Lubricants

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Chapter Outline:

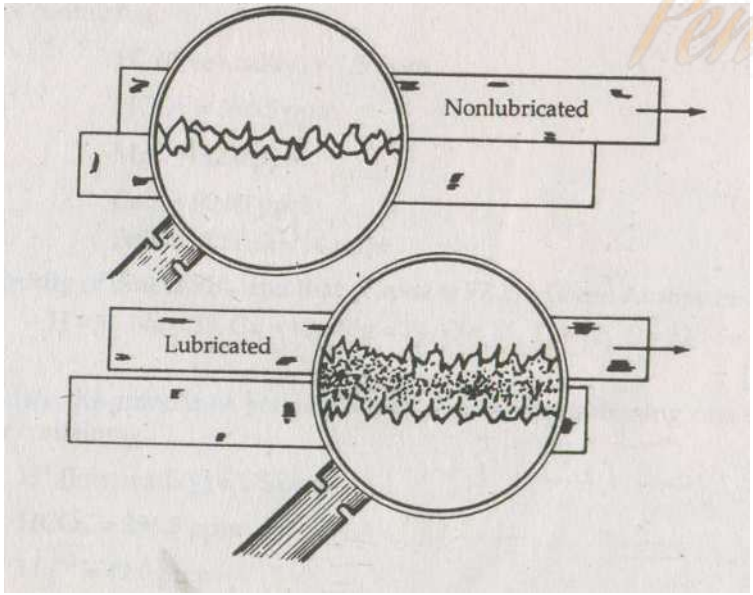
- Definition of Lubricant
- Functions of Lubricants
- Mechanisms of Lubrication
- Classification of Lubricants
- Properties and testing of Lubricating oil
- Greases and Graphite

Definition:

A lubricant may be defined as a substance which reduces the friction when introduced between two moving/sliding surfaces and the phenomenon is known as lubrication.

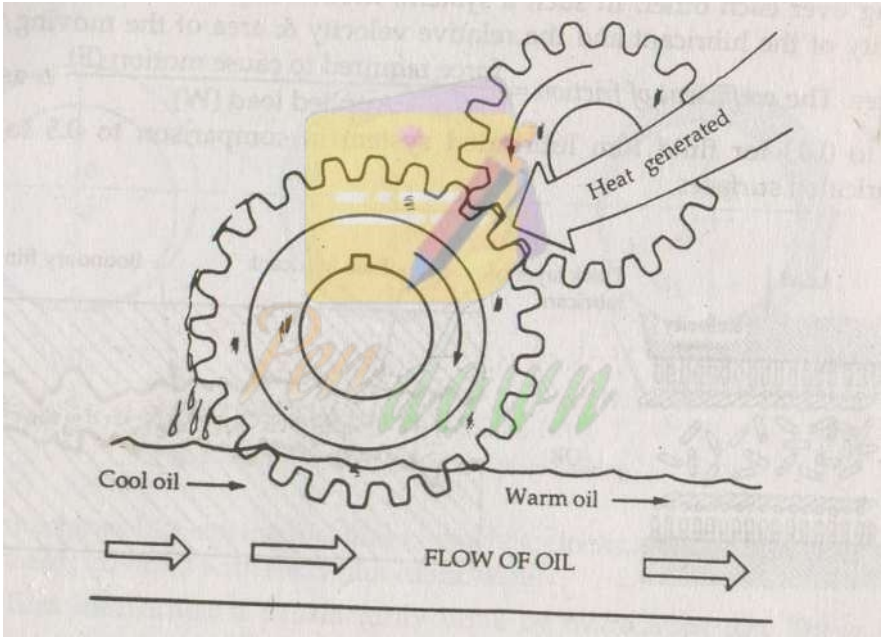
Functions of lubricants:

1) **To reduce friction between two moving/sliding surfaces.**



2) Reduces wear, tear and surface deformation by avoiding direct contact between the moving /sliding surfaces.

3) Acts as a coolant to carry away heat (applicable for liquid lubricant or lubricating oil only).



