UNIT-V

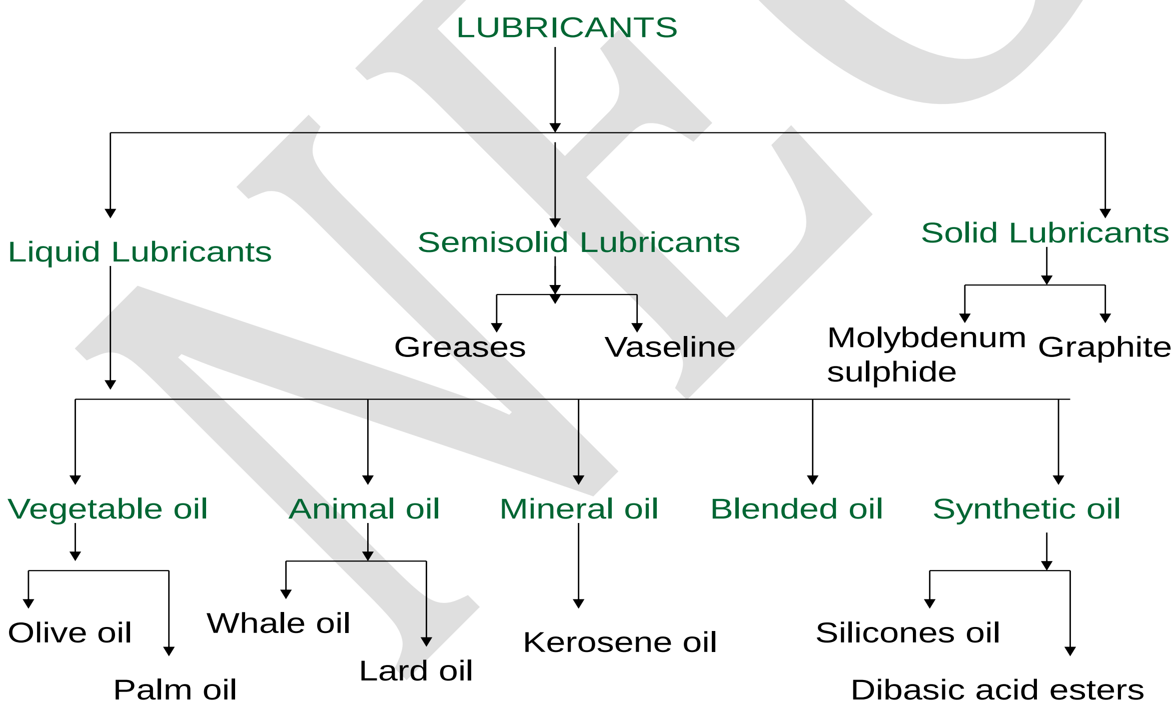
CHEMISTRY OF ENGINEERING MATERIALS

LUBRICANTS

Introduction

- When one solid surface is sliding past over another solid surface, friction and wear is developed due to relative motion of two contacting surfaces which results in loss of energy as heat.
- As the equipment gets heated up it is damaged and sometimes results in welding or seizure.
- Any substance introduced between two moving or sliding surface with a view to reduce the frictional resistance between them is known as lubricants.
- The process of reducing frictional resistance between moving or sliding surface by the introduction of lubricants in between them is called lubrication.

CLASSIFICATION OF LUBRICANTS



Functions of lubricants:

- It reduces frictional resistance between moving or sliding surface.
- It reduces surface deformation, wear and tear, because the direct contact between the rubbing surfaces is avoided.
- It reduces loss of energy in the form of heat in other words it acts as a coolant.
- It reduces waste of energy, so that efficiency of machine is enhanced.

- It reduces expansion of metal by local frictional heat.
- It avoids seizure of moving surfaces.
- It reduces the maintenance and running cost of the machine.
- It also, sometimes, acts as a seal. For example, lubricant used between piston and the cylinder wall of an internal combustion engine acts as seal.

Mechanism of lubrication

1. Fluid-film or Thick-film or Hydrodynamic lubrication
2. Boundary lubrication or Thin-film lubrication
3. Extreme-Pressure lubrications

1. Fluid-film or thick-film or hydrodynamic lubrication:

- In this, the moving/sliding surfaces are separated from each other by a thick-film of fluid (at least 1,000 Å thick), so that direct surface-to surface contact and welding of junctions rarely occurs.
- The lubricant film covers of the sliding/moving surfaces and forms a thick layer in-between them, so that there is no direct contact between the material surfaces.
- The resistance to movement of sliding/moving part is only due to the internal resistance between the particles of the lubricant moving over each other.
- So, the lubricant chosen should have the minimum viscosity and should remain in place and separate the surfaces.
- Delicate instruments, light machines like watches, clocks, guns, sewing machines, scientific instruments provided with this type of lubrication.
- Hydrocarbon oils are considered to be satisfactory lubricants for fluid-film lubrication.

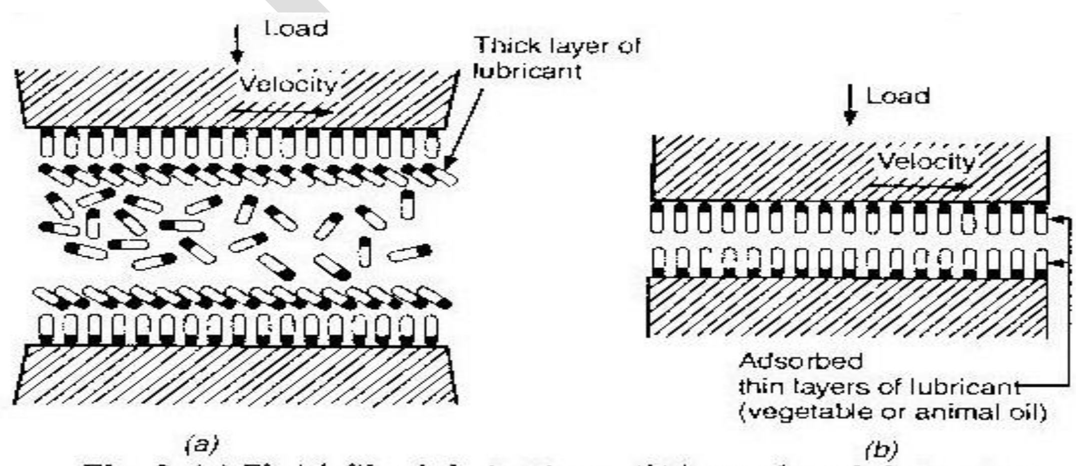


Fig. 3. (a) Fluid-film lubrication ; (b) boundary lubrication.

