Mechanical Equipment - Course 230.1

LUBRICATION

Review of Lubrication Principles

Lesson 430.14-1 in the 430.1 Mechanical Equipment course very briefly outlined the types of friction which occurred, types of lubrication and lubrication properties. It would therefore be very helpful if the reader would read that particular lesson prior to taking this one.

In almost all rotating or reciprocating equipment there will be sliding, rolling and fluid friction forces at work. The main objectives of lubrication are therefore to reduce friction forces (reduce coefficient of friction), reduce wear of moving parts, cooling of bearing material, cleansing action and even to act as a shock absorber. In any bearing because of the friction forces, the temperature of the material will increase, therefore by having a flow of oil through the bearing the temperature rise will be reduced. Oil flowing through the bearing will help keep the bearing clean, flushing away any foreign material. A thick film of oil between metal surfaces will also tend to absorb any impact due to sudden load applications.

Types of Lubrication

There are essentially three modes of lubrication, they being:

(a) boundary lubrication

(b) hydrostatic lubrication

(c) hydrodynamic lubrication

Hydrodynamic and hydrostatic lubrication can also be classified as fluid lubrication in that there is a thick enough film of oil to ensure that the surface irregularities do not come into contact (no metal to metal contact). Hydrodynamic lubrication is where an oil wedge is formed within the bearing due to its design which increases the pressure of the oil, maintaining the metal surfaces apart. The oil wedge term is used because, what in fact happens is that the volume through which the oil flows is decreased, thus attempting to compress the oil increasing the pressure.

Hydrostatic lubrication is where oil is injected between two surfaces at high pressure forcing the two apart. Motion of the surfaces is not necessary. Resistance to motion in hydrostatic lubrication is due strictly to the oil viscosity as there is no metal to metal contact.

Boundary lubrication consists of separation of the bearing surfaces by a lubricant which is at best only a few molecules thick. Requirement of a good boundary lubricant is its ability to cling tenaciously to the surface of a material. The lubricant clings to the surface by either absorption or chemical reaction. In boundary lubrication the resistance to motion is influenced by both the lubricant viscosity and the surface requirements as the surface irregularities penetrate the film of oil, thus resulting in metal to metal contact. In actual fact viscosity will have little effect on the friction forces.

Normally a bearing is hydrodynamically lubricated but gradual transition to boundary can occur when as the speed changes or load is increased the oil wedges separating the surface become thinner and the surface peaks begin to penetrate.

Lubricating Properties

Fluid lubricant properties which are of common use:

1. Viscosity: oil's internal resistance to motion.
2. Oiliness: oil's ability to adhere to the metal surface.
3. Temperature Stability: temperature it can withstand without loss of lubricating properties.
4. Flash Point: temperature at which oil vaporizes.

The most important properties of a lubricating oil is its viscosity which largely determines its suitability for any particular application.

Absolute viscosity is determined either as kinematic viscosity in centistrokes or as dynamic viscosity in centipoise, obtained by multiplying the kinematic viscosity by the density of the oil at the temperature of measurement. Lubricating oils have viscosities ranging from 10 - 1000 centistoke at 100°F at which temperature water has a viscosity of about 1 centistoke.

For crankase oils for both gasoline and diesel engines, the Society of Automative Engineers (SAE) in America has adopted a system which grades the oils into seven categories with their viscosity specified at 210°F. The lightest three, SAE5W, SAE10W and SAE20W, are known as Winter or W grades; they have to meet a viscosity requirement at 210°F and 0°F. The other four grades, 20, 30, 40 and 50 oils, have viscosity at 210°F increasing in that order, but no requirement at 0°F.

Multigrade oils are now in use which fall within more than one SAE grade classification. They cover in one oil a Winter grade and a normal grade specification. Pure mineral oils do not normally fulfill this requirement, and thus additives have to be used. A similar classification is used for transmission and axle lubricants for which SAE grades 75, 85, 90, 140 and 250 are specified in terms of viscosities at 210°F and 0°F.

