UNIT-3
TRIBOLOGY IN MAINTENANCE

3.1 INTRODUCTION

Lubrication can be considered as vital part of a machine as any of the working parts. Of course the various bearings, gears and cams which make up any machine today must be carefully designed and precision made of the best materials to meet the demands of modern high speed production. But without proper lubrication, these same working parts would soon develop rapid wear and eventual failure. Then the machine would be useless as a production tool.

All of us in the plant have an important role to play in an effective lubrication programmed. The foreman and machine operator can be sure of 'getting out the goods' only if the lubrication service man has properly lubricated the machine. In turn, the lubrication service man can lubricate his machines properly only if the engineer has properly designed the machine and specified the right lubricant for it. And in turn, the maintenance mechanic depends upon proper Lubrication to keep the machines running. It is a programmed in which all of us have an important role to play.

TRIBOLOGY

Lubrication is done to minimize friction between two interacting surfaces in relative motion. Friction occurs because a solid surface never microscopically smooth. Even the best machined surface has peaks and valleys called 'roughness'. When two such surfaces come into contact, it is only the peaks on the surfaces that make actual contact. These contacts support the normal load and deform plastically and get cold welded. Depending upon the magnitude of the normal load more and more high spots or peaks come into contact and the 'real area' of contact increases in contrast to the 'apparent area', which is the geometrical area of the surfaces in contact.

This phenomenon is called adhesion. Friction is believed to be caused by this adhesion. When two such surfaces have to be moved in relation to each other, some force will be required to sheer these contacts. This force is called frictional force. We study this in the subject called TRIBOLOGY, which helps in better visualizing conceptually the problems of friction, wear and lubrication involved in relative motion between surfaces.

3.2 FRICTION:

Friction can be defined as resistance to movement between any two surfaces in contact with each other. When friction occurs in machinery, it is not so desirable. It destroys the effectiveness of the equipment through wear, heat and shortened life. We overcome this friction by doing lubrication.

KINDS OF FRICTION

Friction can be classified into two types; solid friction which may be either sliding or rolling, and fluid friction. Sliding friction occurs when two surfaces slide over each other without lubrication as in a plain bearing or between a piston and a cylinder. Rolling friction occurs when a cylindrical or spherical body rolls over another surface without lubrication as in the modern ball and roller bearings. We require less force to overcome rolling friction than sliding friction.

Hence solid friction essentially occurs when there is no lubrication. Now to compare fluid friction with solid friction, if a film of oil is introduced between the same two surfaces, the peaks and valleys are filled up by the particles of oil. When a sufficient number of these particles of oil are placed between the two surfaces to produce a thick strong film, than the peaks and valleys slide by each other without inter-loading. When such surfaces flat, curved or spherical, are kept apart by a fluid film, we have what we call fluid friction and these surfaces are said to be lubricated. Therefore, in lubrication we actually reduce friction to a minimum by substituting fluid friction for solid friction. Friction is governed by following two laws propounded by moutons:

1. The frictional force is proportional to normal loads.
2. Friction is independent of the size of bodies

Adhesive wear means damage resulting when two metallic bodies rub together without the deliberate presence of an abrasive agent.

Abrasive wear is characterized by damage to a surface by harder material introduced between two rubbing surfaces from outside. The severity of abrasive wear depends on size and angularity of abrasive particles and also the ratio between hardness of metal and the abrasive particles, more
the tendency to wear.

Fatigue wear occurs due to cyclic stresses in rolling and sliding contacts as in gears and rolling bearings. Corrosive wear occurs due to corrosion. Rusting is a well known example. The presence of moisture, oxygen availability and dusty conditions accelerate corrosive wear.

3.3 LUBRICATION

Lubrication is the reduction of friction to a minimum by replacing solid friction with fluid friction.
This is achieved by introducing between two surfaces in relative motion, an ideal film of oil or sufficient amount of grease to keep the two metal surfaces separated under the speeds and loads imposed on the bearings. The most important single factor that determines the effectiveness of the oil is the viscosity of the oil.

FUNCTIONS OF LUBRICANTS:

Lubricants are agents introduced between two surfaces in relative motion to minimize friction. Selection and application of lubricants are determined by the functions they are expected to perform. The principal functions of lubricants are to

a) Control friction
b) Control wear
c) Control temperature
d) Control corrosion
e) Remove contaminants
f) Form a seal (grease)

3.4 LUBRICANT APPLICATION METHODS

Considerable care is usually exercised in machines. Sometimes, however, less attention is paid to the consideration of method of application. As a matter of fact, the devices by which lubricant is applied, and their manner of installation contribute greatly to the efficient and economical lubrication of machinery. Therefore, this selection should be a matter of design consideration and a bit of afterthought.

The lubricating device or method selected must be economically compatible with the equipment to be lubricated from cost and maintenance point of view. In order to competently select the most Suitable lubrication method for an application, it is better to have knowledge of the physical design and basic characteristics of each device.

CHARACTERISTICS OF LUBRICATING METHODS

To evaluate a particular method for a specific application, certain characteristics should be considered. Following evaluation criteria given in Table-6 can serve as a checklist to aid in selection of lubricating devices.

CATEGORIES OF LUBRICATION METHODS

The methods for lubricating machine elements can be divided into following categories.

- Manual Devices
- Drop-feed Devices
- Splash or bath lubrication
- Ring, chain, collar oilers
- Pad - and waste-type devices
- Positive force feed lubricators
- Air oil devices
- Pressure circulating systems
- Centralized lubricating systems
- Built-in-lubrication

A. Manual Devices

Lubricating methods may require human action in one form or another. The term manual lubrication applies to methods in which the operator is directly responsible for quantity of lubricant and interval of lubrication. Although the initial cost of manual lubrication is low, the maintenance costs can be high. Reliability may be owing to considerable dependence on human action. The lubricant is quite prone in contamination.
Generally speaking, manual lubrication is satisfactory only for lightly loaded or low speed bearings, typical applications include open gears, chains, wire rope, etc.