2. **Boundary lubrication or thin-film lubrication:**

Boundary lubrication or thin-film lubrication is done when a continuous film of lubricant cannot persist and direct metal-to-metal contact is possible due to certain reasons.

This happens when:

- A shaft starts moving from rest
- The speed is very low
- The load is very high, and
- Viscosity of the oil is too low.

- Under such conditions, the clearance space between the moving/sliding surfaces is lubricated with an oil lubricant, a thin layer of which is adsorbed, (surface attached) by physical or chemical forces or both on both the metallic surfaces.
- These adsorbed layers avoid direct metal-to-metal contact. The load is carried by the layers of the adsorbed lubricant on the both metal surfaces.
- Vegetable and animal oils (glycerides of higher fatty acids) and their soaps possess property of adsorption (or surface attachment), either physically adsorbed to metal surfaces or react chemically at the metal surfaces, forming a thin film of metallic soap, which acts as lubricant.
- The load is carried by the two layers of absorbed lubricant. Although the fatty oils possess a greater linkage property (called oiliness) than mineral oil.
- In order to improve the oiliness of mineral oils, small amounts of fatty oils or fatty acids are added. Graphite and molybdenum disulphide either alone or as stable suspension in oil are used for boundary lubrication.
- These materials form films on the metal surfaces, which possess low internal friction and can, bear compression as well as high temperatures.

For boundary lubrication the lubricant should have:

- Long hydrocarbon chains
- Polar group to promote spreading over the surface
- Lateral attraction between the chains
- Active functional groups & good oiliness
- Resistance to heat & oxidation
- High viscosity index

3. **Extreme-pressure lubrication:**

- When the moving/sliding surfaces are under very high pressure and speed, a high local temperature is attained and under such conditions, liquid lubricants fail to stick and may decompose and even vaporize.
- To meet these extreme-pressure conditions, special additives are added to mineral oils. These are called "extreme-pressure additives". These additives form on metal surfaces more strong films, capable of withstanding very high loads and high temperatures.
- Important additives are organic compounds having active radicals or groups such as chlorine (as in chlorinated esters), sulphur (as in sulphurized oils) or phosphorus (as in tricresyl phosphate).
- These compounds react with metallic surfaces, at prevailing high temperatures, to form metallic chlorides, sulphide or phosphides. These metallic compounds possess high melting points and serve as good lubricant under extreme-pressure and extreme-temperature conditions.

Properties of Lubricants

Lubricants have several properties. Some important properties are

1. **Viscosity**

- Viscosity is the property of a liquid or fluid by virtue of which it offers resistance to its own flow. Any two layers will move with different velocities. Top layer moves faster than the next lower layer, due to viscous drag (i.e., internal friction). The unit of viscosity is poise.
- Viscosity is the most important single property of any lubricating oil, because it is the main determinant of the operating characteristics of the lubricant, if the viscosity of the oil is too low, a liquid oil film cannot be maintained between two moving/sliding surfaces, and consequently, excessive wear will take place. On the other hand if the viscosity is too high, excessive friction will result.

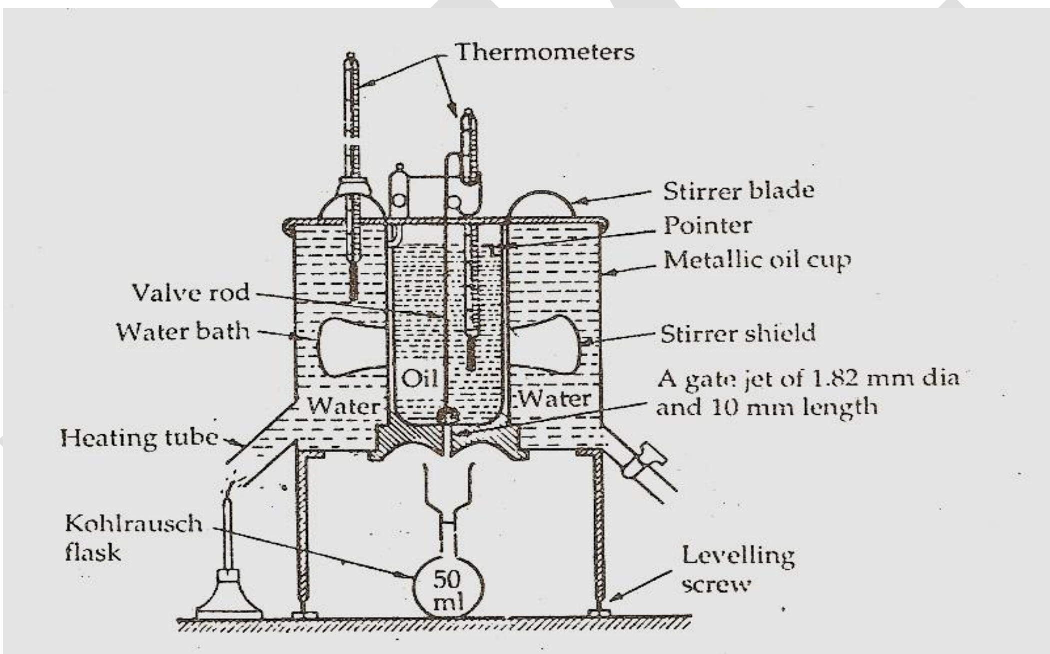
Effect of temperature on viscosity:

- Viscosity of liquids decreases with increasing temperature. Viscosity of good lubricating oil should not change much with temperature, so that can be used continuously, under varying conditions of temperature.