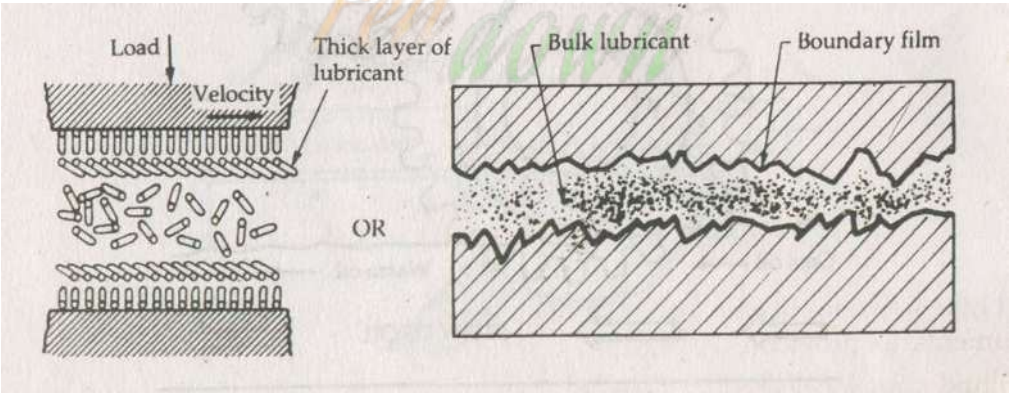
4) Reduces maintenance and running cost of the machine minimizing rust and corrosion (lubricant formulations containing rust inhibitors provide a protective residual film).

Mechanisms of lubrication:

There are three mechanisms of lubrication as described below (A, B and C).

A) Hydrodynamic lubrication or Fluid-film lubrication or Thick-film lubrication:

- **Moving/sliding surfaces are separated from each other by a bulk lubricant film (at least 1000 Å thick).**



- **Light machines like sewing machines, watches, clocks, delicate and scientific instruments use this mechanism of lubrication.**

Lubricant used for Hydrodynamic /Fluid-film lubrication contains:

hydrocarbon oil blended with two additives which are 'long chain polymers' and 'antioxidants'.

(long chain polymers and antioxidants are used as additives).

[Additives are substances that are mixed to make some properties better for the lubricants.]

Reason for using long chain polymers as additive:

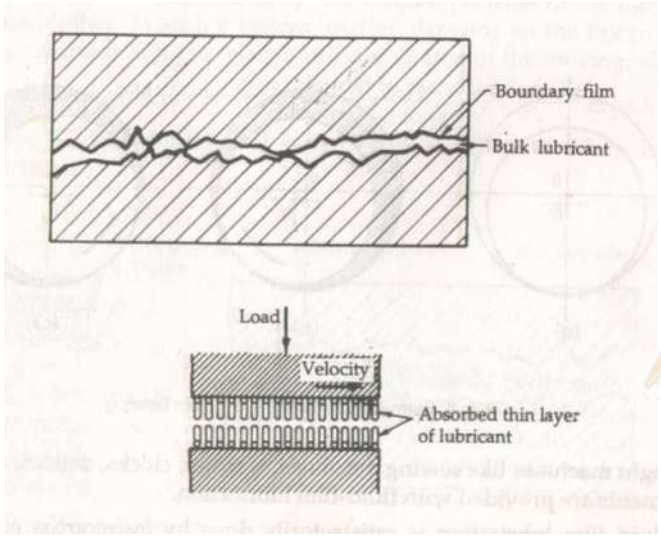
Viscosity of hydrocarbon oil decreases with increase in temperature (increase in temperature may happen due to friction of the surfaces or due to season change). Selected long chain polymers help to maintain viscosity of oil almost constant in all seasons of year and at normal running temperatures of the surfaces.

Reason for using antioxidants as additive:

Hydrocarbon oil is obtained from fractional distillation of petroleum and contains small quantity of unsaturated hydrocarbons which get oxidised under operating conditions to form gums (gums hamper proper lubrication). Antioxidants (like 4-aminophenol) are blended with hydrocarbon oil to minimize the oxidation of unsaturated hydrocarbons.

B) Boundary lubrication or Thin-film lubrication:

❖**A thin layer of lubricant is adsorbed (physical or chemical) on the metallic surfaces which avoid direct metal-to-metal contact. The distance between moving/sliding surface is very small.**



Lubricants used for Boundary lubrication are:

(i) Graphite or MoS_2.

(ii) Mineral oils with small amount of fatty acids or fatty oils.

