7

Lubricants

> *Anybody can become angry – that is easy ; But to be angry with the right person, and to the right degree, and at the right time, and for the right purpose, and in the right way – that is not within everybody's power and is not easy.*

1 INTRODUCTION

In all types of machines, the surfaces of moving, sliding or rolling parts rub against each other. This mutual rubbing of one part against another generates *frictional force* which offers resistance to the relative motion of these surfaces. *Wear* results when this resistance is overcome by applied forces. Hence, friction causes a lot of wear and tear of surfaces of moving/sliding/rolling parts which consequently require repeated *replacement*. Friction also generates heat which gets dissipated thereby causing loss in the *efficiency* of the machine.

These drawbacks of frictional resistance can be minimized by applying a thin layer of certain substances, known as ***lubricant*** in between the moving/sliding/rolling surfaces. A lubricant may thus be defined as a substance which reduces the friction when introduced between two surfaces and the phenomenon is known as *lubrication*.

2 FUNCTIONS OF LUBRICANTS

(i) *The first and foremost function of a lubricant is to reduce friction.* Let us consider two steel blocks one on top of the other. Both the steel blocks have smooth

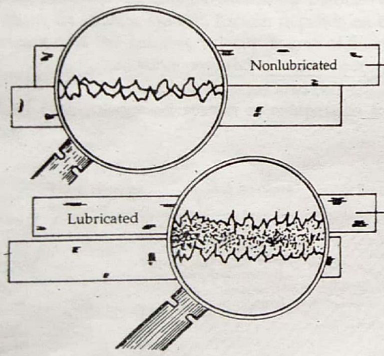


Fig. 1. Lubricants reduce friction.

ground surfaces. Top block can be made to slide over the bottom block by applying force. It is experimentally found that less force is required for this sliding motion when the two steel surfaces are separated by some lubricating oil.

This can be explained by careful analysis of steel surfaces under powerful microscope. This study reveals that steel surfaces actually exhibit minute *peaks* and *valleys* that interlock to prevent the blocks from sliding freely. These peaks are known as *asperities.* The force required to overcome the resistance created by the interlocking asperities and to slide one block past the other is known as the *Frictional Force.* As is shown in Fig. 1, when the two steel surfaces are separated by some lubricating oil, the small peaks and valley do not interlock, and the top block slides very freely over the bottom block.

(ii) *It reduces wear, tear and surface deformation* because the direct contact between the sliding/moving surfaces is avoided. Without the intervening lubricant, some of the small peaks would be sheared off as one block moved over the other. Eventually, this would result in wear, tear and surface deformation.

In actual machinery, excessive wear on any part may result in malfunction of the entire unit. Bearing wear can induce gear misalignment, and in the mill itself, may affect product shape and quality. On an extreme case it may result in breakages, heavy damage and costly delays.

(iii) *It acts as coolant to carry away heat.* In a machine, frictional heat is always produced at the point of contact between the rubbing parts. Cool oil flowing over the heated surface absorbs and carries the heat away. In high speed, high-load sleeve bearings like those used in backup roll serve in hot and cold strip, sheet and tin mills, the heat generated within the oil film is very high because the oil films are very thin and shear rates are high, but as shown in Fig. 2, cool oil flowing through the unloaded side of the bearing meets the heated oil and returns it to the reservoir at a much lower temperature.

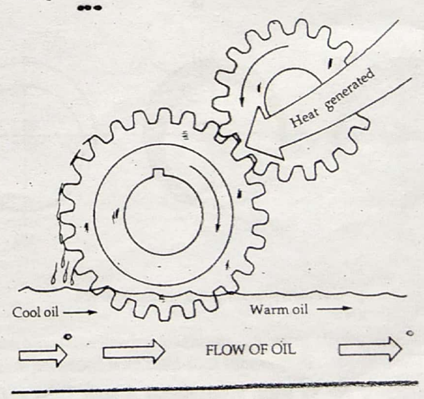


Fig. 2. Lubricants carry away heat.

