SMART MATERIALS AND LUBRICANTS

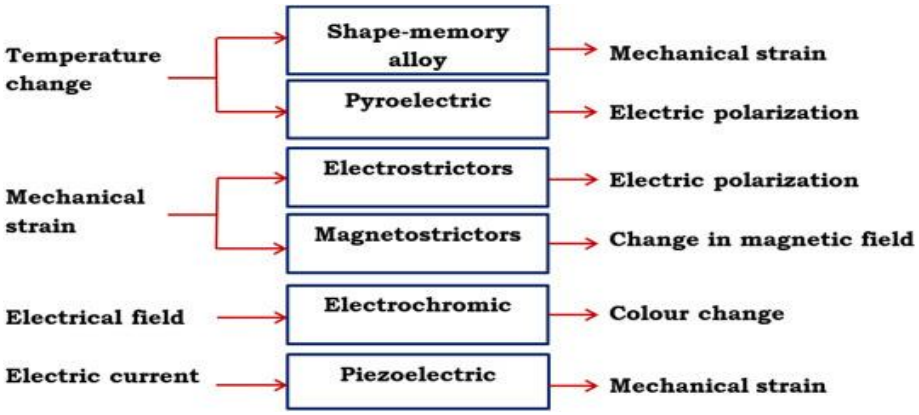
Smart materials: these materials are also called intelligent or responsive materials. Smart materials are those in which properties can be significantly changed in a controlled fashion by external stimuli, such as stress, moisture, electric or magnetic fields, light temperature, PH, chemical or biological components.

(Stimulus —stress, strain, light, electric field, temperature and pressure, etc.

Response —motion or change in optical properties, modulus, surface tension, piezoelectricity etc.)

- Five common fundamental characteristics were defined as distinguishing a smart material from the more traditional materials such as transiency, immediacy, self-actuation, directness and selectivity.
- Smart materials are either passive or active.
- The active smart materials have intrinsic ability to transducer energy, where as passive do not.
  Eg: Piezoelectric materials are active smart materials while fibre optic is passive.
- Generally sensor and actuator are fundamental functions of smart structures for sensing and controlling purposes.
- **Sensor:** Sensor is a device used for the conversion of physical events or characteristics into the electric signals. This is a hardware device that takes input from environment and gives to the system by converting it.
  Eg: a thermometer takes the temperature as physical characteristic and then converts it into electric signals for the system.
- **Actuator:** Actuator is a device that converts the electric signals into the physical events or characterstics. It takes the input from the system and gives output to the environment.
  Eg: Motors and heaters are some of the commonly used actuators.

Some smart materials:

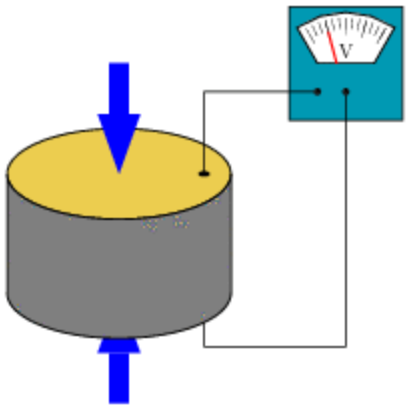


1) **Piezoelectric materials :** the materials that produce a voltage when stress is applied are called piezoelectric materials. Since this effect also applies in the reverse manner, a voltage across the sample will produce stress within the sample. Suitably designed structures made

from these materials can therefore be made that bend, expand or contract when a voltage is applied.

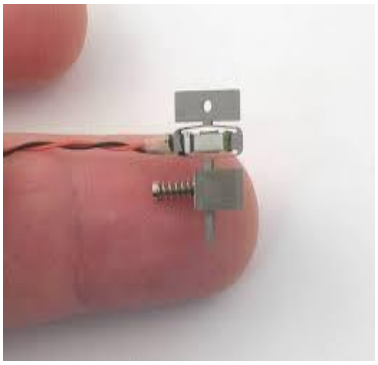
Example: Quartz, BaTiO3,GaPO4

The piezoelectric effect describes the relation between a mechanical stress and an electrical voltage in solids.