(iii) Vegetable and animal oils and their soaps.

C) Extreme-pressure lubrication:

It is done by incorporating extreme pressure additives in mineral oil where high temperature is attained due to very high speed of moving/sliding surfaces under pressure.

Lubricant used for Extreme-pressure lubrication contains:

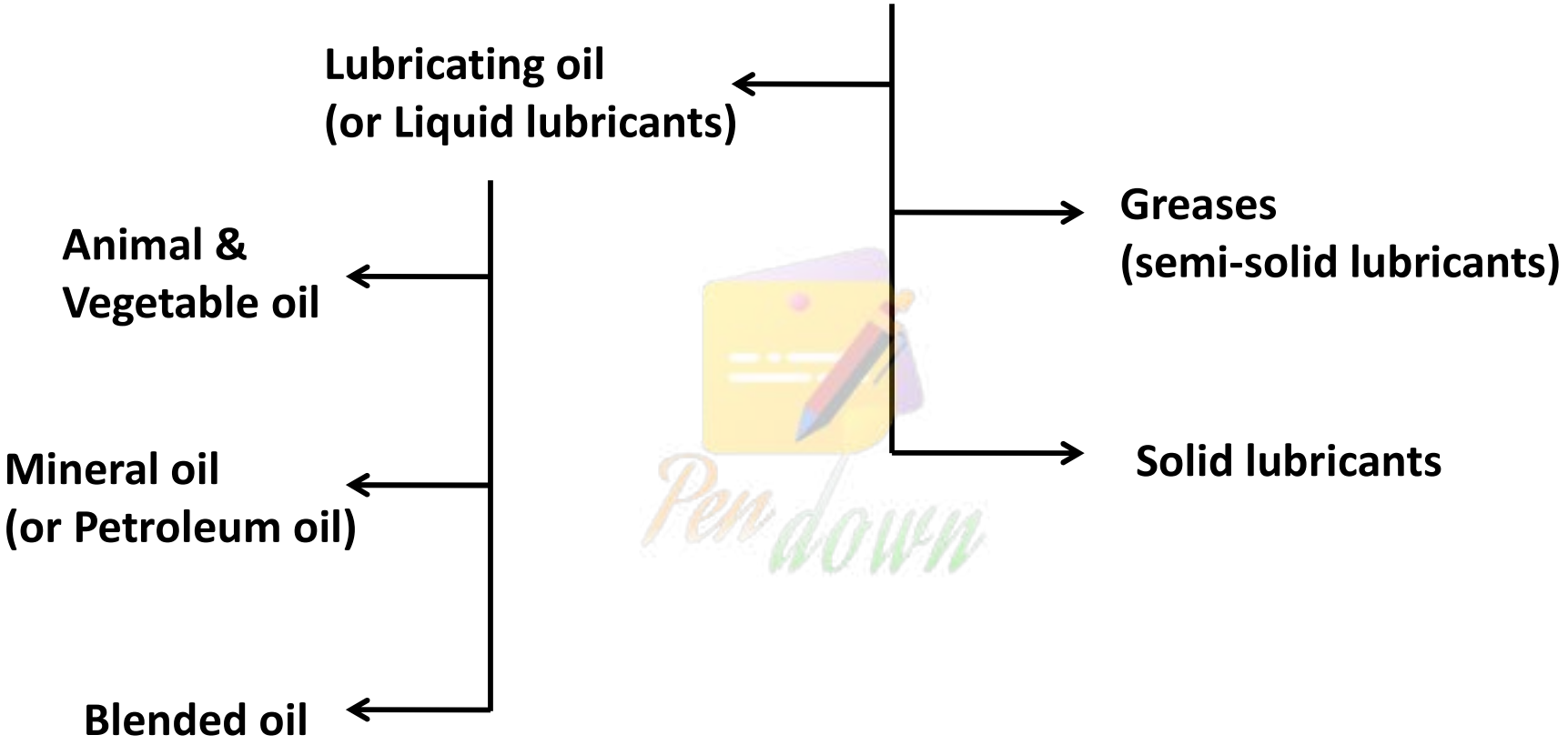
Extreme pressure additives in mineral oil.

