Department of Mechanical Engineering

Subject : Engineering Material

3RD SEM AUTOMOBILE/MECHANICAL ENGG.

PREPARED BY –ER. SANTOSH KUMAR

NILASAILA INSTITUTE OF SCIENCE AND TECHNOLOGY

NH-5, Sergarh-756060, Balasore(Odisha)

Class notes of the Engineering Material (Th 3) for the 3rd semester ME/AE.

Chapater - 1.0

Engineering materials and their properties

Engineering material

Engineering materials refers to the group of materials that are used in the construction of manmade structures and components. The primary function of an engineering material is to withstand applied loading without breaking and without exhibiting excessive deflection. The major classifications of engineering materials include metals, polymers, ceramics, and composites.

Classification of Engineering Materials

The engineering materials are mainly classified as :

1.Metals and their alloys, such as iron, steel,copper, aluminium, etc.

2.Non-metals, such as glass, rubber, plastic, etc.

The metals may be further classified as

(a) Ferrous metals, and (b) Non-ferrous metals

The *ferrous metals*are those which have iron as a constituent, such as cast iron,wrought iron and steel.

The*non-ferrousmetals* are those which havea metal other than iron as their main constituent,such as copper, aluminium, brass, tin, zinc, etc.

Selection of Materials for Engineering Purposes

The selection of a proper material, forengineering purposes, is one of the most difficult problem for the designer. The best material is onewhich serve the desired objective at the minimumcost. The following factors should be consideredwhile selecting the material :

1.Availability of the materials,

2.Suitability of the materials for the working conditions in service, and

3.The cost of the materials

Physical Properties of Metals

The physical properties of the metals include luster, colour, size and shape, density, electric andthermal conductivity, and melting point. The following table shows the important physical propertiesof some pure metals

Table 2.1. Physical properties of metals.

Metal	Density (kg/m³)	Melting point (°C)	Thermal conductivity (W/m°C)	Coefficient of linear expansion at 20°C (μm/m/°C)
Aluminium	2700	660	220	23.0
Brass	8450	950	130	16.7
Bronze	8730	1040	67	17.3
Cast iron	7250	1300	54.5	9.0
Copper	8900	1083	393.5	16.7
Lead	11 400	327	33.5	29.1
Monel metal	8600	1350	25.2	14.0
Nickel	8900	1453	63.2	12.8
Silver	10 500	960	420	18.9
Steel	7850	1510	50.2	11.1
Tin	7400	232	67	21.4
Tungsten	19 300	3410	201	4.5
Zinc	7200	419	113	33.0
Cobalt	8850	1490	69.2	12.4
Molybdenum	10 200	2650	13	4.8
Vanadium	6000	1750	—	7.75

Mechanical Properties of Metals

The mechanical properties of the metals are those which are associated with the ability of the material to resist mechanical forces and load. These mechanical properties of the metal include strength,stiffness, elasticity, plasticity, ductility, brittleness, malleability, toughness, resilience, creep andhardness. We shall now discuss these properties as follows:

1.Strength.

It is the ability of a material to resist the externally applied forces without breaking or yielding. The internal resistance offered by a part to an externally applied force is called stress.

2.Stiffness

It is the ability of a material to resist deformation under stress. The modulus of elasticity is the measure of stiffness.

3.Elasticity

It is the property of a material to regain its original shape after deformation whenthe external forces are removed. This property is desirable for materials used in tools and machines.It may be noted that steel is more elastic than rubber.

4.Plasticity

It is property of a material which retains the deformation produced under loadpermanently. This property of the material is necessary for forgings, in stamping images on coins andin ornamental work.

5.Ductility

It is the property of a material enabling it to be drawn into wire with the application of a tensile force. A ductile material must be both strong and plastic. The ductility is usuallymeasured by the terms, percentage elongation and percentage reduction in area. The ductile materialcommonly used in engineering practice (in order of diminishing ductility) are mild steel, copper,aluminium, nickel, zinc, tin and lead.

6.Brittlenes

It is the property of a material opposite to ductility. It is the property of breakingof a material with little permanent distortion. Brittle materials when subjected to tensile loads, snapoff without giving any sensible elongation. Cast iron is a brittle material.

7.Malleability

It is a special case of ductility which permits materials to be rolled or hammered into thin sheets. A malleable material should be plastic but it is not essential to be so strong. The malleable materials commonly used in engineering practice (in order of diminishing malleability) are lead, soft steel, wrought iron, copper and aluminium

8.Toughness

It is the property of a material to resist fracture due to high impact loads like hammer blows. The toughness of the material decreases when it is heated. It is measured by the amount of energy that a unit volume of the material has absorbed after being stressed uptothe point of fracture. This property is desirable in parts subjected to shock and impact loads.

9. Machinability

It is the property of a material which refers to a relative case withwhich a material can be cut. The machinability of a material can be measured in a number of ways such as comparing the tool life for cutting different materials or thrust required to remove the material at some given rate or the energy required to remove a unit volume of the material. It may be noted that brass can be easily machined than steel

10. Resilience

It is the property of a material to absorb energy and to resist shockand impact loads. It is measured by the amount of energy absorbed per unit volume within elastic limit. This property is essential for spring materials.

11.Creep

When a part is subjected toa constant stress at high temperature for a long period of time, it will undergo a slow and permanent deformation called creep .Thisproperty is considered in designing internalcombustion engines, boilers and turbines.

12. Fatigue.

When a material is subjected to repeated stresses, it fails atstresses below the yield point stresses. Suchtype of failure of a material is known as *fatigue. The failure is caused by means of aprogressive crack formation which are usually fine and of microscopic size. This property is considered in designing shafts, connecting rods, springs, gears, etc.

13. Hardness.

It is a very important property of the metals and has a wide variety of meanings. It embraces many different properties such as resistance to wear, scratching, deformation andmachinability etc. It also means the ability of a metal to cut another metal.

Analysis of Material Performance Requirements

The material performance requirements can be divided into five broad categories:functional requirements, processability requirements, cost, reliability, andresistance to service conditions

1- Functional Requirements

Functional requirements are directly related to the required characteristics of thepart or the product. For example, if the part carries a uniaxial tensile load, theyield strength of a candidate material can be directly related to the load-carryingcapacity of the product. However, some characteristics of the part or product maynot have simple correspondence with measurable material properties, as in thecase of thermal shock resistance, wear resistance, reliability, etc. Under theseconditions, the evaluation process can be quite complex and may depend uponpredictions based on simulated service tests or upon the most closely relatedmechanical, physical, or chemical properties.

2- Processability Requirements

The processability of a material is a measure of its ability to be worked andshaped into a finished part. With reference to a specific manufacturing method,processability can be defined as castability, weldability, machinability, etc.Ductility and hardenability can be relevant to processability if the material is to bedeformed or hardened by heat treatment, respectively.The closeness of the stock form to the required product form can be taken as ameasure of processability in some cases. It is important to remember thatprocessing operations will almost always affect the material properties so thatprocessability considerations are closely related to functional requirements.

3- Cost

Cost is usually an important factor in evaluating materials, because in manyapplications there is a cost limit for a given component. When the cost limit isexceeded, the design may have to be changed to allow for the use of a lessexpensive material or process. In some cases, a relatively more expensive materialmay eventually yield a less expensive component than a low-priced material thatis more expensive to process.

4- Reliability Requirements

Reliability of a material can be defined as the probability that it will perform theintended function for the expected life without failure. Material reliability isdifficult to measure, because it is not only dependent upon the material's inherentproperties, but it is also greatly affected by its production and processing history.Generally, new and nonstandard materials will tend to have lower reliability thanestablished, standard materials. Despite difficulties of evaluating reliability, it isoften an important selection factor that must be taken into account.failureanalysis techniques are usually used to predict the different ways in which aproduct can fail and can be considered as a systematic approach to reliability

evaluation. The causes of failure of a part in service can usually be traced back to defects in materials and processing, faulty design, unexpected service conditions, or misuse of the product.

5- Resistance to Service Conditions

The environment in which the product or part will operate plays an importantrole in determining the material performance requirements. Corrosiveenvironments, as well as high or low temperatures, can adversely affect theperformance of most materials in service. Whenever more than one material isinvolved in an application, compatibility becomes a selection consideration. In athermal environment, for example, the coefficients of thermal expansion of all thematerials involved may have to be similar in order to avoid thermal stresses. Inwet environments, materials that will be in electrical contact should be chosencarefully to avoid galvanic corrosion. In applications where relative movement exists between different parts, wear resistance of the materials involved should be considered. The design should provide access for lubrication; otherwise selflubricating materials have to be used.

Safety

Material safety is a very essential element to be considered in any engineering applications. Selection of material should be considered before construction of any engineeringideas.A material must safely perform its function, otherwise, the failure of the product made out of it may be catastrophic in air-planes and high pressure systems. As another example, materials that gives off spark when struck are safety

hazards in a coal mine.

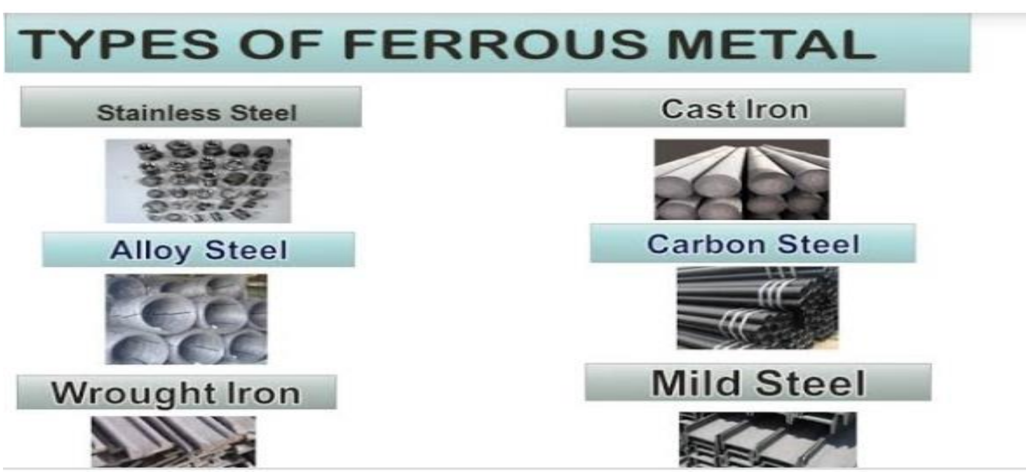
Chapater - 2.0

Ferrous materials and alloys

Ferrous Materials

A ferrous metal is any metal that is primarily composed of iron and has magnetic properties. A ferrous metal is known for its hardness, durability and tensile strength. Some common ferrous metals include:

- Alloy steel
- Carbon steel
- Cast iron
- Wrought iron



Ferrous metals are known and used for their strength. The properties that they possess make them perfect to be used in both the industrial and architectural sector for projects like skyscrapers, bridges, railroad projects and vehicles. Due to their magnetic properties, ferrous metals are also widely used in various appliances and engines. Ferrous metals, however, have high carbon content, which generally makes them more likely to rust; stainless steel is an exception due to its chromium content, as is wrought iron, due to the purity of its iron content. Ferrous metals are widely used in almost all industries such as in the manufacturing of shipping containers, industrial piping, automobiles, railroad tracks, ships and many commercial and domestic tools.