B. Drop-feed Devices :

Drop feed devices are gravity-flow lubricators. They are employed to deliver lubricant drop-by-drop to individual bearings and other machine elements. They give the best advantage when lubricant points are readily accessible.

Their cost is relatively low. Maintenance cost depends on type of service and location. Depending on the lubricator, lubricant flow may or may not be stopped and started automatically. Automatic operation increase reliability.

Typical service applications include journal and roller bearings, gears, chains, engine guides, pumps and compressors.

C. Splash or Bath Lubrication :

This type of lubrication is commonly used for machinery having high speed moving parts. These dip into oil and splash it on to the bearings or other machine elements. The splash system requires enclosing the mechanism to be lubricated.

Initial cost of splash system depends on the expense incurred in enclosing the mechanism. Maintenance costs are low. A splash system is reliable, prevents contamination. Typical applications include internal-combustion engines, chain drives and enclosed gear sets.

D. Ring, Chain, Oilers :

These lubricators are applicable to horizontal rotating shafts. The ring or chain oiler encircles the shaft and turns freely on it. Each provides an automatic oiling system by bringing oil to the bearing clearance from the oil reservoir. Initial cost depends on housing for the bearing that must be built to contain these lubricators. Maintenance cost is usually low. Typical applications include electric motors, fans, blowers, compressors, and line shaft bearings.

E. Pad-and Waste-type Devices :

These lubricators use the oil-retaining properties of felt pads and waste packing to provide the lubricant to a bearing. Oil is lifted from the reservoir by capillary action in the wicking material. This system requires an appropriate housing, which accounts for a large initial cost. Maintenance cost generally depends on the environment in which they are used. They are generally low. This is often used for rail, road and traction motor bearings.

F. Positive Force feed Lubricators :

It consists of one or more plunger-type adjustable-stroke pumps mounted on a common reservoir. The pumps are driven from a rotating shaft through a mechanical linkage. It may have a separate drive motor. Initial cost is high, but maintenance cost is low. The lubricant is free from contamination.

Typical applications include steam cylinders, bearings for diesel and gas engines, oil-drilling rigs, etc.

G. Air-oil Devices :

Air-oil devices operate by injecting or pumping oil drop-by-drop into an air stream. The oil is drawn by the aspiratory action of compressed air passing through an orifice or control valve. The initial-cost is very high. However, maintenance costs are low and efficiency of the devices is high. These are well suited for high speed bearings, enclosed gears, slides and table ways.

H. Pressure Circulating Systems :

Pressure circulating systems employ either gravity or pumps to develop the operating pressures necessary. Generally these are designed to lubricate a number of parts on the machine. Since oil is recirculated maximum economy is possible. Pressure circulating systems are built into the machine. Therefore initial cost is high. Maintenance costs are very low.

Typical applications include steam-turbine bearings, reduction gears, steel-mill gear drives, mill bearings, paper-machine bearings and gears and internal-combustion engines.

I. Centralized Lubrication Systems :

Centralized Systems can be designed for oil or grease. A typical centralized system requires centrally located reservoir and pump, and permanently installed piping and distribution valves.

These deliver measures quantities of lubricant at desired points. It can be either operated manually or automatically.

The piping and intricate dispensing valves make initial cost very high, but maintenance costs are very low. Initial cost is offset by dependability, durability, safety and resistance of system to contamination. Centralized Systems are ideally suited for steel and paper mills, machine tools etc.

J. Built-in-Lubrication :

Built-in lubrication refers to materials or components that do not require any external lubricating device. Materials such as oil saturated porous metals, graphite materials, PTFE, nylon can rub together without a lubricant. These materials may be used for sleeve bearings, gears etc. In this category ball and roller bearings are also included which are pre-lubricated by manufacturers. These require no relubrication during their service life. Machine components have built-in lubrication are well suited for use in inaccessible locations. They can reduce maintenance costs, but should not be used indiscriminately. The various categories of lubrication systems have been very briefly discussed in the above paragraphs. There are, however, very many varieties in each finding specific applications. Depending upon the severity of the working situation of machine elements the most suitable means from cost, maintenance and efficiency point of view should be selected.

3.5 TYPES OF LUBRICANTS

Following are the commonly known types.
1. Liquid Lubricants
a) Plain mineral oil
b) Mineral oil plus additive
c) Synthetic lubricants
2. Quasi-solid Lubricants (Grease)
3. Solid Lubricants

Depending upon a typical application requirement a particular type of lubricant is chosen.

LIQUID LUBRICANTS

Liquids are generally preferred as lubricants because they can be drawn between moving parts by hydraulic action. Apart from keeping the parts separated they also act as heat carriers. In the choice of a liquid lubricant for a given application, primary consideration. Moreover effect of temperature change on viscosity should be minimum Liquid Lubricants should in general be inert toward metal surfaces and other components.

MINERAL OILS

Modern refining technology technicians have made it possible to produce lubricants of good quality from a wide variety of crude oils. Refining crude oil is the process of separating the crude oil into different fractions or cuts. These cuts are called naphtha, gasoline, kerosene, light and heavy oils and residues. Each type of crude oil gives different amount of each 'cut'. Basically crude oils are of two types namely paraffinic and naphthenic.

MINERAL OIL PLUS ADDITIVE

A refinery makes only the base lube oil stocks of different viscosities. They are unsuitable for direct consumption. Therefore, oils are mixed to attain right viscosity and additives are added to improve other qualities.

SYNTHETIC LIQUID LUBRICANTS

Synthetic liquid lubricants can be characterized as oily and neutral liquids. They are not obtained from petroleum crude oils. But they have almost similar properties as petroleum lubricants. These find application in situations where petroleum oils cannot be used. Some specific chemical classes of synthetic lubricants are Di-esters, organic-phosphate esters, silicone polymers etc.

3.6 TYPES OF LUBRICATING OILS

Each major oil company will have over 300 different industrial and automotive types in its line of oils. For simplicity following eleven classifications have been listed.

