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Grease (lubricant)

Grease is a solid or semisolid lubricant formed as a dispersion of thickening agents in a liquid lubricant. Grease generally consists of a soap emulsified with mineral or vegetable oil.

A common feature of greases is that they possess high initial viscosities, which upon the application of shear, drop to give the effect of an oil-lubricated bearing of approximately the same viscosity as the base oil used in the grease. This change in viscosity is called shear thinning. Grease is sometimes used to describe lubricating materials that are simply soft solids or high viscosity liquids, but these materials do not exhibit the shear-thinning properties characteristic of the classical grease. For example, petroleum jellies such as Vaseline are not generally classified as greases.

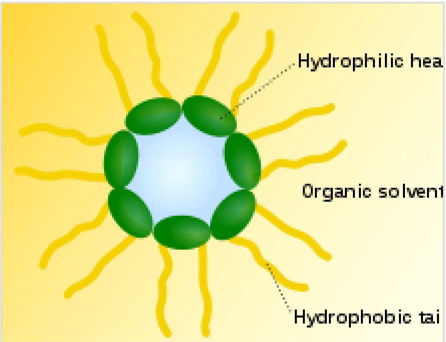
Greases are applied to mechanisms that can be lubricated only infrequently and where a lubricating oil would not stay in position. They also act as sealants to prevent the ingress of water and incompressible materials. Grease-lubricated bearings have greater frictional characteristics because of their high viscosities.

Properties

A *true* grease consists of an oil or other fluid lubricant that is mixed with a thickener, typically a *soap*, to form a solid or semisolid.[1] Greases are usually *shear-thinning* or pseudo-plastic fluids, which means that the viscosity of the fluid is reduced under shear stress. After sufficient force to shear the grease has been applied, the viscosity drops and approaches that of the base lubricant, such as mineral oil. This sudden drop in shear force means that grease is considered a plastic fluid, and the reduction of shear force with time makes it thixotropic. A few greases are rheotropic, meaning they become more viscous when worked.[2] Grease is often applied using a grease gun, which applies the grease to the part being lubricated under pressure, forcing the solid grease into the spaces in the part.

Thickeners

Soaps are the most common emulsifying agent used, and the selection of the type of soap is determined by the application.[3] Soaps include calcium stearate, sodium stearate, lithium stearate, as well as mixtures of these components. Fatty acids derivatives other than stearates are also used, especially lithium 12-hydroxystearate. The nature of the soaps influences the temperature resistance (relating to the viscosity), water resistance, and chemical stability of the resulting grease. Calcium sulphonates and polyureas are increasingly common grease thickeners not based on metallic soaps.[4][5]



An inverse micelle formed when a soap is dispersed in an oil. This structure is broken reversibly upon shearing the grease.

Powdered solids may also be used as thickeners, especially as clays. Fatty oil-based greases have also been prepared with other thickeners, such as tar, graphite, or mica, which also increase the durability of the grease. Silicone greases are generally thickened with silica.

Engineering assessment and analysis

Lithium-based greases are the most commonly used; sodium and lithium-based greases have higher melting point (dropping point) than calcium-based greases but are not resistant to the action of water. Lithium-based grease has a dropping point at 190 to 220 °C (350 to 400 °F). However the maximum usable temperature for lithium-based grease is 120 °C.

The amount of grease in a sample can be determined in a laboratory by extraction with a solvent followed by e.g. gravimetric determination.[6]

Additives

Some greases are labeled "EP", which indicates "extreme pressure". Under high pressure or shock loading, normal grease can be compressed to the extent that the greased parts come into physical contact, causing friction and wear. EP greases have increased resistance to film breakdown, form sacrificial coatings on the metal surface to protect if the film does break down, or include solid lubricants such as graphite or molybdenum disulfide to provide protection even without any grease remaining.[3]

Solid additives such as copper or ceramic powder are added to some greases for static high pressure and/or high temperature applications, or where corrosion could prevent dis-assembly of components later in their service life. These compounds are working as a release agent.[7][8] Solid additives cannot be used in bearings because of tight tolerances. Solid additives will cause increased wear in bearings.

