UNIT 3
LUBRICANTS

Specific requirements for automotive lubricants, oxidation deterioration and degradation of lubricants, additives and additive mechanism, synthetic lubricants, classification of lubricating oils, properties of lubricating oils, tests on lubricants, grease, classification, properties, test used in grease.

LUBRICANTS

In all types of machines, the surfaces of moving or sliding or rolling parts rub against each other. Due to the mutual rubbing of one part against another, a resistance is offered to their movement. This resistance is known as **friction**.

It causes a lot of wear and tear of surfaces of moving parts. Any substance introduced between two moving/sliding surfaces with a view to reduce the friction (or frictional resistance) between them, is known as a **lubricants.**

The main purpose of a lubricant is to keep the moving/sliding surfaces apart, so that friction and consequent destruction of material is minimized. The process of reducing friction between moving/sliding surfaces, by the introduction of lubricants in between them, are called **lubrication.**

Function of Lubricants:

- It reduces wear and tear of the surfaces by avoiding direct metal to metal contact
- Between the rubbing surfaces, i.e. by introducing lubricants between the two surfaces
- It reduces expansion of metal due to frictional heat and destruction of material
- It acts as coolant of metal due to heat transfer media
- it avoids unsmooth relative motion
- It reduces maintenance cost
- It also reduces power loss in internal combustion engines

Theories of Friction:

(1) **Welding theory:** All metal surfaces, regardless how much finely finished they are,

appear as a series of peaks (or asperites) and valleys. So when two solid surfaces are pressed oneover the other, only the peaks of the two surfaces come in real contact. Under the action of a load, the local pressure at the peaks becomes sufficiently great to cause deformation of the peaks to create weld junctions between them.

(2) **Mechanical Interlocking:** When one surface moves over another, the peaks and valleys present on the surface undergo interlocking; restrict the movement of one surface over the other. This accounts for static friction.

(3) **Molecular Attraction:** Atoms of one material are plucked out of the attractive range of their counterparts on the mating surface, lead to the friction.

(4) **Electrostatic Attraction:** When stick-slip phenomenon takes place between rubbing metal surfaces, a net flow of electrons takes place producing clusters of charges of opposite polarity at the interface. These charges are responsible for holding the surfaces together by electrostatic attraction.

Mechanism of Lubrication: The phenomenon of lubrication can be explained with the help of the following mechanism; (a) Thick-Film lubrication (Fluid-Film or hydrodynamic lubrication) (b) Thin Film lubrication (Boundary lubrication) and (c) Extreme Pressure lubrication

Thick-Film lubrication:

In this, moving/sliding surfaces are separated from each other by a thick film of fluid (at least 1000 A° thick), so that direct surface to surface contact and welding of welding of junctions rarely occurs. The lubricant film covers/fills the irregularities of moving/sliding surfaces and forms a thick layer between them, so that there is no direct contact between the material surfaces. This consequently reduces friction.

The lubricant chosen should have the minimum viscosity (to reduce the internal resistance between the particles of the lubricant) under working conditions and at the same time, it should remain in place and separate the surfaces.

Hydrocarbon oils (mineral oils which are lower molecular weight hydrocarbons with about 12 to 50 carbon atoms) are considered to be satisfactory lubricants for thick-film lubrication. In order to maintain the viscosity of the oil in all seasons of year, ordinary hydrocarbon lubricants are blended with selected long chain polymers.

Thin Film lubrication:

This type of lubrication is preferred where a continuous film of lubricant cannot persist. In such cases, the clearance space between the moving/sliding surfaces is lubricated by such a material which can get adsorbed on both the metallic surfaces by either physical or chemical forces. This adsorbed film helps to keep the metal surfaces away from each other at least up to the height of the peaks present on the surface.

Vegetable and animal oils and their soaps can be used in this type of lubrication because they can get either physically adsorbed or chemically react in to the metal surface to form a thin film of metallic soap which can act as lubricant. Although these oils have good oiliness, they suffer from the disadvantage that they will break down at high temperatures. On the other hand, mineral oils are thermally stable and the addition of vegetable/animal oils to mineral oils, their oiliness can also be brought up. Graphite and molybdenum disulphide are also suitable for thin-film lubrication.