Characteristics of ferrous materials:

Ferrous materials are metals or metal alloys that contain theiron as a base material.
Steel is a ferrous alloy, and there are a number of other alloys that contain iron.
Ferrous metals 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.
The principal disadvantages of many ferrous alloys is their susceptibility to corrosion.

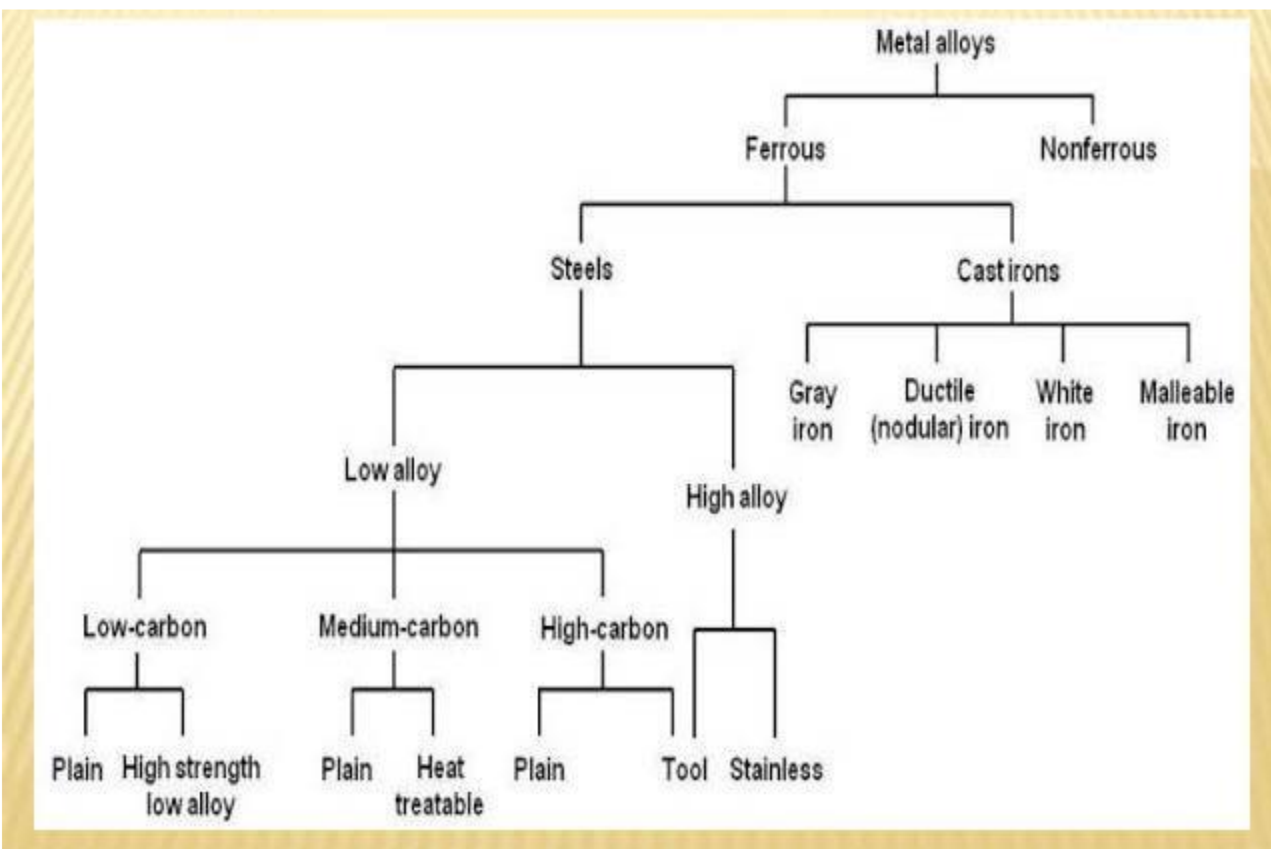
Application:

• Due to the strength and resilience of metals they are frequently used in high-rise building and bridge construction, most vehicles, many appliances, tools, pipes, non-illuminated signs and railroad tracks.
• Corrosion resistance property makes them useful in food processing plants, e.g., steel.
• Cast iron is strong but brittle, and its compressive strength is very high. So used in castings,
manhole covers, engine body, machine base etc.
• Mild steel is soft, ductile and has high tensile strength. It is used in general metal products like
structural, workshop, household furniture etc.

• **Carbon steels are used for cutting tools due to their hardness, strength and corrosion resistance properties.**




Classification



Steel

It is an alloy of iron and carbon in which carbon content is upto 2%.

It may contain other alloying elements.

Cast iron

In cast iron carbon content is 2% to 6.67%

Lower melting point (about 300 °C lower than pure iron) due to presence of eutectic point at 1153 °C and more carbon content.

CAST IRON VERSUS CARBON STEEL

CAST IRON	CARBON STEEL
Cast iron is a hard, relatively brittle alloy of iron and carbon which can be readily cast in a mould	Carbon steel is a type of steel having a high amount of carbon and low amounts of other elements
Contains up to 2-4% carbon	Contains up to 1% carbon
More brittle due to the presence of a high amount of carbon	Stronger than cast iron
Less ductile	More ductile
Has relatively a low melting point	Has relatively a high melting point
Composed of iron along with carbon, silicon manganese and trace amounts of sulfur and phosphorous as well	Contains mainly iron and carbon. Other elements can be present in trace amounts

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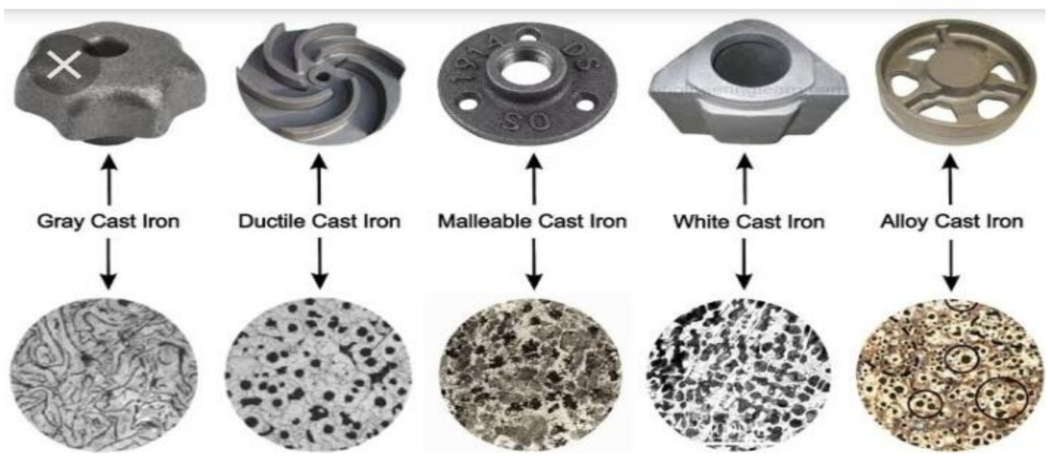
Types of cast iron:

grey, white, nodular, malleable and compacted graphite.



Types of steel:

Low carbon steel-

Carbon content in the range of 0 – 0.3%.

Most abundant grade of steel is low carbon steel (greatest quantity produced; and least expensive).

Not responsive to heat treatment; cold working needed to improve the strength.

It has good weldability and machinability

Medium carbon steel-

Carbon content in the range of 0.3 – 0.8%.

It can be heat treated - austenitizing, quenching and then tempering.

Most often used in tempered condition – tempered martensite

Medium carbon steels have low hardenability and ductility.

Addition of Cr, Ni, Mo improves the heat treating capacity

Typical applications – Railway wheels and tracks, gears,crankshafts.

High carbon steel-

High carbon steels – Carbon content 0.8 – 2%

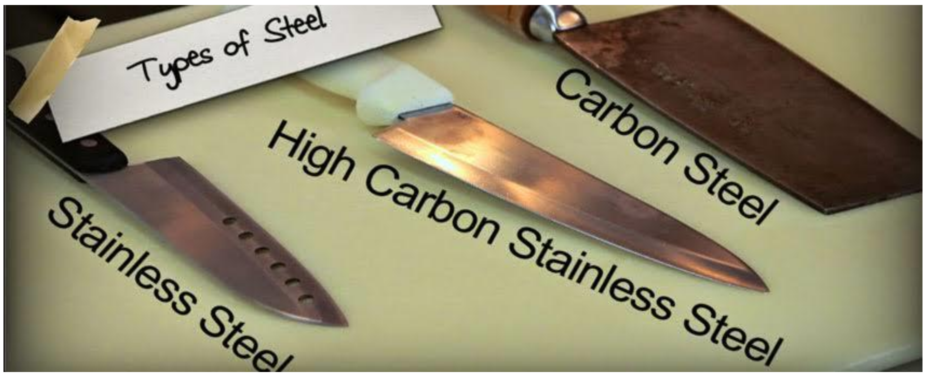
High Carbon content provides high hardness and strength.

Hardest and least ductile.-

Used in hardened and tempered condition

Strong carbide formers like Cr, V, W are added as alloying elements to from carbides of these metals.

Used as tool and die steels owing to the high hardness and wear resistance property.



Tool steel-

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.

Stainless steel-Stainless steel does not readily corrode, rust or stain with water as ordinary steel does, but despite the name it is not fully stain-proof, most notably under low-oxygen, high-salinity, or poor-circulation environments. There are different grades and surface finishes of stainless steel to suit the environment the alloy must

endure. Stainless steel is used where both the properties of steel and corrosion resistance are required. Stainless steel differs from carbon steel by the amount of chromium present.

Plain 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

Low carbon steel or Mild steel:

Low carbon steel or mild steel is further classified in to three types basing on their composition i-e percentage of carbon.

a) Dead mild steel or mild steel containing 0.05 to 0.15% of carbon.

b) Mild steel containing 0.15 to 0.2% of carbon.

c) Mild steel containing 0.2 to 0.3% of carbon.