As was stated in the Level 4 course, viscosity is inversely proportional to temperature. The higher the temperature the thinner the oil (viscosity decreases). In a bearing therefore as the speed is increased, the temperature increases, therefore the oil becomes thinner.

Lubricant Additives

Adding something to lubricants is an old art. Steam cylinder oils compounded with animal fats and the marine steam engine lubricant that boasted of blown rape seed oil were among the first additive lubricants. The growth of additives since these early days has been rapid, meeting the needs of an expanding technological world. High bearing and gear loadings, smaller more powerful prime movers, greater speeds and widening range of operating temperatures have been behind the growth in additives.

There are many reasons for using additives in lubricants. Some are designed to protect the lubricant in service by limiting chemical change or deterioration. Others protect machines from effects of outside contamination (products of combustion, for example) which might form harmful deposits. Some additives improve a lubricant's physical properties or give completely new properties, and still others are designed to reduce surface wear.

A list of the common additives in use today, their functions and their applications, is given in Table 1. From this table, one can see what the requirements are for turbine lube oil, reciprocating and rotary equipment, etc.

Types of Lubricants

Lubricants can be classified into three groups, they being:

1. Fluid Lubrication
2. Greases.
3. Solid Lubricants.

Fluid lubrication, whose properties have been discussed, can be further divided into: mineral ois, fixed oils and synthetics. Mineral oils are extracted from crude petroleum and are the most commonly used. Fixed oils are of animal or vegetable origin. These particular oils have a high degree of oiliness and are used as additives with the mineral oils.

Synthetic oils, as the name implies, are built rather than derived. This particular group is becoming very popular, and has a wider range of application than mineral oils.

Lubricating greases are solid or semi-solid lubricants made by thickening lubricating oils with metallic soaps, silica gel, or other thickening agents. Greases are classified according to the type of thickener and their consistency. Consistency is measured in terms of "penetration", the distance a plunger penetrates into the grease under standard conditions. Groups are classified as 000 - 6 greases according to the penetration classification of the National Lubricating Grease Institue (NLGI) in America, 000 being the softest, 6 the hardest.

Greases in which soap is the thickener are known as soap-base greases and are sub-divided according to the types of soap into aluminum, calcium, lithium or sodium greases.

Aluminum greases are smooth, water resistant and adhesive, and are often used as chassis lubricants. Calcium greases are general purpose greases suitable for operative temperatures up to 50°C (120°F). They have drop points around 100°C (212°F) and are unaffected by water. Drop point of grease is defined as the temperature at which a drop of grease first falls through a small orifice at the bottom of a cup when heated. Sodium greases have higher drop points, about 160°C (320°F), and can be used when temperatures are too high for calcium greases. However they tend to emulsify in water. Lithium greases combine high drop point, up to 200°C (390°F) with good low temperature properties and resistance to water. They are used extensively for automotive and industrial applications. Greases thickened with inorganic thickeners such as clays, silica gel, are known as clay base or microgel greases. They have very high drop points of the order of 300°C (570°F) and can therefore be used to lubricate bearings at high temperatures. Gas turbine engines have created a demand for lubricants that will operate over a wider range of temperatures than can be obtained with conventional mineral oils.

Synthetic greases have a wide range of temperature stability but are also very expensive and their use is limited to specific applications.

Comparative Advantage of Grease and Oil in Bearing

The question is always asked whether an oil or a grease should be chosen for a particular application. Each has advantages which are listed as follows:

Advantages of Grease

1. Maintenance may be reduced, no level to maintain, regreasing is infrequent.
2. Proper grease quantity is easily confined in housing, simplifies design of bearing enclosure.
3. Freedom from leakage.
4. Improves efficiency of labyrinth enclosure, gives better bearing protection.

Advantage of Oil

1. Oil is easier to drain and refill, this is important if lubricating intervals are close together.
2. Use of oil makes it easier to control the correct amount of lubricant.
3. Same lubricant may be used on other types of bearing on the same machine.
4. If bearing must operate under high temperatures, conditions favor oil.