Applications of Piezo electric effect:

In lighters or portable sparkers with a piezofuzea sudden and strong pressure is used to produce a voltage. The spark then ignites the gas.



2) Shape memory alloys:

Shape memory alloys and shape memory polymers are thermoresponsive materials where deformation can be induced and recovered through temperature changes.

Example: Nickel Titanium alloy that “remembers” its original, cold- forged shape By heating it returns back to their deformed shape.

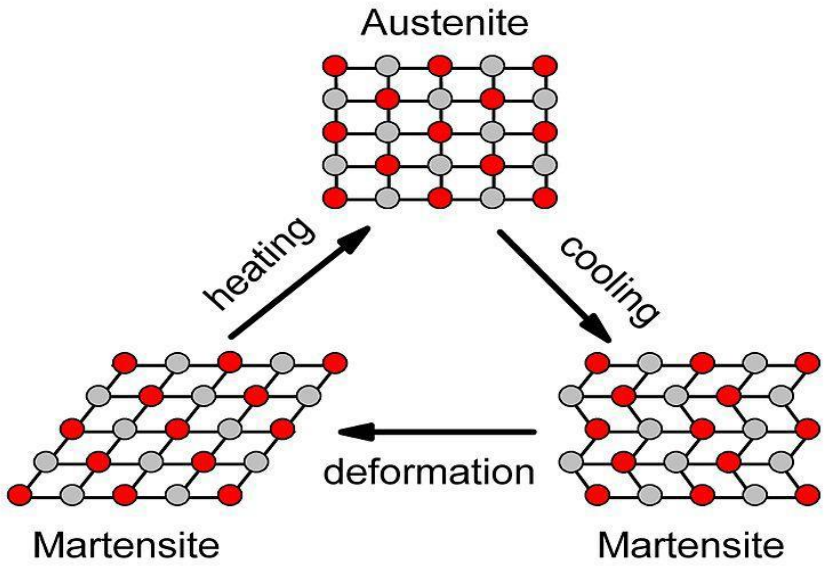
SMAs are materials which can revert back to original shape & size on cooling by undergoing phase transformations.

Examples: NiTiNOL (thermal),
NiMnGa, Fe-Pd, Terfenol-D (Magnetic)

Applications:

Dental Implants (healing of broken bones; misaligned teeth)

Shape Memory Alloys (SMAs) are a unique class of metal alloys that can recover apparent permanent strains when they are heated above a certain temperature.



3) Magnetostrictive materials:

Magneto striction is a property of ferromagnetic materials that causes them to change their shape or dimensions during the process of magnetization.

Ex: Fe, Co, Terfenol–D (UStransducers, sonar, soundbug)

Actuators and Sensors: Magnetostrictive transducers -Convert magnetic energy in to mechanical energy

4) Electro strictive materials: In the presence of electric field, these materials experience a strain (mechanicalchange) which is proportional to strength of electric field.

Eg: Lead Lanthanum Zirconate Titanate (PLZT), Lead Magnesium Niobate (PMN)

5) Thermoelectric materials: These materials when subjected to any temperature difference; they producechange in voltage and vice versa

6) Rheological materials: Materials which can change state instantly through the application of an electric ormagnetic charge/field.

Eg: Silicates, Food additives etc;

7) Chromic materials: These materials have very excellent property to change their color when subjected toexternal impetus (temperature, lights, electric field).

Eg: A variety of dyes, pigments, oxides, organic molecules, conjugated conducting polymers etc;

showchromic phenomenon.

Types: Photochromic, Thermochromic; Electrochromic, Magnetochromic, piezo chromic etc

8) **pH sensitive materials:** This kind of smart materials have properties to change their color when their will be the change in the acidity of the liquid. These kind of smart materials can be use to indicates the corrosionby mixing it with the paint.