Application of Mild Steel:

i) Dead mild steel is used for making steel wire, sheet, rivets, screws, pipe, nail, chain, etc.

ii) Mild steel containing 0.15 to 0.2% carbon is used for making camshafts, sheets, strips
for blades, welded tubing, forgings, drag lines, etc.

iii) Mild steel containing 0.2 to 0.3% carbon is used for making valves, gears, crank shafts, connecting rods, railways axles, fish plates and small forgings, etc.

Medium Carbon Steel

Steel containing 0.3 to 0.7% carbon is known as Medium carbon steel.

Medium carbon steel are of three categories.

- **i) Steel containing 0.35 to 0.45% carbon is used for connecting rod, wires & rod, spring ,clips, gear shaft, key stock, shafts & brakes lever, axle, small & medium forgings, etc.**
- **ii) Steel containing 0.45 to 0.55% carbon is used for railways coach axles, axles & crank pins on heavy machines, splines shafts, crank shafts, etc.**

iii) Steel containing 0.6 to 0.7% carbon is used for drop forging die & die blocks, clutch ,discs, plate punches, set screws, valve springs, cushion ring, thrust washers, etc.

High carbon steel

Steel containing 0.7 to 0.1.5% carbon is known as high carbon steel.

Uses:-

i) Steel containing 0.7 to 0.8% carbon is used for making cold chisels, wrenches, jaws for vice, pneumatic drill bits, wheels for railway service, wire for structural work, shear blades, automatic clutch disc, hacksaws, etc.

ii) Steel containing 0.8 to 0.9% carbon is used for making rock drills, railway rail, circular saws, machine chisels, punches & dies, clutch discs, leaf springs, music wires, etc.

iii) Steel containing 0.9 to 1.0% carbon is used for making punches & dies, leaf & coil springs, keys, speed discs, pins, shear blades, etc.

iv)Steel containing 1.0 to 1.1% carbon is used for making railway springs, machine tools, mandrels, taps, etc.

v) Steel containing 1.1 to 1.2% carbon is used for making taps, thread metal dies, twist drills, knives, etc.

vi) Steel containing 1.2 to 1.3% carbon is used for making files, metal cutting tools, reamers, etc.

vii) Steel containing 1.3 to 1.5% carbon is used for making wire drawing dies, metal cutting saws, paper knives, tools for turning chilled iron, etc.

Alloy Steel:

An alloy steel may be defined as a steel to which elements other than carbon are added insufficient amount to produce an improvement in properties. The alloying is done for specific purposesto increase wearing resistance, corrosion resistance andto improve electrical and magnetic properties,which cannot be obtained in plain carbon steels. The chief alloying elements used in steel are nickel,chromium, molybdenum, cobalt, vanadium, manganese, silicon and tungsten. Each of these elementsconfer certain qualities upon the steel to which it is added. These elements may be used separately orin combination to produce the desired characteristic in steel. Following are the effects of alloyingelements on steel:

1.Nickel.

It increases the strength and toughness of the steel. These steels contain 2 to 5% nickel and from 0.1 to 0.5% carbon. In this range, nickel contributes great strength and hardness withhigh elastic limit, good ductility and good resistance to corrosion.An alloy containing 25% nickel possesses maximum toughness and offers the greatest resistance to rusting, corrosion and burning athigh temperature. It has proved to be of advantage in the manufacture of boiler tubes, valves for usewith superheated steam, valves for I.C. engines and spark plugs for petrol engines. A nickel steelalloy containing 36% of nickel is known asinvar. It has nearly zero coefficient of expansion. So it is in great demand for measuring instruments and standards of lengths for everyday use.

2. Chromium.

It is used in steels as an alloying element to combine hardness with high strength and high elastic limit. It also imparts corrosion-resisting properties to steel. The mostcommon chromesteels contains from 0.5 to 2% chromium and 0.1 to 1.5% carbon. The chrome steel is used for balls,rollers and races for bearings. A nickel chrome steel containing 3.25% nickel, 1.5% chromium and0.25% carbon is much used for armour plates. Chrome nickel steel is extensively used for motor carcrankshafts, axles and gears requiring great strength and hardness.

3. Tungsten.

It prohibits grain growth, increases the depth of hardening of quenched steel andconfers the property of remaining hard even when heated to red colour. It is usually used in conjuctionwith other elements. Steel containing 3 to 18% tungsten and 0.2 to 1.5% carbon is used for cuttingtools. The principal uses of tungsten steels are for cutting tools, dies, valves, taps and permanent magnets.

4. Vanadium.

It aids in obtaining a finegrain structure in tool steel. The addition of a very small amount of vanadium (less than 0.2%)produces a marked increase in tensile strength andelastic limit in low and medium carbon steelswithout a loss of ductility. The chrome-vanadiumsteel containing about 0.5 to 1.5% chromium, 0.15 to 0.3% vanadium and 0.13 to 1.1% carbon haveextremely good tensile strength, elastic limit,endurance limit and ductility. These steels arefrequently used for parts such as springs, shafts,gears, pins and many drop forged parts.

5. Manganese.

It improves the strength ofthe steel in both the hot rolled and heat treated condition. The manganese alloy steels containing over1.5% manganese with a carbon range of 0.40 to 0.55% are used extensively in gears, axles, shafts and other parts where high strength combined with fair ductility is required. The principal uses of manganesesteel is in machinery parts subjected to severe wear. These steels are all cast and ground to finish.

6. Silicon.

The silicon steels behave like nickel steels. These steels have a high elastic limit ascompared to ordinary carbon steel. Silicon steels containing from 1 to 2% silicon and 0.1 to 0.4% carbon and other alloying elements are used for electrical machinery, valves in I.C. engines, springsand corrosion resisting materials.

7. Cobalt.

It gives red hardness by retention of hard carbides at high temperatures. It tends todecarburize steel during heat-treatment. It increases hardness and strength and also residual magnetismand coercive magnetic force in steel for magnets.

8. Molybdenum.

A very small quantity (0.15 to 0.30%) of molybdenum is generally used with chromium and manganese (0.5 to 0.8%) to make molybdenum steel. These steels possess extra tensilestrength and are used for air-plane fuselage and automobile parts. It can replace tungsten in highspeed steels.

ELEMENT	EFFECT ON STEEL	COMMON % USE IN STEEL
Chrome (Cr)	Improves **oxidation resistance** and **hardenability**.	Usually at least 10,5% and up to 18% in stainless steels.
Manganese (Mn)	It increases the **strength** of steel and assists with **de-oxidation**. Manganese has a milder effect on the strength of steel than carbon.	Usually at least 0,3%. Can be up to 1,5% in carbon steels.
Molybdenum (Mo)	Improves **hardenability** and high temperature **strength**.	Usually less than 1%.
Nickel (Ni)	Increases **strength**, **hardness** and hardenability. Also often increases **ductility** and **toughness**. .	Usually 8-10% in stainless steels.
Phosphorous (P)	Increases **machinability**. Can increase strength but majorly **reduces toughness and ductility**, is generally considered as impurity.	Can be added up to 0,1% to low-alloy high-strength steels.
Silicon (Si)	Similar to carbon and manganese. Silicon increases the **strength of steel**. Silicon has a milder effect on the strength than manganese and consequently than carbon.	Usually between 0,1% to 1%. Can be up to 6,5% in electrical steels.
Sulphur (S)	Can reduce **toughness** and **ductility**, is generally considered as impurity.	Should not exceed 0,05% unless the goal is to get resulfirised steel.
Titanium (Ti)	Increases **hardness** and **toughness**. Reduces the oxygen or nitrogen in the molten steel.	Usually between 0,2% and 0,6%.
Tungsten (W)	Improves **high temperatures strength**.	Can vary from 2% to even 18% in high speed steels.
Vanadium (V)	Improves **hardenability** and **high temperatures strength**. Extremely effective.	Usually 0,05%. Can be up to 0,25% in high speed steels.

CHAPTER 3.0

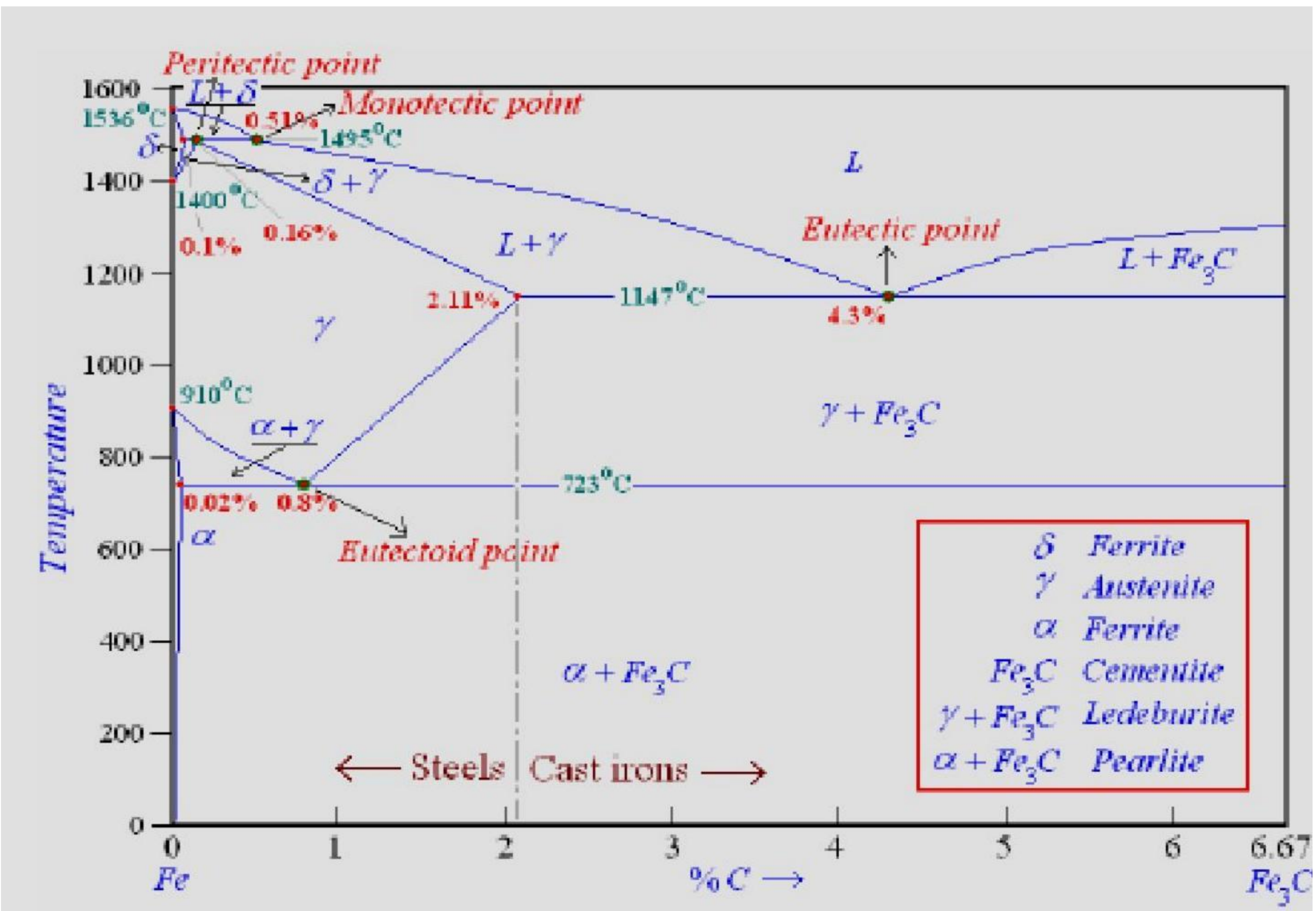
IRON-CARBON SYSTEM

Iron-Carbon Phase Diagram

The iron-carbon phase diagram is widely used to understand the different phases of steel and cast iron. Both steel and cast iron are a mix of iron and carbon. Also, both alloys contain a small amount of trace elements.