1. Spindle oils
2. Gear oils
3. General bearing oils
4. Electric motor oils
5. Steam cylinder oils
6. Turbine oils
7. Air compressor oils
8. Refrigeration compressor oils
9. Hydraulic oils
10. Cutting oils
11. Automotive oils

Each type of oil listed has certain characteristics that make it well adapted for a given application.

SPINDLE OILS

It gets its name for its use on spindles. Spindles are small rotating shafts on upright drills which have high speed and low load characteristics. The viscosity is the most important factor.

temperatures are seldom high enough to make flash point critical, nor low enough to make the pour point an important consideration.

GEAR OILS

Gear oils are of a heavier grade because of the rubbing action of the gear teeth and high pressure on teeth. Gear oil viscosity usually ranges from 60 seconds to over 150 seconds at 210 degrees F. Gear oil should have Anti-foam characteristics. Flash and pour points must be considered if temperatures that will be encountered make these points critical.

TURBINE OIL

It is one of the highest refined oils that we use. These oils should be controlled to very close tolerance in their physical properties. Flash point is very important as operating temperatures are usually higher.

AIR COMPRESSOR OILS

These have to work under very difficult conditions. Under these conditions oil comes into contact with air at high temperatures and pressures. This causes oxidation of oil. Flash point must be high to guard against fire hazard.

REFRIGERATION COMPRESSOR OILS

These are usually straight mineral oils. Flash point is not so critical. However, pour point is an important characteristic due to low temperature.

GENERAL BEARING OILS

Usually used in 'once through' systems, they go through the bearings and are wasted. These are not used in circulating systems because they do not have the ability to stand up under extended circulation and use. Viscosity is an important property speeds, loads and temperatures must be considered to make viscosity selection.

We have only covered six of these classifications of oils. But it should be enough to make us realize that the old saying oil is oil is not exactly true. There are many kinds of oils which have specific use to meet different kind of service conditions.

SOLID LUBRICANTS

A solid lubricant is a thin film of a solid interposed between two rubbing surfaces to reduce friction and wear. The need for solid lubricants has grown rapidly with advance in technology. The solid lubricant should have following characteristics:

1. Low sheer strength
2. Low hardness

3. High adhesion to substrate material
4. Continuity
5. Self-healing ability (The film should reform immediately if broken)
6. Freedom from abrasive impurities
7. Thermal stability
8. Chemical inertness

Various inorganic compounds like graphite, molybdenum disulphide, tungsten disulphide, boron nitride; and organic compounds like aluminum, zinc, sodium, lithium stearate and waxes are used as solid lubricants. Solid lubricants have found wide application where conventional petroleum oils have failed to work at extreme working conditions.

INDUSTRIAL GREASES

Our previous discussion was confined to various types of lubricating oils. There is another class of lubricants which hold just as important a place in industrial lubrication as do oils. These are greases.

A lubricating grease is a semi-solid lubricant. It is usually a mineral oil to which special soap is added to produce a plastic mixture. The soap is called thickener. Certain additives are also added as in the case of oils to impart special characteristics. Thus grease is, Oil or fluid Thickener Additives

ADVANTAGES IN USING GREASES

1. Less frequent application necessary. This results in saving in lubricant cost and maintenance cost.
2. It acts as a seal against entrance of dirt and dust.
3. Dripping and splattering is almost eliminated.
4. Less expensive seals are required for grease lubricated bearings
5. Grease ensures some lubrication even when a bearing is neglected for a long period
6. Due to clinging property of grease, chances of rusting is considerably reduced in the bearings even when the machine is idle.

COMPONENTS OF GREASE

Primary components of a grease are soaps and mineral oils. Soaps may be derived from animal or vegetable fats or fatty acids. In addition certain additives are also present. Sometimes fillers are also added to impart special characteristics.

TYPES OF GREASES

Greases are classified by the soap compound used in their manufacture. The properties of greases are influenced considerably by the type of soap compound used in making the grease. The following are the common types available.

1. Calcium base grease
2. Sodium base grease
3. Lithium base grease
4. Barium base grease

A Calcium base in grease will give the grease a smooth battery appearance. This grease is highly resistant to water. Edible fats such as palm oil or cotton seed oil hydrated lime are used to make soap. This grease requires addition of water as stabilizer. This cannot withstand a temperature above 175 degrees F. It breaks down oil and soap get separated. The separated soap particles become hard and abrasive and cause scoring of bearings.

Sodium base greases on the other hand, can be used where higher temperatures up to 250 degree F. are encountered. The sodium base grease is fibrous in structure. This enables the grease to withstand high loads on ball and roller bearings. However, sodium base grease is less resistant to water.

Barium base grease is good up to 350 degree F. and above. This grease has good water resistance. Lithium base grease is also suitable for high temperature application and has excellent water resistant properties. For low temperature also this grease is suitable.

Special greases:

To withstand very high temperatures and load conditions certain special greases are used as the soap based greases are not able to withstand such conditions. These are called non-soap base greases. Modified bentonites clay and silica gels are used with synthetic fluids. Some soap base greases are used with synthetic fluids instead of mineral oils.

Bentonite:

These greases have a base made of modified Bentonite clay. They have a very high temperature capability and they last much longer. Table-3 gives details and serviceable temperature ranges of greases using synthetic lubricants.

Additives:

As in the case of oils, additives also are added to grease to impart special characteristics. Commonly used additives are antioxidants, corrosion inhibitors, E.P.agents, rust inhibitors and tackiness additives.

CHARACTERISTICS OF GREASE

The two most vital characteristics of grease are consistency and drop point.

Consistency:

It is expressed in numbers in tenths of millimeter. Standard ASTM D217-52T test method is used to determine this property. It is called penetration test. The National Lubricating Grease Institute USA has classified grease into various classes based on their penetration readings determined from the above test. Table-4 gives the NLGI classification.

Drop Point:

It is defined as temperature at which a grease changes from quasi-solid to a liquid state under prescribed conditions of a test. ASTM D566-42 test is used to determine drop point. This is used as a qualitative indicator of resistance to heat.

