROUS ALLOYS (CONTD….)

Low-alloy materials (for high temperature services)

- **P22** contents 0.05 to 0.15% C, <0.5% Si, 0.3-0.6% Mn, <0.025% P, <0.025% S, 1.9-2.6 % Cr, 0.87-1.13 % Mo.
- Has a tensile strength of 415 N/mm2, % elongation of 20 % and yield strength of 205 N/mm2.
- is especially suited for high temperature services such as steam boiler, boiler parts, boiler drum, pressure vessel for the engineering apparatus etc.
- can be used in permanent operation with wall temperatures up to about 590° C.

NON – FERROUS ALLOYS (CONTD….)

Low-alloy materials (for high temperature services)

- **P91** contains 0.08-0.12% C, 0.2-0.5 % Si, 0.3-0.6 % Mn, ≤0.02% P, ≤0.01% S, ≤0.04% Al, 8-9.5% Cr, 0.85-1.05% Mo, ≤0.4% Ni, 0.18-0.25% V, 0.03-0.07% N.
- has a tensile strength of 585 N/mm2, % elongation of 13 % and yield strength of 415 N/mm2
- suited for boiler parts, pressure vessels etc.
- can be used in permanent operation with wall temperatures up to 650 °C
- these possess slowly cooled microstructures, similar to those of plain carbon steel in the same condition namely pearlite, pearlite and ferrite.

NON – FERROUS ALLOYS (CONTD….)

High-alloy Materials

- **Duplex Stainless Steel** contents 0.03% C, 0.2% N, 21.5% Cr, 1.5% Ni, 0.3% Mo, 5% Mn, 5% Cu etc.

Characteristics

- Very good resistance to uniform corrosion
- high mechanical strength
- good abrasion resistance
- high energy absorption
- low thermal expansion
- good weldability

Applications

- pulp and paper industry
- seawater systems
- copper tanks and pipe systems in chemical tankers
- components for structural designs in bridges
- pressure vessels and heat exchangers
- Rotors, impellers, shaft
- water heaters

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CHAPTER-07:

BEARING MATERIAL

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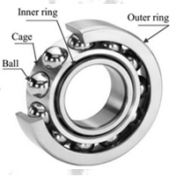
BEARING

Bearing:

- It support moving parts such as shafts and spindles of a machine or mechanism
- It may be classified as

1) Rolling Contact Bearing and **2) Plain Bearing**

- Rolling contact bearings are almost invariably made of steel that can be hardened after machining



PROPERTIES

Properties of Bearing Materials

- Posses low coefficient of friction
- Provide hard, wear resistant surface with a tough core
- Should have high compressive and fatigue strength
- Should be able to bear shocks and vibrations
- Have high thermal conductivity
- Possess adequate plasticity on the bearing load and strength at high temperatures
- Resistance to corrosion
- Maintain a continuous film of oil between shaft and bearing in order to avoid metal to metal contact
- Should be cheap, easily available and can be easily fabricated

TYPES

Classification of Bearing Materials

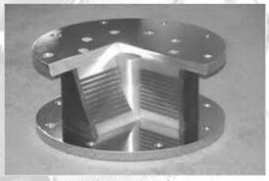
- **Lead or Tin Based Alloys**
- **Cadmium Based Alloys**
- **Aluminium Based Alloys**
- **Silver Based on Lunch**
- **Copper Based Alloys**
- **Sintered Bearing Materials**
- **Non Metallic Bearing Materials**

TYPES

Types of Bearing Materials

1. Lead Based Alloys:

- A lead based alloy contains 75% Pb, 15% Sb, 10% Sn.
- are softer, brittle and cheaper than tin based alloys
- have high co-efficient of friction
- are suitable for light and medium loads
- solidus temperature of 240 ºC
- are used in railroad freight cars