TYPE OF SMART MATERIAL	INPUT	OUTPUT
Piezoelectric	Bending	Potential difference
Electrostrictive	Potential difference	Deformation
Magnetostrictive	Magnetic field	Deformation
Thermoelectric	Temperature	Potential difference
Shape memory alloys	Temperature	Deformation
Chromic materials	Radiation	Color change
Rheological materials	Electric or magnetic field	Physical state change
pH sensitive materials	pH	Color change

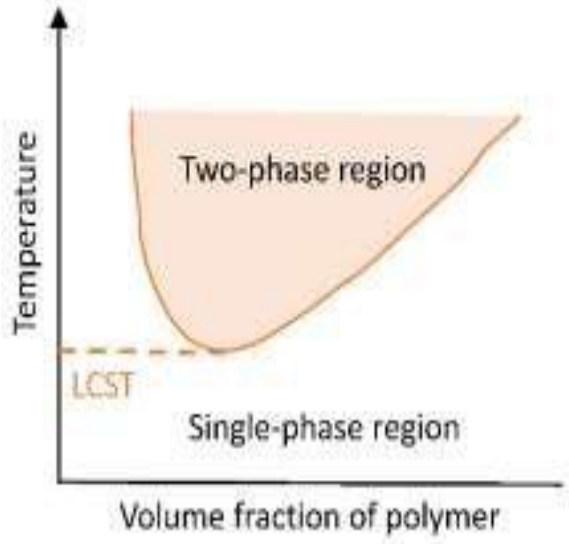
Applications of smart materials:

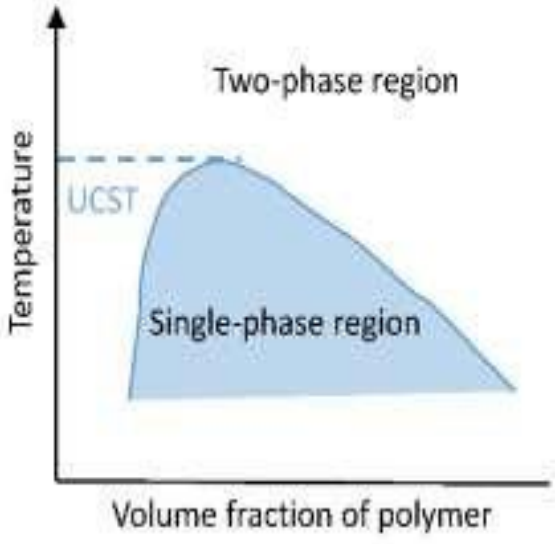
- Some major field of application of smart materials are:
- **Aeronautics:** In aircraft or automotive structure to reduce the vibrations we use piezoelectric materials andshape memory alloy to control the spatial goal.
- **Structural Health Monitoring:** The embedding smart sensors within the structure to monitor the damage and stress and can reduce the repairing cost and can increase their life.

- **In Nuclear industries:** Smart materials and smart structure offers great range of application to the nuclear filed from enhancing safety measures life-cycle cost reduction and performance improvement.
- **In the Civil Engineering:** Smart materials are able to detect the cracks in concrete structure, vibration of tall buildings, to predict the choc waves in the concrete and metallic structure. Can analyze innovative seismic retrofit of buildings and bridges.
- **In Medical field:** For artificial muscle application, polyelectrolyte gels are used, in which a polymer matrix swollen with a solvent that can expand or contract when exposed to an electric field.

Thermo responsive polymers (Temperature-responisve)

- The polymers which exhibit drastic and discontinuous changes in their physical properties with temperature are called thermoresponsive polymers
- These are contrast to temperature –sensitive materials which change their properties continuously with environmental conditions.
- Usually, the temperature responsive term is concerned with solubility property in a given solvent, but not only limited to solubility.
- Based on miscibility gap of the polymers in the phase diagram, polymers can have either lower critical solution temperature (LCST) or upper critical solution temperature (UCST).
- The polymers which are miscible (Single phase) below the phase transition temperature and immiscible (two phases) above the phase transition temperature come under LCST type.
- The polymers which are immiscible (two phases) below the phase transition temperature and miscible (Single phase) above the phase transition temperature come under UCST type.

