

# KCE Society's COEIT, Jalgaon

Department of First Year Engineering (Basic Science)

## Engineering Chemistry

Topic  
Lubricants

# LUBRICANTS

Lubricant may be defined as **‘the substances which are used to reduce friction between two surfaces in contact with each other.’**

## LUBRICATION

The process of reducing frictional resistance between moving surface by the addition of lubricants between them is called lubrication. It is of two types:-

- i) **Solid Lubrication:** In this type, the surface in contact is coated with solid substance such as graphite which lowers the coefficient of friction between them and thus decreases the friction.
- ii) **Fluid Lubrication:** In this type, a fluid film is maintained between the two rubbing surfaces which prevents them to come in contact with each other and reduces the friction between them.

## **FUNCTIONS OF LUBRICANTS**

**It reduces friction:-**Let us consider two steel blocks one over the other & upper block has to slide over lower block by applying force. It is found that less force is required for this motion when two blocks are separated by lubricant as it reduces friction.

**It reduces wear, tear, surface deformations:-** the loss of substance from surface of a body by mechanical action is called wear. Lubricant reduces wear because direct contact between two surfaces is avoided.

**Act as coolant:** - frictional heat is produced by rubbing parts of machine. Cool oil (lubricant) flowing over heated surface absorbs & carries heat away.

**It acts as seal:** - in internal combustion engines, lubricant used between piston & cylinder wall acts as seal. It prevents leakage of gas from cylinder.

**It keeps out dirt particles.**

**It increases efficiency of machine.**

# **FRICTION**

The force resisting the relative motion between two solid surface fluid layers in contact with each other is called friction.

All the surfaces, how smooth they are, have some kind of irregularities that depend on their roughness. They form peaks & valleys also called 'Asperities' when two surfaces are pressed over each other, there is interlocking between them that retard their relative motion called 'Friction/Frictional Resistance.' Now-a-days, different kinds of lubricants are available and are being used in almost all the machines.

## **CLASSIFICATION OF LUBRICANTS**

Lubricants are classified on the basis of physical states:-

1. LIQUID LUBRICANTS
2. SEMI-SOLID LUBRICANTS
3. SOLID LUBRICANTS

## **LIQUID LUBRICANTS: -**

Liquid lubricants reduce friction between two sliding metallic surface by providing fluid film in between them. They exist in liquid form & they act as:

Sealing Agent

Corrosion Prevention

Cooling Medium

They must have following properties:

Low freezing point & High boiling point

Safe storage & handling

Thermal Stability

Sufficient Viscosity

## **Conditions for using:-**

Where solid & semi-solid cannot be used

Machines that are at low speed & ordinary load like watches, sewing machines.

## **Types of Liquid Lubricants:-**

**(1) MINERAL OILS:** - These lubricating oils are obtained by fractional distillation of petroleum at temp of about 400°C. They are cheap & available in abundance. The oils contain impurity like wax & other unwanted material. Their oiliness can be improved addition of stearic acid, oleic acid.

## **Methods of removal of impurities:-**

**A. DEWAXING:** - The wax present in lubricating oils make lubricant unfit for use at low temperature. In this method oil is mixed with suitable solvent & then subjected to cooling then wax gets precipitated and removed by filtration.

**B. SOLVENT REFINING:** - In this method solvent is mixed with phenol, impurities are more soluble in phenol than oil. The contents are allowed to stand undisturbed for some time & the liquid will be separated into two layers.

**C. ACID REFINING:** In this method oil is treated with conc.  $\text{H}_2\text{SO}_4$  & agitated. Some of the impurities are dissolved & others are converted into sludge. The sludge is removed by filtration which is treated with NaOH solution to remove excess of acid.

**(2) VEGETABLE OILS:** - These oils are obtained from vegetable sources. Some important Vegetable oils are:-

**OLIVE OIL:** - It is obtained from olive tree its colour varies from colourless to golden yellow. It is used for the lubrication of bearings.

