COURSE CODE: *MCE 505*

COURSE TITLE: *Tribology*

NUMBER OF UNITS: *3 Units*

COURSE DURATION: *Three hours per week*

COURSE DETAILS:

Course Coordinator: **Prof. P. O. Aiyedun,** *B.Sc, M.Sc, Ph.D*
Email:
Office Location: **COLENG**
Other Lecturers: **Engr. Kuye, S.I**

COURSE CONTENT:

Theories of friction between metallic, non-metallic, dry and lubricated surfaces. Testing and properties of materials, solid and liquid lubricants. Theory of self-acting and pressurized bearing, including Reynolds equation and solutions. Dynamic loading, temperature and pressure effects on viscosity. Elastohydrodynamic lubrication, gears and rolling contact bearings. Design of journal and thrust bearings. Application of tribology.

COURSE REQUIREMENTS:

This is an elective course for 500 level students in the Department of Mechanical Engineering. In view of this, students who registered for this course are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

1. Cameron, A. Basic Lubrication Theory. Longman Group Limited.

LECTURE NOTES

INTRODUCTION

Basic purpose of lubrication: To minimise friction and wear.
Other auxiliary functions: Cooling and cleansing.

Friction
This is the force resisting motion when two contacting surfaces are moved relative to each other. In a dry system, this interaction force differs for a sliding or a rolling action.

For a lubricated system, the friction force between the surfaces depends on the viscosity of the fluid.

When complete separation is attained between the surfaces, the lubricants viscosity becomes the controlling parameter and the condition is termed "hydrodynamic lubrication".

Where surface interaction continues to exert a significant effect, the term "boundary lubrication" is used.

Oil present between two rubbing surfaces forms a lubricant film between the surfaces and this carries part of the load.

(a) Thrust and journal bearings: - mating parts are specially shaped to ensure this.
(b) Gears and rolling bearings elements:- effect of pressure on oil and elastic distortion on the metal part work together to give a film.
(c) Machine tool slideways: thermal distortions of the metal produces a wedge.

The oil film may not carry all the load but it relieves the metal of carrying all of it.

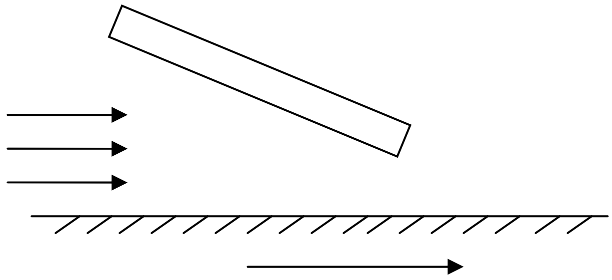
The oil has a surface layer of active molecules (from materials existing in the oils themselves) or agents having more endurance can be added to the lubricant.

High temperature produces an extreme condition on the surface layer.

Once this protective layer vanishes then chance asperity contact causes welding, leading to the destruction of the whole system.

Action of converging wedge
In every lubricated pair, a convergent wedge occurs and it is this convergence coupled with the speed and viscosity that generate the oil pressure film – this is called the pressure hill.

Theory behind oil pressure formation



Oil Wedge

One surface moves and drags a viscous fluid into the gap formed between it and the other (usually fixed) element. Oil is usually the viscous fluid. Other fluids such as water, air, or synthetic fluid are sometimes used.

In the figure above, the lower surface drags oil into the entry gap. As it moves on, it finds less and less space for itself. Oil is virtually incompressible thus it then generates a pressure thus preventing oil from coming into the gap as it meets a rising pressure (the pressure hill).

Once the oil in the gap goes beyond the maximum pressure, the pressure gradient boosts the flow through the reduced space at the end of the convergent pad.

The mathematical expression of this process is fundamental to all lubrication theory. All these equations will be derived and its applications in engineering will be looked into in detail.

TYPES AND PROPERTIES OF LUBRICANTS

Lubricants can be fluids (gases or liquids) or solids. These can be subdivided into 4 groups.