TYPES

2. Tin Based Alloys:

- A Tin based alloy contains 88% Sn, 8% Sb & 4% Cu
- are preferred for higher loads and speeds
- have low coefficient of friction
- find applications in high speed engines, steam turbines etc
- solidus temperature is approximately 222 ºC
- white metals are Tin base or lead base bearing alloys and are usually preferred to as babbits

TYPES

3. Cadmium Based Alloys:

- have a composition of 94.75 to 98% Cd, 2 to 3 % Ni, 0 to 1 % Ag, 0.5 to 1.5 % Cu, 0.75% Zn.
- have a structure consisting of a soft matrix containing harder crystals of intermetallic compounds
- are not very popular because of high priced Cd

They possess:-

- → Low co-efficient of friction
- → high fatigue strength and load carrying capacity
- → low wear
- → poor corrosion resistance
- → greater compressive strength

- were used in automobile and aircraft industries


TYPES

4. Copper Based Alloys:

- bronze is one of the oldest known bearing materials
- it can be easily worked
- has good corrosion resistance and reasonably hard
- A typically bearing bronze contains 80% Cu, 10% Sn, 10% Pb
- Tin bronze (10 to 14% Sn and remainder Cu) is used in the machine and engine industry for bearing bushes made from thin walled drawn tubes
- Copper-based alloys are employed for making bearings required to resist heavier pressure surcharge in railways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CHAPTER-08:

SPRING MATERIALS

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SPRING

Spring:

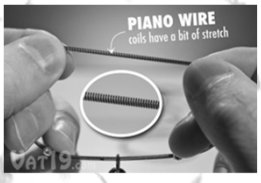
- Springs are fundamental mechanical components found in many mechanical systems which store mechanical energy
- So the material remains under high internal stresses
- The choice of material for springs depends upon the operating conditions

It may be classified as

1) **Iron-based spring materials**
2) **Copper-based spring materials**
3) **Nickel-based spring materials**
4) **Special spring materials**

IRON BASED SPRING MATERIALS

- **Steel** is the best choice as spring material unless the spring is for high temperature **or** a corrosive environment **or** must be non-magnetic etc.
- A good spring still possesses high modulus of elasticity, elastic limit, fatigue strength, creep strength
- steel is used for making helical springs, plate springs, leaf springs, torsional springs, cone spring
- **Steel piano wire** (0.7 to 1 % C, 0.3 to 0.6 % Mn remainder Fe) small sized helical springs

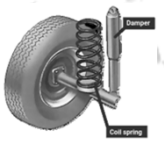


Chapter-08: Spring Material

IRON BASED SPRING MATERIALS

- **Hard drawn spring wire** (0.52 0.75% C, 0.6 to 1.2 % Mn, remainder Fe)
- Used for low stresses, fatigue loading is not involved, high degree of uniformity is not essential
- **Oil hardened spring Steel** (0.55 to 0.75% C, 0.3 to 0.9% Mn, reminder Fe) used in weighing machines, cars





Chapter-08: Spring Material

IRON BASED SPRING MATERIALS

Cr-V spring Steel

- 0.5% C, 0.2 to 0.9 % Cr, 0.8 to 1.1 % Mn, 0.07 to 0.12% V, remainder Fe
- used in engines, Automotive valves, Railway carriages

Stainless steel

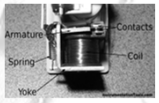
- 18% Cr, 8% Ni, 0.1 to 0.2 % C, remainder Fe.
- Used in valve springs in flowmeters, other applications requiring a high resistance to corrosion.