**PALM OIL:** - It is obtained from kernels of palm. It is pale yellow in colour with pleasant smell. It is used for the lubrication of delicate instruments like watches, clocks

**CASTOR OIL:** - It is obtained from seeds of castor it is colourless to pale green in colour it is used for the lubrication of rough machinery vehicles and bearings.

**(3) ANIMAL OILS:** - These oils are obtained from animals. Some important animal oils are:-

**NEAT FOOT OIL:** - It is pale yellow oil with characteristic smell. It is prepared by boiling fat of neat with water. It is used for lubrication of guns, sewing machine, watches, and clocks.

**WHALE OIL:** - It is obtained from the distillation of whale. It is pale yellow and thin. It is used in light machinery.

**LARD OIL:** - It is colourless lubricant. It is obtained from the kidney, intestine and fats of pigs. It is used for various types of machine

**(4) BLENDED OILS:** - When mineral oils are mixed with animal oil or vegetable oil then mixture formed is called as blended oil. Blended oil is good lubricant. Blending of oil is done to reduce pour point, improve viscosity, increase oiliness, resist oxidation and to improve colour.

A. Oiliness: - coconut oil, fatty acid

B. Thickness: - polystyrene, polyester

C. Viscosity Index: - hexanol

D. Emulsifier:- sodium salt of Sulphuric acid.

**(5) SYNTHETIC OILS:** - These are chemically prepared compounds.

When mineral oils fail to

work then synthetic oils are used. They are used in jet engines, rocket motors, submarines etc.



## **SEMI-SOLID LUBRICANTS OR GREASES: -**

Greases are semi-solid lubricants which consist of metallic soap in lubricating oil.

**Preparation:** - They are made by Saponification of fat with alkali followed by addition of hot lubricating oil with constant stirring. Consistency of grease is governed by amount of oil added.

### **Conditions for using semi-solid lubricants:**

When it is necessary to seal the bearing or joint against the dirty & dust particles.

When the machine is worked at low speed under high load.

When the contamination of lubricating oil is unacceptable and harmful for products.

When the lubricating oil is not suitable for machines.

On the basis of soap used in manufacture of semi solid are classified as:-

**CALCIUM BASED GREASE:** - These greases are prepared by mixing of calcium soap with petroleum oil. They are insoluble in water. These can be used upto  $80^{\circ}\text{C}$ . These are also called 'Cup grease'.

**SODA-BASED GREASE:** - These grease are prepared by mixing of sodium soap with petroleum oil. They are soluble in water. These can be used upto  $175^{\circ}\text{C}$ . These greases are used in ball bearings.

**LITHIUM-BASED GREASE:** - These greases are prepared by mixing of lithium soap with petroleum oil. They are water resistant. They have high stability and suitable for use at high temperature.

**AXLE GREASE:-**These are prepared by adding lime or any metal hydroxide to fatty acids. They are water resisting and suitable for high temp and low speed. These are used in tractor rollers and machines bearings.

## **Emulsion:**

An emulsion is a colloidal dispersion of two immiscible liquids in which one liquid acts as the dispersion medium and other as dispersed phase. They are very important lubricants & used in several machines like boring.

They are prepared by the mixing two immiscible liquid in presence of a stabilizing substance called “Emulsifier” by using high speed mixing machine. They are two phase system where one liquid act as disperse phase & other is in dispersion medium.

The emulsions are of two types-

Oil in water (O/W) type

Water in oil (W/O) type

**OIL IN WATER TYPE (cutting emulsions or cutting oils):-** They are prepared by the mixing oil with water in presence of 3-20% water soluble emulsifying agent like alkyl sulphate.

It usually contains 5-45 % of oil with rest of water. Here oil act as a lubricant & water act as a coolant.

They are used in diesel motor piston & internal combustion engine.

**WATER IN OIL TYPE (cooling liquids):-** They are prepared by the mixing water in sufficient amount of oil in presence of 1-10% water insoluble emulsifying agent like Ca metal soap. Emulsion of 50% oil & water used for lubrication of steam cylinder to keep wall cool with oil consumption.