(c) Extreme Pressure lubrication:

When the moving/sliding surfaces are under very high pressure and speed, a high local temperature is attained under such conditions, liquid lubricants fail to stick and may decompose and even vaporize. To meet these extreme pressure conditions, special additives are added to minerals oils. These are called extreme pressure additives. These additives form more durable films (capable of withstanding very high loads and high temperatures) on metal surfaces. Important additives are organic compounds having active radicals or groups such as chlorine (as in chlorinated esters), sulphur (as in sulphurized oils) or phosphorus (as in tricresyl phosphate). These compounds react with metallic surfaces, at existing high temperatures, to form metallic chlorides, sulphides or phosphides.

Classification of Lubricants:

Lubricants are classified on the basis of their physical state, as follows;

- Liquid lubricants or Lubricating Oils,
- Semi-solid lubricants or Greases and
- Solid lubricants.

(a) Liquid lubricants or Lubricating oils: Lubricating oils also known as liquid lubricants and further classified into three categories; (i) Animal and Vegetables oils, (ii) Mineral or Petroleum oils and (iii) blended oils.

Characteristic of good lubricating oils:

- high boiling point,
- low freezing point,
- adequate viscosity for proper functioning in service,
- high resistance to oxidation and heat,
- non-corrosive properties and
- Stability to decomposition at the operating temperatures.

Animal and Vegetables oils:

Animal oils are extracted from the crude fat and vegetables oils such as cotton seed oil and caster oils. These oils possess good oiliness and hence they can stick on metal surfaces effectively even under elevated temperatures and heavy loads. But they suffer from the disadvantages that they are costly, undergo easy oxidation to give gummy products and hydrolyze easily on contact with moist air or water. Hence they are only rarely used these days for lubrication. But they are still used as blending agents in petroleum based lubricants to get improved oiliness.

Mineral or Petroleum oils:

These are basically lower molecular weight hydrocarbons with about 12 to 50 carbon atoms. As they are cheap, available in abundance and stable under service conditions, hence they are widely used. But the oiliness of mineral oils is less, so the addition of higher molecular weight compounds like oleic acid and stearic acid increases the oiliness of mineral oil.

Blended oils:

No single oil possesses all the properties required for a good lubricant and hence addition of proper additives is essential to make them perform well. Such additives added lubricating oils are called blended oils. Examples: The addition of higher molecular weight compounds like oleic acid, stearic acid, palmetic acid, etc or vegetables oil like coconut oil, castor oil, etc increases the oiliness of mineral oil.

Semi-solid Lubricants or Grease:

A semi-solid lubricant obtained by combining lubricating oil with thickening agents is termed as grease. Lubricating oil is the principal component and it can be either petroleum oil or a synthetic hydrocarbon of low to high viscosity. The thickeners consist primarily of special soaps of Li, Na, Ca, Ba, Al, etc. Non-soap thickeners

Include carbon black, silica gel, polyureas and other synthetic polymers, clays, etc. Grease can support much heavier load at lower speed. Internal resistance of grease is much higher than that of lubricating oils; therefore it is better to use oil instead of grease. Compared to lubricating oils, grease cannot effectively dissipate heat from the bearings, so work at relatively lower temp.

Solid lubricants:

They are preferred where (1) the operating conditions are such that a lubricating film cannot be secured by the use of lubricating oils or grease (2) contamination

(By the entry of dust particles) of lubricating oils or grease is unacceptable (3) the operating temperature or load is too high, even for grease to remain in position and (4) combustible lubricants must be avoided. . They are used either in the dry powder form or with binders to make them stick firmly to the metal surfaces while in use.

They are available as dispersions in non-volatile carriers like soaps, fats, waxes, etc and as soft metal films.

The most common solid lubricants are graphite, molybdenum disulphide, tungsten disulphide and zinc oxide. They can withstand temperature upto 650° C and can be applied in continuously operating situations. They are also used as additives to mineral oils and greases in

order to increase the load carrying capacity of the lubricant. Other solid lubricants in use are soapstone (talc) and mica.

Graphite:

It is the most widely used of all the solid lubricants and can be used either in the powdered form or in suspension. It is soapy to touch; non-inflammable and stable up to a Temperature of 375° C. Graphite has a flat plate like structure and the layers of graphite sheets are arranged one above the other and held together by weak van Der Waal's forces. These parallel layers which can easily slide one over other make graphite an effective lubricant. Also the layer of graphite has a tendency to absorb oil and to be wetted of it.