Apart from the above two characteristics following characteristics are also equally important.

Oil Viscosity:

Fluidized friction characteristics of grease at high rates of shear in an antifreeze bearings depends on viscosity of oil used.

- For antifreeze bearings grease should offer minimum fluid friction. This keeps the operating temperatures low.
- For normal ambient temperatures and for all speeds, grease is made with light to medium body oil.
- Heavy bodied oils are used where high temperatures exist.

Chemical Stability:

A grease must have good oxidation resistance in antifriction bearings. Anti-friction bearings have advantage of operating for long periods without re-lubrication. It, of course, depends on operating conditions. Oxidation causes either hardening of grease or softening of grease thus rendering the bearings unlubricated. Therefore grease must have chemical stability.

Structural Stability:

Grease should have the stability to resist softening. Softening may happen due to milling and Churning in bearings.

Pump ability:

This in influenced by temperature and ability to pump to the system. This is an important property for in centralized greasing systems.

3.7 LUBRICANT ADDITIVES

The purification and manufacturing processes impact good qualities to lubricating oils. But still they cannot be used directly. They will be prone to contamination and decomposition in the exacting working conditions. Hence certain chemical compounds and other agents which are termed as additives are added to the oil. Most modern lubricant additives can be classified as follows:

1. Those designed to protect the lubricant in service by maintaining deterioration.
2. Those that protect the lubricant from harmful fuel combustion products.
3. Those which improve existing physical properties or impart new characteristics.

Use of chemical additives in lubricants is very wide. They are used in the lightest instrument and spindle oils to the thickest gear lubricants; automotive lubricants; cutting oils; and hydraulic fluids. There are over 50 characteristics of lubricating base oils which can be improved by the additives. Generally speaking the additives must have the following properties:

a) Solubility in base petroleum oil
b) Insolubility in and lack of reaction with aqueous solution.
c) Should not impart dark colour to the oil
d) Low volatility
e) Additives must be stable in blending, storage and use
f) Additives should not impart unfavorable odour.

3.8 LUBRICANT CHARACTERISTICS

SPECIFIC GRAVITY
Specific gravity is the ratio of the weight of a given volume of substance at 60 degree F. to that of water.

VISCOSITY

Viscosity is a measure of the oil's resistance to flow. The more the viscosity of the oil more will be its resistance to flow, e.g. compare water and molasses. Water is less viscous and hence flows freely. Whereas molasses, which has a high viscosity, flows sluggishly.

An ideal oil film on a bearing depends on selecting oil with the right viscosity to maintain separation of two metal surfaces. The **speed of the journal** and viscosity are closely allied in maintaining a good oil film in the bearing. The slower the journal speed, the higher viscosity or thicker oil we must use. As journal speeds are increased, a thinner of lower viscosity oil is needed.

Bearing loads must also be considered because the oil must have sufficient viscosity to maintain a good oil film to support the load.

Technically speaking, it is defined as the force required to move a plane surface of one square centimeter area over another plane surface at the rate of one centimeter per second, when the two surfaces are separated by a layer of liquid one centimeter in thickness. The unit of this force is poise and is called absolute viscosity.

Kinematic viscosity is the ratio of absolute viscosity to the specific gravity of the oil at the Temperature at which the viscosity is measured. Its unit is stokes.

For practical purposes, viscosity of petroleum oils is expressed in time in seconds taken by a given quantity of oil to flow through a standard capillary tube. It is expressed as Saybolt universal seconds at 100 degree F. or 210 degree F.

VISCOSITY INDEX

Viscosity index is an expression of effect of change of temperature on the viscosity of oils. This Change can be evaluated numerically and the result is expressed as V.I.

POUR POINT

Pour point of oil is an important quality. It is a temperature at which oil will still remain fluid. It reflects on the capability of the oil to work at low temperatures.

FLASH POINT

Flash point is the temperature at which the oil gives off sufficient vapors which can be ignited. It reflects on the capability of the oil to work at higher temperature without any fire hazard.

3.9 Degradation of lubricant

1. Why is it important to understand a fluid's mode of degradation?
2. What are the possible degradation processes at work in a wind turbine gearbox?
3. What are the variables that determine the mode of degradation?
4. How do you determine the mode of degradation?

Understanding how fluids degrade in an application is critical for establishing a condition monitoring program Identifying ways to stop fluid degradation. Condition Monitoring Program should be set up based on mode of fluid degradation Condition Monitoring is designed to monitor: Health of the fluid, health of the equipment, type and amount of contaminant we cannot adequately monitor the condition of the fluid or equipment without first understanding the mode of degradation Mode of degradation is highly dependent upon:

Oil Formulation Base Oil + Additive System

Exposure to contaminants Dirt, Moisture, Grease, Cleaners, Wear Metals, Misc.

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Types of Degradation

Property

1. Oxidation
2. Thermal Degradation
3. Wear
4. Extreme Pressure Wear
5. Dirt Contamination
6. Water
7. Air/Gas

We can determine the mode of degradation by analyzing and trending the additives and contaminants.

Property Oil Analysis Tests

1. Oxidation RULER, FTIR, AN, NMR, Vis, MPC
2. Thermal Degradation FTIR, NMR
3. Wear FTIR, NMR, RULER
4. Extreme Pressure Wear FTIR, Viscosity (Shearing)
5. Dirt Contamination Metals, Particle Count, MPC
6. Water KF, FTIR
7. Air/Gas DGA

We can determine the mode of degradation by analyzing and trending the additives and contaminants. Drawing Correlations to Modes of Degradation Statistical methods can help determine correlations:

•Oil Type ---What physical and chemical properties of the oil change over time based on the lubricant formulation?

•Service Time --- What is the relationship between changes in oil properties and wear metals over time?

•Application (OEM) --- How do oil properties and wear rates change depending upon gear box manufacturer?

•Operating Environment --- How do oil properties and wear rates change depending upon operating environment?