Extreme pressure additives are: 1) Chlorinated esters
2) Sulphurized oil
3) Tricresyl phosphate

Mechanism:

- **Extreme pressure additives react with metal surfaces at high temperature to produce metallic chlorides, metallic sulphides or metallic phosphides, in the form of durable films.**
- **These films can withstand very high loads and high temperature because of their high melting points.**

Classification of Lubricants
(on the basis of physical state of lubricants)



Properties and Testing of Lubricating oils

There are several properties based on which most suitable oil for a particular requirement is chosen. Here, five properties will be discussed: (i) viscosity, (ii) saponification number, (iii) flash point, (iv) aniline point, (v) steam emulsion number.

(i) Viscosity:

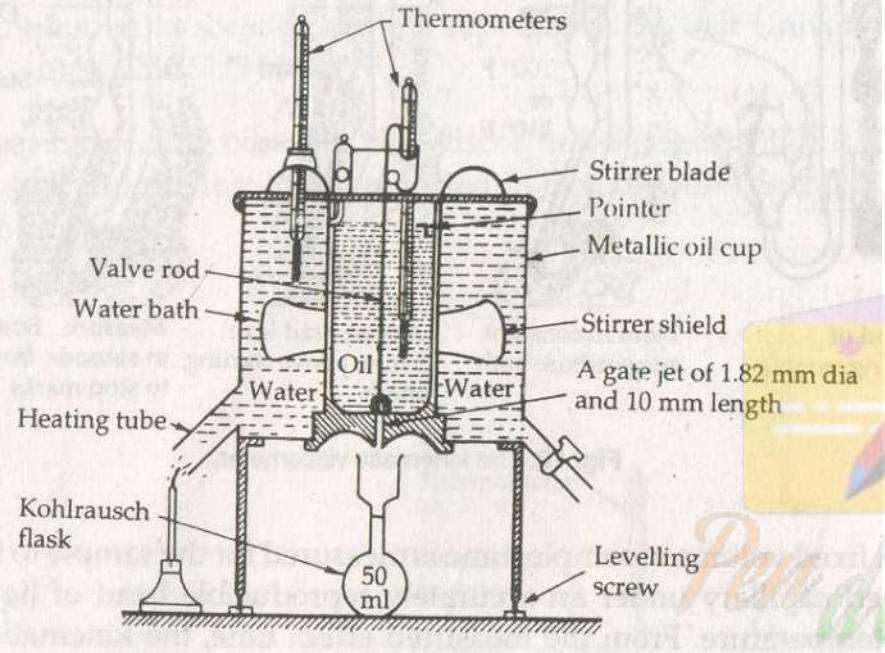
- **Viscosity property of a fluid is that one which determines its resistance to flow.**
- **Lower the viscosity, greater the flowability.**
- **It is due to the forces of cohesion between the molecules of lubricating oil.**

- **Viscosity of lubricating oil inversely proportional to temperature**

- **Importance:**

Viscosity helps in the selection of the good lubricating oil.

Measurement of viscosity



Redwood Viscometers

Results reported in seconds, stating temp. and type of viscometer

	Redwood Viscometer No. 1	Redwood Viscometer No. 2
Dimension of orifice →	L = 10 mm Dia. = 1.82 mm	L = 50 mm Dia = 3.80 mm
Receiving flask →	Smaller mouth	Larger mouth
Used for →	Low viscous oil	High viscous oil

Viscosity Index (VI)

Rate at which the viscosity of an oil changes with temperature is measured by an empirical number, known as Viscosity Index (VI).

- **Relatively small change in viscosity with temp. -------- High VI (Suitable for Industry)**
- **Relatively large change in viscosity with temp. -------- Low VI**

Pennsylvanian Oil (contain mainly paraffin) --- Arbitrarily assigned a VI value of '100'

Gulf Oil (contain mainly naphthenes) --- Arbitrarily assigned a VI value of '0' (zero)

$$\text{Viscosity Index (VI) of test oil} = \frac{L - U}{L - H} \times 100$$

where,

L = Viscosity at 100°F of Low-VI standard oil having VI of 0 (Gulf oil)

H = Viscosity at 100°F of High-VI standard oil having VI of 100 (Pennsylvanian oil)

U = Viscosity at 100°F of oil under test

Sample numerical:

An oil sample under test has a viscosity of 64 seconds at 210°F and 564 seconds at 100°F. Gulf oil shows a viscosity of 64 seconds at 210°F and 774 seconds at 100°F. Pennsylvanian oil has a viscosity of 64 seconds at 210°F and 414 seconds at 100°F. Calculate the viscosity index of the oil sample under test.