- The rate at which the viscosity of oil changes with temperature is measured by an arbitrary scale, known as the "Viscosity-Index" (V.I.).
- If the viscosity of an oil falls rapidly as the temperature is raised, it has a low viscosity-index. On the other hand, if viscosity of oil is slightly affected on raising the temperature, its viscosity-index is high.

Determination of viscosity of lubricating oil by Redwood viscometer

Redwood viscometer is of two types. Redwood viscometer No-1 is commonly used for determining viscosities of thin lubricating oils and it has a jet of bore diameter 1.62mm and length of 10mm. On the other hand Redwood viscometer No-2 is used for measuring viscosities of highly viscous oils like fuel oil. It has jet of diameter 3.8mm and length of 15mm. Redwood viscometer No-1 consists of the following essential parts.



1. **Oil cup:** It is a brass cylinder, open at the upper end. The bottom of the cylinder is fitted with agate jet with a bore of 1.62 mm. For thin film lubricates a jet of a bore of 1.60 mm and 10 mm length and for thick lubricants a jet of 3.8 mm and length 15 mm. is used. There is a valve rod to open and close the jet. A pointer in the oil cup indicates the level of oil in the cup. A thermometer is fitted in the lid of the cup for measuring the temperature of oil.

2. **Heating bath:** Oil cup is surrounded by a cylindrical copper bath filled with water. A thermometer is inserted in to the bath to measure the temperature of water. Heating bath is also provided with a stirrer to maintain uniform temperature of bath and oil cup.
3. **Leveling screws:** There are three leveling screws to level the apparatus.
4. **Kohlrausch's flask:** A flask of 50 ml capacity is placed below the jet to receive the oil from the jet out let.

Working:

- The apparatus is leveled with leveling screws. Water bath is filled with water and a thermometer is inserted into it. Oil cup is thoroughly cleaned and the jet is closed with ball valve.
- The oil is filled in the cup up to the point, and a thermometer is inserted into the cup to note the temperature of oil. Water bath is heated to a certain temperature with constant stirring to maintain uniform temperature of water.
- When the oil acquires desired temperature, heating is stopped and the ball valve in lifted. The time taken to fill the Kohlrausch flask of 50 ml capacity is noted. The valve is immediately closed to prevent the overflow of oil.
- The experiment is repeated and the mean value of time of flow for 50 ml oil sample is reported and the result is expressed in "Redwood No 1 seconds" at a particular temperature.
- Viscosity of liquids decreases with increases in temperature. Good lubricating oil should not undergo change in viscosity with temperature.

Significance of viscosity measurements:

Viscosity is the property of lubricating oil that determines its ability to lubricate and its film strength, viscosity values are used in evaluating load carrying capacity, in denoting the temperature changes.

2. **Flash Point & Fire Point**

- **Flash point** is "the lowest temperature at which the oil lubricant gives off enough vapours that ignite for a moment, when a tiny flame is brought near it." While **Fire point** is the lowest temperature at which the vapours of oil burns continuously for at least five seconds when a tiny flame brought near it.

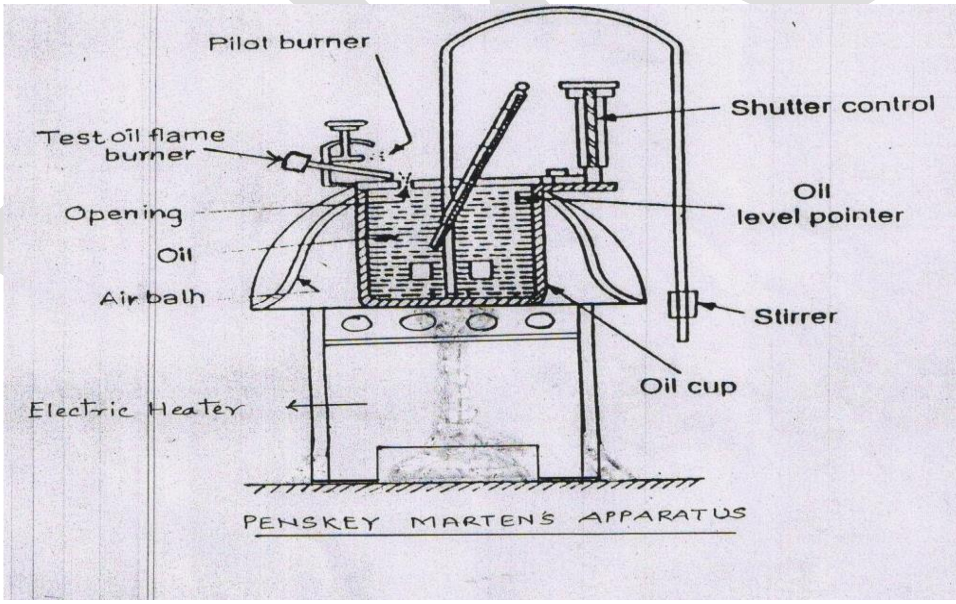
- A good lubricant should have flash point at least above the temperature at which it is to be used. In most of cases the fire point is 5 to 40^{o}C higher than flash point.

