Diploma Engg. Materials (Mech - 3rd Sem.)

Engg. Material & their Properties :-

In order to achieve optimal system performance, mechanical properties include density, hardness & elasticity. Mechanical properties of material reflect relationship between its response to and deformation from an applied load or force.

The Engg. Materials are broadly be classified into these types.

(I) Ferrous (II) Non-Ferrous (III) Plastic (IV) Ceramic & diamond
(V) Composite Materials (VI) Nano-materials

(I) Ferrous :- The word ferrous comes from the Latin word 'ferrum' which means iron.

→ Ferrous Materials :- A ferrous metal is that is primarily composed of iron & has magnetic properties. A ferrous metal is known for its hardness, durability & tensile strength.

→ Ex:- Carbon steel, Stainless steel, Cast iron, Engg. steel etc.

(II) Non-Ferrous :- Non-ferrous means donot contain iron.

→ Non-ferrous materials :- Non-ferrous metals or alloy are materials that are not iron-based like their ferrous counterparts. Non ferrous metals are found in the earth as chemical compounds

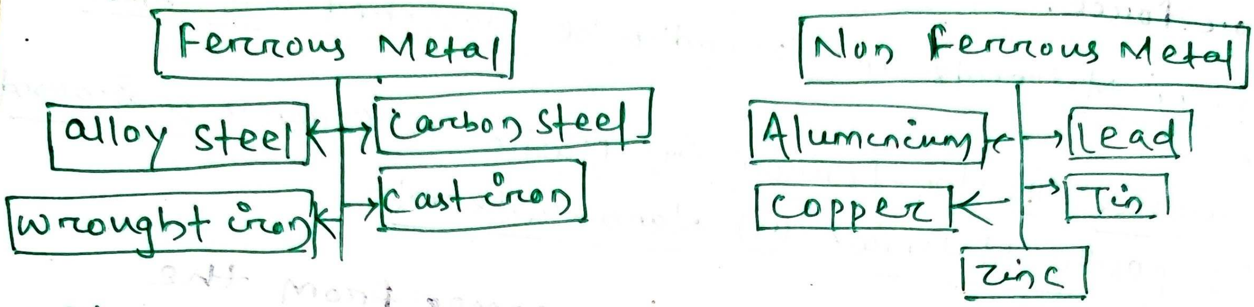
→ Ex:- Copper, Aluminium, lead, Zinc, Tin, Brass Nickel, Titanium, Silver etc.

Alloy :- An alloy is an admixture of metals, or metal combined with one or more other elements.

Ex:- Gold + copper = Red Gold
Gold + Silver = White Gold, etc.

Properties of alloy :- ① Generally alloy have found to be stronger & harder, less malleable, less-ductile & more corrosion resistant than the main metal making the alloy.

② An alloy mixture is stronger because it contains atoms from different that are different in size



→ Physical properties of Materials :-

→ physical properties are things that are measurable

→ Those are things like density, melting point, conductivity, coefficient of expansion etc.

→ Normally these type properties that can be measured or observed without changing the chemical nature of the substance.

→ Chemical Properties of Materials :-

→ chemical properties that can be determined only by changing a substance's molecular structure.

→ Examples include colour, hardness & smell & freezing, melting & boiling points. chemical properties are discovered by observing chemical reactions. They include combustion point, reactivity with acids & toxicity.

→ Mechanical Properties of Materials :-

→ The mechanical properties of a material are those properties that involve a reaction to an applied load.

→ Mechanical properties are also used to help classify & identify material. The most common properties considered are strength, ductility, hardness, impact resistance & fracture toughness.

Density :- The density of a substance is its mass per unit volume.

$$\rho = \frac{m}{V}$$

where ρ = density, m = Mass, V = volume.

Hardness :- Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion.

Elasticity :- Elasticity is the ability of a body to resist a distorting influence & to return to its original size & shape when that influence or force is removed.

Durability :- Durability means it is the ability of a material to remain serviceable in the surrounding environment during the useful life without damage or unexpected maintenance.

Tensile strength :- That means the maximum load that a material can support without fracture when being stretched.

Strength :- The ability to withstand an applied stress or load without structural failure.

Compressive strength :- Compressive strength is the maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture.