Molybdenum Disulphide:

It has a sandwich- like structure with a layer of molybdenum atoms in between two layers of sulphur atoms. Poor interlaminar attraction helps these layers to Slide over one another easily. It is stable up to a temperature of 400° C.

Properties of Lubricants:

- Viscosity
- Flash Point and Fire Point
- Cloud Point and Pour Point
- Aniline Point and
- Corrosion Stability

(1) ***Viscosity*****:** It is the property of liquid by virtue of which it offers resistance to its own flow (the resistance to flow of liquid is known as viscosity). The unit of viscosity is poise. It is the most important single property of any lubricating oil, because it is the main determinant of the operating characteristics of the lubricant. If the viscosity of the oil is too low, a liquid oil film cannot be maintained between two moving/sliding surfaces . On the other hand, if the viscosity of the oil is too high, excessive friction will result.

Effect of temperature on viscosity: Viscosity of liquids decreases with increasing temperature and, consequently, the lubricating oil becomes thinner as the operating temperature increases. Hence, viscosity of good lubricating oil should not change much with change in

Temperature, so that it can be used continuously, under varying conditions of temperature.

The rate at which the viscosity of lubricating oil changes with temperature is measured by an arbitrary scale, known as Viscosity Index (V. I). If the viscosity of lubricating oil falls rapidly as the temperature is raised, it has a low viscosity index. On the other hand, if the viscosity of lubricating oil is only slightly affected on raising the temperature, its viscosity index is high.

(2) ***Flash Point and Fire Point:*** Flash point is the lowest temperature at which the lubricant oil gives off enough vapours that ignite for a moment, when a tiny flame is brought near it; while Fire point is the lowest temperature at which the vapours of the lubricant oil burn continuously for at least five seconds, when a tiny flame is brought near it. In most cases, the fire points are 5° C to 40° C higher than the flash points. The flash and fire do not have any bearing with lubricating property of the oil, but these are important when oil is exposed to high

Temperature service. A good lubricant should have flash point at least above the temperature at which it is to be used. This safeguards against risk if fire, during the use of lubricant.

(3) ***Cloud Point and Pour Point*****:** When the lubricant oil is cooled slowly, the temperature at which it becomes cloudy or hazy in appearance, is called its cloud point; while the temperature at which the lubricant oil cease to flow or pour, is called its pour point. Cloud and pour points indicate the suitability of lubricant oil in cold conditions. Lubricant oil used in a machine working at low temperatures should possess low pour point; otherwise solidification of lubricant oil will cause jamming of machine. It has been found that presence of waxes in the lubricant oil raise pour point.

(4) ***Aniline Point*****:** Aniline point of the lubricant oil is defined as the minimum equilibrium solution temperature for equal volumes of aniline and lubricant oil samples. It gives an indication of the possible deterioration of the lubricant oil in contact with rubber sealing; packing, etc.

Aromatic hydrocarbons have a tendency to dissolve natural rubber and certain types of synthetic rubbers. Consequently, low aromatic content in the lubricant oil is desirable. A higher aniline point means a higher percentage of paraffinic hydrocarbons and hence, a lower percentage of aromatic hydrocarbons. Aniline point is determined by mixing mechanically equal volumes of the lubricant oil samples and aniline in a test tube. The mixture is heated, till homogenous solution is obtained.

Then, the tube is allowed to cool at a controlled rate. The temperature at which the two phases (the lubricant oil and aniline) separate out is recorded at the aniline point.

(5) ***Corrosion Stability*****:** Corrosion stability of the lubricant oil is estimated by carrying out corrosion test. A polished copper strip is placed in the lubricant oil for a specified time at a particular temperature. After the stipulated time, the strip is taken out and examined for

corrosion effects. If the copper strip has tarnished, it shows that the lubricant oil contains any chemically active substances which cause the corrosion of the copper strip. Good lubricant oil should not effect the copper strip. To retard corrosion effects of the lubricant oil, certain inhibitors are added to them. Commonly used inhibitors are organic compounds containing P, As, Cr, Bi or Pb.

Essential requirements or characteristics of a good lubricant are as follows:

[1] It should have a high viscosity index.

[2] It should have flash and fire points higher than the operating temperature of the machine.