3.10 Mechanical Seal and packing

One of the vital parts of any machine in which gases are compressed or expanded is the seal around the reciprocating rod, through which power is put into or taken from the cylinder. This seal is called packing. The word packing comes from the method of sealing in pressure where the stuffing box around a pump or compressor shaft is “packed” with a soft material. The type of seal we will discuss is a mechanical one. It has been called by various names generally indicative of some period of its history or descriptive of some function:”Metallic Packing” from the earliest days when the parts were all metallic; “Floating Packing” by virtue of the fact that the sealing rings are free to move with lateral movement of the piston rod; “Segmental Packing” from the segmented construction of the rings; “Mechanical Packing” since it is a precision machined part which functions on principles of mechanics.

Mechanical packing is made of many materials and sizes, depending upon the specific application involved, and may be utilized to seal pressures ranging from a vacuum to pressures currently as high as 50,000 psi, with sealing rings of all the bearing metals and many plastics. The variables of type of gas, suction and discharge pressures, temperature, speed and length of stroke, lubrication, rod material, and dimensional limitations must be taken into account by the packing designer and will be discussed in detail later. A set of packing may vary in cost from a few dollars to several thousand, depending on construction and material. It is one of the most critical parts involved in the operation of a compressor. Failure of the packing to operate satisfactorily can prove to be very expensive in terms of plant down time and loss of output.

Purpose of packing

The purpose of packing is to prevent leakage of a gas between a cylinder and a piston rod. Is it necessary to seal this clearance when compressing a harmless or inexpensive gas?

Components of mechanical packing
Packing set

The packing unit is made up basically of two parts: the packing case and the packing rings. The case is a series of retainer’s gasket on the surface of the contact of the cylinder, centered on the piston rod by a stuffing box and held in place by a flange bolted to the end of the cylinder. The number of retainers and consequently the number of sealing elements is determined by the operating conditions of the compressor, and by standards established by the individual packing manufacturers for the various conditions. These will vary in number from two or three retainers for pressures up to 200 psi to seven or eight for the highest pressures in the industrial reciprocating compressors. Until a few years ago, pickings with twelve to fifteen sealing elements were not uncommon. However, as relative speed increased and the stroke of the compressor was reduced, it was found that much was to be gained by decreasing the length of the packing necessitating a reduction in the number of sealing elements. This was achieved basically through the ability of the manufacturer to obtain finer finishes on all the sealing parts on a production basis.

How a packing works

As previously described, a packing set consists of a series of sealing units. Mechanical packing is not bottle tight but the amount of leakage is an extremely small fraction of one percent of the capacity of the machine and usually within tolerable limits. If, due to the toxicity of the gas or danger of explosion or corrosion, any leakage exists, it may be vented to a safe place. The fact that the individual rings will leak slightly is the reason for the series of rings. It is through the series of rings that the pressure is broken down from discharge to atmosphere. You will recall that the volume of leakage will increase with an increase in the differential pressure across the rings and will also increase with the time that the differential pressure exists; in other words, the higher the differential pressure and the longer the differential exists, the greater will be the volume of leakage. In normal compressor operation the minimum pressure which will be existent in the cylinder, and consequently to which the packing will be subject, will be equal to the suction pressure. The differential pressure across the packing will fluctuate between suction and Discharge pressure on each compression stroke, with the full discharge pressure existing only instantaneously on each stroke. The problem then is one of sealing a minimum of the differential between suction pressure and atmospheric pressure for a short period of each stroke. These conditions of time and pressure differential give three “normal” patterns of pressure breakdown across a set of packing.

3.11 Repair Method of basic Machine Elements:-

Repair of bed

The bed is engineered and constructed in such a way as to give the best rigidity for the machining operations that the lathe will be subject to during normal operations. Mechanize is actually two things. First, it’s a patented process for casting metals to exact and well-defined engineering specifications. Second, it’s a series of superior engineering cast irons including nodular graphite irons, flake graphite irons and white cast irons.

The dense, fine grain structure of Mechanize metal which assures casting solidity and consistent physical properties relate the carbide stability of the molten metal, both before and after processing to the casting section

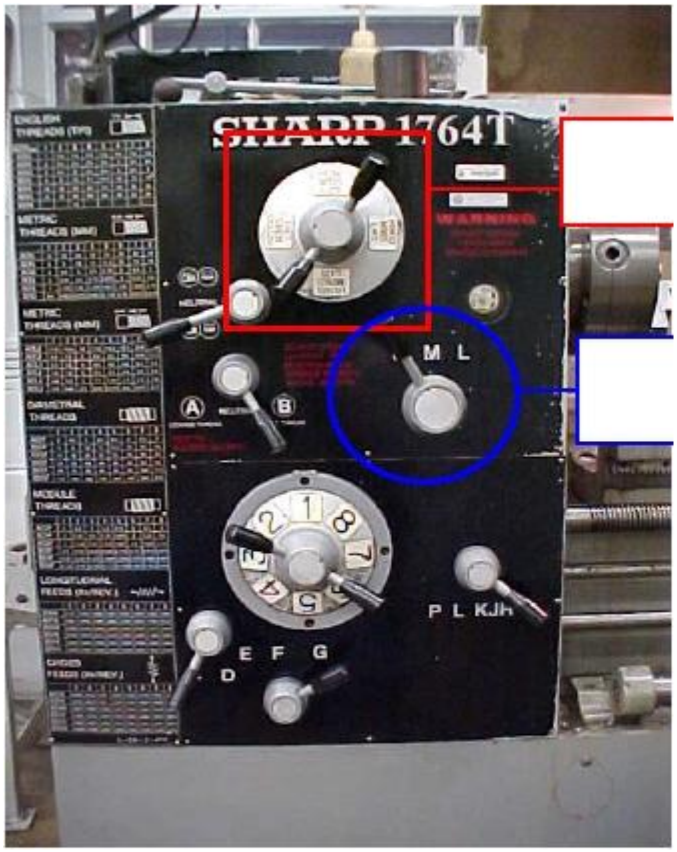
The bed and ways support the remainder of the lathes parts and hold the machines machining accuracy to tight tolerances over extended periods of time so long as the lathe has been properly setup or installed on its foundation.