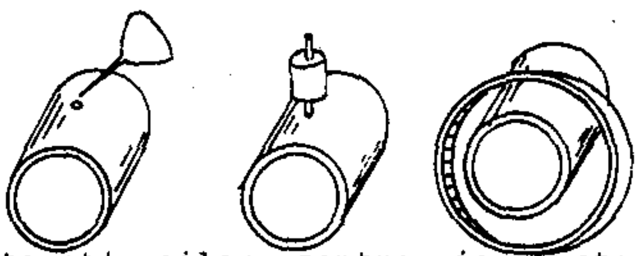
Solid Lubricants

Solid lubricant is simply a solid material between two moving surfaces to prevent metal-to-metal contact. Therefore the application of solid lubricants is generally for boundary lubrication. They may be applied as dry powders, mixtures with grease and oil or mixtures with binders which form dry films when used. Some solid lubricants in use are graphite powder, molybdenum disulfide, pressed carbon, tungsten disulfide, telfon powder and other plastics.

Solid lubricants such as carbon bearings have the advantage that there is no contamination of the system fluid (D_2O). An example would be the main guide bearing (carbon) in the PHT circulating water pumps at Pickering.

Lubricating Systems

The simplest and oldest method of lubricating the single bearing is the hand operated oil can which is a feast of famine situation. This method is not suitable for the critical needs of todays machinery. Figure 1 illustrates various methods of supplying oil or grease to a single bearing. The automatic oiler (wickerfeed, gravity, etc) and the ring oiled bearing provides for a continuous supply of oil to the bearing. The ring picks up oil from a pool beneath the bearing and drags it through a bearing slot, where the moving shaft distributes it between shaft and bearing. Once through, the oil drains to the reservoir between the bearing and housing. For application of greases, three methods are direct application with grease gun, grease cup and finally the spring operated grease applicator.



OIL FEED from automatic oiler, centre, is constant while machine operates. Only attention needed is occasional refilling of reservoir

GREASE FED to bearing by spring pressure from reservoir, right. Spring compresses each time unit is filled from outside grease gun

Single Bearing Lubrication

Figure 1

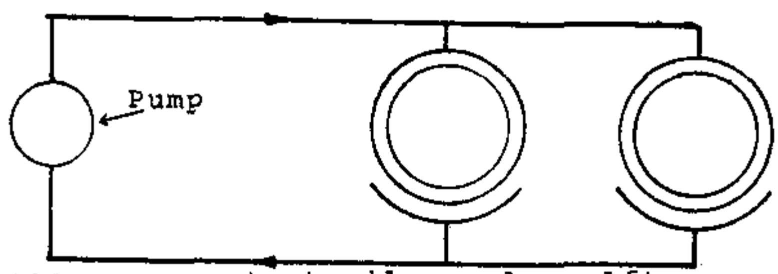
With the possible exception of the ring oiler, the methods just discussed are once through systems. Large power equipment generally uses continuous oil circulation. Advantages of a circulating system are:

1. Adequate oil supply for both lubrication and cooling.

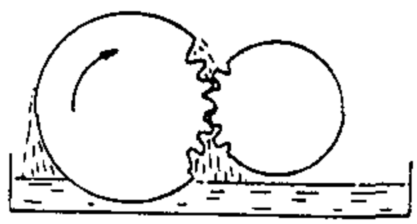
2. Consumption cut by oil recirculation.

3. Dirt removed by flushing action.

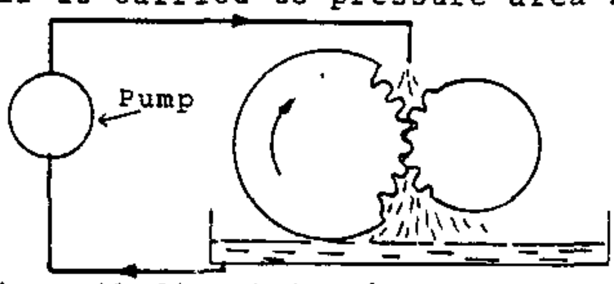
Figure 2 illustrates three basic circulating systems in use today.



