Lubrication and Lubricants

Lubrication

Lubrication can be defined as the application of some materials between two objects moving relative to each other to allow smooth operation as much as necessary. Either oil or grease is used for rolling bearings to prevent noise, wear and tear, and heat from being generated from their rolling and sliding movements, and in some special cases, solid lubricants are occasionally used.

The amounts and kinds of lubricants for rolling bearings are determined depending on operation speed, temperature, and surrounding condition, and so on. Because lubricants have spent their service-life or polluted with foreign materials, they cannot serve their function well hence they have to be periodically replaced or oiled.

Purpose of Lubrication

The main purposes of lubrication are as follows:

i. To prevent wear and premature fatigue by forming the lubrication film on the surface of load transferring parts to prevent contacts between metals.

ii. To enhance the favorable driving characteristics, such as low noise or friction.

iii. To prevent overheating of bearings and to prevent lubricants deterioration by radiating the generated heat to outside. It works particularly well if the circulation lubrication method is adopted.

iv. To prevent foreign material penetration, rust, and corrosion.

Lubrication Methods

For bearing lubrications, either grease or oil is used. It is important to choose the appropriate lubrication method that suits bearing operating conditions and purpose for the bearing to perform well.

Oil lubrication is generally better than grease lubrication in many respects, but grease lubrication is also widely used, because they have merits in that bearings have the available inside spaces for grease and that it is comparatively quite simple to use them.

Grease Lubrication

Lubricating Grease

Grease can be defined as the lubricant of solid or semi-solid state that contains the thickener and some grease contain various special ingredients. Because various kinds of greases have their own distinct characteristics, and sometimes even the same kind of greases produce quite different performance results, one has to be careful when selecting the greases.

(1) Base Oil

Base oil in the grease is the main ingredient which actually provides lubricating function, and it forms 80 to 90% of grease. So, it is important to select the right kind of base oil and its viscosity. There are two main types of base oil, mineral base oils and compound base oils. Mineral oils from low to high viscosity are widely used. Generally, the mineral oils with higher viscosity are used for the locations requiring the lubrications of high load, low speed, and high temperature, and the ones with lower viscosity for the locations requiring the lubrications of low load, low speed, and low temperatures. Compound base oils are generally very expensive and used for the locations requiring the lubrications of extremely high or low temperatures, or wide temperature ranges, and fast speed and high precision. Compound base oils of mainly ester, poly--olefine, or silicon series are generally used, but the use of fluorine compound oils are increasing nowadays.

(2) Thickener

Thickener is one of the most important elements in deciding the properties of the grease, and the thickness of grease depends on how much thickener is mixed in the grease. There are mainly three kinds of thickeners, namely, metal soap, non-organic non-soap, and organic non-soap, but the metal soap thickeners are mostly used, and the non-organic non-soap thickeners are generally used only for the special cases, such as operation in high temperature.

Generally speaking, the grease with high dropping point can be used in high temperatures, and the water-resistance of grease depends on that of thickener. Also for the bearings that come in contact with water or are operated under the high humidity level, the Na soap grease or the grease that contains Na soap cannot be used, because they deteriorate quickly when in contact with the water or moisture.

(3) Additives

Various kinds of additives are used to enhance the grease performance and to meet the customers' demands for different functions. These additives enhance the physical or chemical properties of grease, and/or minimize the wear, corrosion, or rust to the lubricated metals. There are various kinds of additives used for prevention of oxidization, wear and tear, or rust. The appropriate grease containing right kind of additives to the applied location has to be used.

(4) Worked Penetration

Worked penetration is used to represent the hardness of grease, and it is shown as the penetrated depth(1/10mm) to grease by the pendulum of specified weight, and the greater the value is, the softer the grease is.

Polymer Grease

Polymer grease of hardened lubricant mixed with polyamid is generally used, and it allows to supply the grease for a long period. It is widely used for the bearings to which the strong centrifugal force is applied, such as the ones in wire stranding machines or compressors, or to which leaking and pollution to the environment or insufficient lubrication is easy to happen.

Life Span of Grease

The life span of grease is a period from the start of bearing operation to bearing failure due to its insufficient lubricating action. The life span of grease with 10% of bearing failure possibility is denoted by F10. The F10 Life Span Curves can be obtained by laboratory experiments set up close to the real operation situations. In most cases, because users do not know the values of F10, the lubrication interval, tf, is recommended as the minimum value for the life span of the standard grease. Refilling interval is set considerably shorter than the lubrication interval, so as to provide stability. Reliability can be increased sufficiently even for the greases barely meeting the minimum requirements, if lubricated in accordance to specification.