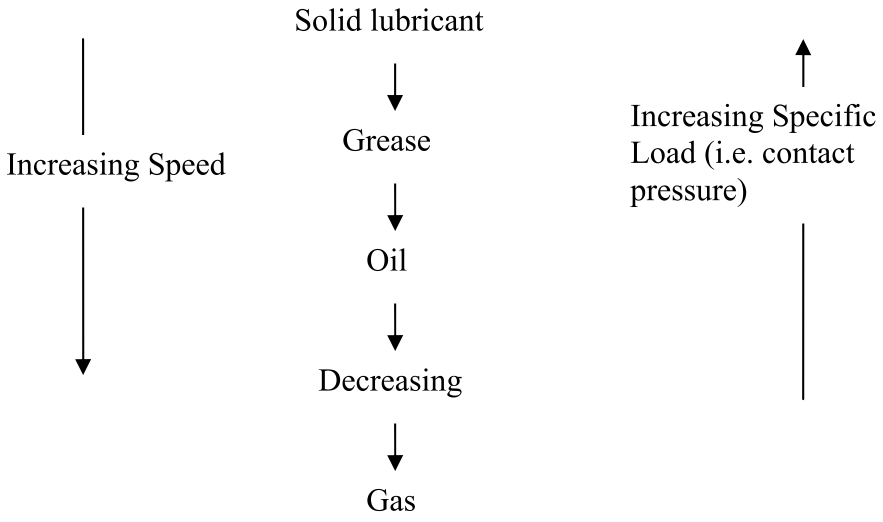
(i) Oils:- A general term used to cover all liquid lubricants, whether they are mineral oils, synthetics or emulsions.

(ii) Greases:- Technically they are oils which contain a thickening agent to make them semisolids but anti-seize pastes and the semi-fluid greases can be included under the same heading.

(iii)Dry lubricants:- Any lubricant that is used in solid form, may be bulk solids, paint-like coatings or loose powder.

(iv)Gases:- The gas usually used in gas bearings is air, but any gas can be used which will not attack the bearings or itself.

Effects of speed and load on lubricant choice



Other factors may outweigh those mentioned above, e.g.

(a) In high vacuum, a solid lubricant may be the only one which will not evaporate.
(b) In textile or food manufacture, a white solid lubricant or a gas may have to be used to avoid all risk of contamination of the product.

Most common fluid lubricants are hydrocarbon oils produced from crude petroleum.

Advantages of hydrocarbon oils

(i) They are available in a range of viscosities that gives a wide choice of load, speed and temperature conditions to the designer.
(ii) They give a low, consistent coefficient of friction and have low compressibility.
(iii) Reasonably effective in carrying away heat from bearing surfaces.
(iv) They are inexpensive lubricants.

There two main categories of hydrocarbon lubricating oils, viz:

(i) PARAFFINIC: Have high pour point (due to the wax they contain), high viscosity indices, and good resistance to oxidation.
(ii) NAPHTHENIC OILS: Have low pour points and relatively low viscosity indices and oxidation stability.

Examples of SYNTHETIC LUBRICANTS are

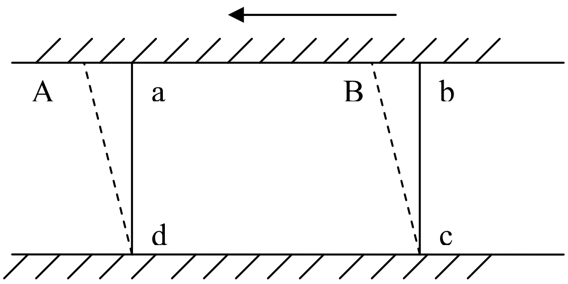
(i) Esters
(ii) Phosphates
(iii) Silicones.

They are used for specialises applications, like aircraft gas turbines where resistance to degradation at high temperatures of up to 300^{o}C are necessary.

Why is water generally not used as a lubricant?
Regardless of its ability to carry away heat fast, it has low viscosity, and low load bearing ability, relatively high freezing point and low boiling point.

Properties of lubricating oils

1. Viscosity: the internal cohesiveness of oil which gives the effort needed to shear a film.



Shear strain on an oil film between 2 surfaces

Sliding between 2 surfaces separated by an oil film produces a shear strain on the film – this is the viscosity of the oil.