EXTERNAL PUMP assures constant oil supply. After passing through bearings, the oil is collected and recirculated, reducing consumption



SPLASH LUBRICATION is simple form of circulating system (like a ring oiler). Oil is carried to pressure area by clinging on the teeth



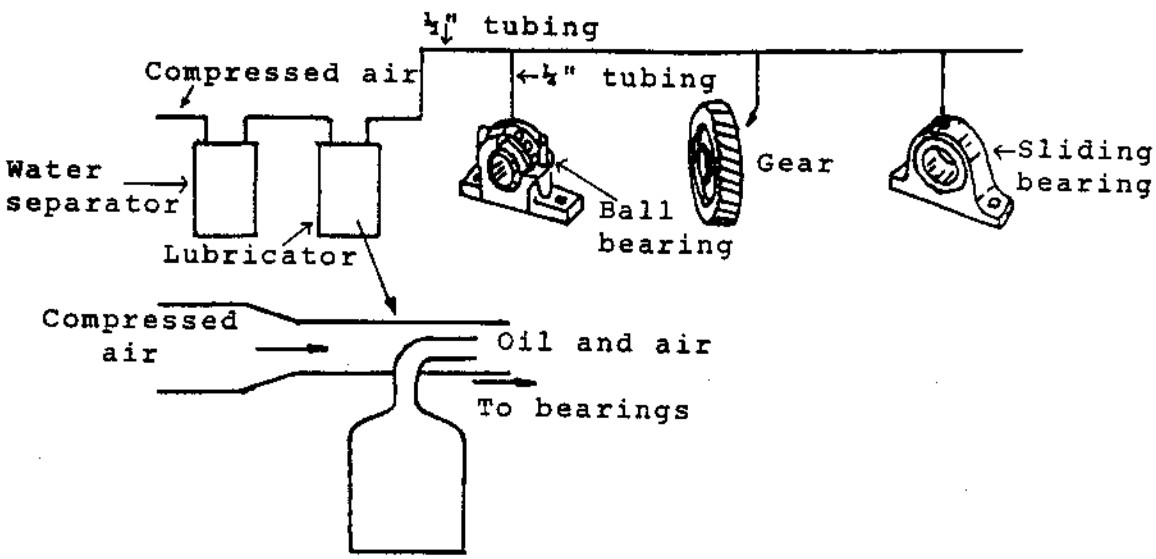
FORCE FEED applies oil direct to the pressure area. Oil conditioning unit can be installed in the feed line to extend life of the lubricant

Basic Circulating Systems

Figure 2

One other method of providing lubrication is to use the aerosol principle. This involves atomization of the oil, and mixing it with air. The mixture is distributed through tubing to bearing surfaces. Moving shaft in bearing actually removes oil out of the air stream, depositing it as a film between the shaft and bearing. Figure 3 illustrates a lubricating aerosol system. Such a system provides continuous lubrication to each bearing. The system is most economical, consumption being in some cases only one tenth as much as for other once through systems.

Airflow through bearings acts as a coolant. Like other systems previously discussed, there is no need for attention other than refilling lubricators as needed.



LUBRICATING AEROSOL carries fine oil particles in suspension until they hit moving surface. Shaft movement drags oil from airborne mixture into the bearing surfaces.

