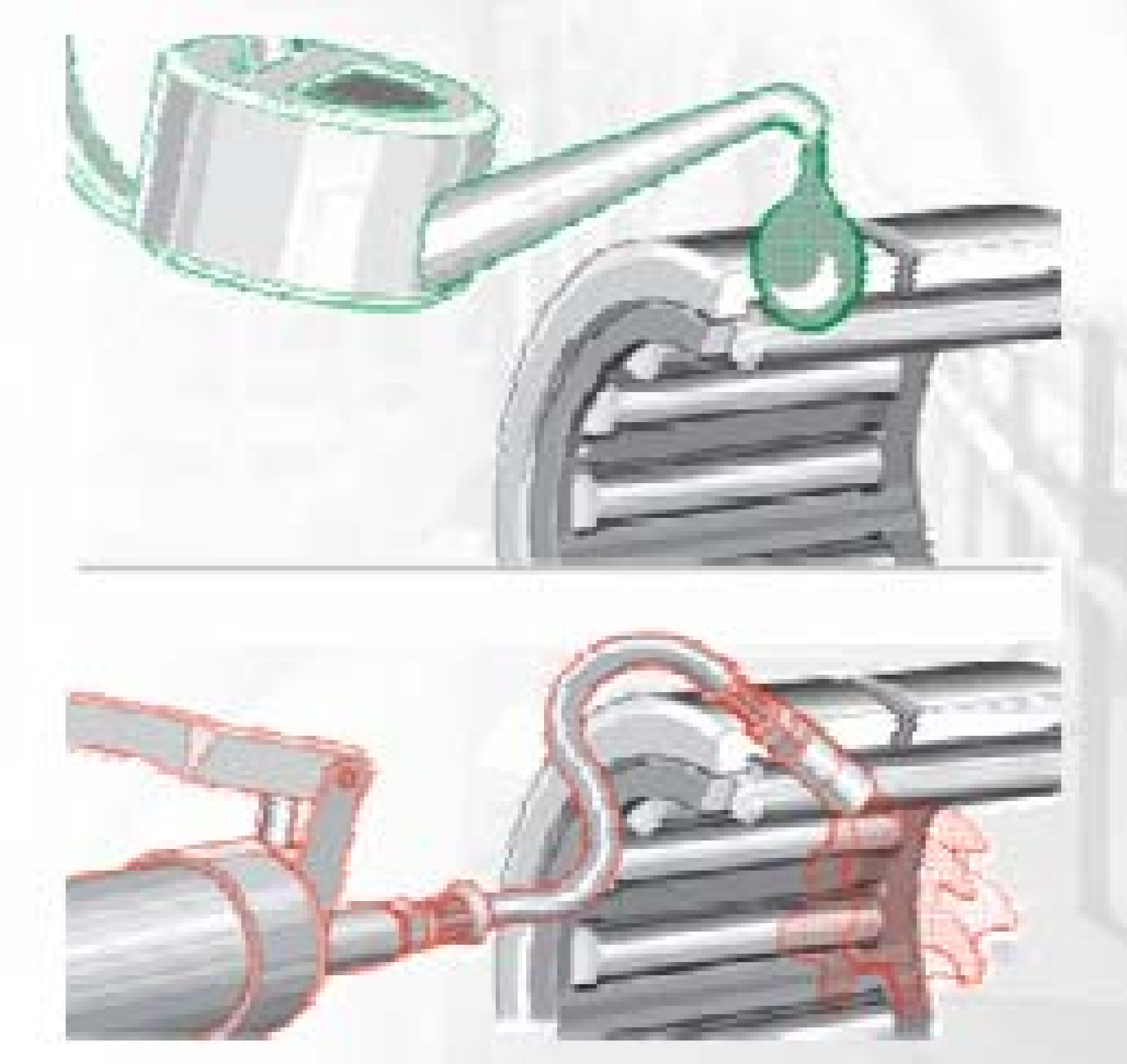
UNIT – 4
L-34-36

• "LUBRICANTS"



Dr. S. Anand Giri
Reader & Head,
Chemistry Deptt.
OPJIT,Raigarh,
C.G.

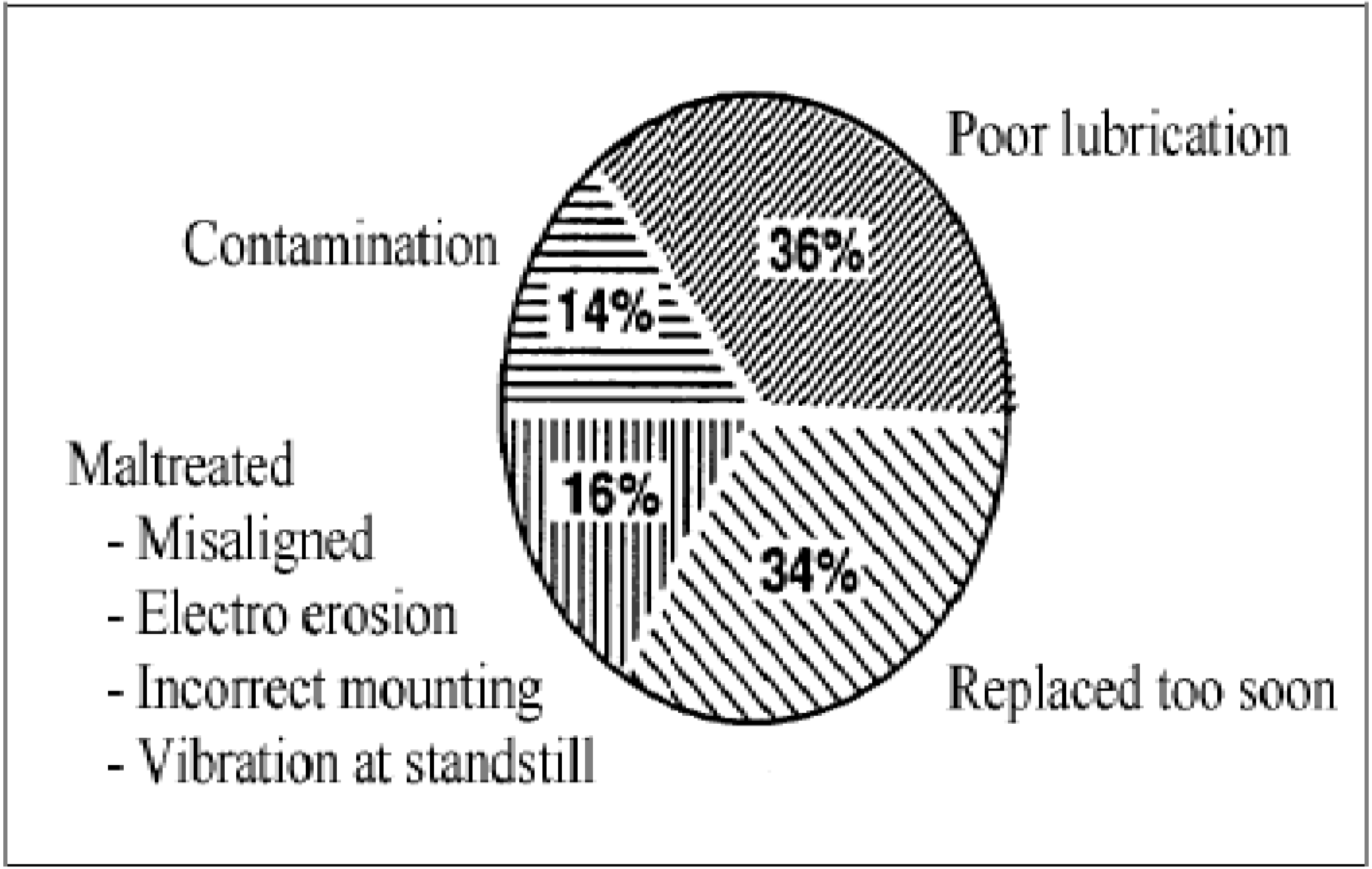
Syllabus

- **Classification of lubricants and mechanism of lubrication.**

INTRODUCTION:-

- In all types of machines, **the surface of moving, sliding or rolling parts rub** against each other.
- This mutual rubbing **generates frictional force and cause resistance** to the relative motion of these surfaces.
- Friction also **generates heat causing loss in the efficiency** of the machine.