Ductility :- Ductility is the ability of a material to be drawn or plastically deformed without fracture. The ductility of steels varies depending on the types & level of alloying elements present.

Toughness :- Toughness is the ability of material to resist impact (i.e. absorb the energy of an impact.) The general rule is that a higher toughness will lessen the risk of cracking.

Malleability :- Malleability means the quality or state of being malleable, such as a capability of being shaped or extened by hammering, forging etc. (capability of being influenced or altered by external force).

Low Carbon steel :-

→ Low carbon steel is a type of steel that has small carbon content, typically in the range of 0.05% to 0.3%. Its reduced carbon content makes it more malleable & ductile than other steel types.

→ Low carbon steel is also known as mild steel.

→ Low carbon steel is one of the most common types of steel. Low carbon steel is ideal for applications in which precision is paramount due to its heightened flexibility. It is less prone to corrosion than other types of steel due to its reduced carbon content.

Medium Carbon steel :-

→ Medium Carbon steel are similar to low-carbon steels, except that they contain carbon from 0.30% to 0.60% & manganeses from 0.60% to 1.65%.

→ Increasing the carbon content to approximately 0.5% with an accompanying increase in manganese allows medium carbon steels to be used in the quenched & tempered condition.

→ These steels are mainly used for making shafts, axles, gears, crankshafts, couplings, & forgings. Steels with carbon ranging from 0.40% to 0.60% are used for rails, railway wheels &

High Carbon steel :-

Any steel with a carbon content of 0.55% or higher, or about one part in 180, is considered high carbon steel. Also known as carbon tool steel, it has arround 0.61% to 1.5% carbon.

→ High Carbon content, high carbon steel is stronger than low & medium carbon steel, and also harder & less ductile than low & medium carbon steel.

→ High carbon steels are very high strength, extreme hardness & resistance to wear & moderate ductility, a measure of material's ability to tolerate being deformed without actually breaking

→ High carbon steel is often used for things like cutting tool that retain their sharp edge, & masonry nails that can be driven in concrete blocks or bricks without bending, and also used in forging grades, rail steels, spring steels wire rope, tire reinforcement, high strength bars.

Alloy Steel :-

Alloy steel is a type of steel alloyed with several elements such as molybdenum, nickel, manganese, chromium, vanadium, silicon & boron.

→ These alloying elements are added to increase strength hardness, wear resistance & toughness.

→ Alloy steels different from carbon steels in that the alloy steels contain a high proportion of other alloying elements.

Alloy steels are classified according to increasing proportion of alloying elements & also phase change during heating & cooling.

- → low alloy steel
- → medium alloy steel
- → High alloy steel

Low alloy steel :- These generally have less than 1.8% nickel, less than 6% chromium, & less than 0.65% molybdenum. The tensile strength range is from 450 - 620 N mm^2 upto 850 - 1000 N mm^2

Medium alloy steel :- These have alloying elements ranging from 5-12%. They don't lend themselves to classification. They include : nickel steels used for structural work, axles, shafts, etc.

→ Nickel - molybdenum steels capable of being case-hardened, which are used for cams, camshafts, rolling bearing races etc.

→ Nickel chrome molybdenum steels of high strength which have good fatigue resistance.

High alloy steel :- These have more than 12% alloying elements. A chromium content of 13-18% (stainless steel) gives good corrosion resistance. High wear resistance is obtained with austenitic steel containing over 11% manganese. Some types have good heat resistance & high strength.

Tool steel :- Tool steels refers to a variety of carbon steel & alloy steel that are particular well suited to be made into tools.

→ There suitability comes from their distinctive hardness, resistance to abrasion & deformation & their ability to hold a cutting edge at elevated temp.