The graph is quite complex but since we are limiting our exploration to Fe3C, we will only be focusing up to 6.67 weight percent of carbon.

This iron carbon phase diagram is plotted with the carbon concentrations by weight on the X-axis and the temperature scale on the Y-axis.



The following phases are involved in the transformation, occurring with iron-carbon alloys:

L–

Liquid solution of carbon in iron;

δ-ferrite –

Solid solution of carbon in iron.

Maximum concentration of carbon in δ-ferrite is 0.09% at 2719 ºF (1493ºC) – temperature of the peritectic transformation.

The crystal structure of δ-ferrite is BCC (cubic body centered).

Austenite –

interstitial solid solution of carbon in γ-iron.

Austenite has FCC (cubic face centered) crystal structure, permitting high solubility of carbon – up to 2.06% at 2097 ºF (1147 ºC).

Austenite does not exist below 1333 ºF (723ºC) and maximum carbon concentration at this temperature is 0.83%.

α-ferrite –

solid solution of carbon in α-iron.

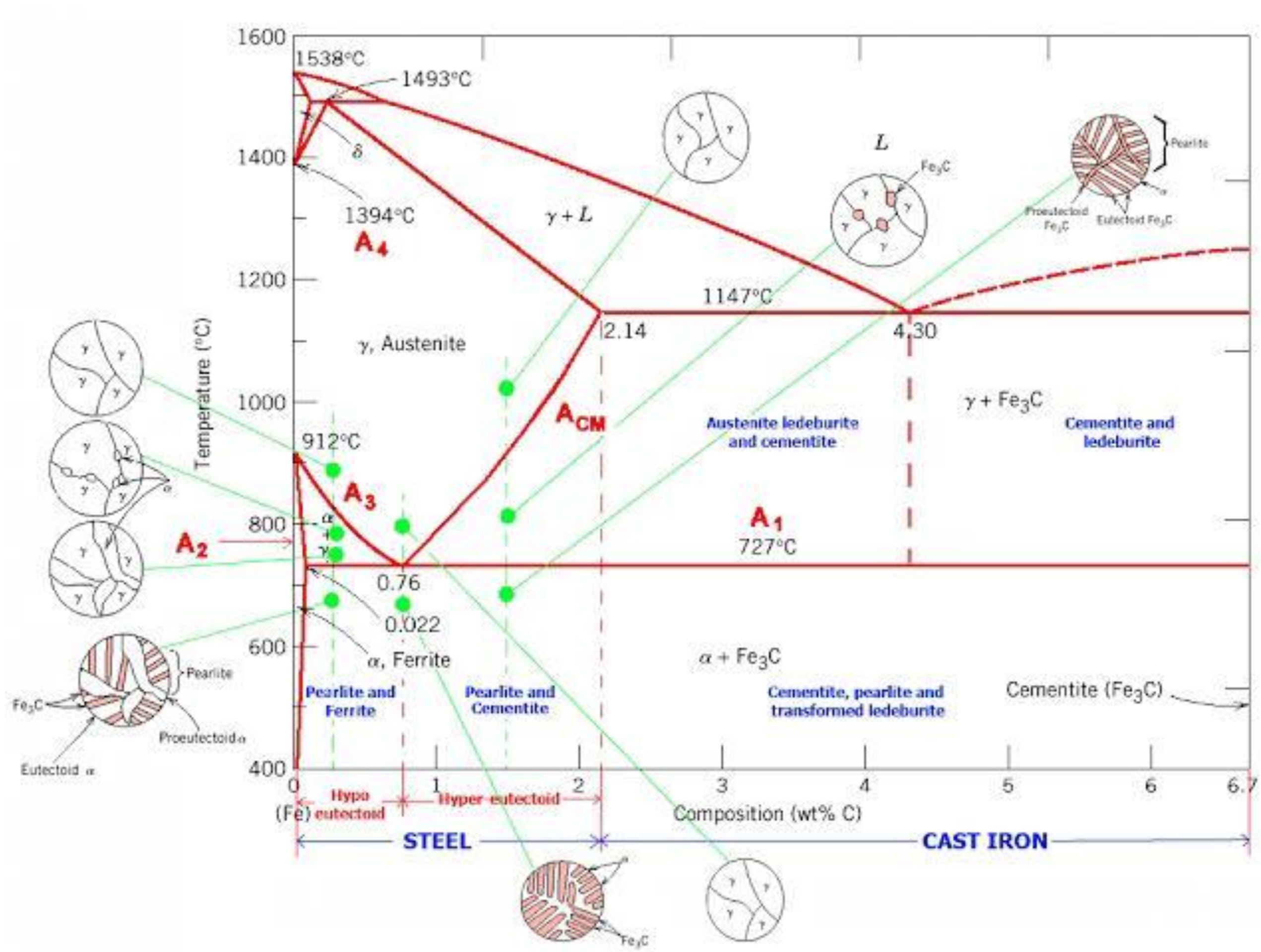
α-ferrite has BCC crystal structure and low solubility of carbon – up to 0.025% at 1333 ºF (723ºC).

α-ferrite exists at room temperature.

Cementite –

iron carbide, intermetallic compound, having fixed composition Fe_3C.

Cementite is a hard and brittle substance, influencing on the properties of steels and cast irons



Boundaries

Multiple lines can be seen in the diagram titled A1, A2, A3, A4, and ACM. The A in their name stands for the word 'arrest'. As the temperature of the metal increases or decreases, phase change occurs at these boundaries when the temperature reaches the value on the boundary.

Normally, when heating an alloy, its temperature increases. But along these lines (A1, A2, A3, A4, and ACM) the heating results in a realignment of the structure into a different phase and thus, the temperature stops increasing until the phase has changed completely. This is known as thermal arrest as the temperature stays constant.

Alloy steel elements such as nickel, manganese, chromium, and molybdenum affect the position of these boundaries on the phase diagram. The boundaries may shift in either direction depending on the element used. For example, in the iron carbon phase diagram, addition of nickel lowers the A3 boundary while the addition of chromium raises it.

Eutectic Point

Eutectic point is a point where multiple phases meet. For the iron-carbon alloy diagram, the eutectic point is where the lines A1, A3 and ACM meet. The formation of these points is coincidental.

At these points, eutectic reactions take place where a liquid phase freezes into a mixture of two solid phases. This happens when cooling a liquid alloy of eutectic composition all the way to its eutectic temperature.

The alloys formed at this point are known as eutectic alloys. On the left and right side of this point, alloys are known as hypoeutectic and hypereutectic alloys respectively ('hypo' in Greek means less than, 'hyper' means greater than).

Phase Fields

The boundaries, intersecting each other, mark certain regions on the Fe3C diagram. Within each region, a different phase or two phases may exist together. At the boundary, the phase change occurs. These regions are the phase fields.

They indicate the phases present for a certain composition and temperature of the alloy. Let's learn a little about the different phases of the iron-carbon alloy.

Different Phases

α-ferrite

Existing at low temperatures and low carbon content, α-ferrite is a solid solution of carbon in BCC Fe. This phase is stable at room temperature. In the graph, it can be seen as a sliver on the left edge with Y-axis on the left side and A2 on the right. This phase is magnetic below 768°C.

It has a maximum carbon content of 0.022 % and it will transform to γ-austenite at 912°C as shown in the graph.

γ-austenite

This phase is a solid solution of carbon in FCC Fe with a maximum solubility of 2.14% C. On further heating, it converts into BCC δ-ferrite at 1395°C. γ-austenite is unstable at temperatures below eutectic temperature (727°C) unless cooled rapidly. This phase is non-magnetic.

δ-ferrite

This phase has a similar structure as that of α-ferrite but exists only at high temperatures. The phase can be spotted at the top left corner in the graph. It has a melting point of 1538°C.

Fe3C or cementite

Cementite is a metastable phase of this alloy with a fixed composition of Fe3C. It decomposes extremely slowly at room temperature into Iron and carbon (graphite). This decomposition time is long and it will take much longer than the service life of the application at room temperature. Some other factors (high temperatures and addition of certain alloying elements for instance) can affect this decomposition as they promote graphite formation.

Cementite is hard and brittle which makes it suitable for strengthening steels. Its mechanical properties are a function of its microstructure, which depends upon how it is mixed with ferrite.

Fe-C liquid solution

Marked on the diagram as ‘L’, it can be seen in the upper region in the diagram. As the name suggests, it is a liquid solution of carbon in iron. As we know that δ-ferrite

melts at 1538°C, it is evident that melting temperature of iron decreases with increasing carbon content.

CHAPTER- 4.0

CRYSTAL IMPERFECTIONS

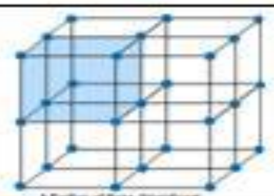
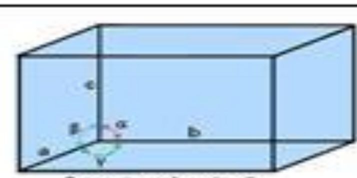
Crystal

A crystal or crystalline solid is a solid material whose constituents are arranged in a highly ordered microscopic structure, forming a crystal lattice that extends in all directions.Whenever atoms arrange themselves in an orderly repetitive three dimensional pattern crystal is formed.

It is a solid which consists of atoms arranged in a pattern in 3-D.

A perfect crystal is constructed by the infinite regular repetition in space of identical structuralunits or building blocks.The symmetry is an important characteristic of most of the crystals.e.g. cube and octahedrons are simple form of the crystal.