Ch


Poor lubrication
36%
Contamination
14%
Maltreated
- Misaligned
- Electro erosion
- Incorrect mounting
- Vibration at standstill
16%
34%
Replaced too soon

INTRODUCTION:-

- The frictional resistance can be minimized by
- **applying a thin layer of certain substances, known as lubricant**
- in between the moving/ sliding/ rolling surfaces.
- A lubricant may thus be defined as
- **“a substance which reduces the friction when introduced between two surfaces & the phenomenon is known as lubrication”.**

INTRODUCTION:-

- **Functions of Lubricants :-**

1. It reduces friction.
2. Reduces wear, tear & surface deformation.
3. It acts as coolant to carry away heat.
4. It keeps out dirt.

INTRODUCTION:-

5. Sometimes, it acts as a seal.
6. It reduces the maintenance & running cost of the machine as it prevents rust & corrosion.
7. It transmits fluid power.
8. It also reduces loss of energy in the form of heat.

Classification of Lubricants :-

- On the basis of their physical state,

Classification of lubricants

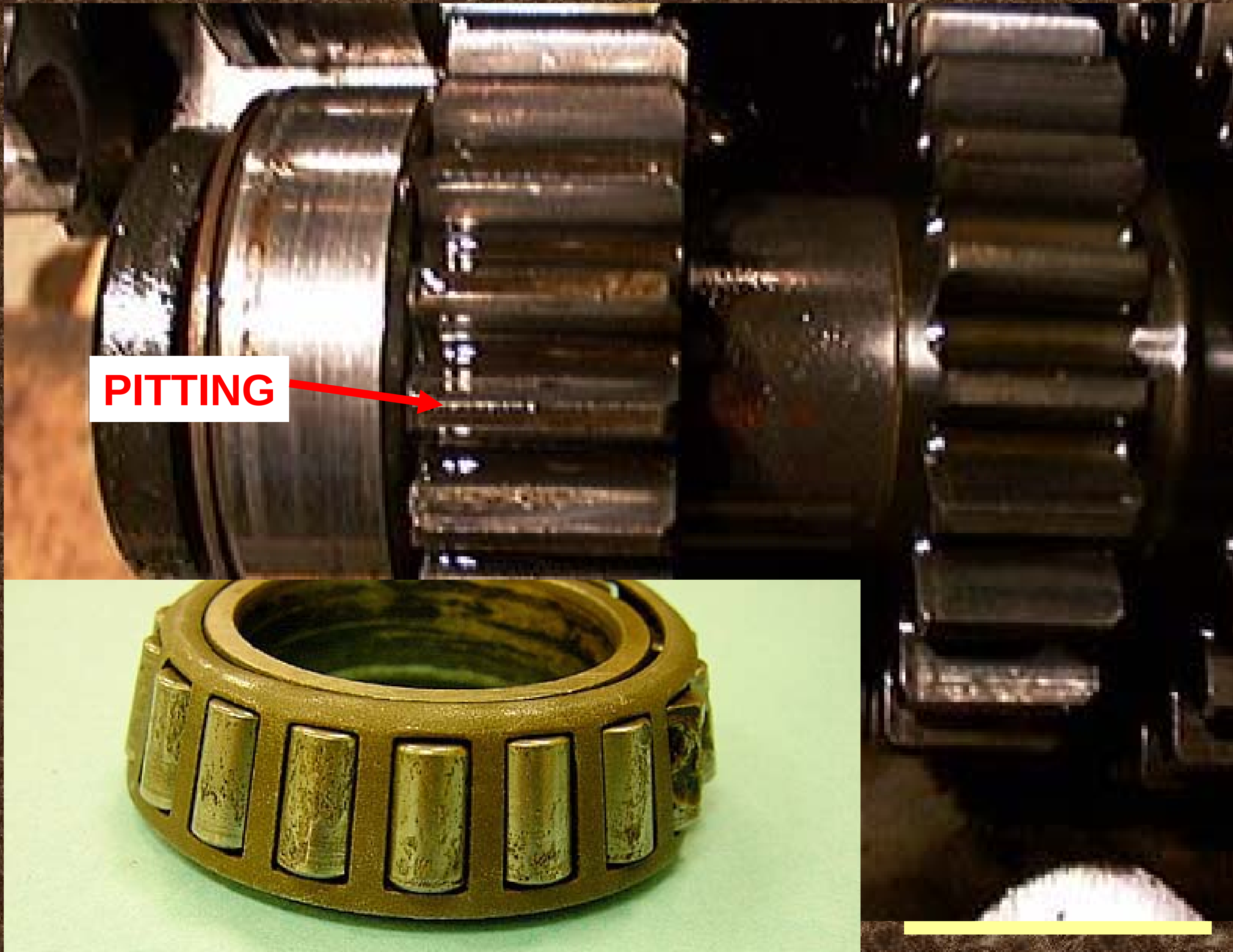
- **Lubricating Oils**
- **Greases**
- **Solid lubricants**

Lubricating Oils

Lubricating Oils :-

- also known as liquid lubricants and
- are further classified into 3 categories viz.

1. Animal & Vegetable oils,
2. Mineral or Petroleum oils and
3. Blended oils.


PITTING

Lubricating Oils

***Characteristics of good Lubricating Oils**

– **High boiling point.**

– **Low freezing point**.

– **Adequate viscosity** for proper functioning in service.

– **High resistance** to oxidation & heat,

– **non- corrosive** properties and

– **stability to decomposition** at the operating temperatures.

Functions of Lubricating Oils

Functions of Lubricating Oils:-

1. Lubricating oils provide a continuous fluid film in between moving/sliding/rolling surfaces &
2. reduce friction, wear & heat generation.
3. They also act as

   i. **Cooling agent**

   ii. **Sealing agent.**

   iii. **Corrosion preventer.**

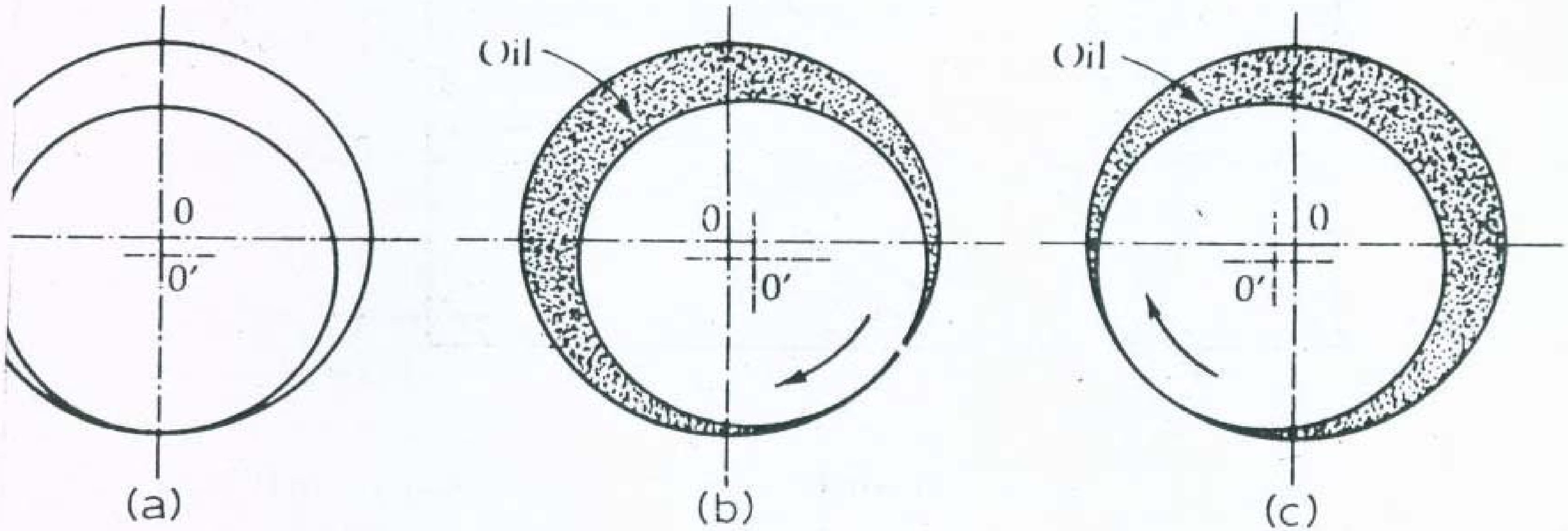
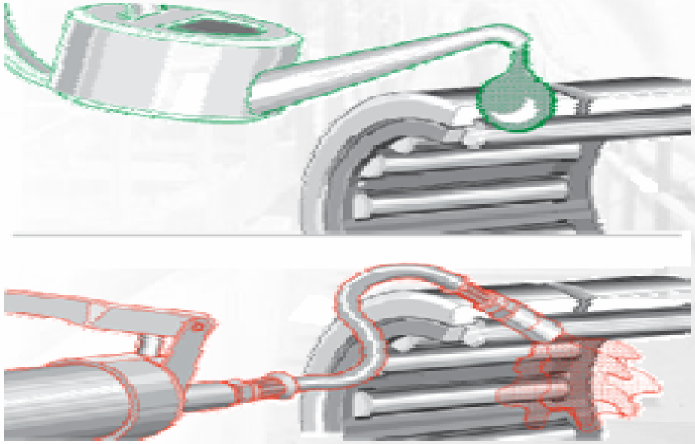


Fig. . Formation of fluid film in a plain bearing.