The Flash point & Fire point are usually determined by

- Pensky-Marten's Apparatus
- Abel's Apparatus
- Cleavland open cup Apparatus

Determination of flash and fire point by Pensky-Marten's Apparatus:

- The flash and fire points of a lubricating oil are determined experimentally by Pensky - Marten's apparatus. The apparatus consists of a small cup of 5 cm diameter and 5.5 cm. height.
- The cup is closed at the top with a lid containing three openings for inserting a thermometer, stirrer and for introducing test flame.
- A shutter which can be moved on the top of the container by lever mechanism is used to open the lid for introducing the test flame.



Working:

- The container is filled up to the standard mark with the lubricating oil. The cup is gradually heated using a burner.
- Stirrer is worked and oil is exposed to the flame for every 1^{o}C rise in temperature of lubricating oil.

- The temperature at which the introduced test flame produces a flash is noted as the flash point. Similarly the temperature at which the oil ignites and continues to burn for at least 5 seconds is noted as the fire point of the oil.

Significance of Flash point & Fire point:

The Flash point & Fire points are used to indicate the fire hazards of petroleum product and evaporation losses under high temperature operations. Knowledge of flash & fire points in lubricating oil aids in precautionary measures against fire hazards.

3. Oiliness

Oiliness of a lubricant is a measure of its capacity to stick on to the surfaces of machine parts, under conditions of heavy pressure or load. When a lubricating oil of poor oiliness is subjected to high pressure, it has a tendency to be squeezed out of the lubricated machine parts; thereby its lubrication action stops. On the other hand, lubricants, which have good oiliness, stay in between the lubricated surfaces, when they are subjected to high pressure.

Significance of Oiliness:

Oiliness is very important property of lubricants, particularly for extreme pressure lubrication. Mineral oils have got very poor oiliness; while vegetable oils have good oiliness. So, in order to improve the oiliness of mineral oils, additives like vegetable oils and higher fatty acids (such as oleic and stearic acids) are added to them.

4. Cloud and Pour point

- The lubricating oil is derived from petroleum. It contains dissolved paraffin wax and other resinous impurities. These impurities tend to separate out of oil at lower temperatures.
- The temperature at which the impurities begin to separate out from the solution and lubricating oil becomes cloudy or hazy in appearance is called "**cloud point**" while the temperature at which the oil ceases to flow or pour is called "**pour point**".
- Cloud point and pour points indicate the suitability of lubricants in cold conditions. Machines working with low temperatures like refrigerator plants, aircraft engines, lubricants with low cloud and pour points are preferred.

Determination of cloud and pour points:

- The cloud and pour points are determined experimentally using cloud and pour point apparatus. The apparatus consists of flat bottomed glass tube filled with lubricating oil of standard height enclosed in an air jacket.
- The jacket is surrounded by freezing mixture (ice + $CaCl_2$). A thermometer is introduced in the oil. As the cooling proceeds slowly, the temperature falls continuously.
- For every 1^oC fall of temperature, the tube is withdrawn from air jacket for a moment and observed for cloudiness.
- The temperature at which cloudiness is noticed is recorded as cloud point. Similarly after sometime the temperature at which the lubricating oil solidifies and resists to flow is recorded as the pour point.

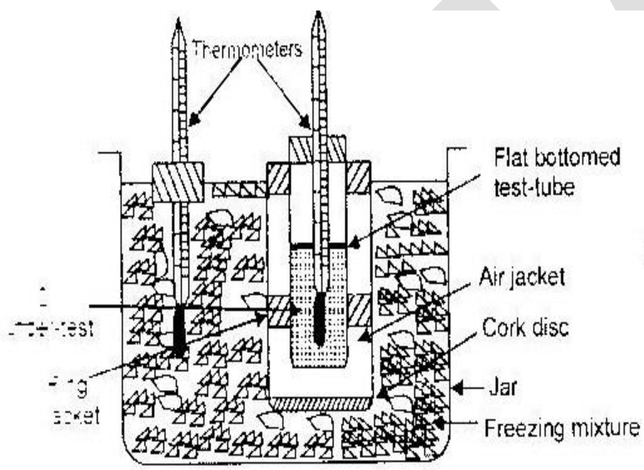


Fig. 8. Cloud and pour-point apparatus.

Significance of Cloud and pour-points:

Cloud and pour-points indicate the suitability of lubricants in cold conditions. Lubricant used in a machine working at low temperatures should possess low pour-point; otherwise solidification of lubricant will cause jamming of the machine. It has been found that presence of waxes in the lubricating oil raise the pour-point.

5. Emulsification

- Emulsification is the property of oils to get intimately mixed with water, forming a mixture, called emulsion. Certain oils form emulsions with water easily.
- Emulsions have a tendency to collect dirt, grit, foreign matter, etc., hereby causing abrasion and wearing out of the lubricated parts of the machinery.
- So, good lubricating oil should form an emulsion with water, which breaks off quickly.

- In this, 20 mL of oil is taken in a test tube and steam at 100°C is bubbled through it till the temperature is raised to 90°C.
- The tube is then placed in a bath maintained at 90°C and the time in seconds is noted, when the oil and water separate out in distinct layers.
- The time in second in which oil and water emulsion separates out in distinct layers, is called "**Steam Emulsion Number**" (S.E.N.). A good lubricant should possess a low steam emulsion number.

Significance of Emulsification:

To avoid corrosion of polished steel surfaces like roll necks and to insure proper lubrication.

6. Carbon residue

- Lubricating oils contain high percentage of carbon in combined form. On heating, they decompose depositing a certain amount of carbon.
- The deposition of such carbon in machine particularly in internal combustion engines and air-compressors.
- A good lubricant should deposit least amount of the carbon of the carbon in use. The estimation of carbon residue is generally carried out by Conradson's Method.