2. Thermal or temperature stability: if an oil becomes hot in use, the heat generated should not breakdown the oil for effective lubrication.
3. Chemical stability: Oil can be chemically attacked by oxygen from air, or by water, or other substances. Chemical stability means the ability to resist chemical attack. This is related to thermal stability because the speed of chemical reaction increases as the temperature increases.
4. Compatibility: any interaction between the oil and other materials present. E.g. an oil may cause a seal rubber to swell or shrink or to soften or harden.
5. Corrosiveness (corrosivity): this is a type of incompatibility in which the oil or something in the oil attacks a metal component in the system. A non-corrosive oil may become corrosive after a period of use.
6. Thermal or heat conductivity: important where the oil is supposed to conduct heat away from the bearing.
7. Heat capacity (specific heat): in an oil circulation system, the amount of heat which oil can carry depends on the rate of flow and on the specific heat.
8. Flammability: the oil should not catch fire under the conditions it is used. Important in aviation and coal mining industries.
9. Toxicity: all aspect and respect in which a substance can affect health.
10. Availability; must be readily available.
11. Price: a single bearing failure in a critical position may cost the company the loss of lots of money. So the choice of the right type of oil should never be ignored for price reasons.

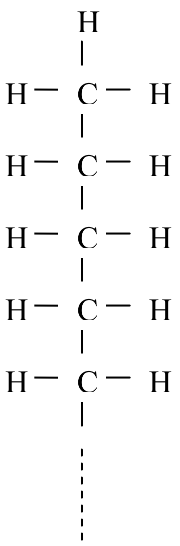
Why are tests carried out on lubricants?

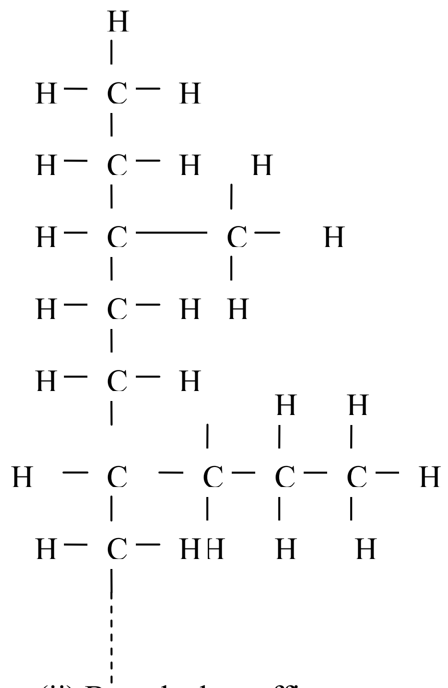
(i) To indicate its composition, chemical and otherwise.
(ii) To know its performance.
(iii) To know the suitability of a particular oil for a particular use by
  (a) Laboratory engine tests
  (b) Controlled field trials
(iv) To find out the additives added to the oil.

MINERAL OILS

These are lubricating oils obtained from petroleum. Their chemical compounds are mainly hydrocarbons, i.e. containing only carbon and hydrogen.

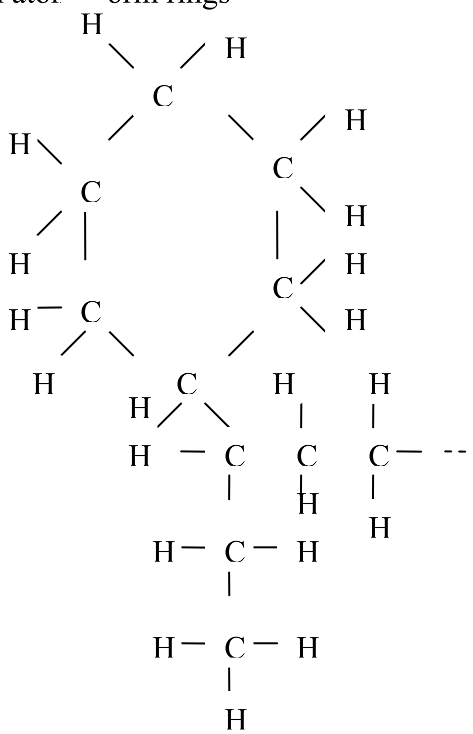
(a) Paraffins: carbon atoms are in straight or branched chains but not rings.