History

Grease from the early Egyptian or Roman eras is thought to have been prepared by combining lime with olive oil. The lime saponifies some of the triglyceride that comprises oil to give a calcium grease. In the middle of the 19th century, soaps were intentionally added as thickeners to oils.[9] Over the centuries, all manner of materials have been employed as greases. For example, black slugs *Arion ater* were used as axle-grease to lubricate wooden axle-trees or carts in Sweden.[10]

Classification and standards

Jointly developed by ASTM International, the National Lubricating Grease Institute (NLGI) and SAE International, standard ASTM D4950 *“standard classification and specification for automotive service greases”* was first published in 1989 by ASTM International. It categorizes greases suitable for the lubrication of chassis components and wheel bearings of vehicles, based on performance requirements, using codes adopted from the NLGI's *“chassis and wheel bearing service classification system”*:

- LA and LB: chassis lubricants (suitability up to mild and severe duty respectively)
- GA, GB and GC: wheel-bearings (suitability up to mild, moderate and severe duty respectively)

A given performance category may include greases of different consistencies.[11]

The measure of the consistency of grease is commonly expressed by its NLGI consistency number.

The main elements of standard ATSM D4950 and NLGI's consistency classification are reproduced and described in standard SAE J310 *“automotive lubricating greases”* published by SAE International.

Red wheel bearing grease for automotive applications.

Standard ISO 6743-9 *“lubricants, industrial oils and related products (class L) — classification — part 9: family X (greases)”*, first released in 1987 by the International Organization for Standardization, establishes a detailed classification of greases used for the lubrication of equipment, components of machines, vehicles, etc. It assigns a single multi-part code to each grease based on its operational properties (including temperature range, effects of water, load, etc.) and its NLGI consistency number.[12]

Other types

Silicone grease

Silicone grease is based on a silicone oil, usually thickened with amorphous fumed silica.

Fluoroether-based grease

Fluoropolymers containing C-O-C (ether) with fluorine (F) bonded to the carbon. They are more flexible and often used in demanding environments due to their inertness. Fomblin by Solvay Solexis and Krytox by duPont are prominent examples.

Laboratory grease


Grease is used to lubricate glass stopcocks and joints. Some laboratories fill them into syringes for easy application. Two typical examples: Left - Krytox, a fluoroether-based grease; Right - a silicone-based high vacuum grease by Dow Corning.

Apiezon, silicone-based, and fluoroether-based greases are all used commonly in laboratories for lubricating stopcocks and ground glass joints. The grease helps to prevent joints from "freezing", as well as ensuring high vacuum systems are properly sealed. Apiezon or similar hydrocarbon based greases are the cheapest, and most suitable for high vacuum applications. However, they dissolve in many organic solvents. This quality makes clean-up with pentane or hexanes trivial, but also easily leads to contamination of reaction mixtures.

Silicone-based greases are cheaper than fluoroether-based greases. They are relatively inert and generally do not affect reactions, though reaction mixtures often get contaminated (detected through NMR near δ 0[13]). Silicone-based greases are not easily removed with solvent, but they are removed efficiently by soaking in a base bath.

Fluoroether-based greases are inert to many substances including solvents, acids, bases, and oxidizers. They are, however, expensive, and are not easily cleaned away.

Food-grade grease

Food-grade greases are those greases that may come in contact with food and as such are required to be safe to digest. Food-grade lubricant base oil are generally low sulfur petrochemical, less easily oxidized and emulsified. Another commonly used poly-α olefin base oil as well. The United States Department of Agriculture (USDA) has three food-grade designations: H1, H2 and H3. H1 lubricants are food-grade lubricants used in food-processing environments where there is the possibility of incidental food contact. H2 lubricants are industrial lubricants used on equipment and machine parts in locations with no possibility of contact. H3 lubricants are food-grade lubricants, typically edible oils, used to prevent rust on hooks, trolleys and similar equipment.