The “ways” of the lathe are an integral part of the lathe bed and are precision ground to exacting tolerances to allow for the precision machining of a work piece in the longitudinal direction (using the carriage feed). The ways also locate the tailstocks centerline in line with the headstocks centerline throughout the tailstocks travel on the ways.

Repair of gears

Speed Change Gears

The different spindle speeds are selected by turning the spindle speed selector to the desired position and moving the speed selector lever to the High, Medium or Low range as needed for the desired spindle RPM .

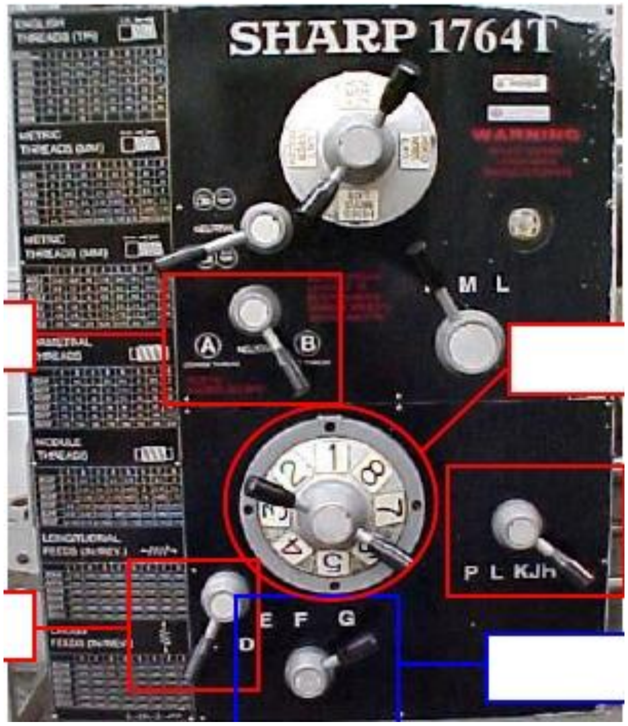


Shifting of spindle speed gears should be done with the spindle stopped and either manually turning the chuck by hand or using the control panel "JOG" button while moving the speed dial and/or speed range (high, medium and low) lever.

Efforts to change speeds with the spindle in motion can result in catastrophic damage to the spindle speed gears or at the very least, chipped or otherwise damaged gear teeth that may transmit the imperfection into the machining surfaces of the work piece during normal machining operations

Feed pitch change of gear

The lathe is equipped with 48 different rates of feed selections for turning, facing and boring operations. By placing the gear selection levers in a certain configuration or position the operator Can change the rate at which the carriage or cross slide will move with each revolution of the spindle based on the feed charts located on the headstock



For turning, facing and boring operations the C-D Lever is always in the "D" position and the "C" position is used only for cutting Metric or Module threads. The A-B Lever selects heavy or light feeds when performing turning, facing or boring operations while it selects coarse or fine threads during threading operations with "A" equaling heavy or coarse and "B" equaling light or fine. The feed rate for "longitudinal" (carriage) feeds is different from those in the cross feed (cross slide) direction. The finest longitudinal feed is 0.002 (two-thousandths of an inch) per spindle revolution while the finest cross feed is 0.0005 (½ thousandth of an inch) per spindle revolution. The different feed rates are a result of the final gearing in the carriage apron and are necessary because the surface speed of the work piece decreases as the tool is fed towards the center of the material.

Lever Position	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
ADEH	**0.1122**	**0.0998**	**0.0838**	**0.0816**	**0.0781**	**0.0748**	**0.0690**	**0.0641**
ADFH	**0.0561**	**0.0499**	**0.0445**	**0.0408**	**0.0390**	**0.0374**	**0.0345**	**0.0320**
ADGH	**0.0280**	**0.0249**	**0.0224**	**0.0204**	**0.0195**	**0.0187**	**0.0172**	**0.0160**
BDEH	**0.0140**	**0.0124**	**0.0112**	**0.0102**	**0.0097**	**0.0093**	**0.0086**	**0.0080**
BDFH	**0.0070**	**0.0062**	**0.0056**	**0.0051**	**0.0048**	**0.0046**	**0.0043**	**0.0040**
BDGH	**0.0035**	**0.0031**	**0.0028**	**0.0025**	**0.0024**	**0.0023**	**0.0021**	**0.0020**

The feed selections for the carriage (longitudinal) feed are shown in the chart above and reflect the different positions of the feed levers and feed dial. You will notice that the P-L-KJH lever is always in the "KJH" or "H" position when turning, facing or boring a work piece. This is reflective of the fact that the "K and "J" positions are for threading only with the designation "K" having only one thread pitch (threads per inch) selection of 19-threads per inch when machining "English" threads.

Repair of Cross slide

The cross slide is used for manual positioning (along with manual movement of the carriage) of a tool in the tool holder for any machining operation and it may also be used for manual facing of a work piece.

The cross slide is also used in automatic feed facing of a work piece and/or when used in conjunction with a taper attachment. Manual use of the cross slide is accomplished by turning the manual hand wheel either clockwise, which moves the cross slide "in" towards the work piece or by turning the hand wheel counter clockwise which moves the cross slide "out" or away from the work piece.

Automatic feeding of the cross slide is accomplished by pulling out on the carriage/cross slide Push-pull knob and pushing down on the automatic feed lever to engage the feed gear. "In" or "out" feed is accomplished by positioning the forward/reverse push-pull knob in the desired direction of feed.

3.12 BEARINGS AND THEIR LUBRICATION

Bearings are one of the most vital parts in any rotating machinery. To a large extent proper working of a machine depends on the type of bearing used and their lubrication and application at various speeds. Rotating speeds vary from less than 100 rpm for large bearings, such as found in calendars and those used on tool room grinders.