Rolling bearings can be lubricated with grease or oil. The decisive factors in determining the appropriate type of lubrication and quantity of lubricant are:

- the operating conditions
- the bearing type and size
- the adjacent construction
- the lubricant feed.



Types of Lubricating Oils

Types of Lubricating Oils :-

(1) Animal & Vegetable Oils:-

(2) Mineral or Petroleum oils

(3) Blended oils

Animal & Vegetable Oils

Animal & Vegetable Oils:-

- possess good “**oiliness”** & hence these
- **stick to the surface** of machine parts,
- even **under high temperatures & heavy loads**.

Animal & Vegetable Oils

- These have limited uses at present because these are

i) Costly and

ii) have **less resistance to oxidation** &

form

gummy and acidic products.

iii) They **get thickened** in contact with air.

iii) With **humidity or moisture** these have **tendency to hydrolyze.**

Animal & Vegetable Oils

Actually these oils are

used as **blending agent** for mineral oils

to produce, **desired effects**.

Animal & Vegetable Oils

Uses : Animal Oils

Lard Oil

1. For lubricating **ordinary** machine parts.

2. For lubricating **clocks & sewing** machines

3. particularly suitable for **light machinery**.

Animal & Vegetable Oils

II Vegetable Oils

Castor Oil

Very good lubricant for bearing and machinery operating at high speeds & low pressures like racing cars.

Palm Oil

For lubricating **delicate instruments such as scientific equipments.**

ECOLOGICAL ASSESSMENT

Comparison of biodegradability of used dispersion phases and greases tested according to CEC-L-33 T-82 standard*

Kind of the dispersion phase and lubricating grease	Biodegradability [%]	Category of biodegradability according to the three-stage scale
BASE OIL		
MINERAL OIL	40	potentialy biodegradable
SYNTHETIC OIL	97	easily biodegradable
VEGETABLE OIL	98	easily biodegradable
GREASES		
MINERAL GREASE	40	potentialy biodegradable
SYNTHETIC GREASE	84	easily biodegradable
VEGETABLE GREASE II	87	easily biodegradable

Mineral or Petroleum Oils

Mineral or Petroleum Oils:-

- These are **lower molecular weight hydrocarbons**
  with about 12 to 50 carbon atoms.
- The **viscosity increases with the length** of
  hydrocarbon chain.
- They are obtained by distillation of petroleum.

Mineral or Petroleum Oils

As they are

1) **cheap,**
2) **available in abundance &**
3) **stable under service conditions,**

hence these are widely used.

- In comparison to animal and vegetable oils, **oiliness of mineral oils is less.**

- Oiliness can be increased by **adding the higher molecular weight compounds** like **oleic acid and stearic acid,**

Blended Oils

Blended Oils:-

- **Desirable characteristics** of lubricating oils can be
- **improved** by adding small quantities of
- **various additives.**

The oil thus obtained are known as **blended oils or compounded oils.**

Blended Oils

- **Various additives, their purpose functions & typical examples are summarized below:**

1. **Lubricant Protective Additives:-**
2. **Surface Protection Additives:-**
3. **Performance Additives:-**

Lubricant Protective Additives

• Additive Examples	Purpose	Functions	Typical Type
1.Antioxidant	Retard oxidative decomp- -osition	**Terminate free** radical chain reactions and Decompose **peroxides**	Aromatic amines, Hindered Phenols etc.
2.Metal Deactivator	Decrease catalytic effect of metals on oxidative rate,	By complexing with metal ions they form **inactive layer** On metal surfaces	Amines, Sulphides or Phosphites etc.
3.Antifoamant	Prevent foam formation by lubricant	Speed collapse of foam by reducing **surface tension**	Silicon, Polymers

Surface Protection Additives:-

Additive Type	Purpose	Functions	Typical Examples
1.Rust and Corrosion inhibitor	Prevent rusting and corrosion of metal parts in contact with the lubricant	Neutralisation of corrosive acids & preferential adsorption of polar constituent on metal surface to provide a protective film.	Metal phenolates, basic metal sulfonates, fatty acids and amines.
2.Anti wear & EP agent	Reduce friction & wear and prevent scoring and seizure	Prevent metal to metal contact by chemical reaction with metal surfaces to form a film with lower shear strength than the metal	Zinc dithio-phosphates, organic phosphates & acid phosphates, sulfurized fats etc.

Surface Protection Additives:-

Additive Type	Purpose	Functions	Typical Examples
3.Friction modifier	Change coefficient of friction	Preferential adsorption of surface active materials	High molecular wt. phosphorus & phosphoric acid esters organic fatty acids & amines
4.Detergent	Keep surfaces deposits free	Neutralize the sludge & varnish precursors and keep them soluble	Magnesium phenolates, phosphates & sulfates

Surface Protection Additives:-

Additive Type	Purpose	Functions	Typical Examples
5.Dispersant	Keep insoluble contaminants dispersed in the lubricant	Prevent agglomeration of contaminants-which are bonded by polar attraction to dispersed molecules and remain suspended.	Alkyl succinimides, polymeric alkyl thiophosphonates.

Performance Additives

Additive Type	Purpose	Functions	Typical Examples
1.Viscosity modifier	Reduce the rate of viscosity change with temperature	Polymer expand with increasing temperature to counteract oil thinning	Polymers & co-polymers of olefins, styrenes, methacrylates &butadiene.
2.Pour point Depressant	Enable lubricant to flow at low temperature	Reduce interlocking by modifying wax crystal formation	Polymethcrylates phenolic polymers & napthalenes.
3.Seal swell agent	Cause swelling of elastomer by chemical reaction		

Greases or Semi – Solid Lubricants

- **Greases or Semi – Solid Lubricants :-** A semi – solid lubricant, consisting of

➡ **soap dispersed throughout a liquid lubricating oil.**

- The oil may be **Petroleum oil or any synthetic oil** and
- It may contain any of the additives according to requirement.

Greases or Semi – Solid Lubricants

- **Greases or Semi – Solid Lubricants :-** A semi – solid lubricant obtained by combining **lubricating oil with thickening agent** is termed as "Grease".
  - **Shear or frictional resistance** of Greases is **much higher than oils** hence they can support **much heavier load at lower speed**.

Spur Gear

Rolling Bearings

Planetary Gear

HEAVY-LOADED LUBRICATED MACHINE COMPONENTS

Base Fluids can include:

Mineral Oils (Paraffinic and Naphthenic)

Vegetable Oils (Rapeseed Oil, Sunflower Oil, etc.)

Synthetic Fluids (Polyalphaolefins, Polyglycols, Polybutenes, Silicones, Ethers, Esters, Alkylates, Fluorocarbons, etc.)

Additives can include:

Antioxidants

Anti-wear

Extreme Pressure

Anti-rust

Solid lubricants (Graphite, Molybdenum Disulphide, etc.)

WHAT ARE THE DIFFERENT TYPES OF GREASE?

Greases are in the main divided into soap-thickened and non-soap thickened varieties, and can be based on mineral oil (most common) or on other types of fluid base.

Soaps can include:

Lithium

Calcium (Hydrous and Anhydrous)

Sodium

Barium

Aluminium

Lithium Complex

Calcium Complex

Aluminium Complex

Non-soaps can include:

Bentone clays

Silica

Polyurea

Greases or Semi – Solid Lubricants

- **Coefficient of friction of greases is**
- **much higher** than that of lubricating oils.
- Therefore, if possible**,**
- **it is better to use an oil** instead of grease.
- **BUT**
- **greases cannot effectively dissipate heat from the bearing.**

- That's why the **grease lubricated bearing works at relatively lower temperatures**.

Greases

Preparation :-

Grease are made by

- **saponification of fat with alkali** followed by adding hot **lubricating oils**

  with constant mixing under agitation

- **Consistency** of the finished greases depends on **total amount of the mineral oil.**

Greases

Applications :-

1. In **rail axle boxes**.
2. In **bearings & gears** working at high temperatures.

3. In machines of **paper, textiles, edible articles etc.**

   where dripping of oils is not wanted.