Oil Lubrication

Lubricants

Lubricants can be largely divided into two groups, namely mineral oil base lubricants and synthetic lubricants.

When selecting a lubricant, its viscosity is one of the most important factors to be considered. If its viscosity is too low at its operating temperature, oil film cannot be sufficiently formed, causing abrasion and/or burning-and-sticking. And, if it is too high, its viscosity resistance becomes higher, causing temperature/friction rise and subsequent abnormal power loss. In general, lubricants with low viscosity are used when it runs at high speed and low load, and ones with high viscosity when at low speed and high load. Lubricants should be selected in accordance with viscosity specified by ISO, and its viscosity index can be used conveniently for references. Although it depends on viscosity indices, its viscosity gets reduced by half whenever the temperature of lubricant increases by 10.

Oil Lubrication Methods

(1) Oil Sump Lubrication

It is the most generally used lubrication method, especially for low or medium speed operations. Oil surface should be, in principle, placed at the center of lowest rolling element, and it is better to be able to confirm the location of oil surface by using the oil gauge.

(2) Drip Feed Lubrication

This method is widely used for small bearings that operate at a relatively high speed, and oil supply is controlled by adjusting the volume of oil drip.

(3) Throwaway Lubrication
This is a method that utilizes gear or circulation ring to supply oil to bearings. It is widely used for automotive transmissions or gears.
(4) Circulation Lubrication
It is widely used when it is necessary to cool the bearing parts that revolve at a high speed or that with high surrounding temperature. Oil is fed through feed pipe and recovered through recovery pipe, which is cooled down and re-fed again. The diameter of recovery pipe should be bigger than that of feed pipe, so as to prevent back pressure from occurring to the oil inside a bearing.
(5) Jet lubrication
It is widely used for high speed revolution bearings and oil is jet-sprayed through one or several nozzles under constant pressure into the inside of a bearing. In general, jet stream speed should be faster than 1/5 of circumferential speed of inner ring outer surface because air wall formed by surrounding air revolving with bearing tends to weaken the jet stream. Provided that total volume of lubricant is same, the more the number of nozzles are, the smoother and the greater the cooling effect is.
(6) Spray Lubrication
Spray lubrication is a method that vaporizes the lubricant by blowing in the air to be sprayed into bearing. It has following merits.
- Due to small volume of lubricant required, its churning resistance gets smaller, which in return makes it suitable for high speed revolution bearings.
- Because it minimizes volume of discharged lubricant, the pollution to the equipment can be also kept to the minimum.
- Because fresh lubricant is fed all the time, bearing life can be extended. Therefore, it is widely used for various machining.

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, is called lubrication.

Function of Lubricants:
(1) 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
(2) It reduces expansion of metal due to frictional heat and destruction of material
(3) It acts as coolant of metal due to heat transfer media
(4) It avoids unsmooth relative motion
(5) It reduces maintenance cost
(6) It also reduces power loss in internal combustion engines

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
(a) Thick-Film lubrication:
In this, moving/sliding surfaces are separated from each other by a thick film of fluid, so that direct surface to surface contact and 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.

(b) 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 tricresylphosphate). 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;

(a) Liquid lubricants or Lubricating Oils, (b) Semi-solid lubricants or Greases and

(c) 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: (1) high boiling point, (2) low freezing point, (3) adequate viscosity for proper functioning in service, (4) high resistance to oxidation and heat, (5) non-corrosive properties and (6) stability to decomposition at the operating temperatures.

(i) 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.

(ii) 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.

(iii) 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.

(b) 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 temperature.

(c) 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 nonvolatile 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 up to 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 Vander 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 inter-laminar attraction helps these layers to slide over one another easily. It is stable up to a temperature of 400° C.

Properties of Lubricants:

(1) Viscosity (2) Flash Point and Fire Point (3) Cloud Point and Pour Point (4) Aniline Point and (5) 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 lubricating oil should not affect 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.

Additives

The additive content in lubricating oils ranges from just a few parts per million to several percentage points and, depending on the function that these products have to carry out, they may be classed as:

• Substances intended to improve the intrinsic characteristics of the base oils (viscosity index modifiers and pour point improvers).

• Lubricant protective substances (antioxidants).

• Substances giving new properties and protecting the metal surfaces of engines (detergents, dispersants, friction modifiers, anti-wear/Extreme Pressure (EP) additives, rust and corrosion inhibitors).

