LUBRICANTS AND LUBRICATION

1. Introduction

- A **lubricant** is a substance that reduces **friction, wear, and heat** between moving surfaces.
- **Lubrication** is the process of applying a lubricant to minimize direct contact between surfaces.
- Used in **machinery, engines, and industrial applications** to improve efficiency and lifespan.

---

2. Mechanism of Lubrication

There are three primary lubrication mechanisms:

(i) Fluid Film Lubrication (Hydrodynamic Lubrication)

- A **thick film** of lubricant separates the moving surfaces completely.
- Reduces **metal-to-metal** contact and wear.
- Used in **engine crankshafts, turbines, and journal bearings**.

(ii) Boundary Lubrication

- A **thin layer** of lubricant remains adsorbed on the surface.
- Occurs under **high pressure and low speed** conditions.
- Used in **gears, brakes, and machine tools**.

(iii) Extreme Pressure (EP) Lubrication

- Special additives (**sulfur, phosphorus, chlorine**) chemically react with metal to form **protective coatings**.
- Used in **heavy-load applications like cutting tools, gears, and high-pressure engines**.

---

3. Classification of Lubricants

(i) Liquid Lubricants (Oils)

- Examples: **Mineral oils, synthetic oils, vegetable oils.**
- Properties: **Low viscosity, good thermal stability, easy flow.**
- Used in **automobiles, turbines, compressors.**

(ii) Semi-Solid Lubricants (Greases)

-

- Made of **oil + thickening agent (soap, clay, silica).**
  Used in **wheel bearings, chains, and heavy machinery.**
- Properties: **Retains lubrication even under high loads and extreme temperatures.**

(iii) Solid Lubricants

- Examples: **Graphite, molybdenum disulfide (MoS_2), PTFE (Teflon).**
- Used in **space applications, high-temperature environments, and extreme conditions.**

(iv) Synthetic Lubricants

- **Chemically engineered oils** with superior properties.
- Examples: **Silicones, fluorocarbons.**
- Used in **aerospace, extreme temperature applications.**

Outcomes:

- Understanding the function and importance of lubricants in machinery.
- Learning different lubrication mechanisms and their applications.
- Knowing the classification and selection of lubricants based on industrial needs.

Viscosity & Viscosity Index

1□Viscosity

- **Definition:** Viscosity is the **resistance of a fluid to flow** due to internal friction between its molecules.
- **Units:**

✓ SI Unit: **Pascal-second (Pa·s) or N·s/m²**

✓ CGS Unit: **Poise (P), Centipoise (cP) [1 cP = 0.001 Pa·s]**

- **Types:**

✓ **Dynamic Viscosity (η):** Shear stress per unit velocity gradient.

✓ **Kinematic Viscosity (ν):** Ratio of dynamic viscosity to density:

- ν=ηρν = \frac{η}{ρ}ν=ρη
- (Units: **m^2/s or Stokes (St), 1 St = 10^{-4} m^2/s**)

2□Significance of Viscosity

- ✓ Determines **lubricating ability** of oils.

✓ Affects **fluid flow in pipelines and engines**.

✓ Important for **fuel efficiency & wear reduction**.

✓ Used in **pharmaceuticals, food industry, and polymers**.

3□Determination of Viscosity

- **(A) Redwood Viscometer (For Lubricating Oils & Fuels)**

✓ Oil is allowed to flow through a **standard orifice**, and the time taken for **50 mL** of oil to flow is measured.

✓ The **higher the time**, the **higher the viscosity**.

- **(B) Ostwald Viscometer (For Liquids & Solutions)**
- ✓ A fixed volume of liquid flows through a **capillary tube** under gravity.

  ✓ Viscosity is calculated using **Poiseuille's equation**:
- $$\eta_1 = \eta_2 \times \frac{\rho_1 t_1}{\rho_2 t_2}$$
- where **η** = viscosity, **ρ** = density, **t** = flow time.