1. In machines where **bearing needs to be sealed against** entry of dust, dirt, grit or moisture,

Greases

Classification of greases on the basis of the soap used in their manufacture

i) **Calcium – based greases or cup greases**

ii) **Soda – based greases**

iii) **Lithium – based greases**

Greases

Classification of greases on the basis of the soap used in their manufacture

i) Calcium – based greases or cup greases

Are emulsions of petroleum oils with calcium soaps generally prepared by

adding **calcium hydroxide to a hot oil like tallow** under agitation

Greases

i) Calcium – based greases

Cheapest and most commonly used.

- **Water resistant**
- **Above 80^0C oil and soap get separated**

These are suitable for lubricating

- **caterpillar treads,**
- **tractors,**
- **water pumps** etc.

Greases

- **ii) Soda – based greases**

  are petroleum oils thickened by mixing with sodium soaps.

  As **sodium soap is soluble in water** so the greases **are** **not water resistant.**

- can be **used up to 175^{0}C.**

These are suitable for use in

- **ball bearings which**
- **Generates frictional heat.**

Greases

iii) Lithium – based greases

employ lithium soaps as thickening agent in petroleum oils. These are

- **resistant to water**.
- **stable in storage,**
- **high mechanical strength&**
- **High oxidation stability.**
- Used at **low tempertures only about 15^{0}C.**

Greases

iv) Axle greases (Ca)

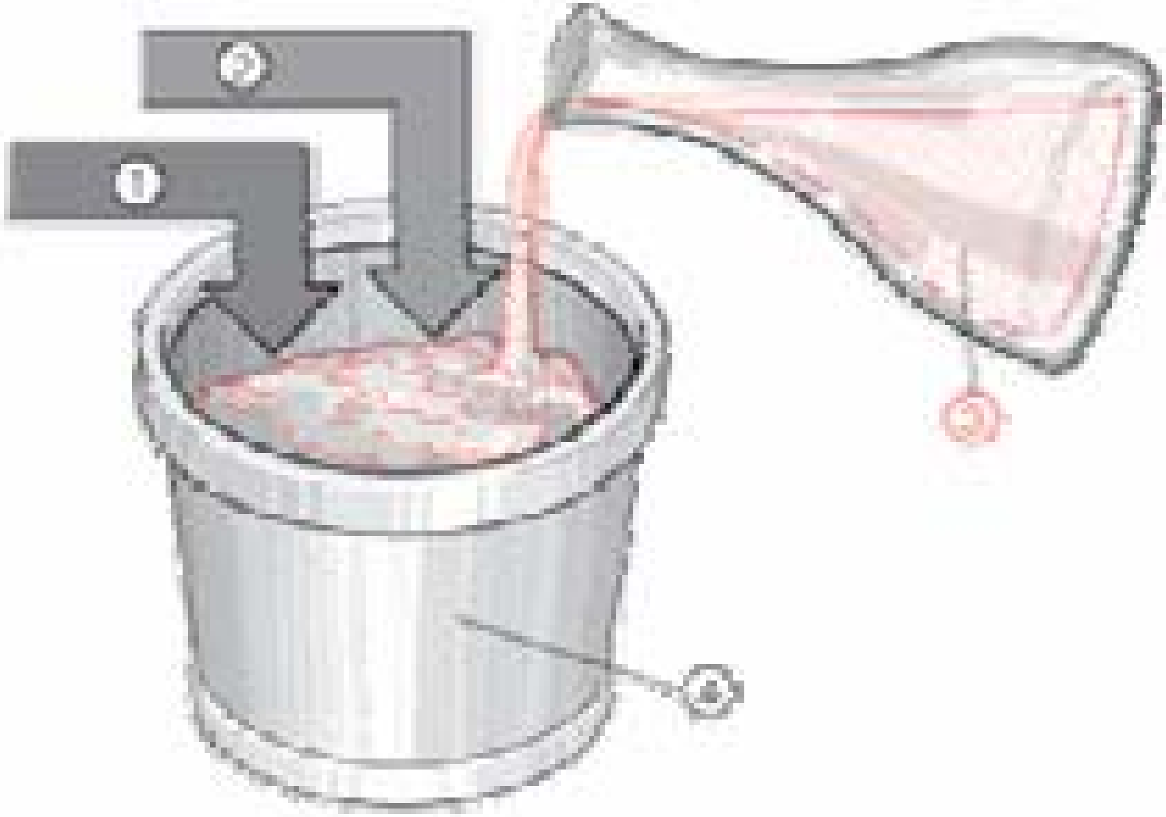
These are very **cheap resin** greases.

prepared by adding

lime to resin & fatty oils.

Talc, mica and suitable **filter** is also added.

- These are **resistant to water** &
- used for less delicate equipments
- working at **low speeds & high loads.**



1. Thickener -
2. Additives -
3. Base oil -
4. Grease

1. Thickener - 5-30% (organic soaps or inorganic non-soaps)
2. Additives - EP, AW, AC
3. Base oil - 70-95% (Mineral, Synthetic, Vegetable)
4. Grease

1. In a starved grease lubrication situation, the degree of starvation increases with increasing base oil viscosity, grease thickener concentration and rolling speed.
2. Starvation decreases with increasing temperature.
3. A higher thickener concentration reduces the bleeding of the base oil from the grease, hence the rolling contact becomes more starved.
4. At real rolling bearing speeds the film thickness may drop to a fraction of the fully flooded thickness.

1. Low base oil viscosity decreases the starvation of the lubrication situation.
2. Low consistency causes the grease to drift away from the vicinity of the contact zone. This phenomenon increases the starvation of the lubrication situation.
3. The high thickener concentration increases the starvation.
4. Low kappa value eliminates the starvation effect of the high thickener concentration.
5. The influence of the bleeding rate on the starvation was difficult to separate from the influences of the other grease parameters. If bleeding rate is high improvement for the lubrication situation is diminished by the low consistency of the grease.

Solid Lubricants

Solid Lubricants :-

- These lubricants reduce friction by separating two moving surfaces **under**
- **boundary conditions.** These are used either in the
- **dry powder** form or
- mixed **with oil or water.**

Solid Lubricants

Applications of Solid lubricants :-

1. **Commutator brushes of electric generators and motors**

   where contamination of grease or is not acceptable.

   or

   Where Lubricating film cannot be made by using oils or greases

- **because of the high operating conditions.**

Solid Lubricants

2. **Internal combustion engines** where a **tight film is desired** between the piston rings & the cylinder for increasing compression.

In such conditions **where combustible lubricants must be avoided.**

Most commonly used solid lubricants are :-

1. Graphite **2. Molybdenum Disulphide**

Solid Lubricants Graphite:-

1. Graphite:-

Graphite consists of number of flat plates made up of network of hexagons (Fig. 1(a)).