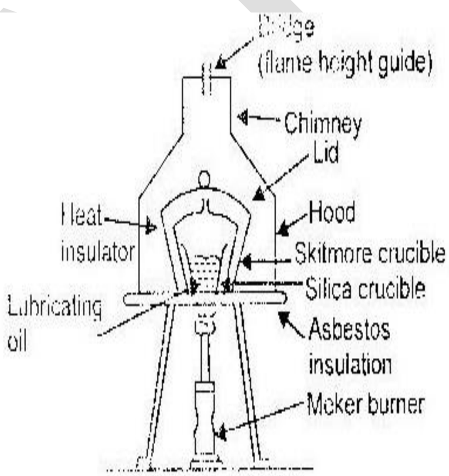


Fig. 9. Conradson's apparatus for residue estimation.

Determination of Carbon residue:

- A weighed quantity of oil is taken in silica crucible. Skitmore crucible is provided with a lid, having a small tube type opening for the escape of volatile matter.
- The combination is then placed in wrought iron crucible covered with chimney shape iron hood. The wrought iron crucible is heated slowly for 10 minutes, till flame appears.

- Slow heating is continued for 5 minutes more. Finally, a strong heating is done for about 15 minutes, till vapours of all volatile matter are burnt completely.
- Apparatus is then allowed to cool and weight of residue left is determined. The result is expressed as percentage of the original weight of oil taken.

Significance of Carbon Residue:

Certain lubricating oils tent to deposit carbon in the internal combustion engines. Excessive built-up of carbon deposits in the combustion chamber result in decreased volume of charge at the end of compression stroke.

7. Aniline point

- Aniline point of oil is defined as "the minimum equilibrium solution temperature for equal volumes of aniline and oil sample".
- Aniline point is determined by mixing mechanically equal volumes of the oil sample and aniline in a test-tube.
- The mixture is heated, till homogenous solution is obtained. Then, the tube is allowed to cool at a controlled rate.
- The temperature at which the two phases (oil and aniline) separate out is recorded at the aniline point.

Significance of Aniline point:

Aniline point gives an indication of the possible deterioration of oil in contact with rubber sealing's, packings etc.

8. Neutralization number (Acid value):

Lubricating oil acidity and alkalinity is determined in the term of neutralization number.

- **TAN (Total Acid Number):** "The number of milligrams of potassium hydroxide (KOH) required neutralizing any acid in 1 g of the oil.
- **TBN (Total Basic Number): "**The number of milligram of hydrochloric acid (HCl) required neutralizing any base in 1 g of the oil."

Significance of Neutralization number:

This test shows relative changes in oil due to oxidation. Comparing the TAN of TBN with the values of new oil will indicate the development of harmful products or effect of additive depletion. This will consequently lead to corrosion.

9. Saponification number

- Saponification number is the number of milligrams of KOH required to saponify 1 g of oil. Mineral oils do not saponify at all, but vegetable and animal oils do.
- Consequently, this test helps us to ascertain whether the oil under reference is animal and vegetable oil or a compounded oil containing mineral and vegetable oils.

Significance of Saponification number:

Mineral oils do not undergo saponification but animal & vegetable oil undergo saponification hence it indicates the amount of animal and vegetable oils added to improve oiliness.

10. Iodine value

Iodine value of oil is the number of milligrams of iodine that can be taken by 1 g of oil. Iodine is absorbed by the oil, due to unsaturation.

Significance of Iodine value:

Iodine value provides an idea of the extent of unsaturation in the oil. Consequently, it is an indicative of its drying quality. Iodine value thus can serve as basic for the classification of vegetable oils as “drying” or “semi-drying” or “non-drying” oils.

CEMENT

- Cement is a dirty greenish powder which finds its importance as a building material.
- It is described as a material which possesses adhesive property to bind rigid masses like stones, bricks, building blocks etc.
- Cement is hydraulic in nature i.e., it possesses the property of setting and hardening in the presence of water.

Classification of cement

1. **Natural cement:** it is prepared by the reaction between clay and lime stone, during the reaction calcium reacts with silicates and aluminum present in clay to form calcium silicates and calcium aluminates.
2. **Puzzalona cement:** It is prepared from ash of lava. This ash contains silica and alumina which is on reaction with lime (CaO) forms calcium silicates and aluminates.
3. **Slag cement:** It is prepared from slag which is obtained from furnace ash. This slag contains silica and alumina which is on reaction with lime (CaO) forms calcium silicates and aluminates.
4. **Portland cement:** It is made by calcining (at 1500^{o}C) an intimate mixture of clay and lime containing raw materials in correct proportion. After calcinations gypsum is added.

Composition of Portland cement

Calcium Oxide or Lime (CaO)	=	60-70%
Silica SiO_2	=	20-24%
Alumina (Al_2O_3)	=	5-7.5%
Magnesia (MgO)	=	2-3%
Ferric Oxide (Fe_2O_3)	=	1-2.5%
Sulphur Trioxide (SO_3)	=	1-1.5%
Sodium Oxide (Na_2O)	=	1%
Potassium Oxide (K_2O)	=	1%

Preparation of Portland cement

Raw Materials:

- **Calcareous Materials:** Materials which supply lime.

Ex: Limestone, Cement rock, Chalk, and Waste $CaCO_3$ from industrial process.

- **Argillaceous Materials:** Materials which supply silica, alumina and iron oxide.

  Ex: Clay, Blast furnace, Slag, Ashes, Shale and Cement rock.

Gypsum: It is added during the final grinding and it controls the ration of setting and hardening.

Mixing of raw materials

A mixture of finely ground limestone and clay (3:1) is made for any one of the following.