Water-soluble grease analogs

In some cases, the lubrication and high viscosity of a grease are desired in situations where non-toxic, non-oil based materials are required. Carboxymethyl cellulose, or CMC, is one popular material used to create a water-based analog of greases. CMC serves to both thicken the solution and add a lubricating effect, and often silicone-based lubricants are added for additional lubrication. The most familiar example of this type of lubricant, used as a surgical and personal lubricant, is K-Y Jelly.

Cork grease

Cork grease is a lubricant used to lubricate cork, for example in musical wind instruments. It is usually applied using small lip-balm/lip-stick like applicators.[14]

See also

- Bearing (mechanical)
- Lubrication
- Lubrication theory
- Penetrant
- Society of Tribologists and Lubrication Engineers
- Timken OK Load

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NLGI consistency number

The **NLGI consistency number** (sometimes called *“NLGI grade”*) expresses a measure of the relative hardness of a grease used for lubrication, as specified by the *standard classification of lubricating grease* established by the National Lubricating Grease Institute (NLGI). Reproduced in standards ASTM D4950 *(“standard classification and specification of automotive service greases”)* and SAE J310 *(“automotive lubricating greases”)*, NLGI's classification is widely used. The NLGI consistency number is also a component of the code specified in standard ISO 6743-9 *“lubricants, industrial oils and related products (class L) — classification — part 9: family X (greases)”*.[1]

The NLGI consistency number alone is not sufficient for specifying the grease required by a particular application. However, it complements other classifications (such as ASTM D4950 and ISO 6743-9). Besides consistency, other properties (such as structural and mechanical stability, apparent viscosity, resistance to oxidation, etc.) can be tested to determine the suitability of a grease to a specific application.

Test method

NLGI's classification defines nine grades, each associated to a range of ASTM worked penetration values, measured using the test defined by standard ASTM D217 *“cone penetration of lubricating grease”*. This involves two test apparatus. The first apparatus consists of a closed container and a piston-like plunger. The face of the plunger is perforated to allow grease to flow from one side of the plunger to another as the plunger is worked up and down. The test grease is inserted into the container and the plunger is stroked 60 times while the test apparatus and grease are maintained at a temperature of 25 °C.

Once worked, the grease is placed in a penetration test apparatus. This apparatus consists of a container, a specially-configured cone and a dial indicator. The container is filled with the grease and the top surface of the grease is smoothed over. The cone is placed so that its tip just touches the grease surface and the dial indicator is set to zero at this position. When the test starts, the weight of the cone will cause it to penetrate into the grease. After a specific time interval the depth of penetration is measured.

Classification

The following table[2] shows the NLGI classification and compares each grade with household products of similar consistency.

NLGI consistency numbers

NLGI number	ASTM worked (60 strokes) penetration at 25 °C *tenths of a millimetre*	Appearance	Consistency food analogy
000	445-475	fluid	cooking oil
00	400-430	semi-fluid	apple sauce
0	355-385	very soft	brown mustard
1	310-340	soft	tomato paste
2	265-295	"normal" grease	peanut butter
3	220-250	firm	vegetable shortening
4	175-205	very firm	frozen yogurt
5	130-160	hard	smooth pâté
6	85-115	very hard	cheddar cheese

Common greases are in the range 1 through 3. Those with a NLGI No. of 000 to 1 are used in low viscosity applications. Examples include enclosed gear drives operating at low speeds and open gearing. Grades 0, 1 and 2 are used in highly loaded gearing. Grades 1 through 4 are often used in rolling contact bearings. Greases with a higher number are firmer, tend to stay in place and are a good choice when leakage is a concern.

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Lubricant

A **lubricant** (sometimes shortened to **lube**) is a substance that helps to reduce friction between surfaces in mutual contact, which ultimately reduces the heat generated when the surfaces move. It may also have the function of transmitting forces, transporting foreign particles, or heating or cooling the surfaces. The property of reducing friction is known as lubricity.