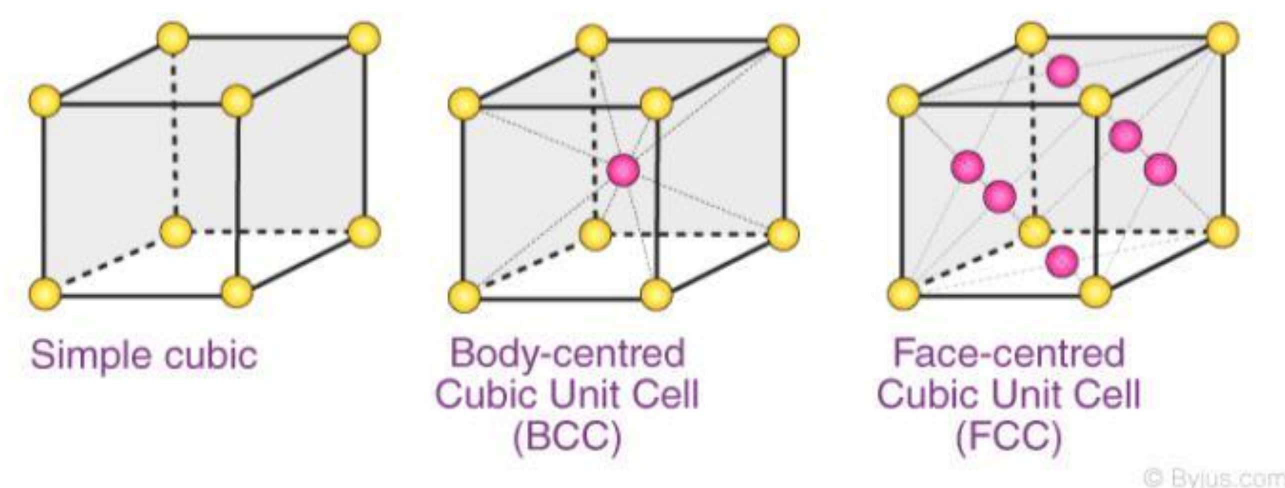
All metals are crystalline, where atoms are arranged in a definite periodic order.

Crystal lattice	Unit Cell
Orderly three dimensional arrangements of atoms in space is called crystal lattice. It is diagrammatic representation of constituent particles, such as atoms, ions or molecules of a solid.	The smallest unit of a crystal lattice is called unit cell. Repeated unit cells form crystal lattice.
	 Parameters of a unit cell

.

Crystalimperfections

On the basis of periodic arrangement of atom crystal are grouped into seven system.
The systems are:
Cubic ,tetragonal,orthorhombic, rhombohedral, hexagonal,monoclynic and triclynic.
In the present context,only cubic and hexagonal crystal structure are considered as most of the metals and alloys belong to these two systems.
In crystal structure,the smallest unit is one unit cell which characterized the whole arrangement.
There are three types of cell are as follows:



Simplecubic

Each layer is stacked on the previous layer perfectly.
There are 8eighths(one is each corner).for total of one atom in the unit cell.

BCC(bodyCentred cubic)

Each layer is offset from the layerbefore.Arrangements duplicate themselves every other layer.

There are 8 eighths (one is each corner)and one full atom in the centre for a total of two atom in the unit cell .

FCC(Face centredcubic)

There are 8eighths (one is each corner),and six halves (one on each face of the cube)for a total of four atom in the unit cell.

Ideal Crystals

In ideal crystals, the angles between the faces required to determine the crystal form aresame.

Crystal Imperfections

Crystals are not perfect. An important characteristic which determines some importantproperties of crystalline materials is the presence of imperfections. Except some ideal crystalsmost of the crystals have some type of defects or imperfections. All crystals are not composed ofidentical atoms on identical sites throughout a regularly repeating 3D lattice. These imperfection ordefects are used to describe any deviation from an orderly periodic array of atoms and influencethe characteristics like mechanical strength, electrical properties and chemical reactions.

Classification of imperfections

Defects one classified into point, line or place and volume imperfections.

1. POINT DEFECTS

These are the lattice errors at isolated points , takes place due to the imperfect packing of atoms during crystallization or due to the vibrations of atoms at high temperatures.

number of defects at equilibrium concentration , at a certain temperature is given by

$$n = N * \exp [-Ed/kbT]$$

Where

n —number of imperfections

N—number of atomic sites per mole

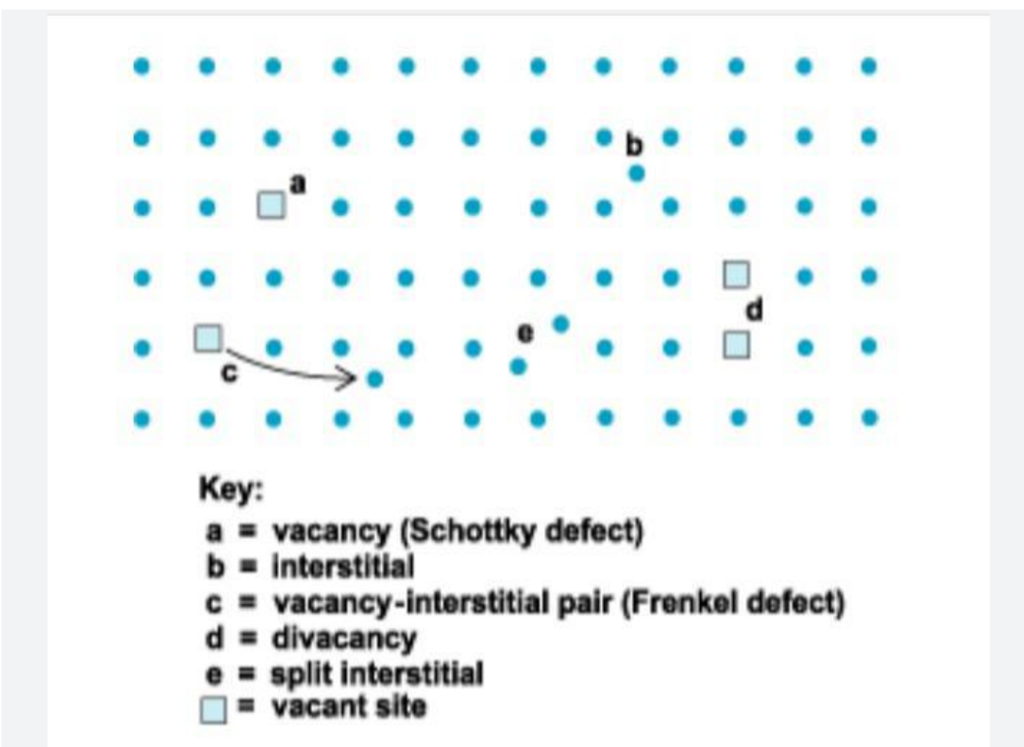
Ed—free energy required to form defects

kb—Boltzmann's constant (kb= 8.62*10-5 eV/K)

T —Absolute temperature

(a)VACANCIES

A simplest point defects in a crystal.RefersRefers to missing atom or vacant atomic site.Arise either from imperfect packing during original crystallisation or from thermal vibrations at high temperatures.

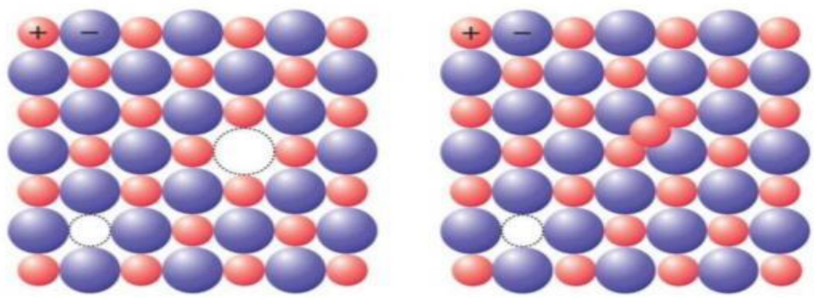


(b)FRENKEL DEFECT

It is formed by a cation leaving its normal position and moving into an interstial site.

(c)SCHOTTKY DEFECT

It is formed by removing one cation and one anion from the interior of the crystal and then placing them both at an external surface.



(a) Schottky defect (b) Frenkel defect

LINE IMPERFECTIONS/ DISLOCATIONS

- **1-D defects around which some of the atoms are misaligned.**
- **These are responsible for the useful property of ductility in metals, ceramics and crystalline polymers.**
- **Types :- Edge Dislocations and Screw Dislocations.**

(a)EDGE DISLOCATIONS

- **The perfect crystal is considered to be made up of vertical planes parallel to one another and to the side faces. If one of these vertical planes doesn't extend from top to bottom of the crystal but ends partway within the crystal then there exists a Dislocation.**

• The bond lengths above the slip plane are compressed to smaller than that of the equilibrium value. And below the slip plane bond lengths are found to be pulled apart and are in a state of tension.

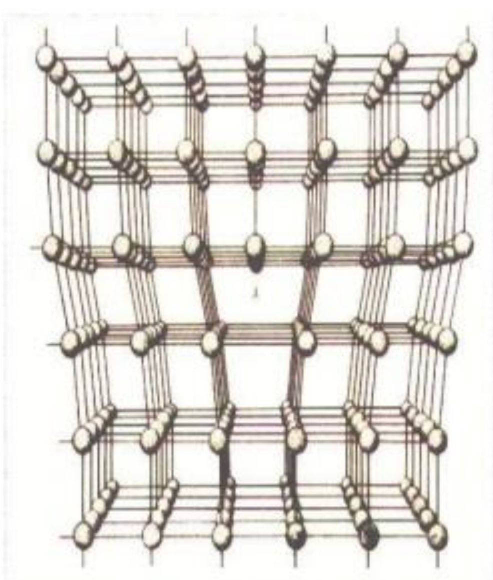
BURGERS VECTOR.

• The magnitude & direction of the lattice distortion associated with a dislocation is expressed in terms of a BURGERS VECTOR.