Bearing is a support for a moving part. It consists of a hole in a block inside which a shaft can rotate. The part of the shaft which rests on the block is called a journal. The function of a bearing is to hold the moving parts in the proper space relating to other moving or stationary parts.

We know that friction is of two types namely, sliding friction and rolling friction. Bearings are also of two types namely, plain or friction bearing and anti-friction bearing. Ball bearings and roller bearings are called anti-friction bearings.

PLAIN BEARINGS

Plain bearings use in sliding friction. In these bearings one surface moves against another
with a sliding motion. Plain bearings are of three categories:

a) **Journal Bearings** are used to support a rotating shaft. The load on the bearing acts at right angles to the axis of the shaft. There are four variations in the design of journal bearings:
i) Solid bearings, usually referred to as 'sleeve bearings' or 'bushings'.
ii) Half bearings are used when the load on the shaft is always in one direction. A good example is on the ordinary rail road car journal.
iii) Split bearings are used when the shaft cannot be easily pulled out of the bearings. The shaft may have a flange that is too big to be pulled through the bearing, or, the shaft may be so big and heavy that it is easier to move the bearing than the shaft.
iv) Multi-part bearings are used for same reason a split bearing is used - so it will be easy to make bearing changes. The multi split allows to make adjustments of the bearing to allow for wear and to maintain the necessary clearances.

b) Guide Bearings : It is used to support a shaft or other machine part that is moving in a straight line. The movement to be guided is usually cross head on a steam engine and on some air compressors.

c) Thrust Bearings: They are used to support a vertical rotating shaft and to keep a horizontal rotating shaft from moving end ways along the shaft.
Example – automobile cooling fan, aircraft engine, worm and hypoid gears.

In each of the above types the bearing must meet certain requirements. They are

- Support the load
- Resist wear
- Resist deformation
- Reduce friction
- Accommodate a lubricant

BEARING MATERIAL REQUIREMENTS:

For satisfactory performance a bearing material should have

i) **Compressive strength** to withstand loads applied to it. It must also resist deformation.
ii) **Low co-efficient of friction.**
iii**) Durability** - the bearing should have sufficient strength to withstand repeated stresses.
iv) **Embed ability** - The bearing must be able to assimilate small abrasive particles without causing damage to bearing surface.
v) **Workability** - The metal must be easy to work and to machine.
vi) **High Heat Transfer rate -** Bearing material should be sufficiently heat conductive to dissipate the heat.
vii) **Corrosion resistance.**

BEARING MATERIALS

There is no limit to the number of materials that have been used for the bearings. Arbitrarily they can be broken down into several classes:

1. Ferrous metals
2. Bronze and non-ferrous metals
3. Babbitt and white metals
4. Alloy bearings
5. Miscellaneous metallic bearings
6. Miscellaneous non-metallic bearings

SIZE OF BEARINGS

The diameter of the hole is kept slightly larger than the journal or shaft. The difference between the size of the shaft and diameter of the bearing is called clearance. The clearance helps in:

1. Rotation of the shaft with ease
2. To take up thermal expansion
3. To take up the defection or unevenness
4. Providing space for oil and to permit assembly.

Normally clearance is equal to .001" per inch diameter of the shaft plus .002". For example a 3" diameter shaft should have clearance equal to 3x.001" + .002" = .005". This may be taken as a guide. It can be less for precision spindle bearings and can be considerably more for rough duty.

GROOVING OF PLAIN BEARINGS

Grooving of plain bearings is an important design factor. These are provided as a reserve or lubricant. These can be used for either oil or grease depending on requirement of the bearings. A groove is providing for the following:

i) To aid in distribution of oil to entire rubbing surface
ii) To provide a reserve of oil within the bearing
iii) To provide enough flow of oil for adequate cooling effect

A faulty grooving way makes good lubrication impossible. Therefore correct design and placement of grooves is important to proper lubrication of bearing. Factors to be considered are location of pressure areas in the bearing, size of the grooves etc. The location of grooves is very important. The oil must be conducted from low pressure area to high pressure area. In a one piece journal bearing, a longitudinal groove cut at the top, and extending through the oil inlet hole to near each end will provide good distribution of lubricant.

In a two-part bearing, proper oil distribution can be obtained by providing longitudinal groove or chamfer on each side of the bearing. Both sides are chamfered as it is necessary to provide for rotation in both directions. For grooving of vertical bearings, the oil inlet should be placed near the top of bearing. This aids gravity distribution of oil.

Complicated grooving should be avoided. They are neither necessary nor desirable. In many cases they are harmful to good lubrication. Complicated grooves may seriously reduce the supporting area and effectiveness of oil film.

DESIGN OF GROOVES

When cutting oil grooves, we should always use a round nose tool. All edges should be chamfered in the direction of rotation to allow the lubricant to be drawn out of the groove by rotating shaft. Sharp edges of grooves should be scrapped round and smooth. Sharp edges tend to act as scrappers and wipe off the lubricant from the shaft.

Dimensions of oil grooves vary according to the type of bearing. The length of groove is determined by the length of the bearing. Cutting grooves too close to the ends of the bearings will result in unnecessary oil leakage. The ratio between width and depth of the groove is usually 2 to 4.

LUBRICATION OF PLAIN BEARINGS

Considered purely from lubrication point of view, oil can hardly be excelled. Nevertheless there are a great many instance in which for practical reasons grease offers certain advantages over oil. Grease can stay put longer and serve some extreme conditions. Plain bearings are relatively leaky and require frequent application of grease. Correct grease will maintain thick film for maximum length of time. It is important that the grease should only be of correct consistency but also of adequate load carrying ability. Grease lubricated plain bearings are generally lubricated by means of pressure guns or grease cups.

ANTI-FRICTION BEARINGS

The anti-friction bearings are so called due to the fact that these utilize rolling friction of rollers or balls instead of sliding friction as in the case of plain bearings. Anti-friction bearings have much less friction during starting as compared to plain bearings.