(*iv*) ***It keeps out dirt.*** The proper use of a lubricant can prevent foreign matter or dirt from entering a bearing and damaging the smooth surface of the journal and bearing.

(*v*) Sometimes, it ***acts as a seal.*** For example, in an internal combustion engine, the lubricant used between the piston and the cylinder wall acts as a seal. This seal prevents the leakage of gases under high pressure from the cylinder.

(*vi*) It reduces the maintenance and running cost of the machine as it ***prevents rust and corrosion.*** Generally, lubricant formulations containing rust inhibitors provide a protective residual film to ward off the attack of an external corrosive substance.

(*vii*) It ***transmits fluid power.*** The hydraulic lift that raises automobiles in a service station uses a plunger or piston inside a cylinder for transmitting power or force by means of petroleum oil. The petroleum oil also protects the sliding, contacting surfaces. The viscosity of petroleum oils for this function is low. More-over they require to be anti wear, rust and oxidation inhibited.

(*viii*) As the use of lubricant minimizes the liberation of frictional heat hence it avoids seizure of moving surfaces and expansion of metal. It also reduces loss of energy in the form of heat. Hence, it improves the efficiency of the machine.

MECHANISM OF LUBRICATION

Lubrication mechanism can be classified into following types :

(*a*) ***Hydrodynamic Lubrication or Fluid Film Lubrication.*** In this, the moving/sliding surfaces are separated from each other by a bulk lubricant film (at least 1000 A° thick). This bulk lubricant film prevents direct surface-to-surface contact so that the small peaks and valleys do not interlock. This consequently reduces friction and prevents wear. Fluid film lubrication is shown in Fig. 3(*a*). The small friction (if any) is only due to the internal resistance between the particles of the lubricant moving over each other. In such a system, friction depends on the thickness & viscosity of the lubricant and the relative velocity & area of the moving/sliding surfaces. The *coefficient of friction* = $\frac{\text{force required to cause motion (F)}}{\text{Applied load (W)}}$ is as low as 0.001 to 0.03 for fluid film lubricated system in comparison to 0.5 to 1.5 for unlubricated surfaces.

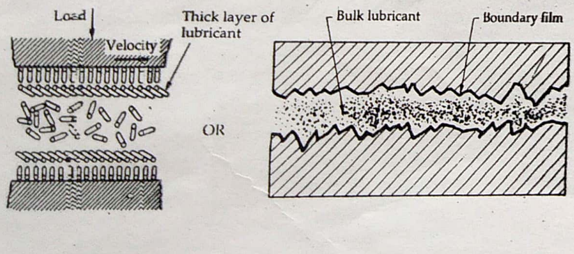
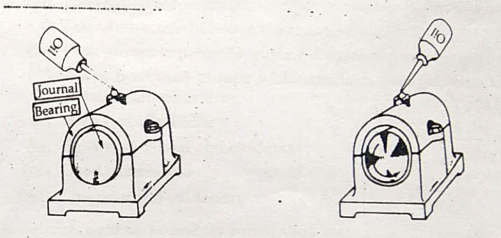


Fig. 3. Fluid film Lubrication — Surfaces separated by Bulk Lubricant film

Let us now consider how the hydrodynamic film is actually generated between a bearing and a rotating journal. Fig. 4(*a*) shows a journal resting on the bottom of the bearing before motion. Fig. 4(*b*) shows the oil film which separates the surfaces when the journal rotates. Fig. 5 is a simplified drawing of this process, that shows how, after start up, the journal begins to climb up one side of the bearing ; as its pumping action draws oil under it, the journal is forced to the other side by the "oil wedge". At start-up, the coefficient of friction is high in the presence of boundary lubrication. After start-up, however, the coefficient falls rapidly. This is due to the fact that metal surfaces do not come into direct contact with each other. The resistance to movement is only due to the internal resistance of the lubricant.