- Dry Process
- Wet Process

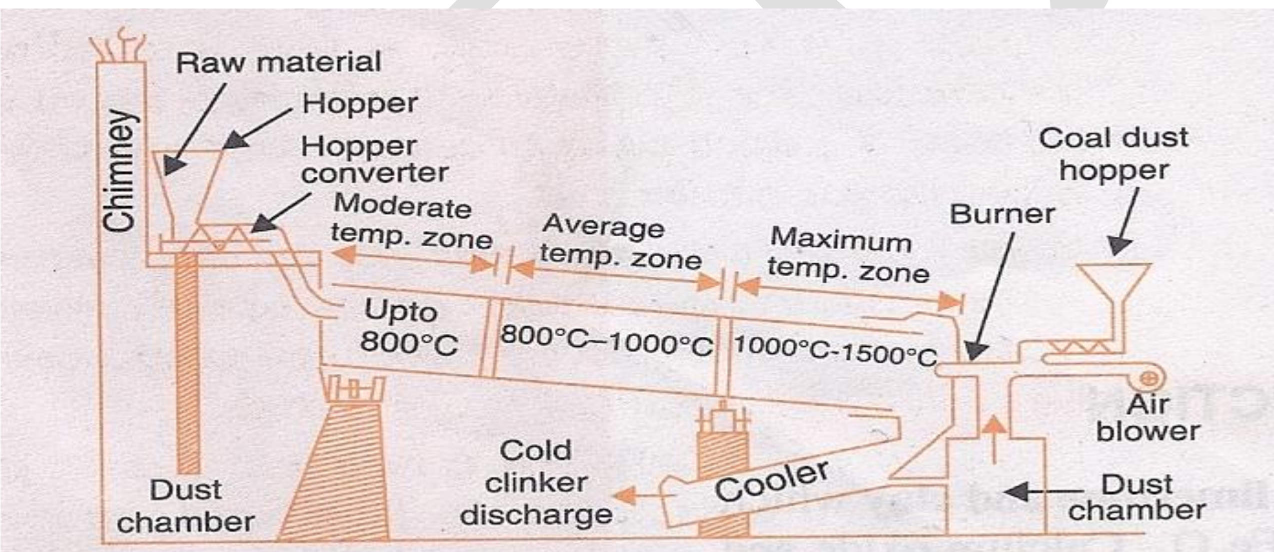
- **Dry Process:**
  - Dry process produces a fine ground powder.
  - This process is employed if lime and clay are hard.
  - In this process, initially limestone is crushed into pieces and then it is mixed with clay in the proportion of 3:1.
  - This mixture is crushed to a fine powder and is stored in storage bins and later on, it is introduced into the upper end of the rotary kiln.

- **Wet Process:**
  - The wet process takes place in the presence of water and usually results in a slurry formation.
  - This process is preferred if limestone and clay are soft.
  - In this process, initially limestone is crushed into pieces and then it is mixed with clay in the proportion of 3:1.
  - Powdered limestone is then mixed with the clay paste in a proper proportion (3:1).
  - The mixture is then finely ground and homogenized to form slurry containing about 40% of water.

Burning the mixture in a Rotary Kiln

- The rotary kiln is an inclined steel cylinder 150-200ft long, 10ft in diameter and it is lined inside with fire bricks.
- The kiln can be rotated at a desired speed of 1 r.p.m.
- As the kiln rotates, the mixture of raw materials stored from the above two process, passes slowly from the upper to the lower end.

- Burning fuel and air are introduced from the lower end of the kiln.
- As the mixture or slurry gradually descends the temperature rises and in fact this creates different zones in the rotary kiln, with increasing temperature.
- The clinkers are cooled and then ground to requisite fines.
- The finely ground clinkers set quite rapidly by absorption of moisture from the atmosphere.
- In order to reduce the rate of setting it is mixed with 2 to 3% gypsum ($CaSO_4.2H_2O$).
- After the initial setting, Al_2O_3 which is a fast setting constituent of clinkers react with gypsum to form the crystals of tricalcium sulphoaluminate, which is insoluble.
- The formation of insoluble tricalcium sulphoaluminate presents too early reactions of setting and hardening.
- This mixture of clinkers and gypsum powder is known as Portland cement.



Zones in Rotary Kiln

- Drying Zone
- De-carbonating Zone
- Burning Zone

- **Drying Zone**
  - This is present in the upper part of the kiln where the temperature is around 400°C.
  - In this zone most of the water in the slurry gets evaporated because of the hot gases.
  - The clay is broken as Al_2O_3, $2SiO_2$, Fe_2O_3 i.e.

$$Al_2O_3.\ 2SiO_2.Fe_2O_3.2H_2O \rightarrow Al_2O_3 + 2SiO_2 + Fe_2O_3 + 2H_2O$$

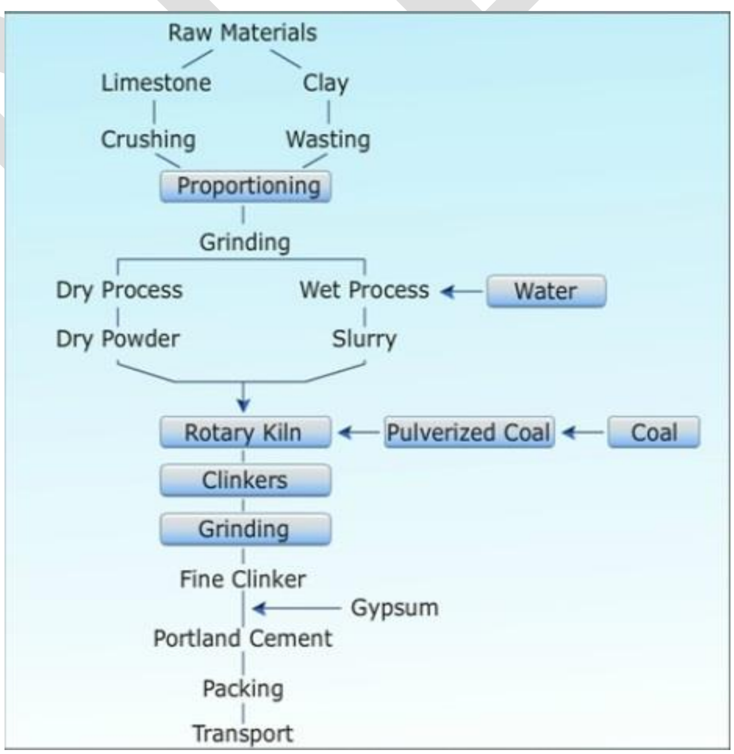
- **De-carbonating Zone**
  - This zone is located in the middle portion of the kiln where the temperature is of the order 1000^oC.
  - In this zone the limestone is completely decomposed into CaO which exists in the form of small lumps, called as noduls.