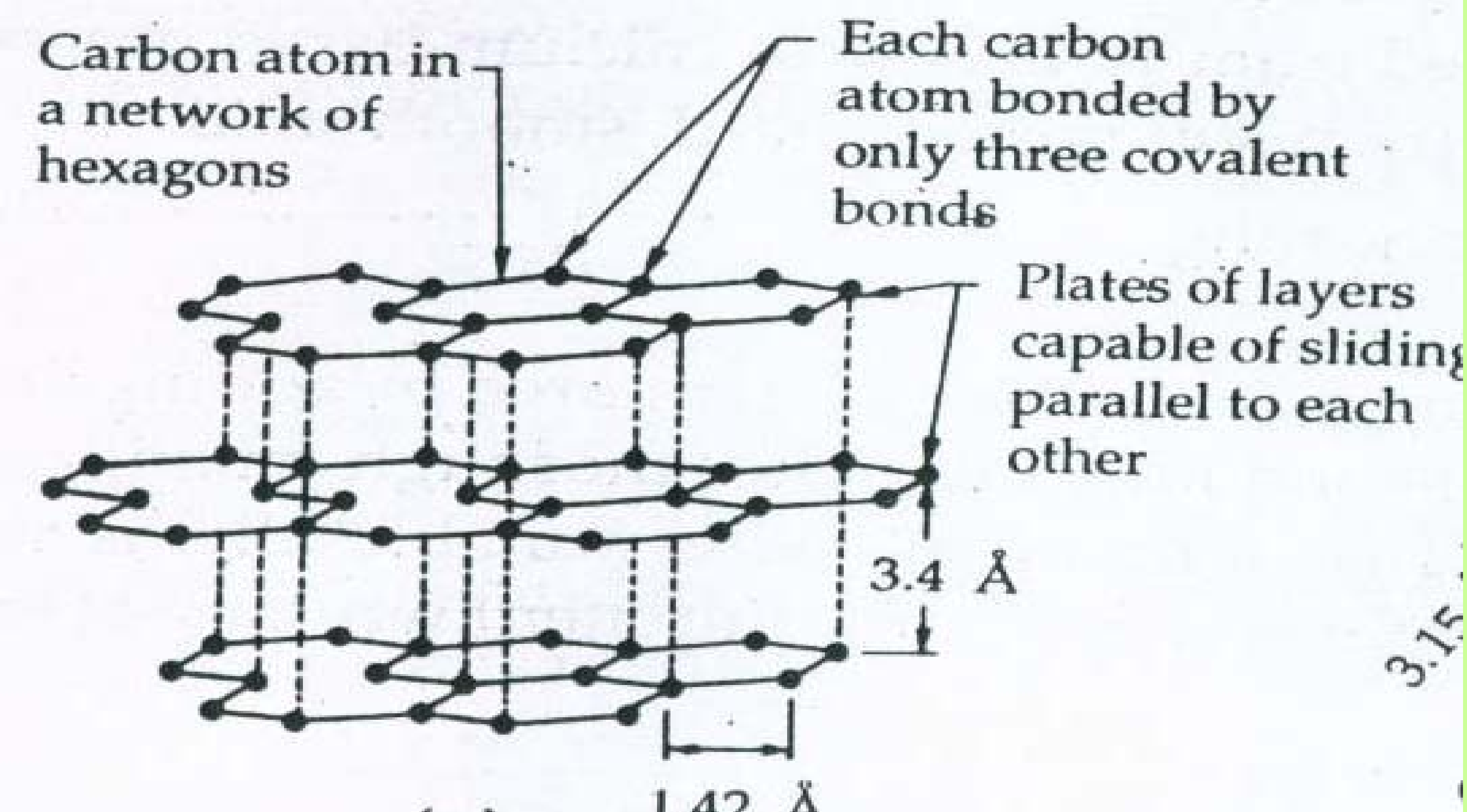


Fig.1(a)

Solid Lubricants

Graphite:-

1. **Graphite:-**

Graphite consists of number of flat plates made up of network of hexagons in which each carbon is in **sp2 hybridization state** (Fig. 1(a)).

- The plates are separated from each other by 3.4 ^{0}A & are held together by
- **weak Vander Wall's forces** so that
- even a small force is sufficient to
- slide the layers parallel to each other. Hence, it has **low coefficient of friction.**

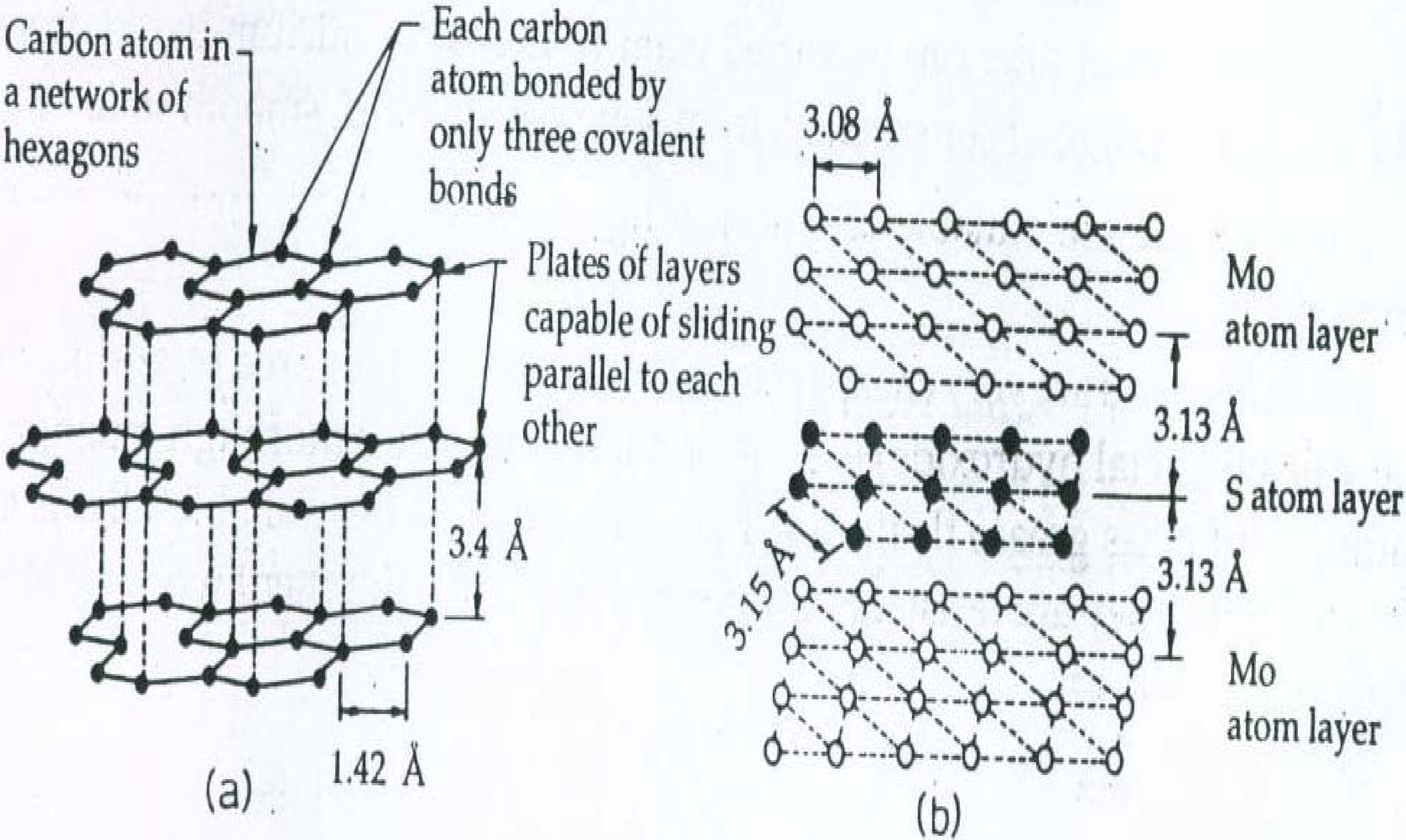


Fig. 5. (*a*) Layered structure of graphite : (*b*) Sandwitch-like structure of molybdenum disulphide.

Solid Lubricants

Graphite:-

Properties:-

- **It is very soapy to touch,**
- **non – inflammable &**
- **not oxidized in air below 375^0C.**

Uses :-

1. It is used in the **powdered form** or as
- **suspension in oil or water and tannin as emulsifying agent.**

Solid Lubricants

Graphite:-

Uses :-

2 ***Aquadag*** **is** Graphite dispersed in water.

- useful where a lubricant **free from oil** is needed **e.g.Foodstaff industries**.