(*a*) Journal at rest (*b*) Journal in motion

Fig. 4. Formation of oil wedge in a bearing.

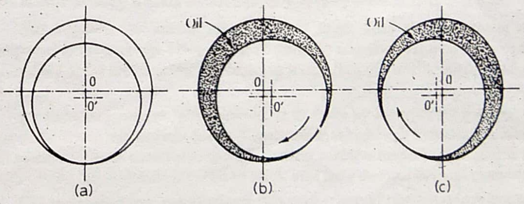


Fig. 5. Formation of fluid film in a plain bearing.

Light machines like sewing machines, watches, clocks, delicate and scientific instruments are provided with fluid-film lubrication.

Fluid film lubrication is satisfactorily done by *hydrocarbon oils.* These are generally blended with selected long chain polymers in order to maintain viscosity of the oil constant in all seasons of year.

This is necessary also because the viscosity of hydrocarbon oil decreases with rise in temperature. Hence, an hydrocarbon oil might be satisfactory when an engine is cold but it may become too "thin" to maintain an adequate lubricant film at normal running temperatures.

The viscosity of hydrocarbon oils increases with increasing molecular weight. Hence, for different applications, appropriate fractions from petroleum refining are blended to meet the requirement. But these fractions generally contain small quantity of unsaturated hydrocarbons which get oxidised under operating conditions, forming gums. Hence it is essential that **antioxidants** (like aminophenols) to be blended with hydrocarbon oils.

In practice, some decomposition of these hydrocarbon oils might occur leading to the formation of solid carbon particles. Organometallic 'detergent' compounds need to be added in the oils to keep these carbon particles in suspension in the lubricating oil.

(*b*) ***Boundary Lubrication or thin-film lubrication.*** When the lubricant is not viscous enough to generate a film of sufficient thickness to separate the surfaces under heavy loads, friction may yet be reduced with the proper lubricant. Such an application is known as *Boundary lubrication*. Solid lubricants, greases and oils with proper additives function in this manner

A thin layer of lubricant is adsorbed on the metallic surfaces which avoids direct metal-to metal contact. The load is carried by the layer of the adsorbed lubricant on both the metal surfaces (see Fig. 6.) In boundary lubrication, the distance between moving/sliding surface is very small of the order of the height of

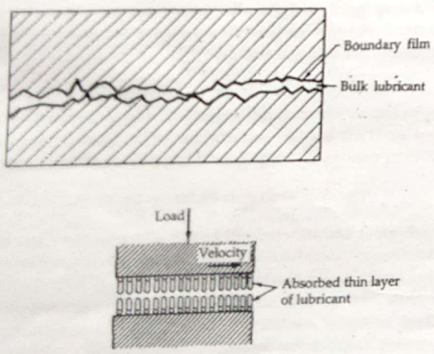


Fig. 6. Bounday lubrication – performance essentially dependent on boundary film.

the surface asperities. The contact between the metal surface is possible by the squeezing out of lubricating oil film. When this occurs the load would be taken on the high spots of the journal and the bearing, and the two surfaces tend to become welded together by the appreciable heat that is generated. This prevents motion as the two surfaces adhere together. This is known as *seizure*. If motion proceeds with the removal of some metal from one of the surfaces the result is known as *scuffing*.

In practice, seizure or scuffing are delayed by the fact that metals tend to form films on their surfaces by chemical action leading to adsorption which temporarily prevents metal to metal contact.

For boundary lubrication the lubricant molecules should have

(*i*) Long hydrocarbon chains,
(*ii*) Lateral attraction between the chains,
(*iii*) Polar groups to promote wetting or spreading over the surface,
(*iv*) Active functional groups which can form chemical bonds with the metals or other surfaces,
(*v*) High viscosity-index ;
(*vi*) Resistance to heat and oxidation ;
(*vii*) Good oiliness and
(*viii*) Low pour and oxidation.