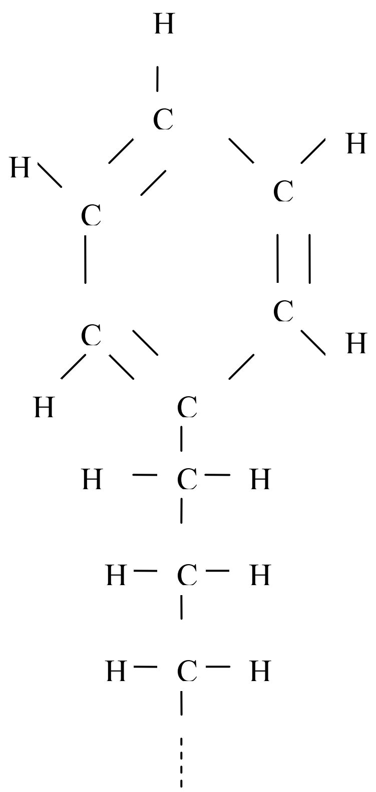
(i) n-paraffin (ii) Branched paraffin

(b) Naphthenes: some carbon atoms form rings



Naphthenes

(c) Aromatics (about 2%): carbon rings are again present but the proportion of hydrogen is reduced. The number of carbon atoms in a ring and the alternate single and double bonds give special properties to aromatic compounds.



Aromatic

(d) Asphaltenes: other compounds in mineral oils apart from the 4 types of hydrocarbons above. They contain other atoms such as oxygen, sulphur, phosphorus and nitrogen.

General rules

1. If the amount of carbon present in paraffin chains is much higher than the amount in naphthene rings, the oil is called "paraffinic" oil.
2. If the proportion in naphthene rings is only a little less than the proportion in paraffin chains, the oil is called "naphthenic".
3. Although the amounts of aromatics and asphalthenes present are always small, they play an important part in boundary lubrication.

Composition of a typical paraffinic and naphthenic oils

S/N	Constituents	% present in Paraffinic oil	% present in Naphthenic oil
1.	Carbon atoms in paraffin chains	63	52
2.	Carbon atoms in naphthene rings	33	44
3.	Carbon atoms in aromatic rings	2	2
4.	Sulphur (by weight)	0.5	1
5.	Asphaltenes	1	2

VISCOSITY

This is the resistance of a liquid to flow. Kinematic viscosity is measured in centistokes (cst) i.e. mm^2s^{-1}.

Water at 20^oC has a viscosity of approx. 1cst.

20W/50 motor oil at 20°C has a viscosity of approx. 300cst.
It is important to know the variation in viscosity with temperature.

Viscosity Index (VI) = $\dfrac{100(L-U)}{(L-H)}$

where,
U = the viscosity of the oil sample in centistokes at 40°C
the viscosity at 40°C of an oil of O viscosity index having the same viscosity at 100 °C as the sample.
H = viscosity at 40°C of an oil of 100 viscosity index having the same viscosity at 100 °C as the oil sample.

Oils with VI > 80 are called High Viscosity Index HVI oils
Oils with VI < 30 are called Low Viscosity Index LVI oils
Oils with 30 < VI < 80 are called Medium Viscosty Index .

Factors affecting choice of viscosity

Low viscosity	Intermediate viscosity	High viscosity
High bearing speed		Low bearing speed
Low load		High load
Fully enclosed	Some air access	Well ventilated
Full oil circulation	Splash or dip	No oil feed
Very small bearings		Large bearings

There are various graphical guides for the choice of viscosity selection.