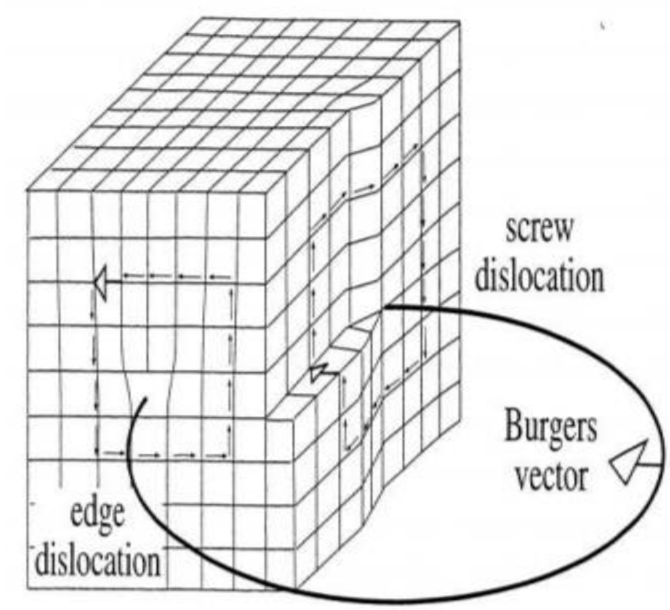
• If The BURGERS Vector and the orientation of the dislocation line are known , then the dislocation is completely described.

• This vector indicates how much and at what direction the lattice above the slip plane appears to have been shifted with respect to the lattice below the plane.

• The burgers vector is perpendicular to the dislocation line in Edge Dislocations and it is parallel to the dislocation line in Screw Dislocations.



Edge dislocation



3. SURFACE IMPERFECTIONS

• Two Dimensional defects.

• These arise from a change in the stacking of atomic planes on or across a boundary.

(a) External surface imperfections

• Imperfections represented by a boundary.

• The external surface of a material is an imperfection itself because the bonds do not extend beyond it since surface atoms are not entirely surrounded byother atoms on other side, they posses higher energy than that of internal atoms.

(b) Internal surface imperfections

These are manifested by such defects as Grain boundaries, Tilt boundaries, Twin boundaries, Stacking faults.

Grain boundaries:

These separate crystals/ grains of different orientation in a polycrystalline material during crystallisation. The shape of a grain is usually influenced by the presence of surrounding grains. Hence a region of transition exists in which the atomic packing is Imperfect.

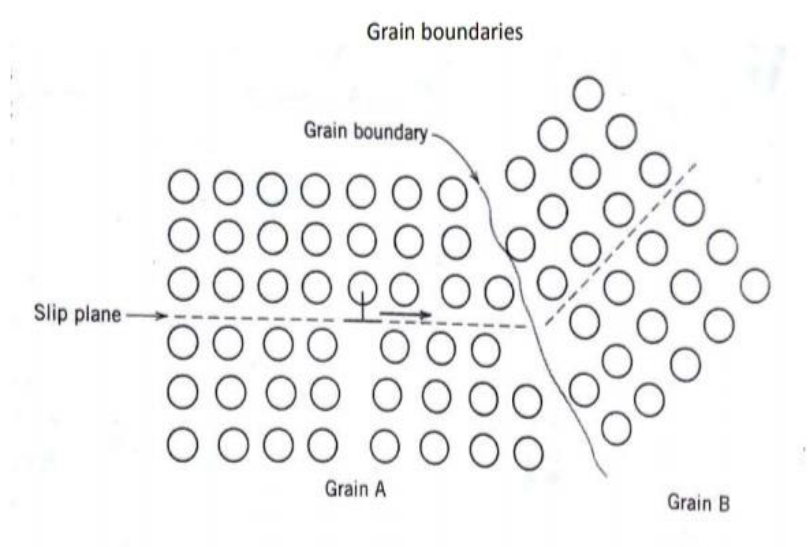
• In the boundary where the crystal or grains change abruptly, the orientation of difference between neighboring grains is more than 10˚-15˚ ,& the boundaries are known as high angle grain boundaries. The boundary between 2 crystals which have different crystalline arrangements or different compositions is called an interface.

Effect of imperfections on material properties.

It affects or influence the characteristics like mechanical strength, electricalproperties andchemical reactions. The role of imperfections in heat treatment is very important. Imperfectionsaccount for crystal growth , diffusion mechanism, annealing and precipitation, besides this, othermetallurgical phenomena, such as oxidation, corrosion, yield strength, creep, fatigue and fractures'are governed by imperfections. Imperfections are not always harmful to metals. Sometimes theare generated to obtain the desired properties. For example, carbon is added to steel as interstitialimpurity to improve the mechanical properties and this properties are furtherimproved by heattreatment.

Deformation by slip and twinning

Slip



It is defined as the process or mechanism by which a large displacement of one part of thecrystal 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. Slipbegins when the shearing stress acting along the slip planes in the direction of slip exceeds acertain value known as critical slip planes are planes of high atomic densities while the directionof slip along these planes is always the direction of highest atomic density.

Twins and Twinning

Other than slip, twinning also gives rise to plastic deformation in crystals. It may be called asa special case of slip movement. In twinning, instead of whole blocks of atoms moving differentdistances along the slipping planes, each plane of atoms concerned moves a definite distance andthe total movement at any point relative to the twinning plane is proportional to the distance fromthis plane. In bcc and hcp it occurs frequently.

Effect of deformation on material properties

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

CHAPTER-5

HEAT TREATMENT

Heat Treatment of Steels

The term heat treatment may be defined as an operation or a combination of operations, involving the heating and cooling of a metal or an alloy in the solid state for the purpose of obtaining certain desirable conditions or properties without change

in chemical composition. The aim of heat treatment is to achieve one or more of the following objects :

1. **To increase the hardness of metals.**
2. **To relieve the stresses set up in the material after hot or cold working.**
3. **To improve machinability.**
4. **To soften the metal.**
5. **To modify the structure of the material to improve its electrical and magnetic properties.**
6. **To change the grain size.**
7. **To increase the qualities of a metal to provide better resistance to heat, corrosion and wear.**

Following are the various heat treatment processes commonly employed in engineering practice:

Normalising.

The main objects of normalising are :

1. **To refine the grain structure of the steel to improve machinability, tensile strength and structure of weld.**
2. **To remove strains caused by cold working processes like hammering, rolling, bending, etc., which makes the metal brittle and unreliable.**
3. **To remove dislocations caused in the internal structure of the steel due to hot working.**
4. **To improve certain mechanical and electrical properties.**

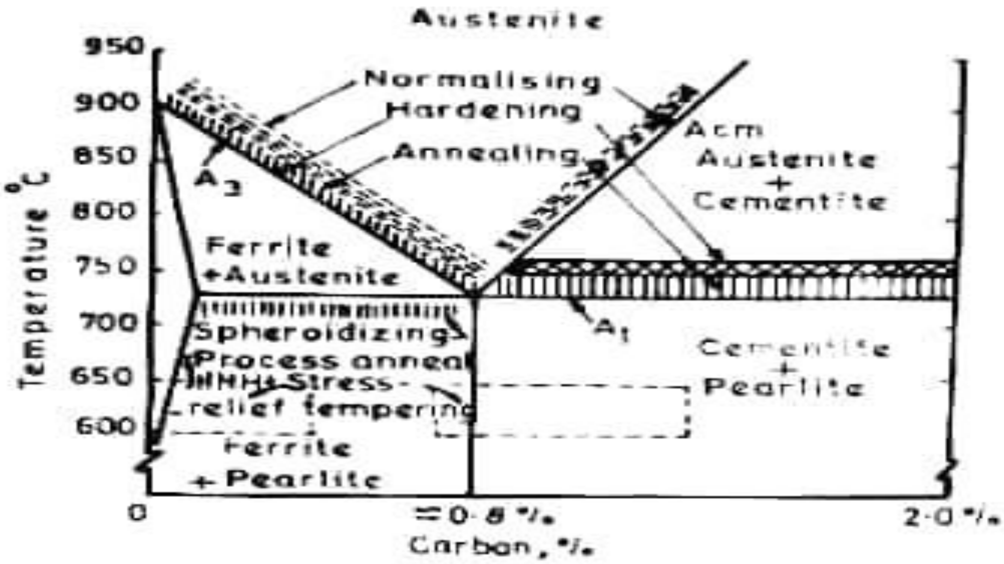
The process of normalising consists of heating the steel from 30 to 50°C above its upper critical temperature (for hypoeutectoid steels) or Acm line (for hypereutectoid steels). It is held at this temperature for about fifteen minutes and then allowed to cool down in still air.

This process provides a homogeneous structure consisting of ferrite and pearlite for hypoeutectoid steels, and pearlite and cementite for hypereutectoid steels. The homogeneous structure provides a higher yield point, ultimate tensile strength and impact strength with lower ductility to steels. The process of normalising is frequently

applied to castings and forgings, etc. The alloy steels may also be normalised but they should be held for two hours at a specified temperature and then cooling in the furnace.

Notes : (a) The upper critical temperature for a steel depends upon its carbon content. It is 900°C for pure iron, 860°C for steels with 2.2% carbon, 723°C for steel with 0.8% carbon and 1130°C for steel with 1.8% carbon.

(b) Steel containing 0.8% carbon is known as eutectoid steel, steel containing less than 0.8% carbon is called hypoeutectoid steel and steel containing above 0.8% carbon is called hypereutectoid steel.



Heat treating tempertaures in Steel

Annealing.

The main objects of annealing are :

1. To soften the steel so that it may be easily machined or cold worked.
2. To refine the grain size and structure to improve mechanical properties like strength and ductility.
3. To relieve internal stresses which may have been caused by hot or cold working or by unequal contraction in casting.
4. To alter electrical, magnetic or other physical properties.

5. To remove gases trapped in the metal during initial casting. The annealing process is of the following two types :

(a) Full annealing:

. The purpose of full annealing is to soften the metal to refine the grain structure, to relieve the stresses and to remove trapped gases in the metal. The process consists of steps like:

(i) heating the steel from 30 to 50°C above the upper critical temperature for hypoeutectoid steel and by the same temperature above the lower critical temperature i.e. 723°C for hypereutectoid steels.

(ii) holding it at this temperature for sometime to enable the internal changes to take place. The time allowed is approximately 3 to 4 minutes for each millimetre of thickness of the largest section, and

(iii) cooling slowly in the furnace. The rate of cooling varies from 30 to 200°C per hour depending upon the composition of steel

(b) Process annealing

. The process annealing is used for relieving the internal stresses previously set up in the metal and for increasing the machinability of the steel. In this process, steel is heated to a temperature below or close to the lower critical temperature, held at this temperature for sometime and then cooled slowly. This causes complete recrystallisation in steels which have been severely cold worked and a new grain structure is formed. The process annealing is commonly used in the sheet and wire industries.

3. Spheroidising.

It is another form of annealing in which cementite in the granular form is produced in the structure of steel. This is usually applied to high carbon tool steels which are difficult to machine. The operation consists of heating the steel to a temperature slightly above the lower critical temperature (730 to 770°C). It is held at this temperature for some time and then cooled slowly to a temperature of 600°C. The rate of cooling is from 25 to 30°C per hour.

The spheroidising improves the machinability of steels, but lowers the hardness and tensile strength. These steels have better elongation properties than the normally annealed steel.