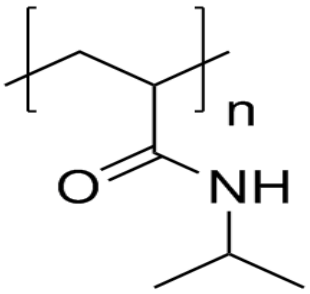




❖ POLY ACRYLAMIDE:

- The most commonly studied and first reported thermoresponsive polymer in aqueous solution is Poly (N-isopropyl acryl amide) (PNIPAM).
- PNIPAM is considered to be the gold standard of thermoresponisve polymers, especially for biomedical applications.

Structure:



Poly(N-isopropyl acryl amide)

Preparation:

- Free radical polymerization of N-isopropyl acryl amide monomers using radical initiator (azo bis-isobuytronitrile)

Advantages:

- LCST lies between body and room temperature i.e., ~32^{o}C, suitable for biological applications.
- Robust phase behaviour.
- LCST of PNIPAM does not depend on chain length or Environmental such as P^{H}.

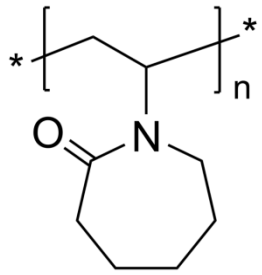
Disadvantages:

- Very high glass transition temperature (~140^{O}C to 150^{O}C) may lead to vitrification of high concentrated polymers.

❖ POLYVINYL AMIDE:

- This class of thermo-responsive polymers are second most explored polymer
- Poly N-Vinyl caprolactum (PVCL) is the best example of this category.

Structure of Poly N-Vinyl caprolactum:



- It can be prepared by free radical polymerisation of N-Vinyl caprolactum by using azo bis-isobutyronitrile as free radical initiator,

Advantages:

- Low critical solution temperature (LCST) of this polymer lies in between body and room temperature (~31°C).
- LCST of PNIPAM does not depend on chain length or Environmental such as P^H.

Disadadvantages:

- Very high glass transition temperature (~130^{O}C to 140^{O}C) may lead to vitrification of high concentrated polymers.

<u>Applications of thermosreponsive polymers</u>:

- Drug delivary
- Tissue engineering
- Liquid chromatography
- Bio separation

LUBRICANTS

❖ **Define lubricant? What are the functions of a good lubricants.**

Def: Lubricant is a substance used in between two moving surfaces to reduce the friction. Lubrication is a process of reducing friction and wear between two moving surfaces by adding lubricant in between them.

Criteria of a good lubricant:- A good lubricant must have the following functions:

1) The first and foremost function is to reduce friction.
2) It reduces surface deformation, wear and tear because the direct contact between the rubbing surfaces is avoided.
3) It reduces waste of energy. Hence the efficiency of the machine is enhanced.
4) It reduces expansion of metal by local frictional heat.
5) It avoids seizure of moving surfaces as the lubricant minimises the liberation of frictional heat.
6) It avoids unsmooth relative motion of moving parts.
7) It reduces the maintenance and running cost of machine, by preventing rust and corrosion.
8) It also acts as a seal.

❖ **Discuss the Classification of Lubricants**?

Classification of Lubricants:Lubricants may be broadly classified as follows:

1) Solid lubricants : Eg:(a) Graphite, (b) Molybdenum disulphide , (c) Talc, (d) Mica.
2) Semi – solid Lubricants: (a) Greases (b) Vaseline's
3) Liquid lubricants:
(a) Vegetable oils – eg: palm oil & castor oil
(b) Animal oils - eg: Whale oil & lard oil
(c) Mineral oils – eg: petroleum fractions.
(d) Blended or compounded oils: Eg:Mineral oils with various additives to induce desired properties.
(e) Synthetic oils – eg: Silicones.