Viscosity range for various applications

Oil Types	Viscosity range (cst) at operating Temperature
Clock or instruments oils	5 – 20
Sewing machine oils	10 – 25
Motor oil	10 – 50
Turbine oil	10 – 50
General purpose household oils	20 – 50
Hydraulic oil	20 – 100
Roller bearing oil	10 – 300
Plain bearing oil	20 – 1500
Gear oils	
Low speed spur, helical, bevel	200 – 800
Medium speed spur, helical, bevel	50 – 150
High speed gears	15 – 100
Hypoid gears	50 – 600
Worm gears	200 – 1000
Open gear lubricants	100 – 50,000

Boundary lubrication

This arises when two surfaces are not completely separated by an oil film, and contact takes place between asperities on the surfaces.
This can happen if the oil viscosity is too low, or bearing speed too low or bearing load too high. It can also happen if bearing becomes too starved of lubricant or if surfaces are not designed to produce a converging wedge e.g. spool valve, flat-face sliding valve, or a machine tool slideway.
When asperities rub against each other, friction and wear set in. these can be reduced by substances which either absorb on the asperity surfaces or react with them to produce films with less tendency to adhere to each other.
Oils containing naphthenes, sulphur, aromatics or asphaltenes will provide adequate boundary lubrication or " anti-wear additives" can be added to the oils. Most high quality lubricants or hydraulic oils contain 0.1% - 0.7% of such additives.
For severe rubbing contact due to high load or moderate load and high sliding speed e.g. metal working and hypoid gear boxes. In such case "extreme pressure additives" are needed.

S/N	Antiwear additives	Extreme pressure additives
1.	Ethyl stearate	Cetyl chloride
2.	Stearic acid	Sulphurised oleic acid
3.	Tri-para-cresyl phosphate	Chlorinated wax
4.	Tri-xylyl phosphate	mercaptobenzothiazole
5.	Rapeseed oil	Lead naphthanates
6.	Methyl stearate	Sulphurised sperm oil
7.	Zinc diethyl dithiophosphate	Chlorinated paraffinic oils
8.	Dilauryl phosphate	Molybdenum disulphide

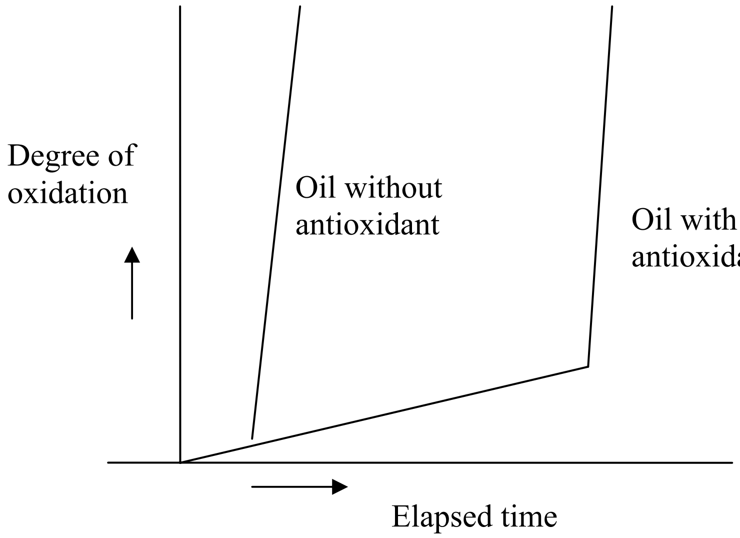
ADDITIVES USED FOR SPECIFIC EQUIPMENT

Equipment	Additives
Petrol engines	Anti-oxidant; corrosion inhibitor; viscosity index improver; detergent/dispersant, anti-wear.
Diesel engines	Anti-oxidant; corrosion inhibitor; detergent/dipersant; antiwear; anti-foam: basic additives (to neutralise acids).
Steam engines	Anti-oxidant; corrosion inhibitor
compressors	Anti-emulsifier
Gears; spur or bevel	antiwear; anti-oxidant, anti-foam; sometimes corrosion inhibitor
Gears; spiral bevel	Extreme pressure, anti-oxidant, anti-foam
Gears; worm	Friction reducer, anti-oxidant, corrosion inhibitor
Machine tool slideways	Friction controller, antioxidant, anti-wear, corrosion inhibitor
Hydraulic systems	Anti- oxidant, anti-wear, anti-foam; corrosion inhibitor, pour-point depressant, viscosity-index improver.