Properties of tool steel :-

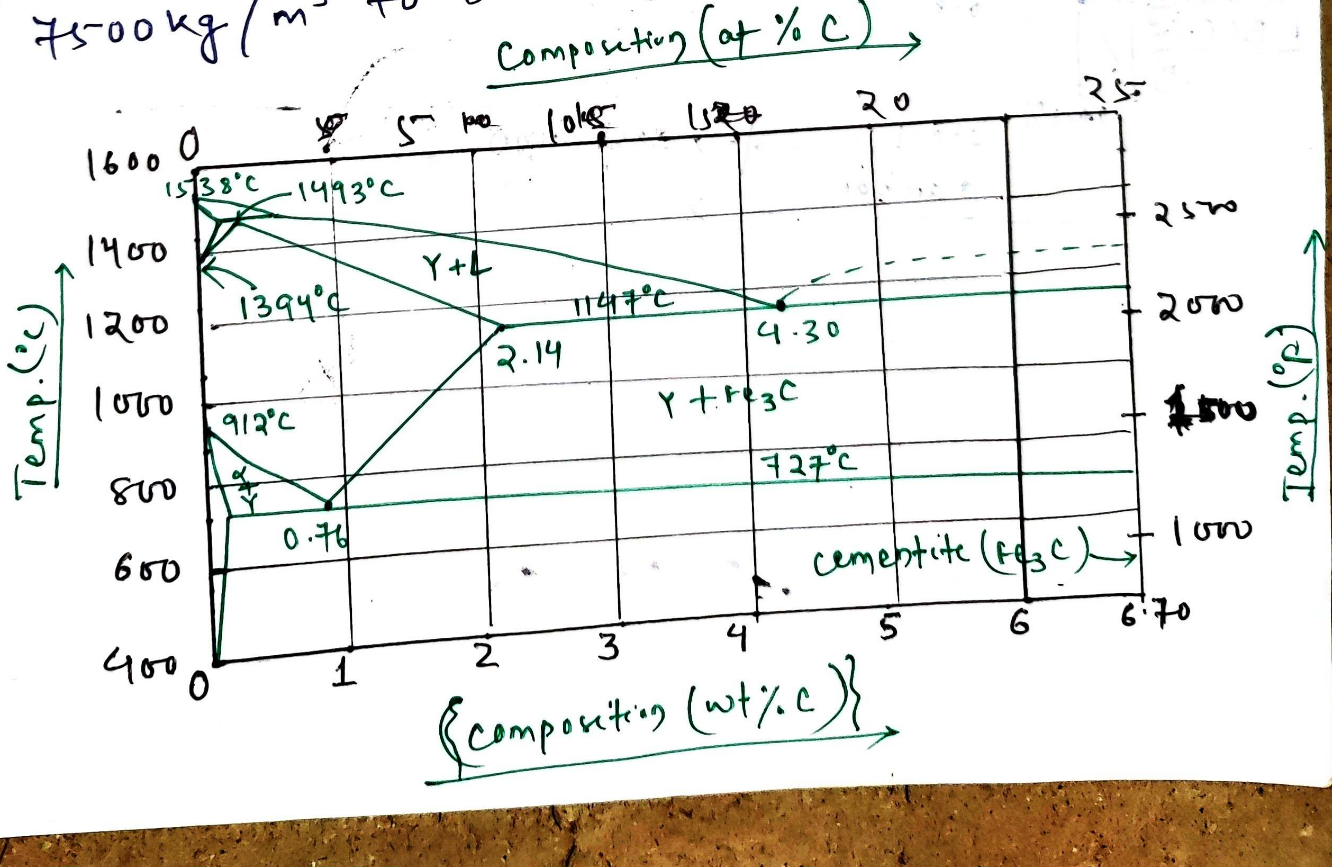
→ Hardness :- resistance to deforming & flattening
→ Toughness :- resistance to breakage & chipping
→ wear resistance :- resistance to abrasion & erosion.

Stainless steel :-

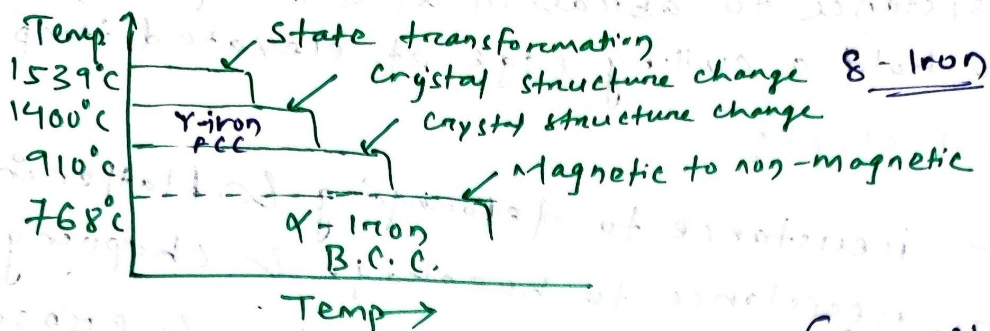
→ stainless steel is a corrosion - resistance alloy of iron, chromium and, in some cases, nickel & other metal.