In addition to industrial applications, lubricants are used for many other purposes. Other uses include cooking (oils and fats in use in frying pans and baking to prevent food sticking), to reduce rusting and friction in machinery, bioapplications on humans (e.g., lubricants for artificial joints), ultrasound examination, medical examination, and sexual intercourse. It is mainly used to reduce friction and to contribute to a better, more efficient functioning of a mechanism.

History

Lubricants have been in some use for thousands of years. Calcium soaps have been identified on the axles of chariots dated to 1400 BC. Building stones were slid on oil-impregnated lumber in the time of the pyramids. In the Roman era, lubricants were based on olive oil and rapeseed oil, as well as animal fats. The growth of lubrication accelerated in the Industrial Revolution with the accompanying use of metal-based machinery. Relying initially on natural oils, needs for such machinery shifted toward petroleum-based materials early in the 1900s. A breakthrough came with the development of vacuum distillation of petroleum, as described by the Vacuum Oil Company. This technology allowed the purification of very nonvolatile substances, which are common in many lubricants.[1]

Properties

A good lubricant generally possesses the following characteristics:

- A high boiling point and low freezing point (in order to stay liquid within a wide range of temperature)
- A high viscosity index
- Thermal stability
- Hydraulic stability
- Demulsibility
- Corrosion prevention
- A high resistance to oxidation
- Pour Point (the minimum temperature at which oil will flow under prescribed test conditions)

Formulation

Typically lubricants contain 90% base oil (most often petroleum fractions, called mineral oils) and less than 10% additives. Vegetable oils or synthetic liquids such as hydrogenated polyolefins, esters, silicones, fluorocarbons and many others are sometimes used as base oils. Additives deliver reduced friction and wear, increased viscosity, improved viscosity index, resistance to corrosion and oxidation, aging or contamination, etc.

Non-liquid lubricants include powders (dry graphite, PTFE, molybdenum disulphide, tungsten disulphide, etc.), PTFE tape used in plumbing, air cushion and others. Dry lubricants such as graphite, molybdenum disulphide and tungsten disulphide also offer lubrication at temperatures (up to 350 °C) higher than liquid and oil-based lubricants are able to operate. Limited interest has been shown in low friction properties of compacted oxide glaze layers formed at several hundred degrees Celsius in metallic sliding systems, however, practical use is still many years away due to their physically unstable nature.

Additives

A large number of additives are used to impart performance characteristics to the lubricants. Modern automotive lubricants contain as many as ten additives, comprising up to 20% of the lubricant, the main families of additives are:[1]

- Pour point depressants are compounds that prevent crystallization of waxes. Long chain alkylbenzenes adhere to small crystallites of wax, preventing crystal growth.
- Anti-foaming agents are typically silicone compounds which increase surface tension in order to discourage foam formation.
- Viscosity index improvers (VIIs) are compounds that allow lubricants to remain viscous at higher temperatures. Typical VIIs are polyacrylates and butadiene.
- Antioxidants suppress the rate of oxidative degradation of the hydrocarbon molecules within the lubricant. At low temperatures, free radical inhibitors such as hindered phenols are used, e.g. butylated hydroxytoluene. At temperatures >90 °C, where the metals catalyze the oxidation process, dithiophosphates are more useful. In the latter application the additives are called metal deactivators.
- Detergents ensure the cleanliness of engine components by preventing the formation of deposits on contact surfaces at high temperatures.
- Corrosion inhibitors (rust inhibitors) are usually alkaline materials, such as alkylsulfonate salts, that absorb acids that would corrode metal parts.
- Anti-wear additives form protective 'tribofilms' on metal parts, suppressing wear. They come in two classes depending on the strength with which they bind to the surface. Popular examples include phosphate esters and zinc dithiophosphates.[2]
- Extreme pressure (anti-scuffing) additives form protective films on sliding metal parts. These agents are often sulfur compounds, such as dithiophosphates.
- Friction modifiers reduce friction and wear, particularly in the boundary lubrication regime where surfaces come into direct contact.[3]

In 1999, an estimated 37,300,000 tons of lubricants were consumed worldwide.[4] Automotive applications dominate, including electric vehicles[5] but other industrial, marine, and metal working applications are also big consumers of lubricants. Although air and other gas-based lubricants are known (e.g., in fluid bearings), liquid lubricants dominate the market, followed by solid lubricants.