OIL STABILITY
Oils deteriorate with time because the base oils and the additives break down chemically. Main source of chemicals breakdown is oxidation.

Order of resistance to oxidation is
Paraffins
Naphthenes
Aromatics
Additives
Asphalthenes
Unsaturates

With paraffins being the most resistant and unsaturates being the least resistant.
So mineral oils are refined in order to remove the aromatics, small amounts of unsaturates, molecules containing sulphur, oxygen or nitrogen.
As oxidation resistance is improved the boundary-lubricant performance declines.
Substance oxidation rate increases at higher temperature.
Antioxidants are additives which reduce the harmful effects of oxidation. The anti-oxidants react with organic peroxide thus blocking the chemical chain reaction.



Oxidation produces acidic compounds which can cause corrosion together with increase in viscosity and eventually tarry deposits and insoluble oxidation products.

Thermal stability
Even without oxygen, oil will still decompose when heated above a certain temperature. This type of breakdown is called "Thermal degradation", it causes dislocation of the oil, and a change in viscosity. Thermal stability can be improved by removing compounds which lower the oxidation resistance.
A guide for the minimum possible temperature is the "pour point" - it is the temperature below which the oil will not pour.

Contaminations
These cause the oil to deteriorate in service because of contaminations. Possible types are:
water from condensation
unburned fuel in an engine
wear debris
dust from the atmosphere
process liquids
chemicals in chemical plants

soot from faulty fuel combustion
breakdown products of additives
organic debris from microbiological attacks

Dust, corrosion products and wear debris can increase wear and thus produce more wear debris.

Ways of coping with contamination problems

(i) Prevent entry of contaminants like atmospheric dust and moisture, chemical and process liquids can be controlled by efficient sealings, filteration of air supplies.

(ii) Removal of contaminants: by filtration or centrifuging. Filtration for solid particles and centrifuging for liquids. Large ferrous particles can be removed by a magnetic plug.

(iii)Dispersing contaminants: things like soot and oil breakdown products accumulate together and form large particles blocking oilways or filters. Sometimes it is preferable to keep contaminants dispersed in the oil using dispersants or detergent additives – keeping the particles too fine to cause any problems. This is less satifactory than removing the contaminants.

(iv)Neutralisatio: acidic products from oil breakdown or from burning of sulphur-containing fuels may be neutralised by basic additives such as calcium compounds in order to prevent corrosion.

Compatibility

Lubricants and other materials shouldn't have any undesirable effect on each other. E. g. lubricating oils and rubber (seals flexible holes), oils and plastics, adhesives and paints: synthetic oils on metals.
Mineral oils **cannot** be used with natural rubber or SBR (a common synthetic rubber).
Mineral oils **can** be used with medium or high nitrite and neoprene.
Copper, brass and bronzes **should be avoided** if possible in all situations.

Corrosion

Oils which are to be used in situations where there could be a particular risk of corrosion will often have a corrosion inhibitor added to them.

Examples of corrosion and rust inhibitors
Zinc diethyldithiophosphate
Trialkyl phosphates
Sulphurised terpenes
Calcium or barium sulphates.

Reasons for using a different base oil in place of a mineral oil are:

(i) Temperature too high or too low for mineral oil
(ii) Lower flammability needed
(iii)Compatibility problems e. g. with natural rubber
(iv)Contamination problems e. g. with food.

Other types of oils used for lubrication

(i) Natural oils: vegetables oils and animal fats. They are excellent boundary lubricants, but much less stable and tend to breakdown giving sticky deposits.
Rapeseed is still used to improve boundary lubrication in mineral oil or used on its own. It doesn't cause carburization of steel.
Castor oil is used for its good compatibility with natural rubber.