Chapter-08: Spring Material

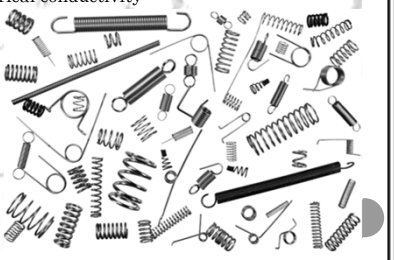
COPPER BASED SPRING MATERIALS

- They possess high electrical conductivity, good resistance to corrosion and lack of magnetic properties
- Can be classified as
  a) one which can be hardened only by cold deformation
  b) others which can be hardened also by heat treatment
- **Phosphor Bronze** (92% Cu, 8% is Sn)- used in high quality springs for switches, relay contacts
- **Brass** (67% Cu, 33% Zn)- used in switches and contact Springs
- **Nickel Silver** (56% Cu, 18% Ni, 25% Zn)- used as same as brass but for better quality
- **Beryllium Copper** (98% Cu, 2% Be) – used in brushes, relays, switches with relatively good resistance to wear, good conductivity and good resistance to corrosion.


PROPERTIES OF SPRING MATERIALS

- should possess high modulus of elasticity
- should have high elastic limit
- should have high fatigue and creep strength
- should have hide notch toughness
- should have good resistance to corrosion
- should have high electrical conductivity



SPRING MATERIALS

The following is a list of spring materials and their references:

Spring Material	ASTM Reference
Music Wire	ASTM A228 (0.80%-0.95% carbon)
Oil-Tempered MB Grade	ASTM A229 (0.60%-0.70% carbon)
Oil-Tempered HB Grade	SAE 1080 (0.75%-0.85% carbon)
Hard-Drawn MB Grade	ASTM A227 (0.60%-0.70% carbon)
Cold-Rolled Spring Steel, Blue-Tempered or Annealed	SAE 1074, 1064, 1070 (0.60%-0.80% carbon)
Cold-Rolled Spring Steel, Blue-Tempered Clock Steel	SAE 1095 (0.90%-1.05% carbon)
Chromium Vanadium	ASTM A231
Chromium Silicon	ASTM A401

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CHAPTER-09:

POLYMERS

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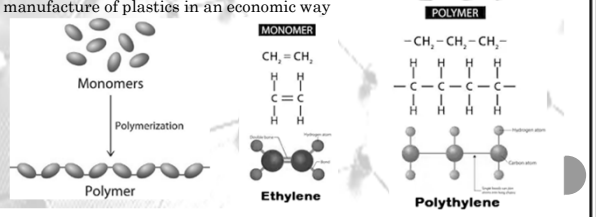
POLYMERS

Monomer

The simplest substance consisting of one primary chemical

Polymer

- Monomers are to be combined to form Polymers by the process known as **polymerization.**
- The polymer molecule is also called a **macro-molecule**
- A polymeric material consists of a large number of these long chain molecules
- The properties such as strength, rigidity and elasticity are considerably improved by the polymerization and it is further leads to the manufacture of plastics in an economic way



POLYMERS

Characteristics

- low density and coefficient of friction
- good moldability and corrosion resistance
- can be produced with close dimensional tolerances
- excellent surface finish can be obtained
- poor tensile strength and temperature resistance
- economical but lower mechanical properties

Classification

- The word **"mer"** stands for a **"unit",** monomer stands for a single unit and polymer means many units joined together by a chemical reaction
- According to the mechanical response at elevated temperatures, Polymers are classified into two types.
  - *Thermoplastics or Thermoplastic Polymers*
  - *Thermosets or Thermosetting Polymers*

POLYMERS

Thermoplastics or Thermoplastic Polymers

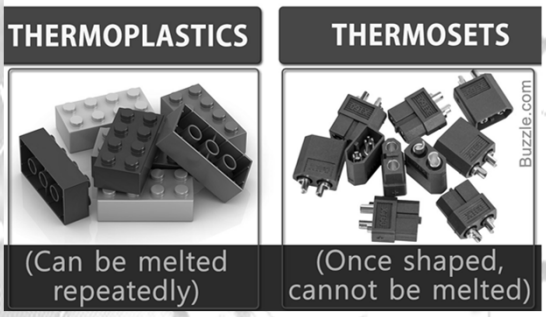
- These polymers soften when heated (and liquefy) and harden when cooled
- These processes are totally reversible and may be repeated
- These materials are normally fabricated by the simultaneous application of heat and pressure
- Most linear Polymers and those having some branched structures with flexible chains are thermoplastic
- Thermoplastics are relatively soft and ductile
- Since thermoplastics have low melting temperatures and can be repeatedly molded and remoulded to the desired shapes they have a resale value
- Example: Polyvinyl Chloride (PVC), Polystyrene as plastic walls and floor tiles