❖ **Explain the different theories of the mechanism of lubrication.**

Mechanism of lubrication:-

There are mainly three types of mechanisms by which lubrication takes place. They are:

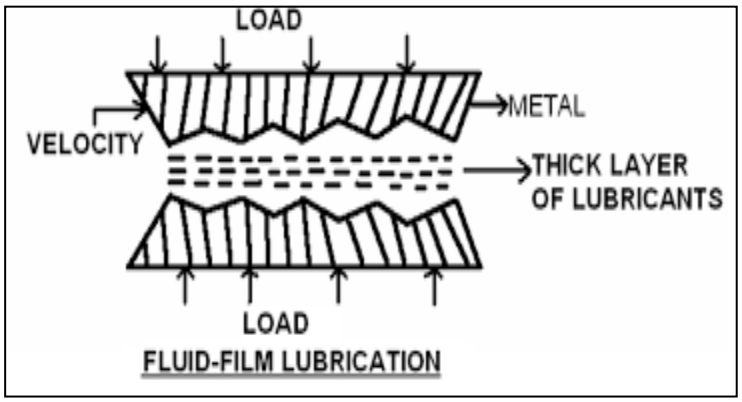
1) Fluid-film lubrication (Thick-film lubrication).
2) Boundary lubrication (Thin-film lubrication).
3) Extreme pressure lubrication.

1) Fluid-film lubrication:

It is known as thick film lubrication or hydrodynamic lubrication. It is done by lubricants which are liquid in nature. The thickness of lubricants in this case is about 1000 A0, hence the name 'Thick-Film lubrication'

In this type of lubrication, the moving or sliding surfaces are separated from each other by a thick film of fluid, so that there is no direct contact between them. The lubricant film covers the irregularities of the surfaces and reduces friction and wear and tear. The resistance to movement of sliding or moving parts is due to internal resistance between the particles of the lubricant moving over each other. For this, the lubricant should have minimum viscosity under working conditions. It should remain in place and separate thesurfaces.

This type of lubrication is used in delicate and light machines like watches, clocks, guns, sewing machines and in heavy machines like turbines, submarines etc. Fluid film lubrication is satisfactory done by hydrocarbon oils. Hydrocarbon oils used are generally mixed with long chain polymers in order to maintain the viscosity of the oil constant in all the season of the year.



2) Boundary lubrication: (Thin-film lubrication):

It is also known as thin-film lubrication because the thickness of the lubricant used in this type may not exceed one or two molecular layers. Boundary lubrication is necessary when fluid film lubrication fails to maintain the lubrication.

This type of lubrication occurs when a continuous film of lubricant cannot persist and direct metal to metal is possible. In these conditions, the space between the moving or sliding surfaces is lubricated so that a thin layer of lubricant is adsorbed on the metallic surfaces due to physical or chemical forces. This adsorbed layer helps to avoid the direct metal to metal contact between the rubbings surfaces. This load is carried by the layers of adsorbed lubricant on both the metal surfaces.

The coefficient of friction varies from 0.05 to 0.15.

For boundary lubrication, the lubricant molecules should have;

1. Long hydrocarbon chains.
2. Polar groups to promote wetting or spreading over the surface.
3. Lateral attraction between the chains.
4. Active functional groups which can form chemical bonds with metals or other surfaces.
5. High viscosity index,
6. Good oiliness,
7. Resistance to heat and oxidation.

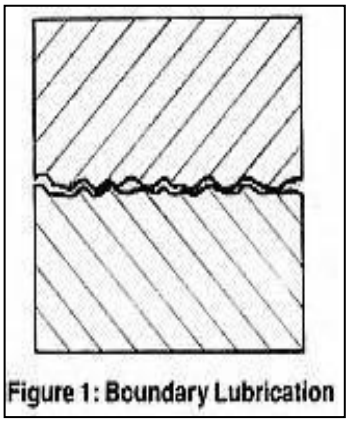


Figure 1: Boundary Lubrication

Solid lubricants, greases and oils with proper additives function as lubricants in this type of lubrication. For example, graphite, molybdenum disulphide, mineral oils with additives of fatty acids or fatty oils, vegetable and animal oils and their soaps. These materials form films on the metal surfaces having internal friction. So they can bear compression and high temperatures.