→ stainless steel can be found in many everyday objects. it also plays a prominent roles in an array of industries, including energy, transportation, building research, medicine, food & logistics.

→ The density of stainless steel is approximately 7500 kg/m³ to 8000 kg/m³ depending upon alloy.



COOLING CURVE OF PURE IRON



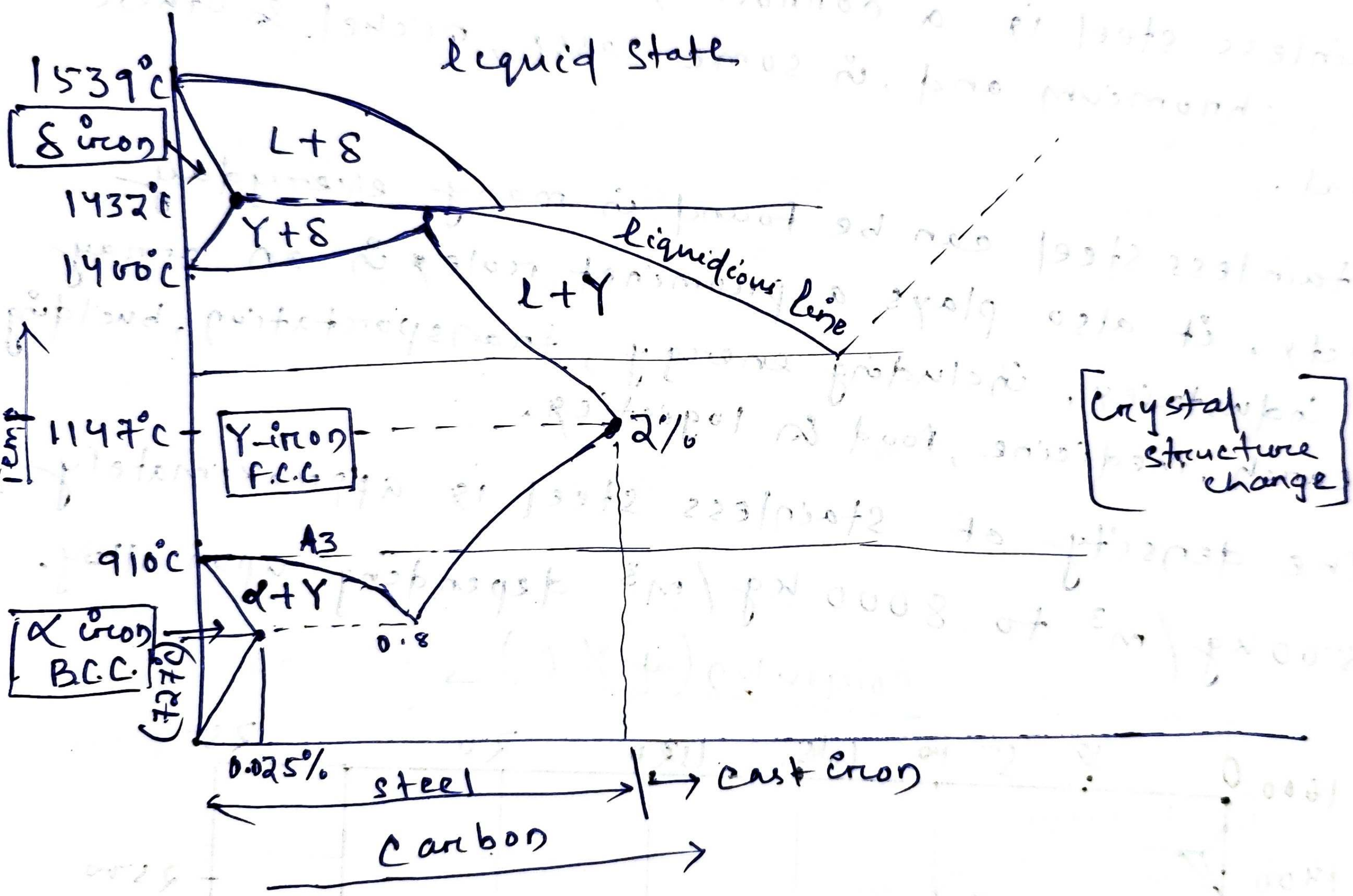
δ-Iron δ Delta

Gamma

B.C.C Body center cubic (Cementite)