Ans. Here, L = 774 s, H = 414 s, U = 564 s.

$$\text{VI of the oil under test} = \frac{L - U}{L - H} \times 100$$

$$= \frac{774 - 564}{774 - 414} \times 100$$

$$= 58.33$$

(ii) Saponification Number:

"The number of mg of KOH required to saponify the fatty material present in 1 g of the oil".

❖**It is determined by refluxing a known quantity (weight) of test oil with a known excess volume of alcoholic aqueous KOH solution and titrating the unused alkali against a standard acid. A blank titration (where same weight of solvent is used instead of oil) is also performed using exactly same procedure.**

$$\text{Saponification number} = \frac{56.1\,(B - S)\,N}{W}$$

where, B = titre value of standard HCl for blank titration (in mL),
S = titre value of standard HCl for sample titration (in mL),
N = strength of HCl in normality,
W = weight of oil taken (in g).

Importance:

(1) **Most animal and vegetable oils have known characteristic saponification number. Any deviation from this value indicates the probability and extent of adulteration.**

(2) **To ascertain whether the oil under study is animal and vegetable oil or mineral oil or compounded oil.**

Sample numerical:

1.6 g of oil was taken in a conical flask and 25 ml of alcoholic aqueous KOH was added to it and refluxed. The resultant solution consumed 2.8 ml of 0.55 N HCl solution. 20.8 ml of same HCl solution was consumed for blank titration. Calculate saponification number of the oil.

Ans. B = 20.8 ml, S = 2.8 ml, N = 0.55 N, W = 1.6 g

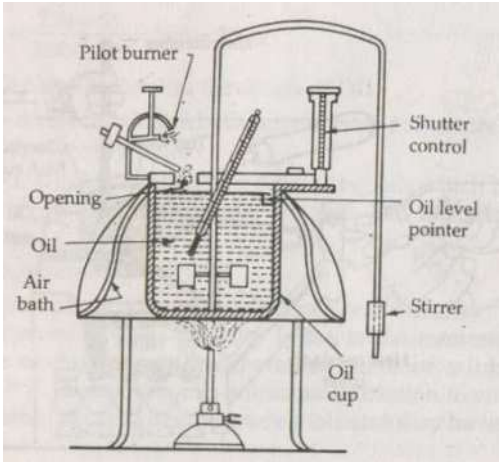
$$\text{Saponification number} = \frac{56.1\,(B - S)\,N}{W}$$

$$= \frac{56.1\,(20.8 - 2.8)\,0.55}{1.6}$$

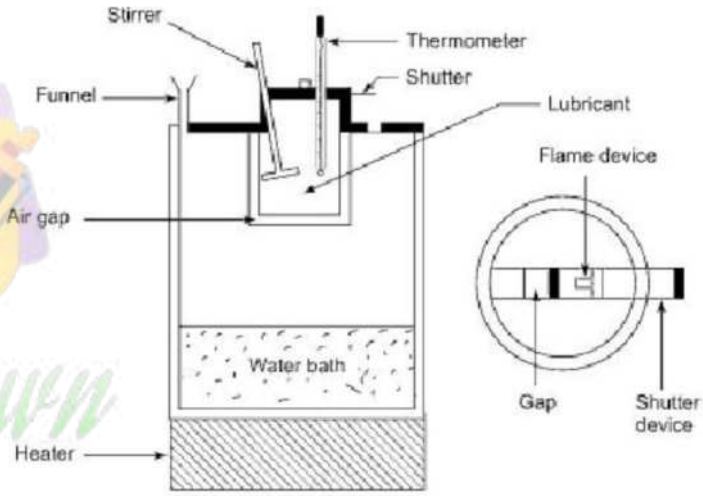
$$= 347.12$$

(iii) Flash Point:

Flash Point of an oil is the lowest temperature at which oil gives off vapors that will ignite for a moment when a small flame is brought near it.
Two apparatus are used for determination of flash point: Abel's apparatus and Pensky-Martin's apparatus.