**SOLID LUBRICANTS:-**“The lubricants that exist in solid form are called solid lubricants”. E.g.: - graphite, molybdenum disulphide etc. They are used in heavy machines under high load and low speed.

**Conditions for using Solid Lubricants:-**

Machines that are under high load and low speed.

When liquid and semi-solid lubricants are highly combustible.

In machines where liquid and semi-solid lubricants can't work.

When contamination of oil and grease with dust particles is noticed.

## **Graphite as solid lubricant:-**

It is soapy in touch.

It is non – inflammable.

It is not oxidized in air up to 3750C

It is used either in powdered form or in suspension form.

When graphite is dispersed in oil, it is called 'oil dag' and when it is dispersed in water; it is called 'aquadag'. Oil dag is useful in internal combustion engine and aquadag is useful in food stuffs industry.

## **Molybdenum disulphide as solid lubricant:-**

It has sand-witch like structure. The layer of molybdenum atoms lie between two layers of sulphur atom. These layers are held together by very weak vander Waals forces. Due to these forces, it is soft & smooth in nature.

It possesses very low coefficient of friction

It is stable in air up to 400<sup>0</sup>C.

It has high specific gravity than graphite.

It is used as either in powdered form or in additives

# **PRINCIPLES OF LUBRICATION , BOUNDARY LUBRICATION**

## **EXTREME PRESSURE LUBRICATION:-**

When the moving surfaces are under very high pressure and speed, high temperature is attained. This high temperature can change properties of lubricants due to decomposition & lubricant may evaporate also. Here any normal lubricants don't work, here EPL works. Extreme pressure lubricants contains organic compounds having active groups such as chlorine, sulphur and phosphorus, such compound react with surface at high temperature and form metallic chloride, sulphide or phosphide. These layers can withstand high temperature, high pressure because of their strength and high melting point.

## **FLUID FILM, THICK FILM OR HYDRODYNAMIC LUBRICATION**

This type of lubrication is done with liquid lubricants. In this method lubricant fills the irregularities of sliding surface and forms a thick layer ( $1000\text{\AA}$ ) in between them and keep the material surface away from each other. Here the lubricant should have minimum viscosity during working condition and it should remain inside and separate the surface.

This friction is quite common in the case of shaft running at a fair speed in a well lubricated bearing with moderate load. This type of lubrication is done in delicate Instruments like watch, clock, guns, and sewing machines and in scientific instruments.

**BOUNDARY LUBRICATION & THIN FILM LUBRICATION:-** This type of lubrication is done when continuous film of lubricants cannot persist and direct metal to metal Contact is possible. This will happen when:-

- Shaft starts moving
- Viscosity of oil is very low
- Speed is very low & Load is very high

In this thin layer lubricant binds with the molecule of metal surface & can't be removed easily.. These adsorbed layers avoid direct metal to metal contact. Mineral oil, blended oil with some vegetable or animal oils are used for thin film lubrication.

Vegetable oil and their soaps have good property of adsorption but they break at high temp and mineral oil have of oiliness therefore blended oil is used for thin film lubrication.

## **The lubricant oil must have following characteristics:-**

It should have long hydrocarbon chain.

It should have active group or atoms.

It should have good oiliness.

It should have high viscosity index.

It should have low pour point.

It should have good resistance to heat & oxidation



# Difference Between fluid film lubrication & boundary lubrication

- |   |   |
|---|---|
| 1. Lubricants having low viscosity are used in this lubrication.            | 1. Lubricants having high viscosity are used in this lubrication.                                       |
| 2. The thickness of lubricating oil film is more than 100A                  | 2. The thickness of lubricating oil film is less than 100A.   |
| 3. These are used as such no metallic surfaces are required for adsorption. | 3. The thin film of lubricating oil is adsorbed by physical or chemical forces at the metallic surface. |
| 4. The load applied is sufficient to keep apart the moving surface.         | 4. The load applied is carried by the layers of adsorbed lubricants.                                    |
| 5. These are used in the machines working under light load & high speed.    | 5. These are used in the machines working under heavy load & low speed.                                 |
| 6. <b>For example:</b> Watches, clocks, gums, sewing machines.              | 6. <b>For example:</b> Rollers, Gears, Tractors, Railway track joint.                                   |

## **ADDITIVES FOR LUBRICANT**

No single lubricant can behave ideally for various applications. Therefore their properties can be improved by addition of some suitable compounds. They are called additives for lubricants.