[3] It should have high oiliness.

[4] The cloud and pour points of a good lubricant should always be lower than the operating temperature of the machine.

[5] The volatility of the lubricating oil should be low.

[6] It should deposit least amount of carbon during use.

[7] It should have higher aniline point.

[8] It should possess a higher resistance towards oxidation and corrosion.

[9] It should have good detergent quality.

SYNTHETIC LUBRICANTS

Synthetic lubricants ara a combination of synthetic base oil plus thickeners and additives that will give the grease or oil lubricant a number of performance advantages over conventional mineral based lubricants.

Synthetic oil is a lubricant consisting of chemical compounds that are artificially made (synthesized). Synthetic lubricants can be manufactured using chemically modified petroleum components rather than whole crude oil, but can also be synthesized from other raw materials. Synthetic oil is used as a substitute for lubricant refined from petroleum when operating in extremes of temperature, because, in general, it provides superior mechanical and chemical properties to those found in traditional mineral oils. Aircraft jet engines, for example, require the use of synthetic oils, whereas aircraft piston engines do not. Synthetic lubricants are also used in metal stamping to provide environmental and other benefits, when compared to conventional petroleum and animal fat based products. These products are also referred to as "non-oil" or "oil free".

Advantages

The technical advantages of synthetic motor oils include:

- Better low- and high-temperature viscosity performance at service temperature extremes
- Better (higher) Viscosity Index (VI)
- Better chemical and shear stability
- Decreased evaporative loss
- Resistance to oxidation, thermal breakdown, and oil sludge problems
- Possibility to extended drain intervals, with the environmental benefit of less used oil waste generated
- Improved fuel economy in certain engine configurations
- Better lubrication during extreme cold weather starts
- Possibly a longer engine life
- Superior protection against "ash" and other deposit formation in engine hot spots (in particular in turbochargers and superchargers) for less oil burn off and reduced chances of damaging oil passageway clogging.
- Increased horsepower and torque due to less initial drag on engine
- Improved Fuel Economy (FE) - from 1.8% to up to 5% has been documented in fleet tests

Disadvantages

The disadvantages of synthetic motor oils include:

- Substantially more expensive (per volume) than mineral oils.
- Potential decomposition problems in certain chemical environments (predominantly in industrial use.)

TESTS ON LUBRICANTS

Basically, there are two different types of lubricant testing

1. chemico-physical

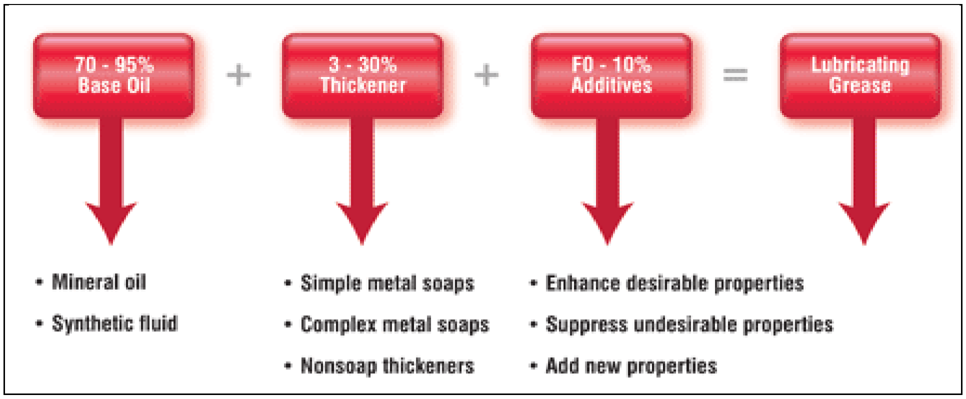
2. mechanico-dynamical.

Chemico-physical tests only concentrate on certain lubricant properties, whereas mechanico-dynamical tests try to simulate the effects of load, speed, media and temperature on the friction and wear behavior of a tribo-system.

Chemico-physical tests generally precede mechanico-dynamical tests. Depending on the lubricant type and the requirements there are many different test procedures.

GREASE

Lubricating grease is defined as a solid to semi fluid product of dispersion of a thickening agent in liquid lubricant. There are three components that form lubricating grease. These components are oil, thickener and additives. The base oil and additive package are the major components in grease formulations. The thickener is often referred to as a sponge that holds the lubricant (base oil plus additives).