Hardmaterial - Tungsten, Lithium, α-iron

F.C.C: Gold, allumimum (Austinite)



The Iron - Carbon System :-

This is binary (two-element) diagram, it is essentially a map of the phase that exist in iron at various carbon contents & temp. under equilibrium conditions.

The iron-carbon system may be divided into two parts: an iron-rich portion, as in figure below & the other for compositions between 6.70 & 100 wt% C (pure graphite). The composition axis extends only to 6.70 wt% C which is compound iron carbide or cementite (Fe_3C).

Solid Solⁿ :- Carbon is an interstitial impurity in iron & forms a solid solⁿ (α-iron, δ-iron & γ-iron) single phase field in figure.

α-iron :- α-iron has a BCC crystal structure, maxᵐ Solubility is 0.022 wt% at 727°C. This phase is relatively soft, may be made magnetic at temp. below 768°C & has a density of 7.88 g/cm³

γ-iron :- γ-iron has FCC, The maximum solubility of carbon in austenite, 2.14% occurs at 1147°C. Austenite is nonmagnetic.

δ-iron :- δ-iron same as α-iron, has a BCC, except for the range of temp. over which each exists.

Fe_3C (cementite) contains 6.70 wt% C, is extremely hard & brittle (like a ceramic material)

Eutectic Reaction :- There are one eutectic exists for the iron - iron carbide system, at 4.30 wt% C & 1147°C.

$$L \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \gamma + Fe_3C$$

Eutectoid Reaction :- it occurs for the iron-carbon system at 727°C & 0.76 wt% C. Upon cooling, a solid γ phase transforms into α-iron & cementite

Reaction

$\gamma(0.76\ wt\%\ C) \underset{Heating}{\overset{Cooling}{\rightleftharpoons}} \alpha(0.025\ wt\%\ C) + Fe_3C(6.7\%\ C)$

Peritetic Reaction

A peritetic exists for iron-carbon system at 1493°C & 0.18 wt% C.

$S + L \underset{Heating}{\overset{Cooling}{\rightleftharpoons}} \gamma$

There are three types of ferrous alloys
(i) iron (ii) steel (iii) Cast iron

(i) iron :- (less than 0.008 wt% C) & is composed ferrite phase at room temp.

(ii) steel (0.008 — 2.14 wt% C) consists of both α & Fe_3C phase.

(iii) Cast iron :- (2.14% — 6.70 wt% C)

Date 23/11/2021 Unit Test - 1 Full mark 30

1. Answer all the Questions [2 × 5]
a) what is density ?
b) What is ferrous Metal ? with Example ?
c) define alloy & Example ?
d) define Toughness ?
e) what are the uses of Stainless Steel ?

2. Answer any two [5 × 2]
a) Describe the properties of Materials ?
b) what is alloy steel & describe types of alloy steel ?
c) define Carbon steel & describe types ?

3. Briefly describe about iron-carbon diagram? ~~with~~ [10]

Crystal :- A crystal or crytalline solid is a solid material whose constituents (such as atoms, molecules or ions) are arranged in a highly ordered microscopic structure, forming a crystal lattice that extends in all directions.

Crystal Structure?