(ii) Organic esters: compounds obtained by reaction of an alcohol with an acid. They can withstand higher temperature than mineral oils e. g. gas turbine engines.
(iii)Phosphate esters: produced by the reaction of alcohol and phosphoric acid. They are used for their outstanding fire resistance qualities. Limited to temperature greater than 100^oC because of poor thermal stability. Attacks paints, plastics and rubbers.
(iv)Silicones: has good high temperature properties. Chemically inert, repel water, non-toxic and electrically insulating. Not good boundary lubricants for steel against steel.
(v) Chlorinated and fluorinated compounds: include chlorinated biphenyls, fluorocarbons, chlorosilicones and fluorosilicones. Good chemical inertness giving them good fire resistance, good thermal stability. Costly and not particularly good lubricants.
(vi)Polyglycols: when heated above temperature of 200^oC, they decompose cleanly. Used at temperature of up to 400^oC or higher because they will not leave any deposits of coke or ash. Some of them are soluble in water.
(vii) Emulsions: water dispersed in oil or oil dispersed in water in form of tiny droplets. The dispersion is stabilised (i.e. droplets can not combine together and separate out) by surface active materials like soap or detergent giving all the droplets same electrical charge and the water around them some opposite charge thus the droplets will repel each other and can not combine or coalesce. Normal emulsion is oil dispersed in water. Invert emulsions are water dispersed in oil.
(a) Soluble oils: dilute emulsions of oil in water. 0.5 – 1.0% of oil. Used as coolants in metal working; grinding, drilling, boring, turning, milling etc. Water does the cooling and oil droplets lubricate the tool surface and reduce wear and adhesion of the swarf.
(b) Rolling oil emulsions: oil in water emulsions used in metal and plastic rolling. Oil may be mineral, animal, vegetable or synthetic. Cools the rolls and control friction between roll and strip, reduce roll wear and prevent strip sticking to the rolls.
(c) Invert emulsion: contains up to 35% of water dispersed in mineral oil. Used as fire resistant hydraulic fluids.

METAL WORKING LUBRICANTS

Functions of lubrication in metal working processes are:
(i) To lubricate contacting surfaces of tool and work piece
(ii) To reduce wear of tool
(iii)To avoid seizure or breakage
(iv)To cool the tool and work piece at high temperature so as to avoid seizing or welding together
(v) To provide a protective oxide film on the freshly exposed metal surfaces

1. Extrusion, tube drawing and wire drawing: high loads are used to produce high deformation of workpiece. Main objective is to reduce friction for movement to occur. Viscous lubricants such as soaps at low temperatures or molten glass at high temperatures or solid lubricants such as graphite are used.
2. Rolling: objective is to keep friction down and to prevent rolled stock from sticking to rolls. Reducing friction reduces power needed to drive the rolls or enables higher reductions to be obtained for the same power. Lubricants used are kerosene, synthetic oils and many types of emulsions.
3. Metal cutting: objective – to cool the tool and prevent chips or swarf from sticking to it. Sticking problem is removed by means of extreme pressure additives e.g. sulphur and chlorine-containing extreme pressure additives.

Best coolant is water so most metal cutting lubricants are water based. E.g. emulsions of 5 – 10% oil in water, 'soluble' oils with 0.5 – 1.0% oil in water to 'synthetics' with extreme pressure additives dissolved directly in water.
It would have been lovely to use the same liquid lubricating the cutting operation to also lubricate the bearings and slideways, and also to act as a hydraulic fluid, but this is not possible because of the decrease in the proportion of mineral oils in the cutting operation lubricants.

Why the need for rationalisation of lubricating oils?
(a) With a large variety of oils, the purchasing and storage problems are increased.
(b) If smaller variety of oils are needed, they can be bought in larger quantities thus there is the advantage of bulk price reduction
(c) With fewer oils, there is less risks of wrong one being used in a particular application.

Lubrication rationalisation depends on the following considerations:
1. The oil viscosities: for most applications, an increase of 30 – 50% over the ideal viscosity is usually harmless. BS 4231 indicates the viscosities at 3 different reference temperatures; 37.8 ^oC, 60 ^oC, and 98.9 ^oC, respectively.
2. Type of base oil and additives present: these should be chosen such that the performance of the chosen oil meets the most severe requirements for various applications, e.g. oxidation resistance should be good enough for the highest bearing temperatures. Boundary lubrication should be adequate for the severe loadings; and pour points should be low enough for the coldest starts.