3. Graphite greases are **useful for high temperature applications.**

Solid Lubricants

Graphite:-

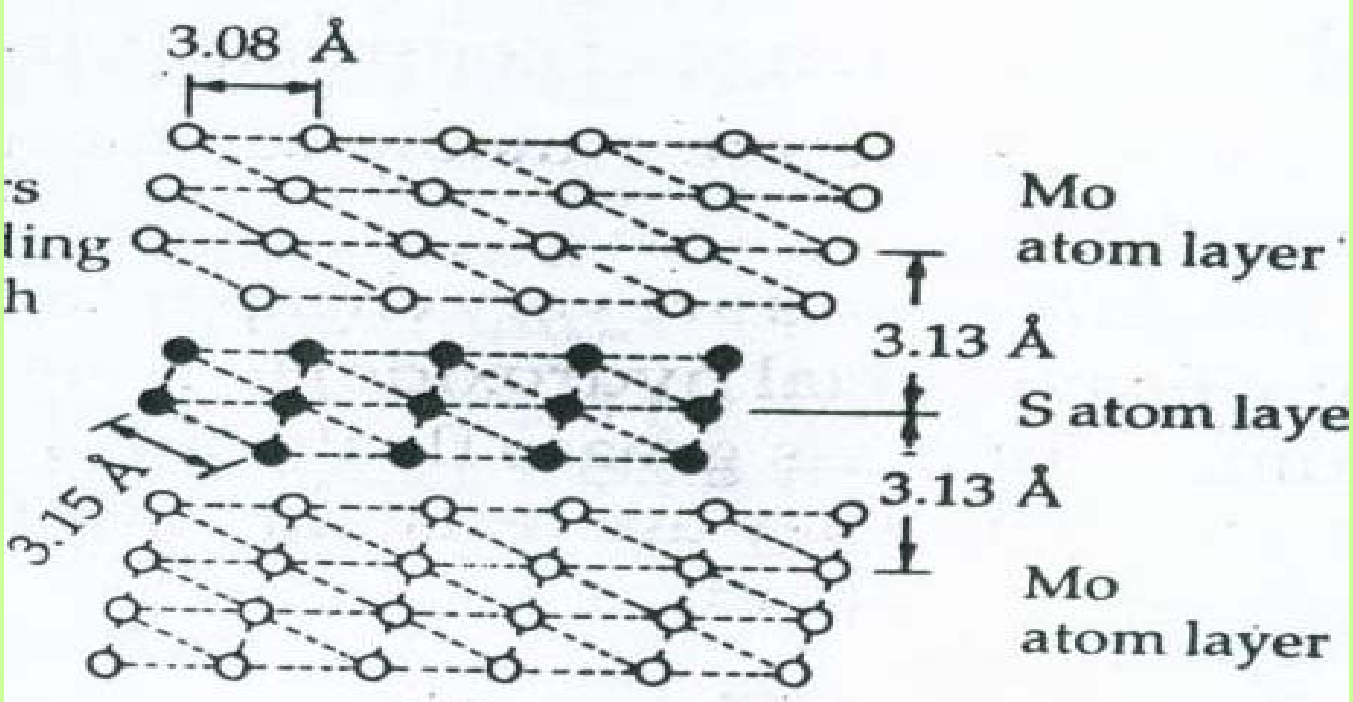
4. ***Oildag is*** Graphite dispersed in oil.

used in

- **internal combustion engines** as it gives a **tight – fit** contact by forming a film between
- the piston rings & the cylinder thereby increasing compression.

Solid Lubricants Molybdenum Disulphide

- **Molybdenum Disulphide :-** It is a **sandwitch** like structure in which a **layer of molybdenum** atoms lies between two **layers of sulfur,** which are 6.26 A^0 apart; see fig. 1(b).



(b)

Solid Lubricants Molybdenum Disulphide

Properties:-

- **MoS_2 has low shear strength** in a direction parallel to the layers due to poor interlaminar attraction.
- That's why MoS_2 has **very low coefficient of friction.**
- It is stable in air up to 400^0C.

Solid Lubricants Molybdenum Disulphide

Uses :-

- A solid – film lubricating surface for **space vehicles** is made from **70% MoS_2 + 7% graphite with 23% silicates,** which can withstand
  - **extreme temperatures,**
  - **low pressure and**
  - **nuclear radiation.**

Synthetic Lubricants

Synthetic Lubricants :-

These are **manufactured** or **synthesized** in **chemical plants or refineries,**

that can be used at

severe or extreme condition as

these exhibit unique properties like

- **high temperature stability,**
- **extended temperature range,**
- **long service life even in**
- **reactive environments etc.**

Synthetic Lubricants

Properties:-

1. **Thermal stability** even at high operating temperatures.
2. **Chemical stability** even in corrosive environments.
3. **High viscosity – index.**
4. **Non – inflammability & high flash points.**
5. **Low freezing point.**

Synthetic Lubricants

Remarkable Applications of Synthetic lubricants:

i) **Di-2 ethyl sebacate (Diester)**

ii) **Phosphate esters**

iii) **Poly alkene glycol (PAGs)**

iv) **Fluorocarbons**

v) **Silicone Moisture – repellent lubricants**

Synthetic Lubricants

Remarkable Applications of Synthetic lubricants:

i) Di-2 ethyl sebacate (Diester)

Used in **turbo – jets**

Satisfactory performance

from **50^0C to 230^0C.**

ii) Phosphate esters An additive lubricants

Improves **boundary lubrication properties.**

Synthetic Lubricants

Remarkable Applications of Synthetic lubricants:

iii) Poly alkene glycol (PAGs)

Aircraft turbine lubricants Stable at

- high temperature and
- high rates of mechanical shear.
- Free from corrosive action.

Synthetic Lubricants

iv) Fluorocarbons

Used in submarines

- Less susceptable to oxidation and cracking,
- **high chemical & thermal stability**

v) Silicone **Moisture – repellent lubricants**

for

clocks, tuners & other electronic devices

- Prone to **oxidize at high temperatures** forming **gels**

Mechanism of Lubrication

- **Mechanism of Lubrication :-** Lubrication mechanism can be classified into following type:

  1. **Hydrodynamic Lubrication or Fluid Film Lubrication**

  2. **Boundary Lubrication or Thin Film Lubrication**

  3. **Extreme Pressure Lubrications**

Mechanism of Lubrication

Hydrodynamic Lubrication or Fluid Film Lubrication :-

Hydrodynamic Lubrication or

- **Fluid Film Lubrication :-**
  - In this, the moving / sliding surfaces are separated from each other by a
  - **bulk lubricant film**
  - **at least 1000 A thick.**

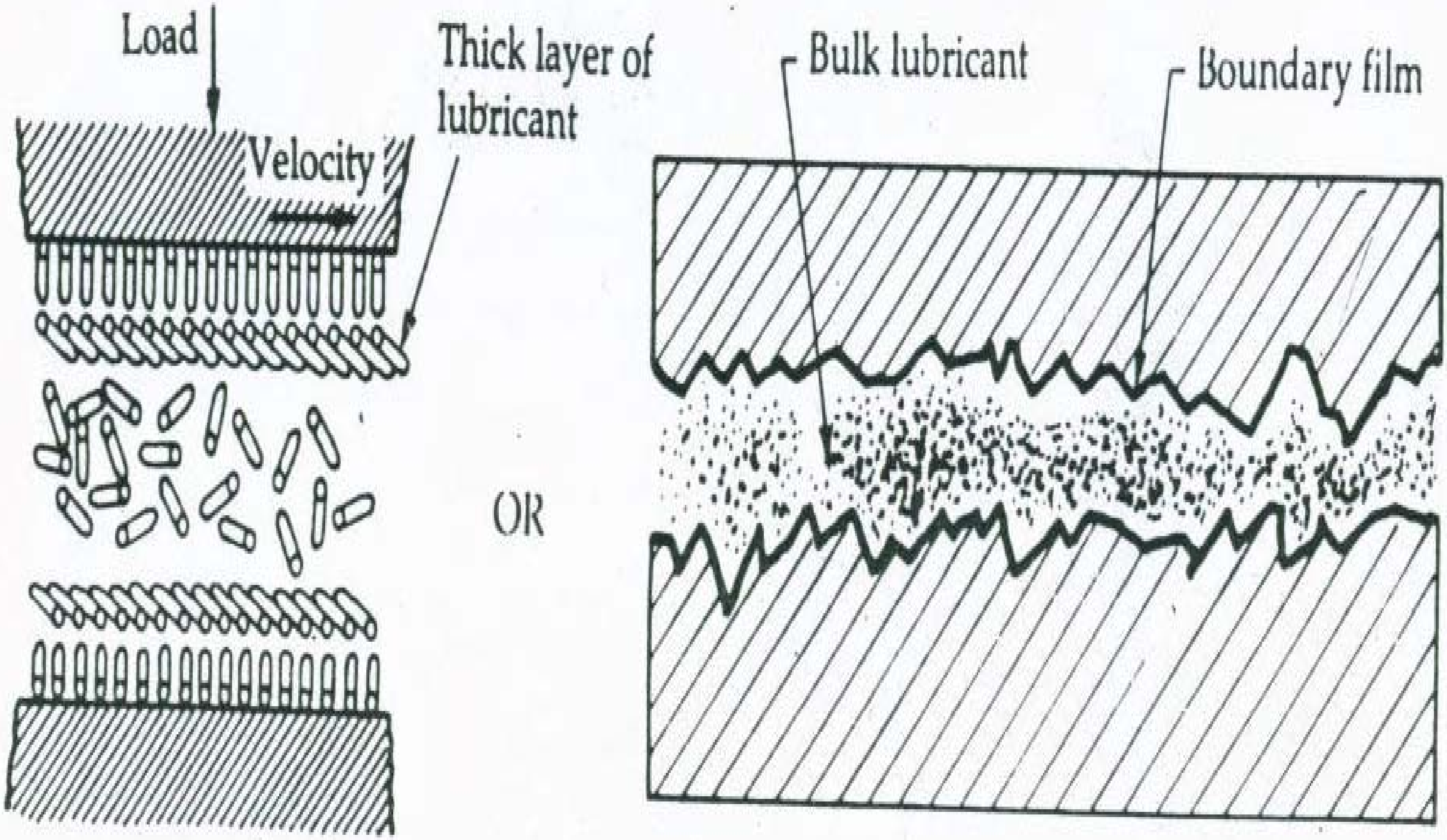


Fig3.aFluid film Lubrication – Surfaces separated by Bulk Lubricant film

Mechanism of Lubrication

Hydrodynamic Lubrication or Fluid Film Lubrication :-

This bulk lubricant film **prevents direct surface-to-surface contact** so that

the small peaks & valleys do not interlock.