The additives added to improve lubricating oils include;

Viscosity index modifiers
Viscosity is the main physical property of a lubricant and is a measure of the intermolecular interactions of the oil and hence of the resistance to flow. As temperature increases the viscosity of the lubricant tends to diminish also causing a decrease in the thickness of the lubricating film between parts in relative motion. Viscosity Index Improvers (VII), or Viscosity Modifiers (VM) influence the viscosity-temperature trend, slowing down the diminution in viscosity as temperature increases thanks to the conformation variations that their structure undergoes as a result of the temperature.
VIIs are polymers with a variable molecular weight belonging to the following main categories:
• Hydrogenated ethylene-propylene copolymers (also called OCP, Olefin Co-Polymers).
• Hydrogenated polyisoprenes which may be linear, partly branched or star-shaped.
• Polymetacrylates (PMA) of long-chain alcohols variable from C12 to C18, linear and/or partly branched.
• Hydrogenated styrene-isoprene copolymers, which may be linear, partly branched or star-shaped.
• Polyisobutenes (PIB).
At a low temperature, these polymers have a closely-knit structure which minimizes interactions with the lubricant base; as temperature increases, the polymer increases its interactions with the base, extending its chains and expanding, countering the decrease in viscosity of the base. In the production of VMs, control of the molecular weight and its distribution represents a critical element as these parameters regulate two important characteristics of the polymer, i.e. its thickening power and its mechanical shear stability.

Pour point improvers
These additives (Pour Point Depressants, PPD) improve the pour-point characteristics of the lubricant at a low temperature. The main types of these are polymethacrylates, ethylene-vinyl acetate copolymers and polyfumarates.
The effect of PPDs depends largely on the characteristics of the bases used and on their concentration. Normally, the action of these additives is more effective compared to fluid bases (SN 80, SN 150). Each class of PPD has a limit to its effectiveness; above a certain percentage the effect on the pour point ceases (and in certain cases it could worsen) and the thickening effect starts to make itself felt. The typical treatment percentages vary between 0.1 and 1%.

Antioxidants
Oxidation is the result of the interaction of the components of the lubricant with oxygen at the working temperatures of the engine. It is the chief cause of the degradation of oil and leads to the formation of acid species which gradually increase in molecular weight, giving rise to dirt and sludges which lead to an increase in the viscosity of the lubricant and form deposits in the cold areas of the engine. The oxidative degradation of the lubricant occurs due to a complex series of radical chain reactions, which can be acted upon by special antioxidant additives or oxidation inhibitors. These additives on the one hand interrupt the chemical reactions responsible for the processes mentioned, and on the other hand decompose the first degradation products preventing any further evolution towards more harmful species.
The main types of this class of substances are: alkylated aromatic amines, sterically hindered phenols, zinc dialkyl dithiophosphates, and derivatives of dialkyl dithiocarbamic acid. The amines and the hindered phenols act as radical scavengers, transforming the reactive peroxides into inactive species. The zinc dithiophosphates, apart from acting with these mechanisms, decompose the hydroperoxides (ROOH) heterolithically and deactivate them.

Detergents and dispersants
These are two of the most important categories of additives to engine oils and their function is to keep the engine clean. This aim is pursued by trying to reduce the formation of deposits and to keep the insoluble substances produced by them in suspension, hindering their further aggregation and adhesion to the hot/cold metal surfaces.

Metallic detergents: These serve to neutralize the acid products of combustion (organic acids and sulphur oxides), to reduce sludges and deposits on the pistons and to prevent problems for the piston rings under severe temperature conditions. Generally, they consist of colloidal dispersions in carbonaceous lubricant bases of alkaline or alkaline-earth metals, stabilized by an adsorbed layer of surfactant molecules. The carbonaceous nucleus, typically amorphous, represents the base reserve necessary to neutralize the acid compounds, whereas the surfactant layer consists of oleophilous chain acid salts (soap) long enough to ensure the stability of the colloid. The main chemical classes of metal detergents usually employed are: sulphonates, sulphophenates and salicylates. The value of the basicity number (BN) determines the neutralizing capacities of the additive while the soap content determines its effective detergent action.

Detergents are classified as neutral (BN_25) or supra basic (BN_25) according to their neutralizing ability. For heavy-duty vehicles, detergents having a base of alkaline-earth metals are used, above all those with a calcium base.

Dispersants: These additives are fundamental for purposes of performance as they control the state of aggregation of sludge and, in diesel engines, of soot; in the lubricant they account for more than 50% of the quantity of additives.