$$CaCO_3 \rightarrow CaO + CO_2$$

- **Burning Zone**
  - This zone is at the bottom and is considered to be the hottest portion of the kiln.
  - The temperature over here ranges around 1400-1500^oC.
  - In this zone the mixture melts and forms little rounded pasty masses of about the size of peas, which are called as clinkers.

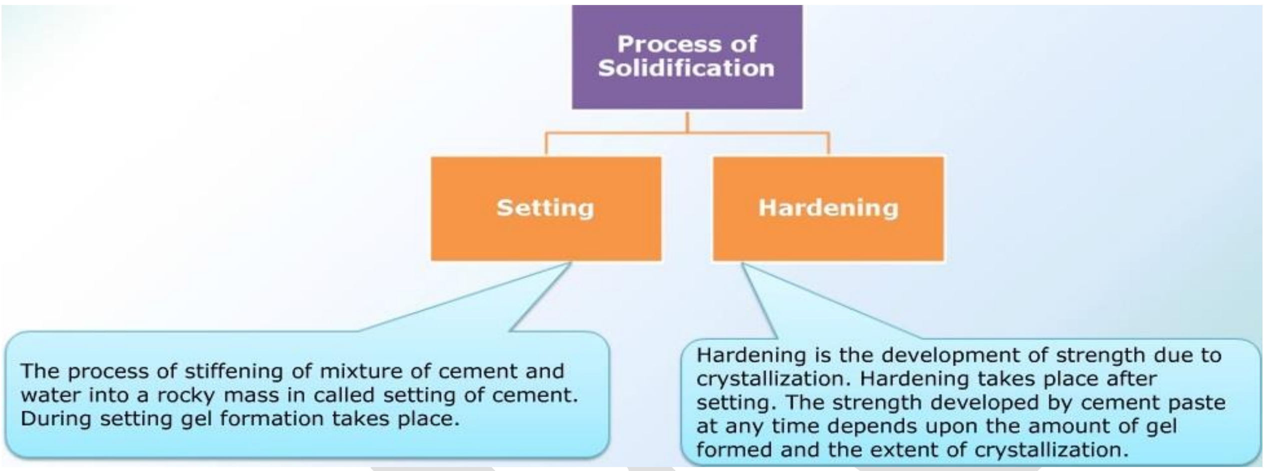
$$CaO + SiO_2 \rightarrow 2CaO.\ SiO_2\ (C_2S)\ \text{(dicalcium silicon)}$$
$$3CaO + SiO_2 \rightarrow 3CaO.\ SiO_3\ (C_3s)\ \text{(tricalcium silicate)}$$
$$3CaO + Al_2O_3 \rightarrow 3CaO.\ Al_2O_3\ (C_3A)\ \text{(tricalcium aluminate)}$$
$$4CaO + Al_2O_3 \rightarrow 4CaO.\ Al_2O_3\ (C_4\ AF)\ \text{(tetracalcium alumina ferrite)}$$

Flow Chart of Cement Manufacturing



Setting and Hardening of Cement

- When cement is mixed with water, a plastic mass known as cement paste is formed. This results in the formation of gel and crystalline products which surround sand, crushed stones and other inert materials and bind them very strongly.
- The process of solidification of cement comprises of:



The chemical reactions that take place during setting and hardening are:

- Initial setting of cement involves the hydration of tricalcium aluminate resulting in the formation of crystalline hydrated tricalcium aluminate. This is called set or flash set.

$$3CaO.Al_2O_3 + 6H_2O \longrightarrow 3CaO.Al_2O_3.6H_2O + 880\ KJ/Kg$$

- Tetra calcium alumino ferrite present in cement reacts with water forming gels and crystalline compounds.

$$4CaO.Al_2O_3.Fe_2O_3 + 7H_2O \longrightarrow 3CaO.Al_2O_3.6H_2O + CaO.Fe_2O_3.H_2O + 420\ KJ/Kg$$

- In the second step gelation takes place in which tobermonite gel is formed.

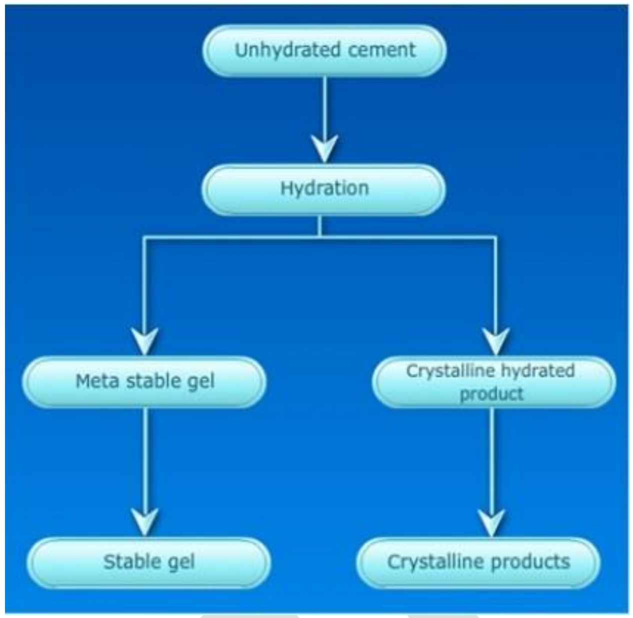
$$2[2CaO.SiO_2] + 4H_2O \longrightarrow 3CaO.2SiO_2.6H_2O + Ca(OH)_2 + 250\ KJ/Kg$$