Lubricants used for boundary lubrication are :

(*i*) *Graphite and* MoS_2 either as solid or as stable emulsion, in oil. These materials reduce friction between metallic surfaces by forming films on the surfaces and they can bear compression as well as high temperature.

(*ii*) *Mineral oils.* These are thermally stable and their adhesion property (Oiliness is improved by adding small amount of fatty acids or fatty oils.

(*iii*) *Vegetable and animal oils and their soaps.* They possess greater oiliness compared to mineral oils. They either physically adsorbed to metal surfaces or react chemically at the metal surfaces, forming a thin film of metallic soap, which acts as lubricant.

(*c*) ***Extreme-pressure lubrications.*** It is done by incorporating extreme pressure additives in mineral oils for applications in which high temperature is attained due to the very high speed of moving/sliding surfaces under high pressure. In such applications, liquid lubricants fail to stick and may decompose and even vaporize.

Chlorinated esters, sulphurized oils and tricresyl phosphate are examples of such additives. These additives react with metallic surfaces, at prevailing high temperatures, to form metallic chlorides, sulphide or phosphides, in the form of durable films. These films can withstand very high loads and high temperatures (because of their high melting points.

Hence, they serve as good lubricant under extreme-pressure and extreme-temperature conditions. These lubricants have an additional advantage that if the low shear strength films formed on the moving parts are broken by the rubbing action, they are immediately replenished.

Applications which demand lubrication by Extreme pressure additives

(*i*) Wire drawing of titanium (requires chlorine containing additive which reacts with the stable oxide film on the metal surface).

(*ii*) In cutting fluids in machining of tough metals. A typical lubricant consists of hydrocarbon oil, a small amount of fatty acid as a boundary lubricant and an organic chloride or sulfide additive.

(*iii*) For hypoid gears used in rear axle drive of cars which has both longitudinal sliding motion and normal rolling movement.

4. CLASSIFICATION OF LUBRICANTS

Classification of Lubricants
- Lubricating oils
- Greases
- Solid lubricants

On the basis of their physical state, lubricants can be classified as :

(*i*) Lubricating oils (or liquid lubricants) ;

(*ii*) Greases (or Semi-solid lubricants) ; and

(*iii*) Solid lubricants.

4.1 Lubricating Oils

Lubricating oils are also known as liquid lubricants and are further *classified into* three categories *viz.* Animal and Vegetable oils, Mineral or Petroleum oils and Blended oils.

Characteristics of good lubricating oils. High boiling point, low freezing point, adequate viscosity for proper functioning in service, high resistance to oxidation and heat, non-corrosive properties, and stability to decomposition at the operating temperatures.

Functions of lubricating oils. Lubricating oils provide a continuous fluid film in-between moving/sliding/rolling surfaces and reduce friction, wear and heat generation. They also act as cooling and sealing agent. They also prevent corrosion.

The types of lubricating oils are briefly described below :

(*a*) **Animal and Vegetable oils.** *Animal oils* are extracted from the crude fat by 'rendering' process in which the enclosing tissue is broken by treatment with steam or the combined action of steam and water. Vegetable oils such as cotton seed oil and castor oil are obtained by crushing the seeds. Before use, both animal and vegetable oils require further treatment. This treatment involves cooling (so that sterarine separates out) ; filtration through animal carbon (for removal of colour and brightening the oil ; Neutralization of free fatty acids by requisite amount of alkali ; coagulation treatment with sulphuric acid which removes suspended impurities by carbonizing and causing them to coagulate and settle out) and *filtration*.

Animal and vegetable oils possess good 'oiliness' and hence they stick to the surface of machine parts, even under high temperatures and heavy loads.