POLYMERS

Thermosets or Thermosetting Polymers

- These Polymers becomes soft during their fast heating and become permanently hard when cooled
- They do not soften on subsequent heating and hence cannot be remolded/ reshaped and don't have resale value
- If heated to excessive temperatures, the polymer decomposition/ degradation takes place
- Thermoset Polymers are generally harder, stronger and more brittle, than thermoplastics and have better dimensional stability
- They are more usable in processes requiring high temperature
- Example: rubbers, epoxies, phenolic


POLYMERS

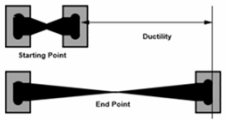


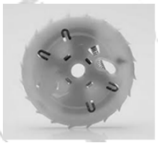
PLASTIC

These are moldable organic resins and consists of large molecules

Properties

- Appearance : Transparent
- Chemical resistance : The plastics offer great resistance to moisture, chemicals and solvents, excellent corrosion resistance.
- Dimensional stability.
- Ductility : The plastic lacks ductility. Hence its members may fail without warning.



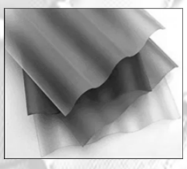
PLASTIC

- Durability : The plastics are quite durable, if they possess sufficient surface hardness.
- Electric insulation : They are far superior to ordinary electric insulators.
- Finishing : Any surface treatment may be given to the plastics.
- Fire resistance : All plastics are combustible.
- Fixing : Can be easily fixed in position
- Humidity : PVC plastics offer great resistance to the moisture



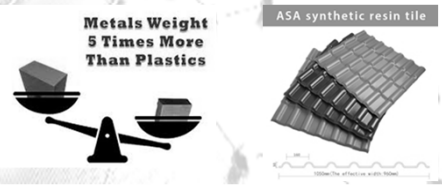
PLASTIC

- Maintenance : It is easy to maintain plastic surfaces. They do not require any protective coat of paints.
- Melting point : Most of the plastics have low melting point and MP of some plastics is only about 50ºC.
- Optical property : Several types of plastics are transparent and translucent.
- Recycling : It does not give a serious problem to pollution as generated by a host of other industries.
- Sound absorption : The acoustical boards are prepared by impregnating fibre-glasses with phenolic resins.



PLASTIC

- Strength : The tensile members are generally made of plastics as their strength to weight ratio in tension very nearly approaches to that of metals.
- Thermal property : The thermal conductivity of plastics is low and it can be compared with that of wood.
- Weather resistance : Certain plastics are seriously affected by sun light, but other plastic can resist weather which as prepared from phenolic resins.
- Weight : The plastics, whether thermo-plastic or thermo-setting have low specific gravity being 1.30 to 1.40.



PLASTIC

Applications

The typical use of plastics in building are as follows :

- Bath and sink units.
- Cistern ball floats.
- Corrugated and plain sheets.
- Decorative laminates and mouldings.
- Electrical conduits.
- Electrical insulators.
- Floor tiles.
- Foams for thermal insulation.
- Joint less flooring.
- Lighting fixtures.
- Overhead water tanks.
- Paints and varnishes.
- Pipes to carry cold water.
- Roof lights.
- Safety glass.
- Wall tiles.