This **consequently reduces friction** & prevents wear.

shown in Fig. 3.

Mechanism of Lubrication

Hydrodynamic Lubrication or Fluid Film Lubrication :-

- **The coefficient of friction =**

$$\frac{\text{force required to cause motion (F)}}{\text{Applied load (W)}}$$

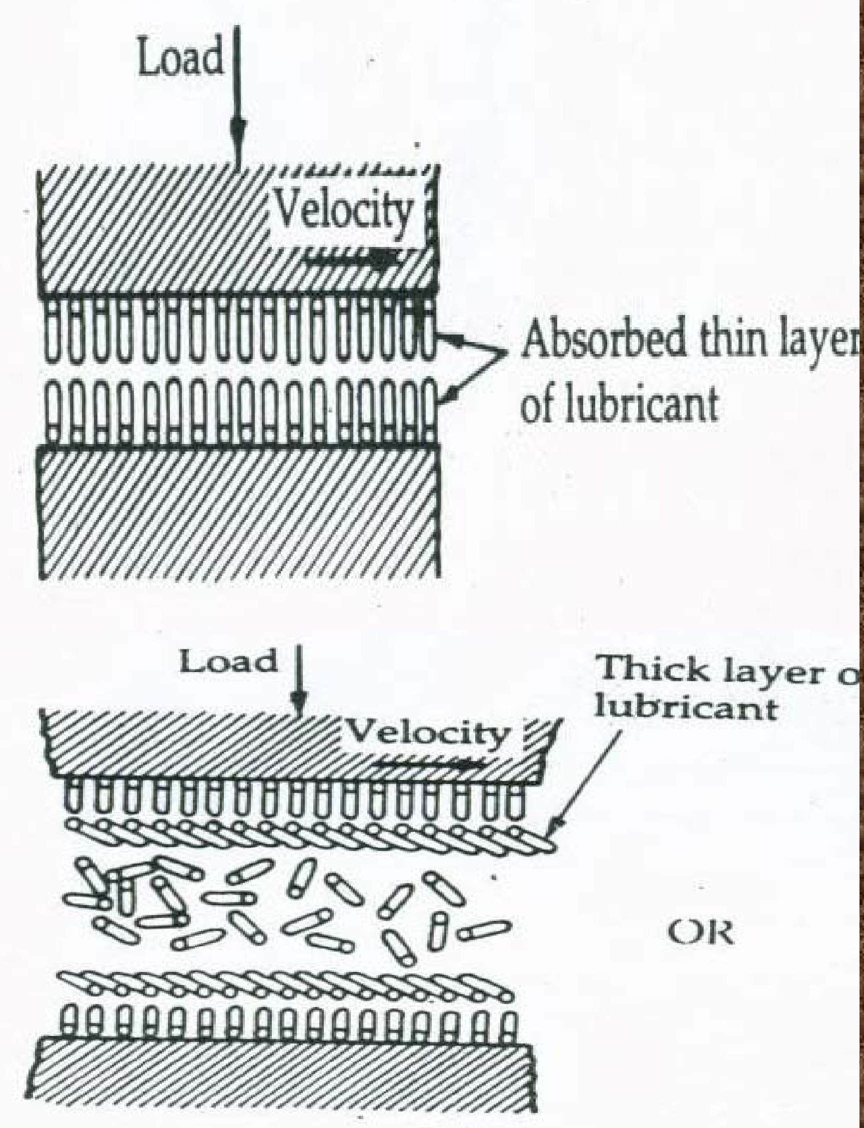
is as low as **0.001 to 0.03 for fluid film** lubricated system in comparison to

0.5 to 1.5 for **unlubricated** surfaces.

Hydrodynamic Lubrication or Fluid Film Lubrication :-

- Fig. 3(a) shows a journal resting on the bottom of the bearing before motion.

- Fig. 3 (b) shows the oil film which separates the surfaces when the journal rotates.



Mechanism of Lubrication

Hydrodynamic Lubrication or Fluid Film Lubrication :-

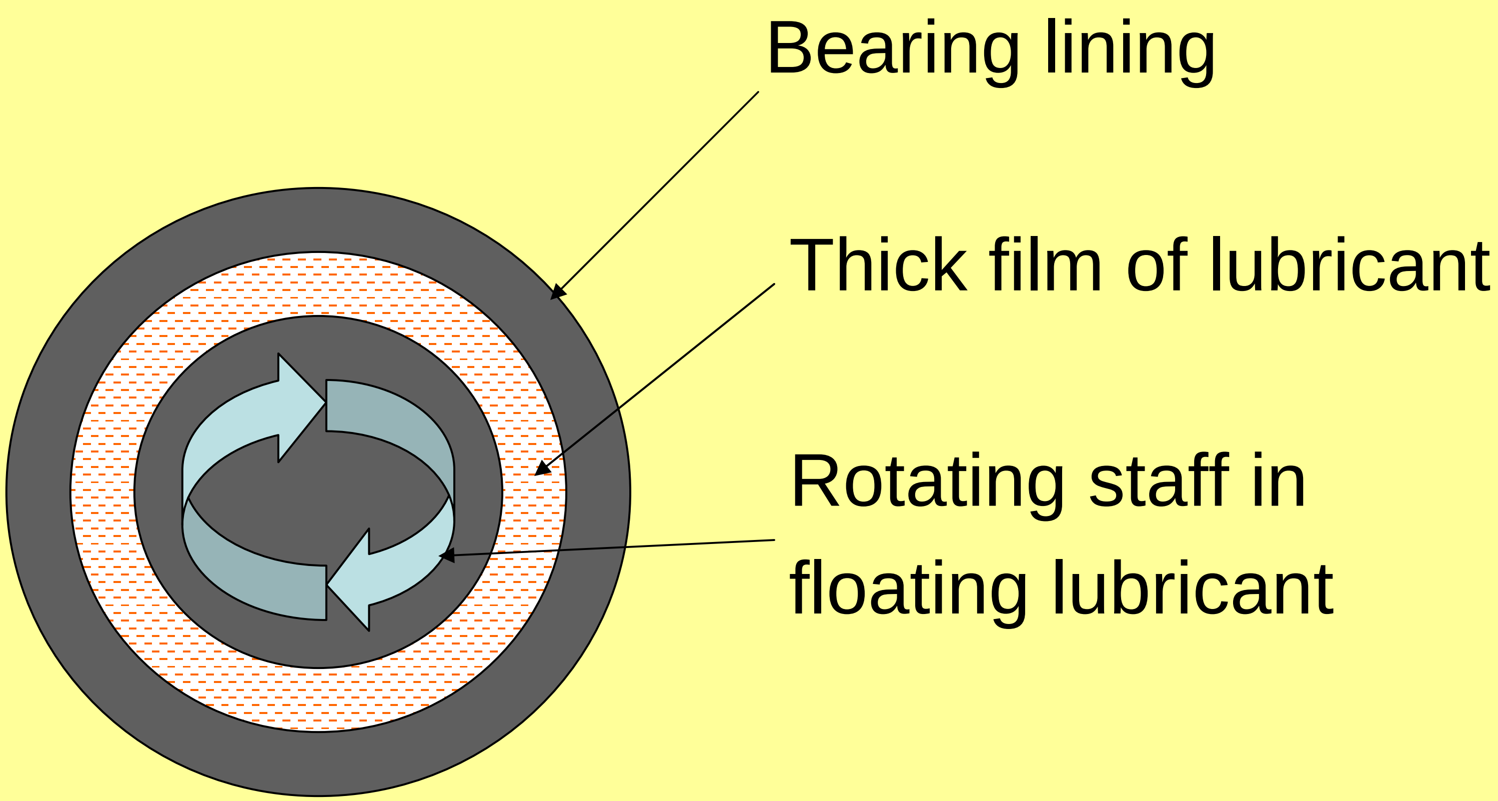
- Light machines like
  - **sewing machines,**
  - **watches clocks, delicate and**
  - **scientific instruments** are

provided with

- **hydrocarbon oils** blended with **selected long chain polymers**

to maintain viscosity of the oil.