Pensky-Martin's Flash point apparatus



Abel's Flash point apparatus

❖**Importance:**

1) **Used to indicate the chance of fire hazards in the industry and to take precautionary measures against fire hazards.**
2) **Good lubricant should have flash point at least above the temperature at which it is to be used.**

(iv) Aniline Point:

"The minimum equilibrium solution temperature for equal volume of aniline and oil sample".

Lower aniline point of a lubricating oil indicates higher % of aromatic hydrocarbon in it.

Aromatic hydrocarbon has the tendency to dissolve natural rubber and certain types of synthetic rubbers. So, higher % of aromatic hydrocarbon or lower aniline point lubricating oil has more chances of degradation when it comes in contact with rubber sealing, rubber packing etc. and lubrication will not work properly.

Hence, low % of aromatic hydrocarbon in the lubricant or high aniline point lubricating oil is desirable.

❖**Importance:**

To prevent/minimize the degradation of lubricating oil by rubber sealing, packing.

(v) Steam Emulsion Number (SEN):

The time in which oil and water emulsion separate out in distinct layers is called steam emulsion number.

❖**The quicker the oil separates out from the emulsion, the lower the steam emulsion number and better the lubricating oil for most purposes.**

❖**Importance:**

To avoid corrosion of surfaces and to ensure proper lubrication.

Greases: Obtained by combining lubricating oil with thickening agent

Lubricating oil (principal component): can be either petroleum oil or synthetic hydrocarbon

Thickeners or thickening agents (minor component): two types

(a) Soap based thickeners: soaps of Li^{+}, Na^{+}, Ca^{2+}, Ba^{2+}, Al^{3+} etc.

(b) Non-soap based thickeners: carbon black, silica gel, polyureas, graphite etc.

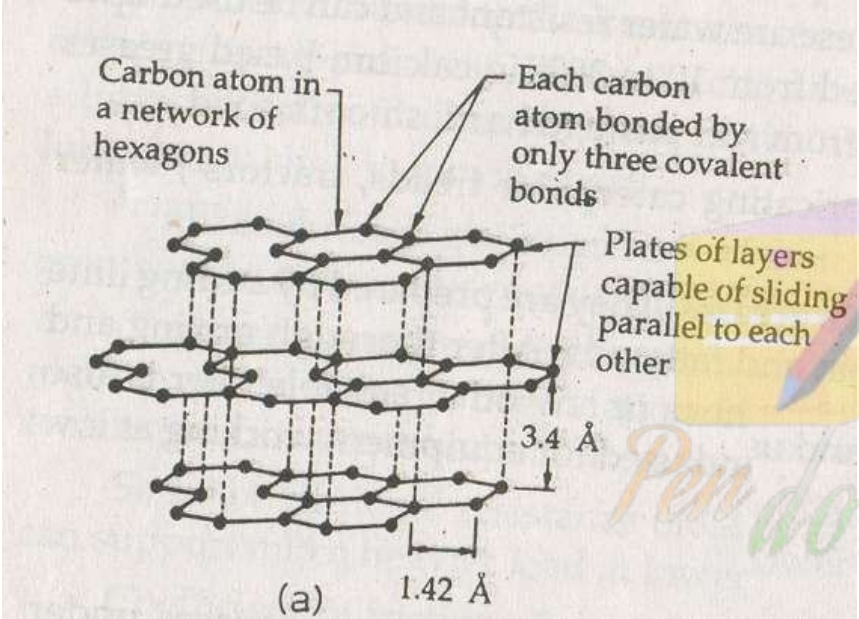
❖Non-soap based thickeners improves the heat resistant property of the greases.

General preparation of greases:

It is prepared by two step method. In first step, saponification of fat with a suitable alkali is performed. In the second step, hot lubricating oil is added to the soap formed in step 1 with constant mixing. This produces the semi-solid lubricant greases.

Solid lubricants:

Graphite



- **Weak Van der Waals' force among the carbon atoms**
- **Used as powder**

or

as suspension in oil or water

Applications:

(i) Used to prepare Graphite greases (graphite mixed with greases) which is useful for higher temperature applications.

(ii) As lubricant in air-compressors, foodstuff industry, railway track-joints etc.