3)Extreme Pressure lubrication:

When the moving or sliding surfaces are under high pressure and speed, a special type of lubricants is used called high pressure lubricants.They withstand high temperatures generated due to friction.When moving surfaces are working under very high temperature and pressure, the ordinary liquid lubricants either vaporises or decomposes. In such cases, extreme pressure lubrication is done.

For this, special additives are used along with the liquid lubricants. Chlorinated esters, sulphurized oils and tricrysl phosphates are some examples. These additive compounds combine with the metallic surfaces at high temperatures and form metallic chlorides, sulphides or phosphides in the form of a durable film. These films can withstand very high loads and temperatures due to their high melting point.

Extreme pressure lubricants have great advantages:

i) They are used in wire drawing machining of tough metals etc.
ii) In cutting fluids in machining of tough metals.

❖ **Write short notes on the following properties of lubricants: (a) Cloud and Pour point (b) Flash and Fire point. (c) Viscosity and Viscosity index.**

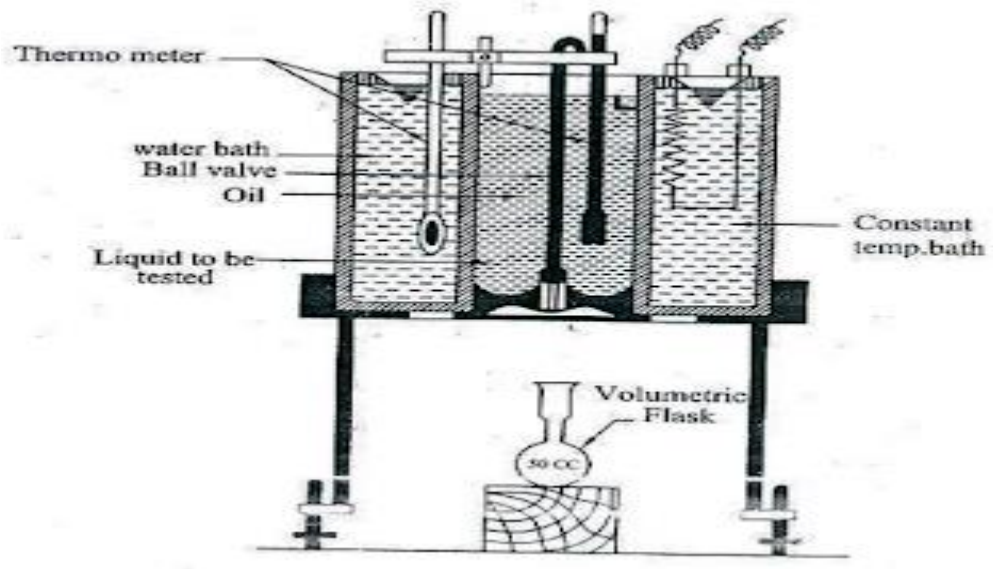
The properties of lubricants:

1. Viscosity
2. Flash and Fire Point
3. Cloud and Pour Point

1.Viscosity:

Viscosity of lubricating oil is the property which creates internal resistance to its flows. Good lubricating oil should always have moderate viscosity. Lower the viscosity, greater the flow ability. If the viscosity of the lubricating oil is high, then restriction of moving or sliding parts of a machine will occur leading towear and tear. Lubricating oil with low viscosity will not be able to form a film and it will be squeezed out of the machine leading to a friction.

Viscosity of oil can be determined with the help of red wood viscometer or sayboltz viscometer. Viscosity of oil is inversely proportional to its temperature.