ELASTOMERS

Elastomers (rubbers)

- An elastomer is a polymeric material that may experience large and reversible elastic deformations
- As per ASTM elastomer is defined as a polymeric material which at room temperature can be stretched to at least twice its length

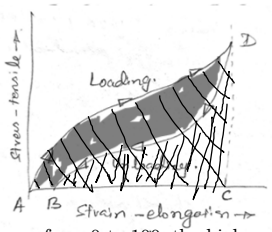
Properties of Elastomers

a) Resilience and Hysteresis

- It is a measure of an elastomer's capacity to store energy and is defined as the ratio of energy output to energy input expressed as a percentage.
- Because some input energy is always lost through internal friction, resilience values must always be less than 1 (or 100%). This loss of energy in the form of frictional heat is known as hysteresis.

ELASTOMERS

- Are ACD under the load curve is the input energy, and area BCD is the output energy. Heat-energy loss or hysteresis is represented by area ABD.



b) Hardness

- The shore durometer scale test is the standard method for measuring elastomer hardness
- On the durometer scale, which runs from 0 to 100, the higher the number the harder the material
- Lower the hardness, the less tendency there is for the elastomer to creep or flow
- Elongation decreases and hardness increases
- Tensile strength generally increases with hardness up to about 50 on the durometer scale, and then falls off if hardness continues to increase.

ELASTOMERS

c) Tensile Strength

- Elastomers are only rarely used for loading in tension, so tensile strength is not directly used for application data
- However it serves as an overall performance indicator
- Values < 1000 psi indicates poor mechanical properties and > 2000 psi indicates good mechanical properties
- Is also used as a measure of an elastomer's deterioration in service

d) Compression Set or Creep

- This characteristic refers to the percentage of deflection or distortion remaining in an elastomer after a load is removed
- It depends on many factors such as strain rate, temperature, type and size of the loading

e) Tear Resistance

- Elastomers have low tear strength
- If tear strength is extremely low, small nicks or cuts can cause catastrophic failure.

ELASTOMERS

f) Abrasion Resistance

- resistance resistance improves with an increasing hardness
- relative Li soft elastomers perform better for small operation particles

g) Deterioration Resistance

- All elastomers undergo changes in properties (deterioration) which is referred to as ageing is affected by many different environmental factors such as sunlight, heat and ozone, all of which accelerate oxidation
- Aging results in a loss of resilience, a decrease of hardness and eventual cracking

h) Oil Resistance

- It is important because many of their applications involve an environment of hydrocarbon fluids such as oil and gasoline
- Resistance to oils is based on how much the elastomer swells in the presence of oil

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CHAPTER-10:

COMPOSITE AND CERAMICS

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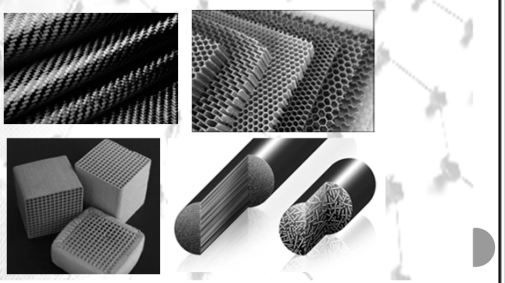
COMPOSITE

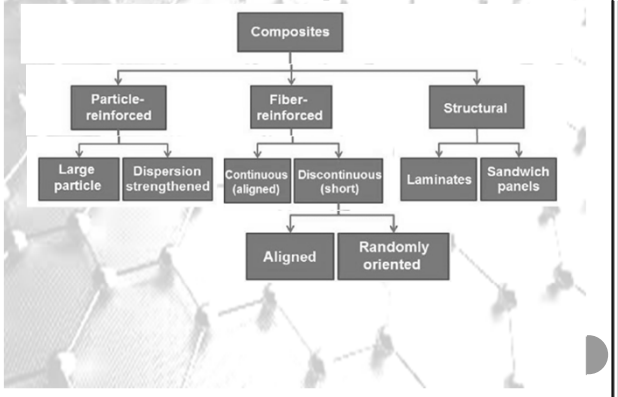
Composite Materials

These 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 materials alone.