**Some of the important additives are:-**

**Oiliness Improver:-** They increase the strength of oil film & prevent its rupture. eg: fatty acids, vegetable oil etc.

**Viscosity Index Improver:-** They reduce rate of change of viscosity with temperature. They prevent oil from thickening at low temperature & from thinning at high temperature. eg:- polystyrene, polyester etc.

**Anti-oxidants:-** They increase resistance of oil towards oxidation. eg:- phenols, amines etc.

**Corrosion Inhibitor:-** They protect bearings & other metal surface from corrosion. eg:- organometallic compounds.

**Rust Inhibitor:-** They protect ferrous metal from rusting. eg:- fatty acid, amine phosphate etc.

**Emulsifier:-** They promote mixing of mineral oil with water & help in formation of emulsions. e.g.:- sodium salt of carboxylic acid, sulphonic acid etc.

**Anti-Foam additives:-** It prevents the formation of stable foam during lubrication. eg:- silicones, glycols etc.

**Pour- point depressants:-** Maintain the fluid characteristics of oil even at low temp. Prevent the formation of gel-like structure in the oil.

**Dispersants:- prevent sludge formation** under low temperature conditions. eg:- polymethacrylates, alkyl succinimides.

**Detergents & deflocculants:-** Clear the machine parts from dirt & dust. Prevent the formation of deposits in engine under high temperature conditions. E.g. Calcium & Barium salts of phosphonates & sulphonates.

## **SYNTHETIC LUBRICANTS:-**

They are the lubricants that are prepared in laboratory.

They are prepared in laboratory.

They are much better than ordinary lubricants because they can work under extreme conditions. For example: - silicones, chlorinated hydrocarbons, silicate esters etc.

### **Characteristics:-**

They have high thermal stability.

They have high flash point and fire point.

They have high viscosity index.

They have low freezing point.

Non- Inflammable and can be used over wide range of temperature.

## **Biodegradable Lubricants: -**

They are those substances which are able to decompose in natural.

Environment in water, soil without yielding harmful substances by action of micro- organism and also act as lubricants.

They are typically vegetable oil based.

They don't accumulate for longer time.

They are Environment friendly.

They have high viscosity index and high ignition temperature.

## **PROPERTIES OF LUBRICANTS**

**1 OILINESS:** - It is capacity of lubricants to stick on surface of machine parts under high pressure & load.

A good lubricant should have good oiliness

A good lubricant should have low volatility

**2 VOLATILITY:** - It is property by which oil evaporates at high temperature. A good lubricant should have low volatility.

**3 EMULSIFICATION:** - It is property of an oil by which it gets mixed with water & form emulsion. Emulsions have tendency to collect dirt particles & protect machine parts.

**4 CORROSION STABILITY:** - A good lubricant should not take part in corrosion. Corrosion occurs when oil contains some chemicals.

**5 CLOUD-POINT AND POUR POINT:-**

**CLOUD POINT:** - When oil is cooled slowly the temperature at which it becomes cloudy in appearance is called 'cloud point'.

**POUR POINT:** - Pour point of oil is the temperature at which the oil ceases to flow or pour.

**Significance:-**It indicates the suitability of lubricants in cold conditions. A lubricant used in machine working at low temperature should have low pour point, otherwise it will cause jamming of machine.