4. Hardening.

The main objects of hardening are :

* To increase the hardness of the metal so that it can resist wear.
* To enable it to cut other metals i.e. to make it suitable for cutting tools

The process of hardening consists of

(a) heating the metal to a temperature from 30 to 50°C above the upper critical point for hypoeutectoid steels and by the same temperature above the lower critical point for hypereutectoid steels.

(b) keeping the metal at this temperature for a considerable time, depending upon its thickness.

(c) quenching (cooling suddenly) in a suitable cooling medium like water, oil or brine.

It may be noted that the low carbon steels cannot be hardened appreciably, because of the presence of ferrite which is soft and is not changed by the treatment. As the carbon content goes on increasing, the possible obtainable hardness also increases

5. Tempering.

The steel hardened by rapid quenching is very hard and brittle. It also contains internal stresses which are severe and unequally distributed to cause cracks or even rupture of hardened steel. The tempering (also known as drawing) is, therefore, done for the following reasons :

1. To reduce brittleness of the hardened steel and thus to increase ductility.
2. To remove the internal stresses caused by rapid cooling of steel.
3. To make steel tough to resist shock and fatigue.

The tempering process consists of reheating the hardened steel to some temperature below the lower critical temperature, followed by any desired rate of cooling. The exact tempering temperature depends upon the purpose for which the article or tool is to be used.

6. Surface hardening or case hardening.

In many engineering applications, it is desirable that a steel being used should have a hardened surface to resist wear and tear. At the same time, it should have soft and tough interior or core so that it is able to absorb any shocks, etc. This is achieved by hardening the surface layers of the article while the rest of it is left as such. This type of treatment is applied to gears, ball bearings, railway wheels, etc.
Following are the various *surface or case hardening processes by means of which the surface layer is hardened:

1. Carburising, 2. Cyaniding, 3. Nitriding, 4. Induction hardening, and 5. Flame hardening.

CHAPTER-6

NON - FERROUS ALLOYS

Non-ferrous Metals

We have already discussed that the non-ferrous metals are those which contain a metal other than iron as their main constituent. The non-ferrous metals are usually employed in industry due to the following characteristics:

1. Ease of fabrication (casting, rolling, forging, welding and machining),
2. Resistance to corrosion,
3. Electrical and thermal conductivity, and
4. Light Weight

Duralmin

It is one of the oldest and best known alloys of aluminium widely used for aircraft parts. Its composition is 3.5-4.5% copper, 0.4-0.7% manganese, 0.4% silicon and sometimes contain 0.4- 0.7%, magnesium and below 0.5% iron. It developed maximum properties as a result of heat treatment and age hardening which can be worked readily about 5000 C and after quenching ages over a period of 4 to 5 days. Its tensile strength increase from 1.55-1.86ton/cm2 yield point from 1.04-2.325 t/cm2 and hardness from 65 brinell to 95 brinell. Used for highly stressed structural components, aircrafts and automobile parts like front axle, levers, bonnets, connecting rods, chassis from, girders for ships, aeroplane air screws, spares, clips, fitting, levers etc. Also used for surgical and orthopaedics works for non magnetic and other instrument parts.

Y-alloys

Y-alloys are of the best alloys of this groups is a high strength costing alloy which retains its strength and hardness at high temperature.

Its percentage composition is 4% copper, 1.5% magnesium and 2% nickel, each of silicon, manganese is 0.6%. In the cost and heat treated from its ultimate strength is 2.12 tons/cm2 but chill costing after heat treatment show a strength of 3.1 tonnes/cm2. Heat treated forged alloys give an ultimate strength of 3.565 – 4.185 ton/cm2 an elongation of 17 – 22% and brinell hardness of 100-105.

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

Copper alloys

(a) Copper- Aluminium alloys

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.

(b) Copper-Tin

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.

(c) Babbot

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. Edited with the trial version of 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.

(d) Phosphorous bronze

The phosphorous bronzes are the alloys of copper and tin with 0.1 to 1.5% phosphorous.Phosphorous is added both for deoxidising the tin oxide and developing the structure and general properties of the metal. In the form of casting phosphorous bronze gives and ultimate strength of
about 18 tonnes /cm2 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

This 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.

(e) Brass

These are the alloys of copper and zinc with varying percentage of two metals. If small amount of one or more metals are added they provide more specific properties like colour, strength,ductility, machinability.

- - brasses- 36% zinc and 64% cu.
- – brasses – 40 to 44% zn and 64 to 55% cu.
- – brasses possess good tensile strength, good ductility, suitable for producing sheet,strips, tubes, wires etc.
- – brasses are used for hot pressings, stampings.

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.

Predominating elements of lead alloys, zinc alloys and nickel alloys.

Lead alloys

The tin is replaced by lead base alloys and contains 10 – 15% antimony, 15% Cu, 20% Tin and 60% Lead. These alloys are cheaper than tin base alloys, but not strong and do not possess the lead carrying capacity strength decreases with increasing in temperature. An alloy containing 80% lead, 15% antimony and 5% tin or 20% antimony generally used for long bearings with medium loads.

Binary copper lead alloys- lead 10 – 20%, 20 – 30% and above 30%.

Zinc alloys

These alloys used in the form of tooling plate and easy and speed of fabrication.

Brasses – Alloys of Cu and Zn.

Nickel alloys

Nickel is one of the most important metals which is used as a pure metal and alloyed with other elements.

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, stiper duplex materials.

Low alloy materials

Which possess slowly cooled micro structures, similar to those of plain carbon steel in the same condition namely pearlite, pearlite plus ferrite. These low alloy also known as pearlite alloy steel.

High alloy steel

Which possess slowly cooled micro structure, consisting either of martensite, austenite or ferrite plus carbide particle. It is more than 8% in the case of steels.

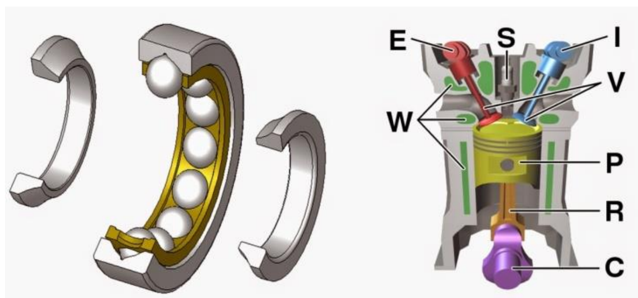
NILASAILA INSTITUTE OF SCIENCE AND TECHNOLOGY

NH-5, Sergarh-756060, Balasore(Odisha)

CHAPTER-07

Bearing Material

Bearings plays an important role in the applications where there is rotary motion. They reduce the friction between two mating parts and hence adjacently save the power.



"Bearing is a mechanical element which locates two machine parts relative to each other and permits relative motion between them."

For the bearings to be effective, they should have the following desirable properties :

- Compressive strength
- Fatigue strength
- Bondability
- Corrosion resistance
- Conformability
- Embeddability
- Thermal conductivity
- Cost and availability

Compressive Strength:

The max pressure that is acting on the bearing is greater than the average pressure. Hence in order to withstand this maximum pressure, the bearing material should have high compressive strength

Fatigue strength: In some applications, the bearings are subjected to high fluctuating loads. So to avoid fatigue failure, the bearing material should have sufficient endurance strength.

Bondability: It is the ability of the material to form a strong bond with other materials. Generally strong bonds are formed with steel. High capacity bearings are made by one or more thin layers of bearing material with high strength steel.

Corrosion resistance: In the applications where there is high working temperature, this temperature oxidizes the lubricating oil and forms the corrosive acids. This formed acid attacks on bearing material and corrodes it. So corrosion resistance property is also important in case of bearing material.

Conformability: It is the ability of the bearing material to yield and adapt its shape to that of the journal.

Embeddability: It is the ability of the bearing material to embed small particles of dust, dirt or abrasive particles without scoring the journal. The dirt or dust particles in the lubricating oil may cause the jamming in the clearance space. Hence the bearing material should have embeddability characteristics.

Thermal Conductivity: For the rapid dissipation of the heat, bearing material should have high thermal conductivity.
Cost and Availability: The bearing material should have low cost and also it should be easily available in the market for its production.

Commonly used materials for the bearings are :

- Babbits (white metals)
- Bronze
- Copper-lead alloy

- Cast iron
- Silver
- Aluminum alloy
- Sintered metal or porous metal

Babbits (white metals)

Composition

In this, there are two types. One is Lead-based Babbit and the other is Tin-base babbit.

Lead-Base Babbit: Pb-74%, Sn-10%, Sb-15%, Others-1%

Tin-Base Babbit : Pb-87%, Sn-86%, Sb-7%, Cu-6%

Advantages

They have excellent bondability, embeddability, and conformability.

They are good corrosion-resistant.

Limitations

Low compressive and fatigue strength at temperatures above 80 degrees.

Applications

Bearings with Babbit material are used in light-duty applications.

Bronze

Composition

In this also there are two types. One is gunmetal and the other is phosphor bronze.

Gunmetal : Cu-87%, Sn-10%, Zn-2%, Ni-1%

Phosphor Bronze: Cu-90%, Sn-10%

Advantages

Bronze material is cheaper as compared with the babbits.

These are stronger and can withstand higher pressures.

Limitations

Poor conformability and has a tendency to stick the journal surface at high temperatures.

Applications

Bronze is used in applications where temperature, load, speed, etc are considered to be moderate.

Aluminium Alloy

Composition

Al-89.5%, Sn-6.5%, Si-2.5%, Cu-1%, Ni-0.5%

Advantages

They have high thermal conductivity and fatigue strength.

Limitations

They have poor embeddability.

Applications

As this material is having high thermal conductivity, they are used where an adequate amount of lubricant is not provided.

Copper-Lead Alloy

Composition

Cu-60 to 75%, Pb-25 to 40%

Advantages

They have high compressive as well as fatigue strength and can withstand higher temperatures.

Limitations

Embeddability is average and conformability is very poor.

Applications

These materials are used where temperature, speed, and load are higher.

Cast Iron

Composition:

C.I.(cast iron)

Advantages

They have higher compressive strength.

Limitations

They have poor conformability and embeddability.

Applications

Light duty applications are preferred for C.I. material.

Sintered Metal

Composition

Copper-based and Iron-based sintered bearings.

Advantages

As the bearing material is porous, it can absorb 15-30% of lubricating oil.

Limitations

Fatigue strength is poor.

Applications

They are used in machine tools and automobile applications.