COMPOSITE

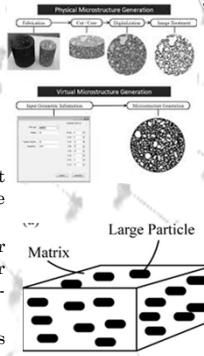
Classification of Composite Materials



COMPOSITE

1) Particle Reinforced Composite

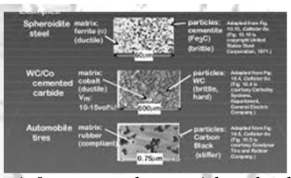
The dispersed page for particle reinforced composites each week we asked (i.e. particle dimensions are approximately the same in all directions)



a) Large Particle Composites

- The term large is used to indicate that particle-matrix interactions cannot be treated on the atomic or molecular level.
- The degree of reinforcement or improvement of mechanical behaviour depends on strong bonding at the matrix-particle interface.
- A familiar large particle composite is concrete, being composed of cement (The Matrix) and sand and gravel (The Particulars).

COMPOSITE

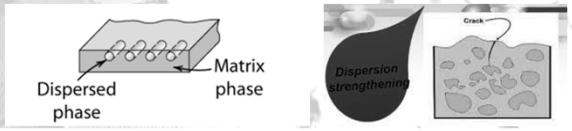


- For effective reinforcement the particles should be small and evenly distributed throughout the matrix.
- The mechanical properties are enhanced with increasing particulate content.
- Large particle composites are utilised with all three material types (metals, polymers and ceramics)
- Both elastomers and plastics are frequently reinforced with various particulate materials.
- Use of many of the modern rubbers would be severely restricted without reinforcing particulate materials such as carbon black.

COMPOSITE

Dispersion-strengthened Composites

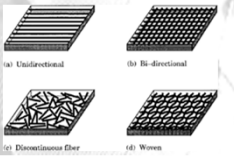
- Metals and metal alloys may be strengthened and hardened by the uniform dispersion of a several volume percent of fine particles of a very hard and inert material.
- The dispersed phase may be metallic or non-metallic oxide material are often used.
- The strengthening mechanism involves interactions between the particles and dislocations within the matrix.
- The high-temperature strength of Nickel alloys may be enhanced significantly by the addition of about 3 volume % of Thoria (ThO_2) as finely dispersed particles, this material is known as thoria-dispersed (or TD) nickel.



COMPOSITE

Fibre-Reinforced Composites

- Fibre reinforced composites with exceptionally high specific strains and moduli have been produced that utilize low-density fibre and matrix materials
- Design goals of fibre-reinforced composites often include high strength and/or stiffness on a weight basis
- The properties of a composite having its fibres aligned are high anisotropic, that is dependent on the direction in which they are measured.
- For continuous fibre reinforcement the strain in the matrix and the strain in the fibre under load are initially the same.



COMPOSITE

a)The Fibre Phase

- **Fibre:-** any polymer, metal or ceramic that has been drawn into a long and thin filament

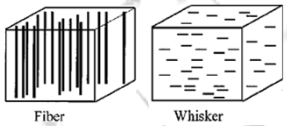
on the basis of diameter and character, fibres are grouped into three different classifications-

i. **Whiskers:-** are very thin single crystals that have extremely large length to diameter ratios
As a consequence of their small size, they have a degree of crystalline perfection and are virtually flaw free, which accounts for their exceptionally high strength

i. **Fibres:-** are either polycrystalline or amorphous and have small diameters; fibrous materials have small diameters; fibrous materials are generally either Polymers or ceramics

ii. **Wires:-** have relatively large diameters; typical materials include steel, molybdenum and tungsten.