Dispersants, too, consist of amphiphilic molecules in which the lipophilic portion usually consists of polyolefinic chains (generally polyisobutene) with a molecular weight that varies between 700 and 3,000, while the polar group is, in general, the derivative of a polyamine or of a polyol. The bond between these two parts of the final molecule is obtained by means of different chemical reactions. The most important classes of dispersants are: succinimides, succinic esters, alkylphenolamine (Mannich bases), and polymeric dispersants. Of them all, the succinimides are probably the most important class and the one produced in the largest volumes. They are prepared in two stages: the first consists of functionalizing the chain of an alkyl oligomer (polyolefin, preferably polyisobutene) with maleic anhydride to produce a polyisobutylene succinanhydride (PIBSA), while in the second stage the PIBSA is converted into the final polyisobutylene succinimide (PIBSI) causing it to react with an N-amino-polyalkylamine (for example hexaethylene hepta-amine, HEHA; tetraethylene penta-amine, TEPA, etc.).

The succinic esters used as dispersants for lubricants for motor transport vehicles are products formed by esterifying a succinic derivative of a polyolefin (analogous to those used for succinimides) with mono- or poly-alcohols (for example pentaerythritol), so as to produce dispersants having molecular weights in general of the same order of magnitude as those of succinimides. Alkylphenolamines are polyisobutylenic phenols (or polyalkyl-substitutes) made to react with polyalkyleneamine by means of formaldehyde, through the Mannich reaction.

Friction modifiers

These additives are chemical species able to influence the friction coefficient under boundary lubrication conditions. They may consist of very long amphiphilic organic molecules or of metal-organic compounds (generally with a molybdenum base). The reduction of the friction coefficient of the surfaces takes place by means of the formation of an extremely smooth film of molecules over them.

Anti-wear/EP additives

These are additives mainly used for reducing wear under boundary lubrication conditions. Under conditions of medium-to-high or extreme pressure (EP), they react with the metal surfaces forming protective tribo-chemical layers. In engine oils, they perform essentially anti-wear functions. The EP role, which is marginal, is left to metal detergents. The main class of anti-wear additives consists of zinc dialkyl dithiophosphates, whose introduction coincided with the start of the technology of using additives in lubricants. There are also wear-prevention additives with a molybdenum base (dialkyl dithiophosphates, dithiocarbamates), organic compounds and metal detergents.

Widespread use is made of EP additives in transmission oils. Among these, the main ones are: with sulphur (anti-wear/EP), sulphur-phosphorus compounds (anti-wear/EP), chlorinated paraffins (EP). The anti-wear additive, in fact, acts as such because, by breaking down at the metal-metal contact temperatures it reacts with the surfaces and forms layers with a low friction coefficient. As stated, the zinc dithiophosphates also carry out a very effective antioxidant function. Currently, the use of zinc dithiophosphates is limited because the phosphorus contained in them, released during the partial combustion of the lubricant, can interact negatively with the catalytic systems of treating spent gases.

Anti-corrosives/rust-inhibitors

These protect the metal surfaces of the engine against corrosion and against the aggressive agents generated during combustion (water, acid products, oxidants, etc.) or act as protection during transport and storage. They act by reacting a physical barrier on the metal surface, which prevents the corrosive agents from attacking it. The main types are: etoxylate alcohols, long-chain carboxylic acids, phosphoric esters, amines, imidazoline and thioderivatives.

By their nature they are compounds which can vie against other classes of additives (for example, zinc dithiophosphates), with which they often compete for treating metal surfaces, or which can negatively influence other properties of the medium in which they operate. The presence of metal surfaces of a varied nature in the engine, moreover, often requires the use of mixes of various anticorrosion additives.

Review Questions

1. What is lubrication?
2. Mention the purposes of lubrication.
3. What is lubricating grease?
4. Lubrication methods can be _______ and _______.
5. Briefly discuss the following: Base oils, thickeners and additives.
6. Mention the oil lubrication methods.
7. What are lubricants? State the functions of lubricants.
8. Briefly explain the following mechanisms of lubrication: Thick-film lubrication, Thin-film lubrication and Extreme Pressure lubrication
9. How can lubricants be classified? Briefly explain each.
10. Explain each of the property of lubricants: Viscosity, Flash point, Fire point, Pour point, Cloud point, Aniline point and Corrosion stability.
11. What are the characteristics of a good lubricant?
12. What are the functions of additives?
13. The additives added to improve lubrication oils are: Viscosity index modifiers, Pour point improvers, Anti-oxidant, Detergent and dispersant, Friction modifiers, Anti-wear/EP additives and Anti-corrosive/rust inhibitors. Briefly state the function of each additive in improving lubricating oils.