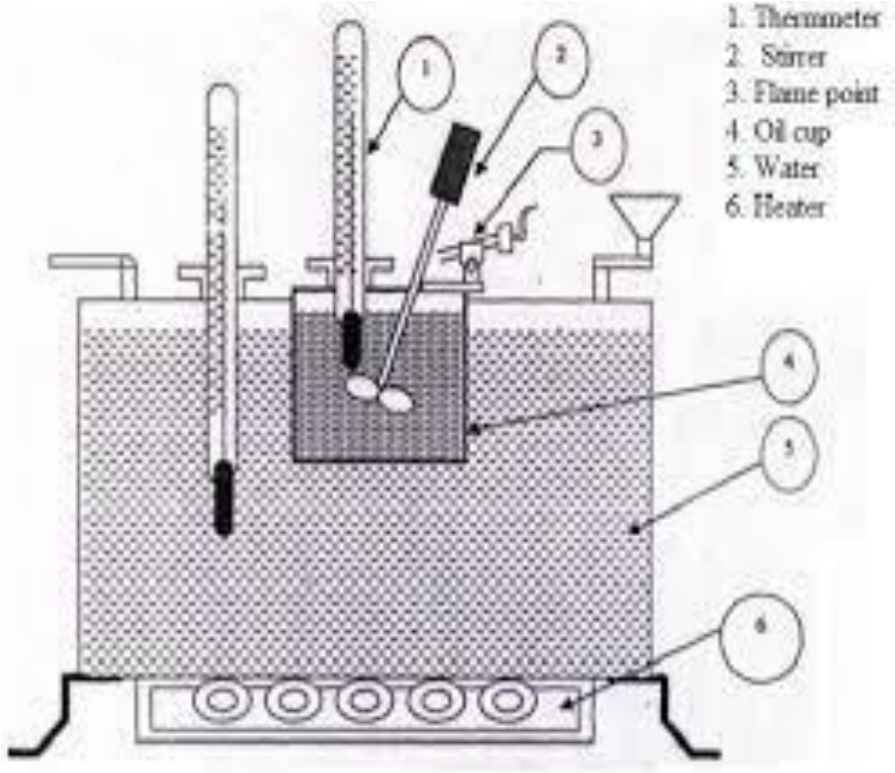


Significance:

Viscosity helps in the selection of good lubricating oil. Viscosity helps in the selection of good lubricating oil. Light oils have low densities and easy flow abilities and are used on parts moving a high speed. Heavy oils are used on parts moving at slow speed under heavy loads.

2. **Flash and Fire point:**
    - Flash point is the lowest temperature at which vapours of the oil ignite for a moment when flame is brought near it.
    - Fire point is the lowest temperature at which vapours of the oil burn for few seconds when a small flame is brought near it.
    - Generally fire point is 5 – 30^{o}C higher than flash point.

    Significance:
    - A good lubricant must have higher flash point than working temperature of a machine.
    - The knowledge of flash point and fire point helps in selecting the suitable oil and maintaining necessary conditions to prevent fire accidents while storing or transportation.

    Determination:
    - Flash and fire points are determined with the help of Pensky – Marten's apparatus.
    - Oil is heated in a standard cup with certain rate, the vapours are exposed to flame at certain intervals till fire point and flash points are identified.
    - 

3. **Cloud and Pour point:**
    - Cloud point is the temperature at which the oil becomes hazy when it is cooled.
    - The cloudiness or haziness developed in the oil is due to presence of impurities.
    - When the oil is cooled, the impurities become solidified which appears as cloud.
    - Pour point is the temperature at which the oil cann't flows when cooled to low temperature.

    Determination:
    - Oil is taken in a flat bottomed tube and cooled to low temperature by using freezing mixture.
    - The cloud point and pour points are determined one after another.

    Significance:
    - Cloud point and pour point are due to presence of impurities.

- These two help in deciding the suitability of a lubricant to the machines working at low temperatures.
- A good lubricant must have low cloud and pour points.