4□Viscosity Index (VI)

- **Definition:** Viscosity Index (VI) is a **measure of how much a lubricant's viscosity changes with temperature**.

Higher VI = More stable viscosity with temperature (better lubricant). **Lower VI = Large viscosity changes with temperature** (poor lubricant).

- **Formula for VI Calculation:**
- $$VI = 100 \times \frac{L - U}{L - H}$$
- where:

✓ **L** = Viscosity of a reference oil with **0 VI** at 100°C

✓ **H** = Viscosity of a reference oil with **100 VI** at 100°C

✓ **U** = Viscosity of the test oil at 100°C

- **Significance of VI:**

✓ High VI oils perform well in **extreme temperatures** (engines, aircraft, industrial machines).

Flash Point & Fire Point

1□Flash Point

- **Definition:** The **minimum temperature** at which a liquid gives off sufficient vapor to form an ignitable mixture in air but does not sustain burning.
- **Significance:**

✓ Determines **flammability & safety** of fuels and lubricants.

✓ Used in **petroleum, paints, and chemicals**.

✓ Helps classify **hazardous substances**.

- **Determination Methods**
- ✓ **Pensky-Martens Closed Cup Method (For heavy oils, diesel, lubricants)**

  ✓ **Cleveland Open Cup Method (For fuels like gasoline, kerosene)**

-

• 2□Fire Point

- **Definition:** The **minimum temperature** at which a substance **continues to burn for at least 5 seconds** after ignition.
- **Fire Point > Flash Point** (since more heat is required for continuous combustion).
  Significance:
  ✓ Ensures **safety in handling & storage** of fuels.
  ✓ Prevents **fire hazards** in industries.

- **Outcomes**
- ✓ Understand viscosity, viscosity index, flash & fire points. ✓ Learn how to determine viscosity using viscometers.
  ✓ Analyze the importance of VI for lubricant performance.
  ✓ Identify safe handling temperatures for fuels using flash & fire points.

Key Properties of Lubricants & Oils

---

1. Flash Point & Fire Point

Flash Point:

- **Definition:** The lowest temperature at which an oil gives off vapors that can ignite momentarily when exposed to a flame.
- **Importance:** Determines **safety in handling and storage**.
- **Test Methods:** Cleveland Open Cup (COC), Pensky-Martens Closed Cup (PMCC).

Fire Point:

- **Definition:** The lowest temperature at which oil vapors **continue to burn** for at least 5 seconds after ignition.
- **Importance:** Indicates the **fire hazard level** of the oil.
- **Fire Point is always higher than the Flash Point.**

---

2. Cloud Point & Pour Point

Cloud Point:

- **Definition:** The temperature at which wax **crystals first appear** in oil, making it look cloudy.
- **Importance:** Indicates the **low-temperature performance** of oil.

-

Pour Point:

- **Definition:** The lowest temperature at which oil **ceases to flow** under standard conditions.
- **Importance:** Essential for **cold-weather applications** (lubricants, diesel fuels).

Pour Point is always lower than Cloud Point.

---

3. Aniline Point

- **Definition:** The **minimum temperature** at which equal volumes of oil and **aniline** (a chemical solvent) become **completely miscible**.
- **Importance:**
  - Determines the **aromatic content** of the oil. ○ Higher aniline point = **more paraffinic (less aromatic) oil** (better for lubrication). ○ Lower aniline point = **more aromatic oil** (better solvency but lower lubricity). **Used to determine the compatibility of lubricants with rubber seals and gaskets.**

---

4. Acid Number (Total Acid Number - TAN)

- **Definition:** The amount of **KOH (mg) required to neutralize the acids** in 1g of oil.
- **Importance:**
  - Indicates **oil degradation** (oxidation leads to acid formation).
  - Higher acid number = **more corrosive oil**.
  - Used in monitoring **lubricants, fuels, and transformer oils**.

Lower acid number is desirable for lubricating oils.