Lubricating oils	*Uses*
I Animal oils	
Lard oil	For lubricating ordinary machine parts.
Neats foot oil	For lubricating clocks and sewing machines particularly suitable for light machinery.
Sperm oil	Particularly suitable for light machinery.
II Vegetable oils	
Castor oil	Very good lubricant for bearing and machinery operating at high speeds and low pressures like racing cars.
Palm oil	For lubricating delicate instruments such as scientific equipment

Animal and vegetable oils have very *limited uses* at present because they are costly, have less resistance to oxidation and after oxidation form gummy and acidic products. They get thickened on coming in contact with air. When allowed to remain in contact with humidity or moisture they show some tendency to hydrolyze.

Actually these oils are used as blending agent for minerals oils so as to produce, desire effects in the latter.

(*b*) **Mineral or Petroleum oils.** These are basically lower molecular weight hydrocarbons with about 12 to 50 carbon atoms. Their viscosity increases with the length of the hydrocarbon chain. They are obtained by distillation of petroleum. As they are cheap, available in abundance and stable under service conditions, hence they are widely used. In comparison to animal and vegetable oils, oiliness of mineral oils is less. The addition of higher molecular weight compounds like oleic acid and stearic acid, increases the oiliness of mineral oil.

Purification. Impurities like wax, asphalt, etc. must be removed from crude liquid petroleum oils before they are used. A number of processes are used for removing these unwanted impurities.

Dewaxing means removal of wax from the oil otherwise the wax raises the pour-point and makes lubricating oil unfit for use at low temperatures. For dewaxing, oil is mixed with propane, trichloro ethylene or any other suitable solvent and then refrigerated for the precipitation of wax. Wax is then removed from oil by passing the oil wax suspension through a centrifuge working at 1700 rpm. Finally, distillation is done for solvent recovery.

Acid refining means treatment with conc. H_2SO_4 so that asphaltic and naphthenic impurities and other undesirable constituents can be eliminated from dewaxed-oils. Unwanted impurities either get dissolve in acid or are converted into tarry sludges. Sludge is removed by filtration, while the filtrate is neutralized with a calculated amount of caustic soda for the removal of excess of acid. Finally, the oil is decolorised by passing through fuller's earth.

Solvent refining involves mixing oil with nitrobenzene or some other suitable solvent (like dichloro ethyl ether, furfural, mixture of propane and cresol or sulphur dioxide and benzene, etc). Solvent is such in which oil is immiscible but the undesirable impurities are highly soluble. After proper mixing with such solvent, the oil is left undisturbed for some time so that liquid separates into two layers. 'Solvent layer' containing impurities and 'oil layer' free from impurities, but it might contain some solvent which can be recovered by distillation. Distillation also produces refined oil. Solvent is also recovered by similarly distilling 'solvent layer', when the residue containing asphaltic, naphthenic and resinuous substances is left behind and is used as a source of these or as a fuel oil. It is to be noted that asphalt undergo decomposition at higher temperatures, causing carbon decomposition and sludge formation. We can reduce any chance of formation of carbon deposits by removing asphaltic materials through solvent refining. This process of solvent refining is economical also and the refined oil thus obtained shows less change in viscosity with temperature. Natural oxidation inhibitors present in oil also get removed during solvent refining. Hence, solvent refined oil shows less resistant to oxidation. Moreover, it possesses lower oiliness. These drawbacks can be removed by incorporating some additives in solvent refined oils.

(c) **Blended oils.** Desirable characteristics of lubricating oils can be improved by adding small quantities of various additives. The oils thus obtained are known as blended oils or compounded oils.

An *additive* is a material that imparts a new or desired property to the lubricating oil. It may also enhance a desirable property that the lubricating oil already possesses to some degree. Broadly speaking, there are two types of lubricant additives :

Chemically active additives are those which chemically interact with metals (to form protective films) and with polar oxidation and degradation products (to make them harmless). Dispersants, Detergents Anti-Wear (AW) agents, Extreme Pressure (EP) agents, Oxidation inhibitors, Rust and corrosion inhibitor are few of the examples of chemically active additives.