**DIAGRAM:-**

- Apparatus has a flat bottom tube enclosed in air jacket which is surrounding by a freezing mixture (Ice + NaCl) in a jar.
- The tube is half filled with oil. Now the temperature falls . For every 10C fall in temp., tube is taken out & examined.
- The temperature at which cloudiness appears is called 'cloud point'.
- After this the tube is examined for every 30C fall of temperature. The temperature at which the oil doesn't flow even when tube is kept horizontal for 5 seconds is called 'pour point'

## **6 FLASH AND FIRE POINT:-**

**Flash point:** The lowest temperature at which an oil lubricant gives off enough vapours that ignite for a moment when flame is brought near to it.

**Fire point:** It is the lowest temp. of lubricant at which the lubricant gives off sufficient vapor that ignite continuously for at least 5 seconds when a flame is brought near it.

Generally, the fire point is 5-10<sup>0</sup>C higher than the flash point for any lubricant.

## **Significance:**

It tells the maximum temperature up to which a lubricant can be used.

A good lubricant should have flash and fire point above its working temperature.

### **Factors affecting the flash point and fire point of oil**

**Low molecular weight constituents:** which tends to decrease the flash point.

**Contamination with small amounts of volatile:** Because of their presence irregular flashes can be observed below the true flash point of lubricating oil. It is called “**freaky flash point**”. **Moisture:** It may prevent the oil vapor from igniting and hence raise the flash point.

### **Experimental factors:**

Frequency of application of test frame

Rate of heating, Rate of stirring, Size of test flame

Time of opening the shutter.



# Determination

Flash and fire point of lubricating oil is determined by Pensky – Marten's apparatus which consists of following parts:

- a) Oil cup:** made up of brass with a lid having four openings of standard size for a stirrer, thermometer, an air inlet and test frame.
- b) Shutter:** Present at the top of cup & has a lever mechanism when it is opened, a test flame comes in contact with oil vapor to check the flash a fire point.
- c) Air path:** Oil is placed in an air-bath which ensures very slow and uniform change in temp. It is heated either by a gas burner or electricity.
- d) Pilot burner:** It is always lighted to support the burning of test flame burner.
- e) Flame test burner:** Burner by which test flame is introduced into cup containing lubricating oil.

**Procedure:**

The oil sample is filled up to the mark in the cup. It is heated with constant stirring at the rate of about  $5^{\circ}\text{C}$  per minute. At every  $1^{\circ}\text{C}$  rise in temp, test flame is introduced for a moment with the help of a shutter. When test flame produces a distance flash in the oil cup, the temperature noted and recorded as flash point. The heating is continued after every  $1^{\circ}\text{C}$  rise in temp, the oil vapors are tested for fire points. The temperature at which the experimenting lubricating oil catches fire at least 5 sec. is recorded as its fire point.

## **7 VISCOSITY: -**

It is the resistance offered by liquid towards its flow. It is determined by Red Wood Viscometer.

## **8 VISCOSITY INDEX (V.I):-**

The rate of change of viscosity with temperature is called viscosity index(V.I

Viscosity generally decreases with increase in temperature.

If the viscosity of oil falls rapidly with temperature it is said to have a low viscosity index.

If the viscosity of the oil does not fall rapidly with temperature it is said to have a high viscosity index.

Good lubricant oil should have a high viscosity index.

## **DIAGRAM:-**

## **DETERMINATION OF VISCOSITY INDEX:-**

Test oil is compared with two standard oils with viscosity index 0 & 100

Oil with viscosity index =0(Gulf coast oil) (L)

Oil with viscosity index =100(Pennsylvanian oil) (H)

$$\text{V.I of test oil} = \frac{V_L - V_U}{V_L - V_H} * 100$$

Where,  $V_L$  = viscosity of Gulf oil at 100°C.

$V_H$  = viscosity of Pennsylvanian oil at 100°C

$V_u$  = viscosity of oil under test

## **VISCOSITY INDEX AND MOLECULAR STRUCTURE:-**

Molecules with linear structures, with flexibility have high V.I.

An oil of high mol. wt possesses a high B.P and high viscosity.