Base Oil

Most greases produced today use mineral oil as their fluid components. These mineral oil-based greases typically provide satisfactory performance in most industrial applications. In temperature extremes (low or high), a grease that utilizes a synthetic base oil will provide better stability.

Thickener

The thickener is a material that, in combination with the selected lubricant, will produce the solid to semifluid structure. The primary type of thickener used in current grease is metallic soap. These soaps include lithium, aluminum, clay, polyurea, sodium and calcium. Lately, complex thickener-type greases are gaining popularity. They are being selected because of their high dropping points and excellent load-carrying abilities.

Additives

Additives can play several roles in lubricating grease. These primarily include enhancing the existing desirable properties, suppressing the existing undesirable properties, and imparting new properties. The most common additives are oxidation and rust inhibitors, extreme pressure, antiwear, and friction-reducing agents.

Function of grease

The function of grease is to remain in contact with and lubricate moving surfaces without leaking out under the force of gravity, centrifugal action or being squeezed out under pressure. Its major practical requirement is that it retains its properties under shear forces at all temperatures it experiences during use.

Functional Properties of Grease

1. Grease functions as a sealant to minimize leakage and to keep out contaminants. Because of its consistency, grease acts as a sealant to prevent lubricant leakage and also to prevent entrance of corrosive contaminants and foreign materials. It also acts to keep deteriorated seals effective.
2. Grease is easier to contain than oil. Oil lubrication can require an expensive system of circulating equipment and complex retention devices. In comparison, grease, by virtue of its rigidity, is easily confined with simplified, less costly retention devices.
3. Grease holds solid lubricants in suspension. Finely ground solid lubricants, such as molybdenum disulfide (moly) and graphite, are mixed with grease in high-temperature service or in extreme high-pressure applications. Grease holds solids in suspension while solids will settle out of oils.
4. Fluid level does not have to be controlled and monitored.

Characteristics of ideal grease

The characteristics commonly found on product data sheets include the following:

Pumpability. Pumpability is the ability of a grease to be pumped or pushed through a system. More practically, Pumpability is the ease with which a pressurized grease can flow through lines, nozzles and fittings of grease-dispensing systems.

Water resistance. This is the ability of grease to withstand the effects of water with no change in its ability to lubricate. Soap/water lather may suspend the oil in the grease, forming an emulsion that can wash away or, to a lesser extent, reduce lubricity by diluting and changing grease consistency and texture.

Consistency. Grease consistency depends on the type and amount of thickener used and the viscosity of its base oil. Grease's consistency is its resistance to deformation by an applied force. The measure of consistency is called penetration. Penetration depends on whether the consistency has been altered by handling or working. ASTM D 217 and D 1403 methods measure penetration of unworked and worked greases. To measure penetration, a cone of given weight is allowed to sink into a grease for five seconds at a standard temperature of 25°C (77°F).

Dropping point. Dropping point is an indicator of the heat resistance of grease. As grease temperature increases, penetration increases until the grease liquefies and the desired consistency is lost. The dropping point is the temperature at which a grease becomes fluid enough to drip. The dropping point indicates the upper temperature limit at which a grease retains its structure, not the maximum temperature at which a grease may be used.

Oxidation stability. This is the ability of grease to resist a chemical union with oxygen. The reaction of grease with oxygen produces insoluble gum, sludges and lacquer-like deposits that cause sluggish operation, increased wear and reduction of clearances. Prolonged exposure to high temperatures accelerates oxidation in greases.

High-temperature effects. High temperatures harm greases more than they harm oils. Grease, by its nature, cannot dissipate heat by convection like circulating oil. Consequently, without the ability to transfer away heat, excessive temperatures result in accelerated oxidation or even carbonization where grease hardens or forms a crust.

Effective grease lubrication depends on the grease's consistency. High temperatures induce softening and bleeding, causing grease to flow away from needed areas. The mineral oil in grease can flash, burn or evaporate at temperatures greater than 177°C (350°F).

Low-temperature effects. If the temperature of grease is lowered enough, it will become so viscous that it can be classified as hard grease. Pumpability suffers and machinery operation may become impossible due to torque limitations and power requirements. As a guideline, the base oil's pour point is considered the low-temperature limit of grease.