---

5. Saponification Number

- **Definition:** The **amount of KOH (mg) needed to completely saponify (convert to soap)** 1g of oil or fat.
- **Formula:** Saponification Number=mg of KOH consumed1g of oil\text{Saponification Number} = \frac{\text{mg of KOH consumed}}{\text{1g of oil}}Saponification Number=1g of oilmg of KOH consumed
- **Importance:**
  - Used for distinguishing **mineral oils (low saponification) from vegetable/animal oils (high saponification).** ○ Higher value → **More fatty acids present → More prone to hydrolysis and degradation.**

Essential in soap, detergent, and biodiesel industries.

Outcomes:

- **Flash & Fire Points:** Help determine **oil safety and fire risk**.

- **Cloud & Pour Points:** Critical for **low-temperature applications**.
- **Aniline Point:** Determines **oil composition & compatibility** with rubber.
- **Acid Number:** Indicates **oil degradation & corrosion tendency**.
- **Saponification Number:** Helps distinguish between **mineral and non-mineral oils**.

Number, Steam Emulsification Number, and Related Numerical Problems

---

1. Emulsification Number

The **Emulsification Number** (EN) represents the ability of an oil to form an emulsion with water. It indicates the presence of **surface-active agents** in the oil.

Formula:

EN=Time taken for complete separation of oil and water (seconds)Fixed Volume of Sample (mL)EN = \frac{\text{Time taken for complete separation of oil and water (seconds)}}{\text{Fixed Volume of Sample (mL)}}EN=Fixed Volume of Sample (mL)Time taken for complete separation of oil and water (seconds)

- **Higher EN** → More stable emulsion (difficult to separate).
- **Lower EN** → Less stable emulsion (easier to separate).

---

2. Steam Emulsification Number (SEN)

The **Steam Emulsification Number (SEN)** measures the **stability of an emulsion formed between oil and water in the presence of steam**. It is used in **lubricant quality testing**.

Formula:

SEN=Volume of oilwater emulsion after steam treatment (mL)Total Volume of Oil Sample (mL)SEN = \frac{\text{Volume of oil-water emulsion after steam treatment (mL)}}{\text{Total Volume of Oil Sample (mL)}}SEN=Total Volume of Oil Sample (mL)Volume of oilwater emulsion after steam treatment (mL)

- **High SEN** → More emulsification → Poor lubricant performance. • **Low SEN** → Less emulsification → Better lubricant performance.

---

3. Numerical Problems

Problem 1: Calculating Emulsification Number

Q: A 20 mL oil sample takes **300 seconds** for complete separation. Find the **Emulsification Number**.

Solution:

EN=30020=15EN = \frac{300}{20} = 15EN=20300=15

Interpretation: The emulsification number is **15**, indicating moderate emulsification tendency.

Problem 2: Steam Emulsification Number Calculation

Q: An oil sample (50 mL) is tested with steam. After treatment, **10 mL of stable emulsion** remains. Calculate **Steam Emulsification Number (SEN)**. **Solution:**

SEN=1050=0.2SEN = \frac{10}{50} = 0.2SEN=5010=0.2

Interpretation: The SEN is **0.2**, suggesting **low emulsification**, meaning the lubricant is **good** for industrial applications.

---

4. Expected Outcomes

- Understanding of **emulsification and steam emulsification numbers**.
- Ability to **interpret lubricant stability** based on numerical results.
- Solving numerical problems related to **emulsification properties of oils**.

---

5. Summary Notes (Arranged Properly)

Concept	Formula	Interpretation
Emulsification Number (EN)	EN=Separation Time (s)Sample Volume (mL)EN = \frac{\text{Separation Time (s)}}{\text{Sample Volume (mL)}}EN=Sample Volume (mL)Separation Time (s)	Higher EN → More stable emulsion
Steam Emulsification Number (SEN)	SEN=Emulsified Volume (mL)Oil Volume (mL)SEN = \frac{\text{Emulsified Volume (mL)}}{\text{Oil Volume (mL)}}SEN=Oil Volume (mL)Emulsified Volume (mL)	Higher SEN → Poor lubricant quality