Where are utilised as a radial Steel reinforcement in automobile tyres, in filament-wound rocket casings and in wire wound height pressure hoses

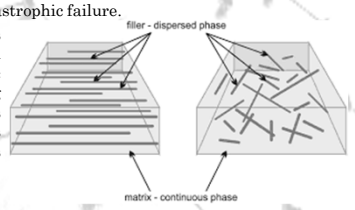


COMPOSITE

b) Matrix Phase

- The matrix phase binds the fibres together and acts as the medium by which an externally applied stress is transmitted and distributed to the fibres; only a very small proportion of an applied load is sustained by the matrix phase
- The Matrix protects the individual fibres from surface damage as a result of mechanical abrasion or chemical reactions with the environment.
- The Matrix separates the fibres and by virtue of its relative softness and plasticity prevents the propagation of brittle cracks from fibre to fibre, which could result in catastrophic failure.

In general, only metals (such as Al, Cu) and commercial thermoplastic and thermosetting polymers are used as matrix materials (because some ductility is desirable)



CERAMICS

Ceramic Materials

- Ceramics is from the Greek word "Keromos" which means burnt stuff.
- Ceramics are in-organic non-metallic materials that are processed and/or used at high temperatures.

Earthenware

Porcelain

Stoneware

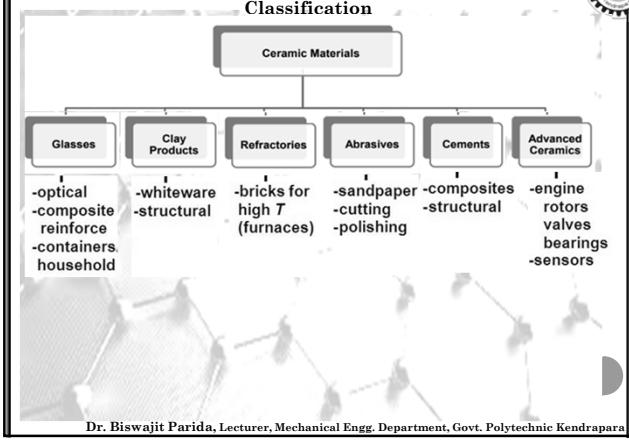
CERAMICS

Characteristics

- They have been subjected to heat treatment.
- They are hard brittle materials that withstand compression very well but do not hold up well under tension compared to the metals.
- They are abrasive-resistant, heat-resistant and can sustain large compressive loads even at high temperatures.
- Many ceramics are chemically inert even at high temperatures which shows their oxidation and reduction resistant properties at these temperatures.
- The nature of the chemical bond in ceramics is generally ionic in character

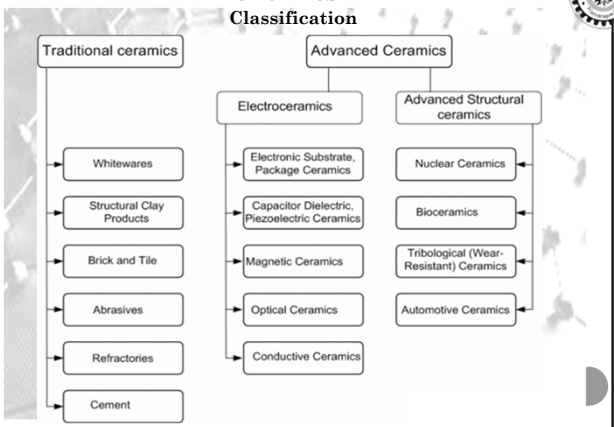
CERAMICS

Classification



CERAMICS

Classification

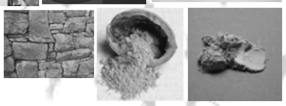


CERAMICS

Uses

Abrasive





Diamond

- wire drawing dies
- drills for drilling hard works
- dressing grinding wheels

Garnet and Flint- used for Sandpaper

Emery- used for polishing metals

Rottenstone and Pumica- used for wood finishing

Walnut Shells- used for cleaning aircraft engine parts

Silicon Carbide- used for making grinding wheel at pipes parts of pumps for pumping sand

Aluminium Oxide- for polishing cast iron non ferrous metals floor sanding machines

Insulators- is used at electric insulators in block insulation pipe fitting blankets etc

Building Stones- used in building construction

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THE END

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