Chemically inert additives are those additives which improve the physical properties that are critical to the effective performance of the lubricant. These additives include : viscosity index improvers, foam inhibitors, Pour point depressants, Demulsifiers, Emulsifiers etc.

These additives, their purpose, functions and typical examples are summarized below :

(I) Lubricant Protective Additives

Additive Type	*Purpose*	*Functions*	*Typical examples*
(i) Antioxidant	Retard oxidative decomposition	Terminate free radical chain reactions and Decompose peroxides	Aromatic amines, Hindered phenols etc.
(ii) Metal Deactivator	Decrease catalytic effect of metals on oxidation rate	By complexing with metal ions, they form inactive layer on metal surfaces	Amines, sulfides or phosphites etc.
(iii) Antifoamant	Prevent persistent foam formation by lubricant	Speed collapse of foam by reducing surface tension	Silicon polymers.

(II) Surface Protective Additives

Additive Type	*Purpose*	*Functions*	*Typical examples*
Rust and Corrosion inhibitor	Prevent rusting and corrosion of metal parts in contact with the lubricant.	Neutralization of corrosive acids and /or preferential adsorption of polar constituent on metal surface to provide a protective film.	Metal phenolates, basic metal sulfonates, fatty acids and amines.
Anti-wear and EP agent	Reduce friction and wear and prevent scoring and seizure	Prevent metal-to-metal contact by chemical reaction with metal surface to form a film with lower shear strength than the metal	Zinc dithiophosphates, organic phosphates and acid phosphates, sulfurized fats etc.
Friction modifier	Change coefficient of friction	Preferential adsorption of surface active materials.	High molecular wt. organic phosphorus and phosphoric acid esters, organic fatty acids and amines.
Detergent	Keep surfaces deposits free	Neutralise the sludge and varnish precursors and keep them soluble.	Magnesium phenolates, phosphates and sulfonates.
Dispersant	Keep insoluble contaminants dispersed in the lubricant	Prevent agglomeration of contaminants as they are bonded by polar attraction to dispersant molecules. Contaminants are kept in suspension due to solubility of dispersant.	Alkyl succinimides, and polymeric alkylthiophosphonates.

III. Performance Additives

Additive Type	*Purpose*	*Functions*	*Typical examples*
(i) Viscosity modifier	Reduce the rate of viscosity change with temperature	Polymer expand with increasing temperature to counteract oil thinning	Polymers and copolymers of olefins, alkylated styrenes, methacrylates and butadiene.

	Additive Type	Purpose	Functions	Typical examples
(ii)	Four point depressant	Enable lubricant to flow at low temperatures	Reduce interlocking by modifying wax crystal formation	Polymethacrylates, phenolic polymers and alkylated naphthalene.
(iii)	Seal Swell Agent	Cause swelling of elastomer by chemical reaction		Aromatic hydrocarbons and organic phosphates.

4.2 Greases or Semi-Solid Lubricants

A semi-solid lubricant obtained by combining lubricating oil with thickening agent 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 lithium, sodium, calcium, barium, aluminium etc. Non-soap thickeners include carbon black, silica gel, polyureas and other synthetic polymers, bentonite clays etc. (They improve the heat resistance of a lubricant). The fibrous structure of the thickener traps the oil and enables the lubricant to cling to moving parts.

Unlike lubricating oils that flow of their own accord (Newtonian fluids), most greases flow only under pressure (Non-Newtonian fluid).

The fiber structure of thickener is adversely affected by water contamination and the grease undergo degradation. Hence, (unless a grease has been formulated to function), it is not used in the presence of water.

Shear or frictional resistance of Greases is much higher than oils hence they can support much heavier load at lower speed.

Coefficient of friction of greases is much higher than that of lubricating oils. Therefore, whenever possible, it is better to use an oil instead of grease.