## ***PROPERTIES OF LUBRICANTS***

### ***SAPONIFICATION VALUE / KOETTSDOER NUMBER***

**“Saponification value of an oil is defined as the number of milligram of KOH required to saponify fatty material present in one gram of oil”.**

#### **Significance:-**

Saponification value gives an estimation of non-fatty impurities present in an oil fat i.e. the extent of adulteration.

Saponification value is used to distinguish between vegetable and animals oil, fatty and mineral oils.

Saponification value is used to identify a given fatty oil, because each fatty oil has its own characteristic value.

#### **Determination:-**

Take 2-3 gm oil+50ml KOH+50ml solvent in titration flask.

Flask is fitted with air condenser & refluxed for 30mins.

After cooling 8 drops of phenolphthalein is added & titrated against N/10 HCl till disappearance of pink colour.

Same titration is done without oil called ‘Blank Titration’

## Calculations :-

Let Weight of oil sample taken = W gm

Volume of KOH added = 50ml

Volume of solvent added = 50ml

Volume of HCL used for oil sample & solvent = A ml

Volume of HCL used for solvent alone = B ml

Volume of HCL equivalent to KOH used in Saponification of wg of oil sample = (B – A)ml

Saponification value of the oil

$$\frac{\text{Volume of KOH used (ml)} \times \text{Normality} \times \text{Eq.wt. of KOH}}{\text{Weight of oil sample}}$$

$$= (B - A) \times 1 \times 56 W$$

## 10 DROP POINT

The temperature at which grease is converted from the semi-solid to the liquid state.

It determines the upper temperature limit of the applicability of grease.

## **Determination**

The experimental grease sample is taken in a metal cup having an opening hole of standard size in its bottom.

Metal cup is enclosed in a glass case having a tight lid.

A thermometer is also inserted in the cup, so that the bulb of thermometer is just above the surface of grease sample.

The whole arrangement is placed in a glass beaker containing water and provided with a stirrer.

The beaker is heated slowly at the rate of  $1^{\circ}\text{C}/\text{min}$ .

As temperature rises, the grease sample converts from semi-solid to liquid state.

At a particular temperature, first drop of grease falls from the opening hole in the bottom of cup.

This temperature is recorded as drop-point of grease.

Dropping point of a grease is increased by adding metallic salts of short chain organic acids like acetic acids or inorganic salts like carbonates or chlorides called as complexing agent.

## PROPERTIES OF LUBRICANTS - NEUTRALIZATION NUMBER

### **12 NEUTRALIZATION NUMBER (ACID VALUE):-**

Lubricating oils acidity or alkalinity is determined in terms of neutralization number. The neutralization number represents the total acid number (TAN) .

**“It is defined as the number of milligrams of KOH required to neutralize the free acid in 1gram of the oil”.**

Acid value gives an idea about the age of the oil because the acid content or value of fatty acids increases with time due to hydrolysis with moisture.

### **DETERMINATION OF ACID VALUE:-**

Taken 3ml oil+50ml solvent+5 drops of phenolphthalein in titration flask, then shaken.

Taken alcoholic KOH in burette & started titration.

Appearance of light pink colour is end point.

Same procedure is repeated for ‘Blanc Titration’.



## CALCULATION:-

Weight of oil sample = W gm

Volume of alc. KOH used in oil titration = A ml

Volume of alc. KOH used in the blanc titration = B ml

Volume of alc. KOH used against the acid present in W gm of oil = (A-B) ml.

Acid value (TAN) = volume of KOH used (ml) \* Normality \* Eq. wt. of KOH.

$$\begin{aligned} &= \frac{(A - B) \times 1 \times 56}{100 W} &= \frac{\text{Weight of oil sample} \times (A - B) \times 0.56}{W} \end{aligned}$$

“Acid value of good oil should be less than oil”

**IODINE VALUE:-**It is the number of grams of iodine absorbed by 100 gm oil. Its value is determined by addition of excess of iodine monochloride (ICl) to glacial acetic acid (Wilf solution) +oil dissolved in CCl<sub>4</sub>.

One molecule of ICl adds on each double bond of oil.