Fig.4 hydrodynamic lubricant



Mechanism of Lubrication

2. Boundary Lubrication or Thin Film Lubrication

This is done

- When the **lubricant cannot** generate a **film of sufficient thickness**
- to separate the surfaces **under heavy loads,**

e.g.

i) a shaft starts moving from rest

ii) the **speed is very low**

iii) the **load is very high**

iv) the **viscosity of the lubricant is very low**.

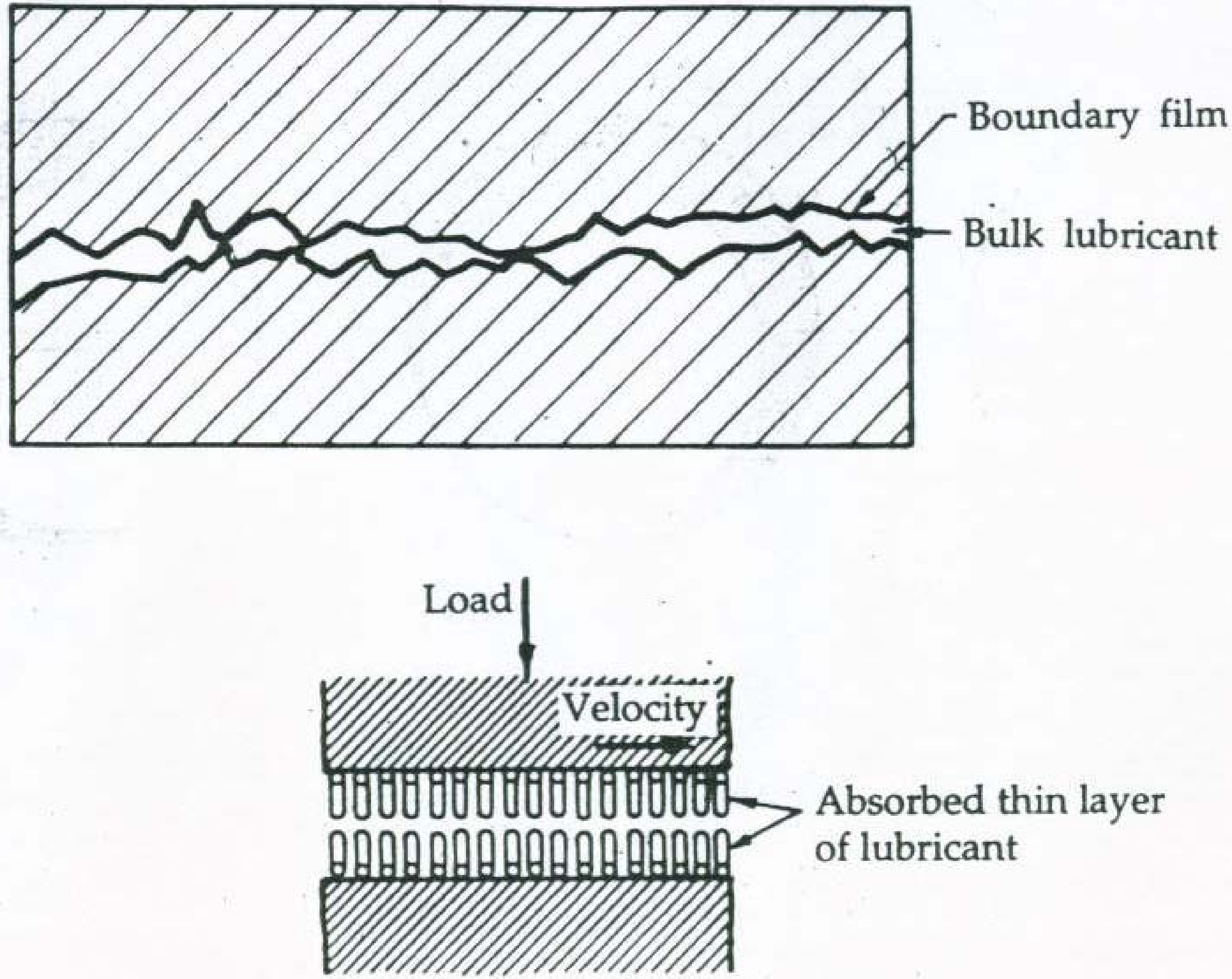
Mechanism of Lubrication

2. Boundary Lubrication or Thin Film Lubrication

A thin layer is **adsorbed by physical or chemical forces on both the metal surfaces**.

- The coefficient of viscosity is between
- **0.05 to 0.15.**

- **Vegetable and animal oils and their soaps** form thin layers of **metallic soaps** which act as lubricant.



3.b
Fig. Bounday lubrication – performance essentially dependent on boundary film.

Mechanism of Lubrication

2. Boundary Lubrication or Thin Film Lubrication

- The oiliness of the mineral oils can be improved by **adding Solid lubricants, greases and fatty oils and fatty acids.**
- A thin layer of lubricant is **adsorbed** on the metallic surfaces which **avoids direct metal – to – metal contact**.
- The load is carried by the **layer of the adsorbed lubricant** on both the metal surfaces (Fig. 4.)

Mechanism of Lubrication

2. Boundary Lubrication or Thin Film Lubrication

The lubricant molecules should possess:-

1. **Long hydrocarbon chains.**
2. **Lateral attraction** between the chains.
3. **Polar groups** to promote wetting or spreading over the surfaces.
4. **Active groups or atoms** to form chemical linkages.

Mechanism of Lubrication

2. Boundary Lubrication or Thin Film Lubrication

The lubricant molecules should possess:-

5. **High viscosity index.**
6. **Resistance** to heat & oxidation.
7. Good **oiliness** and
8. **Low pour point.**

Mechanism of Lubrication

2. Boundary Lubrication or Thin Film Lubrication

Lubricants used for boundary lubrication:

1. Graphite and MoS_2 either as **solid or stable emulsion, in oil.**

These **reduce friction by forming films** and these can bear **compression as well as high temperature.**

2. Mineral oils.

Mechanism of Lubrication

2. Boundary Lubrication or Thin Film Lubrication

Lubricants used for boundary lubrication:

1. Graphite and MoS_2

2. Mineral oils. These are **thermally stable** & have **low adhesion property**. Oiliness is improved by adding small amount of **fatty acids or fatty oils**.

Mechanism of Lubrication

2. Boundary Lubrication or Thin Film Lubrication

3. Vegetable and animal oils and their soaps :

These possess greater oiliness

These are either **physically adsorbed** to metal surfaces or

- **react chemically** at the metal surfaces,
- forming a **thin film of metallic soap**,

.

Mechanism of Lubrication

Extreme Pressure Lubrications

It is done by adding **extreme pressure additives** in minerals oils. Applied where

- **high temperature rises** due to the very **high speed** of moving / sliding surfaces under **high pressure.**

Mechanism of Lubrication

Extreme Pressure Lubrications

In such applications,

- **liquid lubricants fail to stick and**
- **may decompose and vaporize.**

1. **Chlorinated esters,**
2. **Sulphurized oils and**
3. **Tricresyl phosphate**

are examples of such **additives.**

Mechanism of Lubrication

Extreme Pressure Lubrications

- These additives react with metallic surfaces, at high temperatures, to form

- **metallic chlorides, sulphide or phosphides,** in the form of durable films.

Mechanism of Lubrication

Extreme Pressure Lubrications

- These films can withstand very
- **high loads and high temperatures**

  because of high melting points.

- These have an **additional advantage** that

  if the low shear strength films formed on the

  moving parts are broken,
- they are **immediately replenished.**

Mechanism of Lubrication

Extreme Pressure Lubrications

- **Application of lubrication extreme pressure additives**

1. **Wire drawing of titanium**

(requires **chlorine** containing additive which reacts with the **stable oxide film** on the metal surface).

2. **As cutting fluids in machining of tough metals.**

[cutting fluids : Any liquid or gas used to cool and to lubricate the tools].

Mechanism of Lubrication

Extreme Pressure Lubrications

- A typical lubricant consists of

  hydrocarbon oil, a small amount of

  fatty acid as a boundary lubricant and
- an **organic chloride or sulfide additive.**

- Used for **hypoid gears used in rear axle drive of cars** which has both

  longitudinal sliding motion &

  normal rolling movements.