Compared to lubricating oils, greases cannot effectively dissipate heat from the bearing. That's why the grease lubricated bearing works at relatively lower temperatures as compared to the oil-lubricated bearing.

Preparation. Greases are made by saponification of fat with alkali (like Caustic soda) followed by adding hot lubricating oils with constant mixing. Consistency of the finished grease is governed by the total amount of the mineral oil.

Applications. Greases have the following uses :

(*i*) In rail axle boxes (or any other such applications where oil cannot remain in place due to high load, low speed, intermittent operation, sudden jerks etc.)

(*ii*) in bearings and gears that works at high temperatures ;

(*iii*) in machines preparing paper, textiles, edible articles etc. where dripping of oil is undesirable ;

(*iv*) in situations where bearing needs to be sealed against entry of dust, dirts, grit or moisture, as the greases are more resistant to contamina-

Classification of greases on the basis of the soap used in their manufacture :

(*i*) *Soda-based greases employ* sodium soaps as thickening agent in petroleum oils. As the sodium soap content is soluble in water so these greases are not water resistant. These greases can be used up to 175° C. They are suitable for use in ball bearings which generates frictional heat.

(*ii*) *Lithium-based greases* employ lithium soaps as thickening agent in petroleum oils. These greases are resistant to water and have good high-temperature properties. These greases are stable in storage, have high mechanical and oxidation stability. They have high melting point (about 150° C).

For aircraft applications at extreme heights, where temperature as low as – 55° C may exists, lithium-base lubricant (properly formulated) can be used as they permit functioning of the controls under such conditions. These greases are used for special applications only, due to their high cost.

(*iii*) *Calcium-based greases* employ calcium soaps as thickening agent in petroleum oils. These greases are also known as Cap-greases. These greases are the cheapest and most commonly used. These are water resistant and can be used upto 80° C. The amount of lime can be varied from 10 to 30% in calcium-based greases for getting wide range of consistency, from soft paste to hard, smooth solid.

These grease are suitable for lubricating caterpillar treads, tractors ; water pumps etc.

(*iv*) *Axle greases* are very cheap resin greases. They are prepared by adding lime (or any heavy metal hydroxide) to resin and fatty oils. After thorough mixing and standing, stiff mass grease floats out. Talc, mica or any other suitable filler is also added to them. They are resistant to water and used for equipment working at low speeds and high loads.

4.3 Solid Lubricants

These lubricants reduce friction by separating two moving surfaces under boundary conditions. They are used either in the dry powder form or mixed with oil or water. Low spots on the surface of moving parts are filled by these lubricants which then form solid films having low frictional resistance. The usual coefficient of friction of solid lubricants is between 0.005 and 0.01. Solid lubricants find applications in :

(*i*) Commutator bushes of motors and electronic generators where contamination of grease or lubricating oil (by the entry of dust or grit particles) is unacceptable ;

(*ii*) Internal combustion engines where a tight film is desired between the piston rings and the cylinder for increasing compression. In this application, combustible lubricants must be avoided. Lubricating film cannot be secured by using lubricating oils or greases because of the high operating temperatures.

The two most commonly used solid lubricants are :

(*i*) *Graphite.* Graphite consists of number of flat plates made up of network of hexagons in which each carbon is in sp^2 hybridisation state [see Fig. 7(a)]. The plates

So, viscosity-index of the oil-sample under test, $V.I. = \frac{L-U}{L-H} \times 100$

$$\Rightarrow \quad V.I. = \frac{774-564}{774-414} \times 100 = 58.33$$

Example 3. *An oil sample under-test has a Saybolt Universal Viscosity same as that of standard Gulf oil (low Viscosity Standard) and Pennsylvanian oil (high viscosity index standard) at 210° F. Their Saybolt Universal viscosities at 100° F are 61, 758 and 420 s respectively. Calculate viscosity-index of the sample oil.*

Solution. Here, $L = 758$ s, $H = 420$ s, and $U = 61$ s

So, viscosity-index of the sample oil $V.I. = \frac{L-U}{L-H} \times 100$

$$\Rightarrow \quad V.I. = \frac{758-61}{758-420} \times 100 = 206.2$$

Viscosity Index and Molecular Structure of Oil

There is a direct co-relation between molecular structure of lubricating oil with its viscosity and viscosity-index.