Lubricants are generally composed of a majority of base oil plus a variety of additives to impart desirable characteristics. Although generally lubricants are based on one type of base oil, mixtures of the base oils also are used to meet performance requirements.

Mineral oil

The term "mineral oil" is used to refer to lubricating base oils derived from crude oil. The American Petroleum Institute (API) designates several types of lubricant base oil:[6]

- Group I – Saturates < 90% and/or sulfur > 0.03%, and Society of Automotive Engineers (SAE) viscosity index (VI) of 80 to 120

  Manufactured by solvent extraction, solvent or catalytic dewaxing, and hydro-finishing processes. Common Group I base oil are 150SN (solvent neutral), 500SN, and 150BS (brightstock)

- Group II – Saturates > 90% and sulfur < 0.03%, and SAE viscosity index of 80 to 120

  Manufactured by hydrocracking and solvent or catalytic dewaxing processes. Group II base oil has superior anti-oxidation properties since virtually all hydrocarbon molecules are saturated. It has water-white color.

- Group III – Saturates > 90%, sulfur < 0.03%, and SAE viscosity index over 120

  Manufactured by special processes such as isohydromerization. Can be manufactured from base oil or slax wax from dewaxing process.

- Group IV – Polyalphaolefins (PAO)
- Group V – All others not included above, such as naphthenics, polyalkylene glycols (PAG), and polyesters.

The lubricant industry commonly extends this group terminology to include:

- Group I+ with a viscosity index of 103–108
- Group II+ with a viscosity index of 113–119
- Group III+ with a viscosity index of at least 140

Can also be classified into three categories depending on the prevailing compositions:

- Paraffinic
- Naphthenic
- Aromatic

Synthetic oils

Petroleum-derived lubricant can also be produced using synthetic hydrocarbons (derived ultimately from petroleum), "synthetic oils".

These include:

- Polyalpha-olefin (PAO)
- Synthetic esters

- Polyalkylene glycols (PAG)
- Phosphate esters
- Perfluoropolyether (PFPE)
- Alkylated naphthalenes (AN)
- Silicate esters
- Ionic fluids
- Multiply alkylated cyclopentanes (MAC)

Solid lubricants

PTFE: polytetrafluoroethylene (PTFE) is typically used as a coating layer on, for example, cooking utensils to provide a non-stick surface. Its usable temperature range up to 350 °C and chemical inertness make it a useful additive in special greases, where it can function both as a thickener and a lubricant. Under extreme pressures, PTFE powder or solids is of little value as it is soft and flows away from the area of contact. Ceramic or metal or alloy lubricants must be used then.[7]

Inorganic solids: Graphite, hexagonal boron nitride, molybdenum disulfide and tungsten disulfide are examples of solid lubricants. Some retain their lubricity to very high temperatures. The use of some such materials is sometimes restricted by their poor resistance to oxidation (e.g., molybdenum disulfide degrades above 350 °C in air, but 1100 °C in reducing environments.

Metal/alloy: Metal alloys, composites and pure metals can be used as grease additives or the sole constituents of sliding surfaces and bearings. Cadmium and gold are used for plating surfaces which gives them good corrosion resistance and sliding properties, Lead, tin, zinc alloys and various bronze alloys are used as sliding bearings, or their powder can be used to lubricate sliding surfaces alone.

Aqueous lubrication

Aqueous lubrication is of interest in a number of technological applications. Strongly hydrated brush polymers such as PEG can serve as lubricants at liquid solid interfaces.[8] By continuous rapid exchange of bound water with other free water molecules, these polymer films keep the surfaces separated while maintaining a high fluidity at the brush–brush interface at high compressions, thus leading to a very low coefficient of friction.