- In this reaction dicalcium hydrolyses to give tobermonite gel which shows high adhesive property due to high surface area.
- Final setting and hardening of cement paste is due to the formation of tobermonite gel and crystalline of calcium hydroxide and hydrated tricalcium aluminate.

$$2[2CaO.SiO_2] + 6H_2O \longrightarrow 3CaO.2SiO_2.3H_2O + Ca(OH)_2 + 500\ KJ/Kg$$

Tobermonite gel

The setting and hardening of cement can be shown as



Failures of cement

Effect of CO_2:

The cement contains excess lime. In acidic water the lime reacts with CO_2 and it leads to decay of cement. The normal water has pH 7.5-8.5(slightly basic), this pH does not effects the decay of cement. The decay of cement increases with decrease in pH.

$$\mathbf{Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O}$$

Effect of Chloride:

- The chloride ions present in salts & sea water cause corrosion of steel present in cement concrete. Chlorides dissolved in water can diffuse through gaps or cracks present in cement and finally reach the steel.
- The risk of corrosion increases as the content of concrete increases when the chloride content at the surface of the steel exceeds a certain limit called threshold value corrosion will occurs, if water & oxygen are also available.
- The corrosion is prevented by controlling the availability of oxygen & humidity on the concrete.

REFRACTORIES

Introduction

Refractories are materials that can withstand high temperature without softening or suffering a deformation in shape.

Classification

1. **Acidic Refractory:** A refractory that is composed principally of silica and reacts at high temperatures with bases such as lime, alkalies, and basic oxides. These are used in areas where slag and atmosphere are acidic. The steel industries are the largest consumer of acidic refractories. Ex: silica, fire clay for lining of blast furnaces, open hearths and line kilns.
2. **Basic refractory:** These are used on areas where slags and atmosphere are basic, stable to alkaline Materials but reacts with acids. The main raw materialare calcium oxide and magnesia (MgO) is a very common example. Other example includes dolomite and magnesite.
3. **Neutral refractory:** These are used in areas where slags and atmosphere are either acidic or basic and are chemically stable to both acids and bases. The common examples of these materials are alumina (Al_2O_3), chrome (Cr_2O_3) and carbon. Normally we have to use acidic and basic refractories combined but we use neutral bricks to avoid the reaction. The neutral bricks are made of graphite and chromite's.

Properties of refractories

1. **Refractoriness:**

It is the ability of a refractory material to withstand the heat without appreciable softening or deformation under given service condition. Ability to withstand heat without getting deformed under operating conditions**.** It is measured as Softening Temperature. The softening temperature is measured by Seger Cone test. The test is also called Pyrometric Cone test.

Pyrometric/Seger Cone Test:

- Refractoriness is usually determined by comparing the behavior of heat on cone of material to be tested with series of seger cone of standard dimension.

- The refractoriness is expressed in terms of Pyrometric Cone (PCE). Standard Cones are Pyramidal shaped have triangular base 38 mm high and 19 mm long side**.**
- The standard seger cones are assigned numbers. The test cone is heated uniformly at 20^{o}C/hr or 100^{o}C/hr or 150^{o}C/hr or 600^{o}C/hr.
- When the test cone softens one of the standard cone also softens. The serial number of the standard cone is noted. This number is Pyrometric Cone Equivalent (PCE)

2. Strength (or) Refractoriness Under Load (RUL):

- Refractories are used in industrial furnaces have invariably to withstand varying load of products. A good refractory should have high temperature resistance as well as load bearing capacity that is strength.
- Strength is calculated by Refractoriness Under Load (RUL) test. The test is performed by applying a constant load of 3.5 or 1.75 kg/cm^2 to the specimen of size 5 cm and75 cm high and heating at the rate of 10^{o}C/min in a furnace. RUL is expressed as temperature at which 10% deformation takes place.

3. Chemical inertness:

A refractory should be selected that is chemically inactive in use and does not easily form. Fusible products with slags, fuel ashes, furnace gases, etc. usually the environment in most furnaces is either acidic or basic. It is inadvisable to employ an acid refractory in contact with an alkaline product or vice-versa.

4. Porosity:

All refractories contain pores (may opened/closed) due to the manufacturing methods/defects. The porosity of a refractory material is the ratio of its pores volume to the bulk volume.

$$P = (W\text{-}D/W\text{-}A) \times 100$$

Where, W = Weight of saturated specimen in air, D = Weight of dry specimen in air &

A = Weight of saturated specimen in water.

Advantages of high porosity:

- It reduces thermal spalling.
- It is used for lining in ovens, furnaces, etc.

UNIT-V

CHEMISTRY OF ENGINEERING MATERIALS

IMPORTANT QUESTIONS

1. Define lubricant. And describe functions and various types of lubricants.

2. Explain theories for the mechanism of lubricants.

3. Explain the following the properties of lubricants

a) Viscosity b) Flash and Fire point c) Oiliness

d) Cloud and pour point e) Emulsification f) Carbon residue

g) Aniline point h) Acid value i) Saponification value

j) Iodine value

4. Describe the manufacturing of Portland cement with neat diagram.

5. Explain the following

a) Setting and hardening of cement. b) failures of cement

6. What are refectories? Explain porosity and chemical inertness of refractories.

7. Explain the significance of the following properties in the evaluation of refractory material.

a) Refractoriness b) Strength or RUL test