The essential parts of such a bearing include a stationery race a rotating race, and rolling elements that separate the raced while following free motion of the rotating race under load. The rolling elements can be carefully matched balls, or may be cylindrical, tapered, spherical or concave rollers. Broadly speaking anti-friction bearings are of three classes:

1. Ball bearing
2. Roller bearing
3. Needle bearing

Within each class various types are available. For example in Ball bearing class following types are available:
a. Deep groove ball bearing
b. Angular contact ball bearing
c. Double row ball bearing
d. Self-aligning ball bearing
e. Ball thrust bearing

In roller bearing class following various types is available:

a) Cylindrical roller bearing
b) Tapered roller bearing
c) Self-aligning roller bearing
d) Concave roller self aligning bearing

Needle bearings can be considered as a type of roller bearing. These are used to carry heavy radial loads when radial bearing space is severely limited.

BEARING SIZES

The sizes of an anti-friction bearing generally refers to the diameter of its inner race namely to its bore. With any given bore, a given type of bearing may have smaller or larger outer diameters, narrower or wider race ways, and smaller or larger rolling elements. It depends on the duty it has to perform.

BEARING MATERIALS

The operating conditions in which rolling element bearings work require the use of materials which can withstand high compressive stresses. These bearings are made of special alloy steels, carefully heat-treated to give them a required degree of hardness and load carrying ability.

Both case hardening and through hardening steel bearings are used. Through hardening is extensively used in ball bearings. Depending on bearing type, size and material, the hardness of balls, rollers and race falls within the range of 58 to 66 Rockwell C.

RADIAL INTERNAL CLEARANCE

Radial internal clearance is the space between the ball, or roller, and the rolling tracks in the inner and out rings. This clearance permits a radial displacement between the inner and outer rings of the ball and roller bearings. Radial clearance must exist in free bearing because:

a) The interference fits of the rings result in expansion of inner ring and contraction of the outer ring.
b) Differential expansions occur when the inner ring operates at a higher temperature than the outer ring.
c) The ability of ball bearings to handle thrust loading is in terms of radial internal clearance.
d)There are some machining inaccuracies in the shaft and housing settings.

Following four grades of radial internal clearance are available

Group 2	:	0 smallest clearance
Normal Group	:	00 Normal clearances
Group 3	:	000 loose clearance
Group 4	:	0000 longest clearance

Antifriction Bearing Lubrication

Lubrication requirements of rolling - element bearings are less critical than or plain bearings. There are, however, certain sources of friction which might cause immediate failures if bearing were to run without lubricants. These sources include

a) Slipping between rolling elements and race ways
b) Rubbing between rolling elements and their separators
c) Rubbing between adjacent needles or rollers.
While areas of sliding friction require positive lubrication, the critical lubrication requirement is in providing adequate lubrication in heavily loaded contact areas.

LUBRICATION PRACTICES

Both oils and greases are extremely used for all types of rolling elements over a wide range of speeds and operating temperatures. Oil, because of its fluidity, has advantages over grease in its ability to provide more positive lubrication, flush away contaminants and remove heat from heavily loaded bearings. Grease, however, is extensively used as it provides more effective sealing against dirt and contaminants.

Speed and load are primary factors on the basis of which lubricant is selected. Emphasis is also laid on operating temperature and other conditions.

1. Oil Lubrication:

Except for a few special requirements, petroleum oils satisfy most operating conditions.
For severe duty applications of roller bearings exposed to high temperature, it is customary to use heavier oils. The viscosity range for such applications will vary from 50 to 175 SSU at 210 degree F. Oil circulating systems are commonly used to carry away heat from bearings.

2. Grease Lubrication:

Grease lubrication has many advantages for rolling bearings. Foremost of these are simplicity of housing and sealing designs, decreased attention from republication and maintenance, and its overall economy. The major limitation on grease lubrication is high speed application. It is not employed for speed factors (bore in MM x rpm) above 2000,000. For effective results, grease selection must be based on specific application.
Moderate temperature: General purpose greases are used for operating temperature range 20 to 200 degree F. Greases for these applications are made with petroleum oils having a viscosity range of about 200 degree to 500 SSU at 100 deg. F. They are classified according to the type of thickening agent.

Low temperature greases are based on synthetic fluids mostly. For example di-ester, polyesters, silicones are usually used for operation at temperatures of 65 to 100 deg. F. Grease composed of silicon and various thickness are suitable for temperatures of 100 to 450 degree F.

High temperature greases are made with petroleum oils of high viscosity (up to 3000 SSU at 100 degree F). In general use of petroleum greases in rolling bearings is limited temperatures below 300 degree F. For temperatures much in excess of 300 degree F., the choice is largely limited to silicon fluid greases. Majority of such greases are thickened with lithium soap.

The majority of ball and roller bearings operating under conditions of moderate load and speed may be lubricated satisfactorily with NLGI No.2 Grade greases made with oils having viscosity 200 to 500 SSU at 100 degree F. For heavily loaded and high temperature applications, greases made with oil viscosities up to 3000 SSU at 100 degree F have been recommended. Higher viscosities are usually recommended for roller bearings than for ball bearings. for high speed application at a speed factor of 150,000 to 200,000 NLGI No. 3 and No.4 grade greases have been used successfully. These are made with oils of 200 to 500 SSU at 100 degree F.

On an overall basis, following factors must be taken into consideration for bearing lubrication:
1. Speed
2. Temperature
3. Bearing Loads
4. Surrounding conditions.

Lubrication is not a cure-all for all bearing troubles. It must, however, be understood that proper lubrication goes a long way in extending the operating life of bearings.

REVIEW QUESTION

Q.1. Explain the term tribology in maintenance with complete example.

Q.2. Give the friction wear and lubrication with wear mechanism.

Q.3. Explain the types of lubrication mechanism and lubrication process.

Q.4. Write the short nots on types of lubricants and lubricating oil.

Q.5. Explain the additives which are used in lubricating oil.

Q.6. Explain the degradation of lubricants.

Q.7. Give the repair methods of basic machine elements.

Q.8. Explain the bearing lubrication and their failure analysis.