A high V.I. is exhibited by those lubricating oils which have linear or rod-like shaped molecules of higher molecular weights. This is due to the greater intermolecular attraction.

Viscosity-Temperature Curves

the variation of viscosity with temperature can also be indicated by viscosity-temperature curves. In fact, viscosity index is the numerical expression of the average slope of the viscosity-temperature curve of a lubricating oil between 100° F and 210° F. Lubricating oils with small variation in viscosity with temperature exhibit flatter viscosity-temperature plots and they have high VI's.

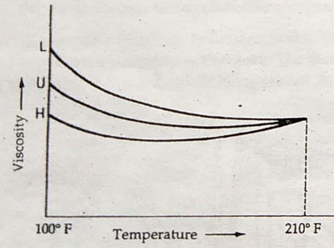


Fig 12. Viscosity-temperature curve.

5.4 Flash and Fire Point

The *flash point* of an oil is the lowest temperature at which it gives off vapours that will ignite for a moment when a small flame is brought near it.

The *fire point* of an oil is the lowest temperature at which the vapours of the oil burn continuously for at least 5 seconds when a small flame is brought near it.

The flash points and fire points are used to indicate the fire hazards of petroleum products and evaporation losses under high temperature operations.

Knowledge of flash and fire points in lubricating oil aids in-precautionary measures against fire hazards. A good lubricant should have flash point at least above the temperature at which it is to be used.

Measurement of Flash and Fire Points of a Lubricating Oil

(*i*) ***Cleveland open cup method.*** By this method we can determine the flash and fire points of all petroleum products except fuel oils and those having an open-cup flash below 175° F. It essentially consists of a open brass cup known as cleveland cup which is supported over the circular opening of a heating plate as shown in Fig. 13. Gas burners or electric heaters can act as a source of heat. A thermometer (– 6° to 400° C) is also required for measuring flash and/or fire point of lubricating oil.

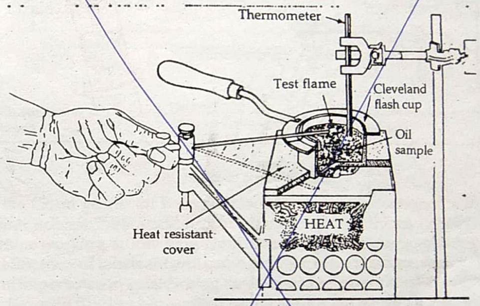


Fig 13. Cutaway view of cleveland open flash cup.

Procedure. The cleveland cup is filled with oil sample to be tested up to the specified filling mark. There should be no oil on the outside of the cup. The thermometer is immersed in the sample which is then heated at a rate of 9° to 11° F per minute.

At every 5° F rise in temperature a small flame is passed over the oil surface. When a flash appears at any point on the surface of the oil, the temperature reading shall be reported as the *flash point*. The heating of the oil is continued at the same rate. The test flame is applied again for every 5° F rise in temperature until oil ignites and continues to burn for at least 5 s. The temperature reading is recorded as the *fire point*. Fire point range from 10° to 70° F higher than the flash point.

Limitation. The flash point of lubricating oil should be greater than 175° F.

(*ii*) ***The Pensky-Marten Closed cup method.*** It is used to determine the flash point of lubricating oils, fuel oils, solvents, solvent containing materials and suspension of solids, except cut-back asphalt.

It consists of a *cup* made of brass, which is about 5.5 cm deep and 5 cm in diameter. The lid of the cup is provided with four openings of standard sizes.