Biolubricant

Biolubricants[9] are derived from vegetable oils and other renewable sources. They usually are triglyceride esters (fats obtained from plants and animals). For lubricant base oil use, the vegetable derived materials are preferred. Common ones include high oleic canola oil, castor oil, palm oil, sunflower seed oil and rapeseed oil from vegetable, and tall oil from tree sources. Many vegetable oils are often hydrolyzed to yield the acids which are subsequently combined selectively to form specialist synthetic esters. Other naturally derived lubricants include lanolin (wool grease, a natural water repellent).[10]

Whale oil was a historically important lubricant, with some uses up to the latter part of the 20th century as a friction modifier additive for automatic transmission fluid.[11]

In 2008, the biolubricant market was around 1% of UK lubricant sales in a total lubricant market of 840,000 tonnes/year.[12]

As of 2020, researchers at Australia's CSIRO have been studying safflower oil as an engine lubricant, finding superior performance and lower emissions than petroleum-based lubricants in applications such as engine-driven lawn mowers, chainsaws and other agricultural equipment. Grain-growers trialling the product have welcomed the innovation, with one describing it as needing very little refining, biodegradable, a bioenergy and biofuel. The scientists have reengineered the plant using gene silencing, creating a variety that produces up to 93% of oil, the highest currently available from any plant. Researchers at Montana State University's Advanced Fuel Centre in the US studying the oil's performance in a large diesel engine, comparing it with conventional oil, have described the results as a "game-changer".[13]

Functions of lubricants

One of the largest applications for lubricants, in the form of motor oil, is protecting the internal combustion engines in motor vehicles and powered equipment.

Lubricant vs. anti-tack coating

Anti-tack or anti-stick coatings are designed to reduce the adhesive condition (stickiness) of a given material. The rubber, hose, and wire and cable industries are the largest consumers of anti-tack products but virtually every industry uses some form of anti-sticking agent. Anti-sticking agents differ from *lubricants* in that they are designed to reduce the inherently adhesive qualities of a given compound while lubricants are designed to reduce friction between any two surfaces.

Keep moving parts apart

Lubricants are typically used to separate moving parts in a system. This separation has the benefit of reducing friction, wear and surface fatigue, together with reduced heat generation, operating noise and vibrations. Lubricants achieve this in several ways. The most common is by forming a physical barrier i.e., a thin layer of lubricant separates the moving parts. This is analogous to hydroplaning, the loss of friction observed when a car tire is separated from the road surface by moving through standing water. This is termed hydrodynamic lubrication. In cases of high surface pressures or temperatures, the fluid film is much thinner and some of the forces are transmitted between the surfaces through the lubricant.

Reduce friction

Typically the lubricant-to-surface friction is much less than surface-to-surface friction in a system without any lubrication. Thus use of a lubricant reduces the overall system friction. Reduced friction has the benefit of reducing heat generation and reduced formation of wear particles as well as improved efficiency. Lubricants may contain polar additives known as friction modifiers that chemically bind to metal surfaces to reduce surface friction even when there is insufficient bulk lubricant present for hydrodynamic lubrication, e.g. protecting the valve train in a car engine at startup. The base oil itself might also be polar in nature and as a result inherently able to bind to metal surfaces, as with polyolester oils.

Transfer heat

Both gas and liquid lubricants can transfer heat. However, liquid lubricants are much more effective on account of their high specific heat capacity. Typically the liquid lubricant is constantly circulated to and from a cooler part of the system, although lubricants may be used to warm as well as to cool when a regulated temperature is required. This circulating flow also determines the amount of heat that is carried away in any given unit of time. High flow systems can carry away a lot of heat and have the additional benefit of reducing the thermal stress on the lubricant. Thus lower cost liquid lubricants may be used. The primary drawback is that high flows typically require larger sumps and bigger cooling units. A secondary drawback is that a high flow system that relies on the flow rate to protect the lubricant from thermal stress is susceptible to catastrophic failure during sudden system shut downs. An automotive oil-cooled turbocharger is a typical example. Turbochargers get red hot during operation and the oil that is cooling them only survives as its residence time in the system is very short (i.e. high flow rate). If the system is shut down suddenly (pulling into a service area after a high-speed drive and stopping the engine) the oil that is in the turbo charger immediately oxidizes and will clog the oil ways with deposits. Over time these deposits can completely block the oil ways, reducing the cooling with the result that the turbo charger experiences total failure, typically with seized bearings. Non-flowing lubricants such as greases and pastes are not effective at heat transfer although they do contribute by reducing the generation of heat in the first place.