Lubricating Aerosol System

Figure 3

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Additive Type	Oxidation Inhibitor	Corrosion Inhibitor	Extreme Pressure, Oiliness or Film-Strength Improver	Detergent Dispersant	Rust Preventive	Metal Deactivator	Antiseptic (bactericide or disinfectant)	Pour-point Depressant	Emulsifier	Foam Inhibitor	Viscosity-index Improver
Typical compounds	Organics containing sulfur, phosphorus or nitrogen, such as organic amines, sulfides, hydroxy sulfides, phenols. Zinc organics are often used.	Organics containing active sulfur, phosphorus or nitrogen. Typical organic sulfides, phosphites, metal salts of thiophosphoric acid and sulfurized waxes.	Chlorine, phosphorus and sulfur compounds such as chlorinated waxes, organic phosphates (tricresyl phosphate), phosphites, lead soaps such as lead nopthenate, fats.	Mettallo-organics (phosphates, phenolates, sulfonates and alcoholates). High-molecular-weight soaps containing tin, barium, magnesium, calcium.	Sulfonates, amines, fatty oils, fatty acids, oxidized-wax acids, phosphates, halogenated derivatives of some fatty acids.	Complex organic compounds containing nitrogen or sulfur; amines and sulfides, some soaps.	Some alcohols, aldehydes, phenals and mercuric compounds. Chlorine-containing compounds.	Wax alkylated napthalenes or phenols and their polymers. Methacrylate polymers are also used.	Certain soaps of fats and fatty acids, sulfonic acids or napthenic acids and surfactants	Silicone polymers and modified waxes.	Polymerized olefins or isoolefins. Butylene polymers, methacrylic - acid - ester polymers, alkylated styrene polymers.
Why additive is used	Minimize formation of varnish and sludge on metal parts, prevent corrosion of alloy bearings	Protect alloy bearings and other metal surfaces from corrosion.	Reduce friction and wear, prevent galling, scoring and seizure.	Keep metal surfaces clean, prevent many types of deposits.	Minimize rusting of metal parts during equipment shutdown, storage and shipment.	Pacify, prevent or counteract catalytic effect of metals on oxidation process.	Control odor, metal staining and emulsion breaking in emulsion type oils.	Lower the pour point of the oil.	To produce a coolant-lubricant type fluid from soluble oils and water. Reduces water washing, rusting.	Prevent the formation of stable foam.	Reduce rate - of - change of viscosity with temperature.
How additive works	Reduces formation of acidic bodies by decreasing amount of oxygen taken up by the oil. Ends oil-oxidation reactions by forming inactive soluble compounds or by taking up oxygen. Additive may be oxidized instead of oil.	Inhibits oxidation, preventing formation of acidic bodies. Allows a protective film to form on metal surfaces. Catalytic oxidation of oil is decreased by this chemical film.	Chemical reaction forms a film on contacting metal surfaces. Film has lower shear strength than base metal, thereby reducing friction. Helps prevent welding, seizure of contacting surfaces when oil film is ruptured.	Chemical reaction prevents deposition of oxidation products and other substances.	Polar or chemical type surface -active materials are preferentially absorbed on metal. Film repels water attack.	Physical or chemical adsorption forms inactive protective film. Catalytically inactive complex is formed with soluble or insoluble metal ions.	Reduces or prevents micro-organism growth particularly harmful to emulsified oils.	Coats wax crystals in oil to prevent growth and interlacing at reduced operating temperatures.	Surface-active chemical agents reduce interfacial tensions so oil can be timely dispersed in water.	Reduces interfacial tension, allowing small bubbles to combine into larger air pockets. Latter will separate faster.	Improvers are less affected by temperature change than is oil. Example: They raise viscosity by a greater proportion at 200 F than they do at 100 F.
Typical lubricant applications and additive that may be used											
Turbines, electric motors, spindles, hydraulic and circulating systems	✓		✓		✓	✓		✓		✓	
Air compressors	✓		✓		✓			✓		✓	
Gears (hypoid, heavy-duty, worm)			✓		✓					✓	
I-c engines	✓	✓	✓	✓	✓	✓		✓		✓	✓
Soluble EP oils			✓		✓		✓		✓	✓	
Fire-resistant non-aqueous hydraulic fluids	✓		✓		✓					✓	✓
Ball- and roller-bearing greases	✓		✓		✓	✓					

ASSIGNMENT

1. Define the following terms:

   (a) Boundary lubrication

   (b) Hydrostatic lubrication

   (c) Hydrodynamic lubrication

2. List four lubricant properties that are considered in choosing the correct lubricant for a specific application.

3. List five lubricant additives stating typical applications.

4. Give four reasons why grease might be used instead of oil.

5. Give four reasons why oil might be used instead of grease.

6. What are the advantages of circulating oil system over a once through system?