Crystal structure is obtained by attaching atoms, group of atoms or molecules. This structure occurs from the intrinsic nature of the constituent particles to produce symmetric patterns. A small group of a repeating pattern of the atomic structure is known as unit cell of structure. A unit cell is the building block of the crystal structure and ~~symmetry with the atom~~ it also explains in details the entire crystal structure & symmetry with the atom positions along with its principal axes and the angle between the unit cells are called lattice constants or lattice parameters

Unit Cell :-

Crystals use x-rays, which excite signals from the atom. The signals given by these atoms have different strengths & they usually depend upon the electron density distribution in closed shells. The signals released by the atoms varies. Lighter the atoms, weaker is their signals. The mutual arrangement of atoms is also known as crystal structures. Crystal structures are derived from the physical density and chemical formulas of solids. Unit cell can be defined as the smallest part of a components of the crystal. A group of atoms, ions or molecules, which are arranged together in a pure manner to build the crystal. The Unit Cells are structured in three dimensional space, which describes the bulk arrangement of atoms of the crystal.

There are 7 types crystal system are there

(I) Triclinic System
(II) Monoclinic System
(III) Orthorhombic System
(IV) Trigonal System
(V) Hexagonal System
(VI) Tetragonal System
(VII) Cubic System

Classification of Crystal imperfections :-

Classification of crystal imperfections can be devided into four basic types

(i) point defect (0-dimensional) (ii) line defect (1-dimensional) (iii) Surface defect (2-dimensional) (iv) volume defect (3-dimensional)

point Defect :- point defects explain about the imperfections of solids along with the types of point defects. Crystalline solids are formed by joining many small crystals. different types of defects are found in crystals after the process of crystallization. point defects are accounted for when the crystallization process occurs at a very fast rate. These defects mainly happen due to deviation in the arrangment of constituting particles. In a crystalline solid, when the ideal arrangment of solids ~~when the ideal arrangment~~ is distorted around a point/atom it is called a point defect.

There are 3 types point defects :-

1. stoichiometric defect
2. Frenkel defect
3. Schottky defect

1. Stoichiometric defect :-

In this kind of point defect, the ratio of positive & negative ions (stoichiometric) and electrical neutrality of a solid is not disturbed: sometimes it is also known as intrinsic or thermodynamic defects.

There are two types :-

(i) vacancy defect
(ii) Interstitial defect

(i) **vacancy defect :-** when an atom is not present at their lattice sites then that lattice site is vacant and it creats a vacancy defect. due to this, the density of a substance decreases.

(ii) Interstitial defect :- It is a defect in which an atom or molecule occupies the intermolecular spaces in crystals. In this defect, the density of the substance increases.

(2) Frenkel Defect :-

→ In ionic solids generally, the smaller ion (cation) moves out of its place and occupies an intermolecular space. In this case, a vacancy defect is created on its original position and the interstitial defect is experienced at its new position.

→ It is also known as dislocation defect.

→ The density of a substance remains unchanged.

→ It happens when there is a huge difference in the size of anions and cations.

(3) Schottky Defect :-

→ This kind of vacancy defects is found in Ionic solids. But in ionic compounds, we need to balance the electrical neutrality of the compound so an equal number of anions and cations will be missing from the compound.

→ It reduces the density of the substance.

→ In this, the size of cations and anions are of almost the same.

These type defects are two types

a) Impurity defects

b) Non-stoichiometric defects

a) Impurity defects :-

Let's understand the impurity defect by an example. If molten NaCl is crystallized with $SrCl_2$ compound the the Sr^{2+} ions replace two Na^+ ions and occupy the place of one Na^+ In this way the lattice site of one Na^+ is vacant and it creates an impurity defect.

b) Non-stoichiometric Defect :-

~~Defect, th~~ In this defect, the cations and anions ratio is ~~disturbed~~ disturbed either because of adding or removing of ions.

Line defect :-

→ A Line defect is a line along which whole rows of atoms in a solid are arranged anomalously. The resulting irregularity in spacing is most severe along a line called the line of dislocation. Line defects can either weaken or strengthen solids.

→ A line defect acting as a boundary between the slipped and non-slipped region in the slip plane is called a dislocation.

→ Dislocations are generated and move when a stress is applied. The strength and ductility of metals are controlled by dislocations

→ dislocations can move if the atoms from one of the surrounding planes break bonds and rebond with the atoms at the terminating edge.

→ A dislocation is a line defect within a crystal which arises during crystal growth or as a result of mechanical deformation of a crystal.

→ Dislocations make a crystal mechanically harder. when a metal bar is cold-worked by rolling or hammering, dislocations and grain boundaries are introduced, causing hardening.

Surface defects :-