Carry away contaminants and debris

Lubricant circulation systems have the benefit of carrying away internally generated debris and external contaminants that get introduced into the system to a filter where they can be removed. Lubricants for machines that regularly generate debris or contaminants such as automotive engines typically contain detergent and dispersant additives to assist in debris and contaminant transport to the filter and removal. Over time the filter will get clogged and require cleaning or replacement, hence the recommendation to change a car's oil filter at the same time as changing the oil. In closed systems such as gear boxes the filter may be supplemented by a magnet to attract any iron fines that get created.

It is apparent that in a circulatory system the oil will only be as clean as the filter can make it, thus it is unfortunate that there are no industry standards by which consumers can readily assess the filtering ability of various automotive filters. Poor automotive filters significantly reduce the life of the machine (engine) as well as make the system inefficient.

Transmit power

Lubricants known as hydraulic fluid are used as the working fluid in hydrostatic power transmission. Hydraulic fluids comprise a large portion of all lubricants produced in the world. The automatic transmission's torque converter is another important application for power transmission with lubricants.

Protect against wear

Lubricants prevent wear by reducing friction between two parts. Lubricants may also contain anti-wear or extreme pressure additives to boost their performance against wear and fatigue.

Prevent corrosion and rusting

Many lubricants are formulated with additives that form chemical bonds with surfaces or that exclude moisture, to prevent corrosion and rust. It reduces corrosion between two metallic surfaces and avoids contact between these surfaces to avoid immersed corrosion.

Seal for gases

Lubricants will occupy the clearance between moving parts through the capillary force, thus sealing the clearance. This effect can be used to seal pistons and shafts.

Fluid types

- Automotive
  - Motor oils
    - Petrol (Gasolines) engine oils
    - Diesel engine oils
  - Automatic transmission fluid
  - Gearbox fluids
  - Brake fluids
  - Hydraulic fluids
  - Air conditioning compressor oils
- Tractor (one lubricant for all systems)
  - Universal Tractor Transmission Oil – UTTO
  - Super Tractor Oil Universal – STOU – includes engine
- Other motors
  - 2-stroke engine oils
- Industrial
  - Hydraulic oils
  - Air compressor oils
  - Food Grade lubricants
  - Gas Compressor oils
  - Gear oils
  - Bearing and circulating system oils
  - Refrigerator compressor oils
  - Steam and gas turbine oils
- Aviation
  - Gas turbine engine oils
  - Piston engine oils
- Marine
  - Crosshead cylinder oils
  - Crosshead Crankcase oils
  - Trunk piston engine oils
  - Stern tube lubricants

"Glaze" formation (high-temperature wear)

A further phenomenon that has undergone investigation in relation to high-temperature wear prevention and lubrication is that of a compacted oxide layer glaze formation. Such glazes are generated by sintering a compacted oxide layer. Such glazes are crystalline, in contrast to the amorphous glazes seen in pottery. The required high temperatures arise from metallic surfaces sliding against each other (or a metallic surface against a ceramic surface). Due to the elimination of metallic contact and adhesion by the generation of oxide, friction and wear is reduced. Effectively, such a surface is self-lubricating.

As the "glaze" is already an oxide, it can survive to very high temperatures in air or oxidising environments. However, it is disadvantaged by it being necessary for the base metal (or ceramic) having to undergo some wear first to generate sufficient oxide debris.