CHAPTER – 9.0

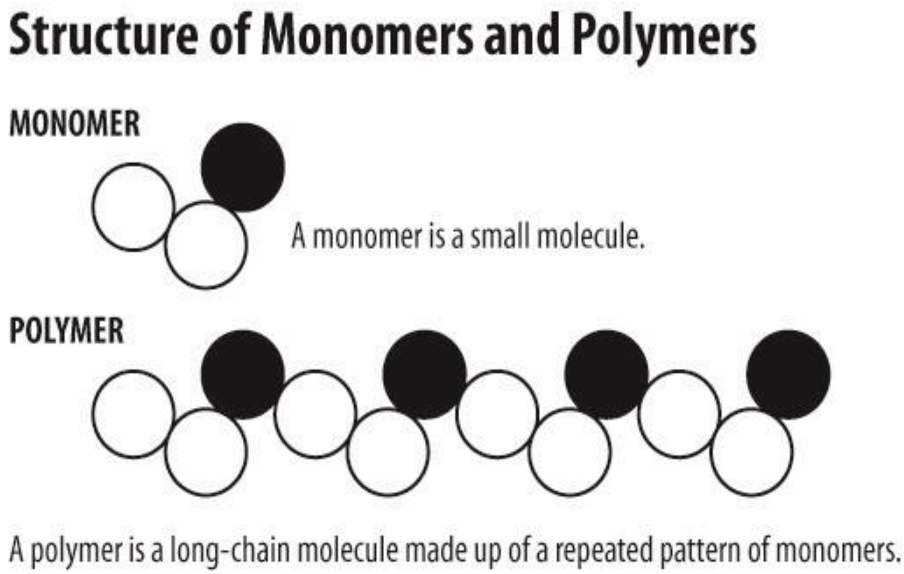
ENGINEERING MATERIAL

Polymer :

The plastic is an organic substance and it consists of natural or synthetic binders or resins with or without moulding compounds. The plastic is manufactured by the polymerization. A polymer consists of thousands of monomers joined together.

Monomer:

The simplest substance consisting of one primary chemical are known as the monomer.



Polymerization:

Monomers are to be combined to form polymers by the process known as polymerization. The polymer molecule is also called a macromolecule.
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 further leads to the manufacture of plastics in an economy way.

CLASSIFICATION OF PLASTICS

The classification of plastics can be made by considering various aspects and for the purpose of discussion, they can be classified according to their:

1. Behaviour with respect to heating.
2. Structure
3. Physical and chemical properties

.

.

1. Behaviour with respect to heating

According to this classification the plastics are divided into two groups:

(i) Thermo-Plastic

(ii) Thermo-Setting

(i) Thermoplastic polymer

The thermo-plastic or heat nonconvertible group is the general term applied to the plastics which become soft when heated and hard when cooled. The process of softening and hardening may be repeated for an indefinite time. Provided the temperature during heat is not so high as to chemical decomposition. It is thus possible to shape and reshape these plastics by means of heat and pressure. One important advantage of this variety of plastics is that the scrap obtained from old and warn-out articles can be effectively used .

(ii) Thermosetting polymer

The thermosetting or heat convertible group is the general term applied to the plastics which become rigid when moulded at suitable pressure and temperature. When they are heated in temperature range of 1270 C to 1770
C, they set permanently and further application of heat does not altered their form or soften them. But at temperature of about 3430C, the charring occurs. This charring is a peculiar characteristic of the organic substances.

Properties

The thermo setting plastics are soluble in alcohol and certain organic solvents when they are in thermo-plastic stage. This property is utilised for making paints and varnishes from these plastics.
These plastics are durable, strong and hard. They are available in a variety of beautiful colours.They are mainly used in engineering application of plastics.

Properties of plastics

1. Appearance : Transparent
2. Chemical resistance : The plastics offer great resistance to moisture, chemicals and solvents, excellent corrosion resistance.
3. Dimensional stability.
4. Ductility : The plastic lacks ductility. Hence its members may fail without warning.
5. Durability : The plastics are quite durable, if they possess sufficient surface hardness.
6. Electric insulation : They are far superior to ordinary electric insulators.
7. Finishing : Any surface treatment may be given to the plastics.
8. Fire resistance : All plastics are combustible.
9. Fixing : Can be easily fixed in position.
10. Humidity : PVC plastics offer great resistance to the moisture.
11. Maintenance : It is easy to maintain plastic surfaces. They do not require any protective coat of paints.
12. Melting point : Most of the plastics have low melting point and MP of some plastics is only about 500C.
13. Optical property : Several types of plastics are transparent and translucent.
14. Recycling : It does not give a serious problem to pollution as generated by a host of other industries. The plastics used for soft drink bottle, milk and juice bottles, bread bags, syrup bottles, coffee cups, plastic utensils etc can be conveniently recycles into carpets, detergent bottles, drainage pipes, fencings, handrails, grocery bags, car battery cases pencil holders, benches, picnic tables, roadside posts etc.
15. Sound absorption : The acoustical boards are prepared by impregnating fibre-glasses with phenolic resins. This material has absorption co-efficient of about 0.67.
16. Strength : The tensile members are generally made of plastics as their strength to weight ratio in tension very nearly approaches to that of metals.
17. Thermal property : The thermal conductivity of plastics is low and it can be compared with that of wood.
18. Weather resistance : Certain plastics are seriously affected by sun light, but other plastic can resist weather which as prepared from phenolic resins.

19. Weight : The plastics, whether thermo-plastic or thermo-setting have low specific gravity being 1.30 to 1.40.

Applications :

The typical use of plastics in building are as follows :

1. Bath and sink units.
2. Cistern ball floats.
3. Corrugated and plain sheets.
4. Decorative laminates and mouldings.
5. Electrical conduits.
6. Electrical insulators.
7. Floor tiles.
8. Foams for thermal insulation.
9. Joint less flooring.
10. Lighting fixtures.
11. Overhead water tanks.
12. Paints and varnishes.
13. Pipes to carry cold water.
14. Roof lights.
15. Safety glass.
16. Wall tiles.

Properties of Elastomers

These plastics are soft and elastic materials with a low modulus of elasticity. They deform considerably under load at room temperature and return to their original shape, when the load is released. The extensions can range up to ten times their original dimensions.

CHAPTER 10

COMPOSITES AND CERAMICS

Composite Material

The composite materials are shortened as composites. They are formed by combining two or more different materials to make better use of their virtues and by minimizing their deficiencies. Each material retains its physical or chemical properties separate and distinct within the finished product.

Composition

The composites are made from two main constituent materials.

1. Strong load carrying material known as reinforcement or reinforcing fibres.
2. Weaker material known as matrix.

1. Reinforcing fibres

Following are the functions of reinforcing fibres :

(i) It provides strength and rigidity.

(ii) It helps to support structural load.

There are three most common types of reinforcing fibres.

(i) Glass fibres

(ii) Carbon fibres

(iii) Aramid fibres

Glass fibers are the heaviest having greatest flexibility and the lowest cost. Aramid has moderate stiffness and cost.

Carbon is moderate to high in cost, slightly heavier than aramid but lighter than glass fibres. Carbon is the strongest.

2. Matrix

Following are the functions of matrix.

(i) It works as a binder

(ii) It maintains the position and orientation of the reinforcement.

(iii) It balances the loads between the reinforcement.

(iv) It protects the reinforcement degradation.

(v) It provides shape and form to the structure.

The most common type of matrix is thermosetting resins.

Epoxy resins are the most widely used thermo setting resins in advanced composites.

Others resins used as matrix are polyester, vinyl ester, phenolic, bismaleimade, epoxy no volar.

Examples :

Composites natural

Wood - Cellulose fibres plus polysaccharide.

Bones, teeth and mollusc shells = Hard ceramic + organic polymer

Man made composites

1. Mud + straw
2. Bricks made up straw + mud
3. Plywood
4. Concrete, plastic, MMC, CMC

Classification and Uses of Ceramics

The term ceramics is used to indicate the potter's art or articles made by the potter.

The ceramics are divided into the following three categories.

1. Clay products
2. Refractories
3. Glass

Clay products

The clay products which are used are tiles, terra-cotta, porcelain, bricks, stoneware's & earth wares.

Tiles are of two types

(1) Common tile

(2) Encaustic tiles

Types of common tiles

(i) Drain tiles

(ii) Floor or paving tiles

(iii) Roof tiles

Types of roof tiles

Allahabad tiles, Corrugated tiles, Flat tiles, Flemish tiles, Guna tiles, Mangalore tiles, pan tiles.

Refractories

The term refractories is used to indicate substances that are able to resist high temperatures.

Classification

(i) According to chemical properties.

(ii) According to resistance to temperature.

According to chemical properties

(a) Acidic

(b) neutral and

(c) Basic

(a) Acidic

Fire clay: It is used for the manufactured of fire bricks, crucibles, hollow tiles.

Quarizite- For making the silica bricks.

Silica- Coke over and lining for glass furnaces.

(b) Neutral refractory materials

Bauxite- For tire bricks

Carbon- Lining material for furnaces

Chromite- Powerful neutral refractory material.

Forsterite- Used in furnaces for melting copper.

(c) Basic Refractory materials

Dolomite- For making refractory bricks.

Magnesia- Magnesia bricks.

According to resistance to temperature

(a) Low quality

(b) High quality

High quality - Used in modern aeroplanes, rockets, jets etc. Molyblendum, tungsten, zirconium and their alloys are used as the refractory materials.

Cermet - Refractory material containing a combination of clay and metal.

Surface Preparation and Industrial Painting

Reasons of corrosion and surface wear.

The term corrosion is defined as an act or process of gradual wearing away of a metal due to chemical or electro-chemical reaction by its surroundings such that the metal is converted into an oxide.

The corrosion indicates the deterioration and loss of material due to chemical attack.

Following are the factors responsible for corrosion :

(i) Congested reinforcement in small concrete sections.

(ii) Excessive water-cement ratio.

(iii) Improper construction methods.

(iv) Inadequate design procedure

(v) Incompetent supervising staff or contractor.

(vi) Initially rusted reinforcement before placing concrete.

(vii) Insufficient cover to steel from the exposed concrete surfaces.

(viii) Presence of moisture in concrete.

(ix) Presence of salt.

(x) Unequal O2 distribution over the steel surfaces.

Factors influencing corrosion

(i) Blow holes, inclusions trapped gases.

(ii) Chemical nature of the metals.

(iii) Eddy electric currents.

(iv) Presence of dust, dirt.

Purpose of painting and methods of industrial pointing:

Purposes

(i) To protect the surface from weathering effects of the atmosphere and actions by other liquids, fames and gases.

(ii) To prevent decay of wood and corrosion in metal.

(iii) To give good appearance to the surface. The decorative effects may be created by painting and the surface becomes hygienically good, clear, colourful and attractive.

(iv) To provide a smooth surface for easy cleaning.