Disposal and environmental impact

It is estimated that about 50% of all lubricants are released into the environment. Common disposal methods include recycling, burning, landfill and discharge into water, though typically disposal in landfill and discharge into water are strictly regulated in most countries, as even small amount of lubricant can contaminate a large amount of water. Most regulations permit a threshold level of lubricant that may be present in waste streams and companies spend hundreds of millions of dollars annually in treating their waste waters to get to acceptable levels.

Burning the lubricant as fuel, typically to generate electricity, is also governed by regulations mainly on account of the relatively high level of additives present. Burning generates both airborne pollutants and ash rich in toxic materials, mainly heavy metal compounds. Thus lubricant burning takes place in specialized facilities that have incorporated special scrubbers to remove airborne pollutants and have access to landfill sites with permits to handle the toxic ash.

Unfortunately, most lubricant that ends up directly in the environment is due to the general public discharging it onto the ground, into drains, and directly into landfills as trash. Other direct contamination sources include runoff from roadways, accidental spillages, natural or man-made disasters, and pipeline leakages.

Improvement in filtration technologies and processes has now made recycling a viable option (with the rising price of base stock and crude oil). Typically various filtration systems remove particulates, additives, and oxidation products and recover the base oil. The oil may get refined during the process. This base oil is then treated much the same as virgin base oil however there is considerable reluctance to use recycled oils as they are generally considered inferior. Basestock fractionally vacuum distilled from used lubricants has superior properties to all-natural oils, but cost-effectiveness depends on many factors. Used lubricant may also be used as refinery feedstock to become part of crude oil. Again, there is considerable reluctance to this use as the additives, soot, and wear metals will seriously poison/deactivate the critical catalysts in the process. Cost prohibits carrying out both filtration (soot, additives removal) and re-refining (distilling, isomerization, hydrocrack, etc.) however the primary hindrance to recycling still remains the collection of fluids as refineries need continuous supply in amounts measured in cisterns, rail tanks.

Occasionally, unused lubricant requires disposal. The best course of action in such situations is to return it to the manufacturer where it can be processed as a part of fresh batches.

Environment: Lubricants both fresh and used can cause considerable damage to the environment mainly due to their high potential of serious water pollution. Further, the additives typically contained in lubricant can be toxic to flora and fauna. In used fluids, the oxidation products can be toxic as well. Lubricant persistence in the environment largely depends upon the base fluid, however if very toxic additives are used they may negatively affect the persistence. Lanolin lubricants are non-toxic making them the environmental alternative which is safe for both users and the environment.

Societies and industry bodies

- American Petroleum Institute (API)
- Society of Tribologists and Lubrication Engineers (STLE)
- National Lubricating Grease Institute (NLGI)
- Society of Automotive Engineers (SAE)
- Independent Lubricant Manufacturer Association (ILMA)
- European Automobile Manufacturers Association (ACEA)
- Japanese Automotive Standards Organization (JASO)
- Petroleum Packaging Council (PPC)

Major publications

- Peer reviewed
  - *ASME Journal of Tribology*
  - *Tribology International*
  - *Tribology Transactions*
  - *Journal of Synthetic Lubricants*
  - *Tribology Letters*
  - *Lubrication Science*
- Trade periodicals
  - *Tribology and Lubrication Technology*
  - *Fuels & Lubes International*
  - *Oiltrends*
  - *Lubes n' Greases*
  - *Compoundings*
  - *Chemical Market Review*
  - *Machinery lubrication*

See also

- Lubrication – The presence of a material to reduce friction between two surfaces.
- Motor oil – Lubricant used for lubrication of internal combustion engines
- Oil analysis – Laboratory analysis of an oil based lubricant's properties and contaminants
- Penetrating oil – Low-viscosity oil

- Tribology – Science and engineering of interacting surfaces in relative motion

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External links

- SAE-ISO-AGMA viscosity conversion chart (https://web.archive.org/web/20190802135047/http://trytoobest.com/)
- Chart of API Gravity and Specific gravity (http://www.widman.biz/Seleccion/Viscosidad/Degrees_API/degrees_api.html)

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