Procedure for selecting the best lubricant oil for a particular situation:
1. Calculate or use figures to obtain the best viscosity for each bearing or gear at the operating temperature.
2. Decide on what VI (viscosity index) is needed to cover the whole temperature range from coldest starting temperature to hottest operating temperature.
3. Convert the viscosity at operating temperature to the viscosity at reference temperature using figures or BS 4231.
4. Decide which BS 4231 or SAE grade meets the needs.
5. Decide which additives are needed.
6. Decide if mineral, natural or synthetic oil will meet the need.
7. If a machine has several different lubricated parts, decide whether the same oil can be used for all of them.

VISCOSITY

Basic definitions: for a cube of unit face area and a shear stress τ put on opposite faces, then movement du of top face relative to the base is:

$$\tau = G.\frac{du}{dz} =$$

Where dz = height of the cube

G = n shear modulus of the material

τ = stress

du, dz = lengths

$\left(\frac{du}{dz}\right)$ is the angle of shear (non-dimensional)

G is in Newtons/m^2

In a fluid, similar state of affairs occurs:

$$\tau = \eta.\frac{du}{dz}$$

Where η written for the modulus of viscosity.

du = a velocity

τ = a stress

dz = a distance

$\eta = \tau \Big/ \left(\frac{du}{dz}\right)$ of units (stress x time) or (force/area x time)

Force = mass x acceleration $= M \times L/T^2$

$$\therefore \quad \eta = M \times L/T^2 . \frac{T}{L^2} = M/LT$$

Fluids obeying Hooke's law are called Newtonian fluids.

For a stress of 1 dyn/cm^2 and velocity gradient $\frac{du}{dz} = 1\sec^{-1}$, then viscosity of the fluid is 1 poise (named after Dr. J. L. M. Poiseuille, 1840)

Viscosity = force/area X time

Poise = $dyn/cm^2 \times s$

Reyns = $lb/in^2 \times s$, hence

$$\frac{lb \times 453.6 \times 980.7}{in^2} \times s = poises$$

OR reyns (lb/in^2 s) = poises X 1.45(03)X10^{-5}

1 poise = 100 centipoises (cP)

Dynamic viscosity:

Dynamic viscosity (v) (greek nu) = $\frac{viscosity(\eta)}{Density(\rho)}$

$$\nu = \frac{\eta}{\rho} = \frac{poises}{density} = Stokes$$

1 stoke = 100 centiStokes (cS)

REYNOLDS EQUATION

Derivation of Reynolds:

Assumptions:

1. Body forces are neglected i.e. there are no extra fields of forces acting on the fluid. This is true except for magnetohydrodynamics.
2. The pressure is constant through the thickness of the film. As the film is only one or two thousandths of an mm thick, it is always true. With elastic fluids there may be exceptions.
3. The curvature of surfaces is large compared with film thickness. Surface velocities need not be considered as varying in direction.
4. There is no slip at the boundaries. The velocity of the oil layer adjacent to the boundary is the same as that of the boundary. (This is universally accepted).

Assumptions 5 – 8 are put in for simplification of the equations (they are not necessarily true.)

5. The lubricant is Newtonian. i.e. proportional to rate of shear.
6. Flow is laminar. In big turbine bearings this is not true and the theory is being developed.
7. Fluid inertia is neglected. Even if Reynolds number is 1000, the pressures are only modified by about 5%.
8. The viscosity is constant throughout the film thickness. This is certainly not true but leads to great complexity if it is not assumed.

HYDRODYNAMIC LUBRICATION

Perfect lubrication: the two surfaces are separated by a film of lubricant; and the behaviour is governed by the fluid characteristics.

Consider hydrodynamic lubrication of

(i) Two parallel surfaces
(ii) Inclined surfaces
(iii) Convergent channel
(iv) Divergent channel
(v) Divergent convergent channel

PRESSURE AND LOAD

CENTRE OF PRESSURE

POWER LOSS DUE TO SHEAR STRESS OF THE SURFACES

POWER LOSS

THRUST BEARINGS

Frictional force

Very short (narrow) bearings

JOURNAL BEARINGS

Pressure Equation – short bearing

Load carried by a journal bearing

Determination of coefficient of virtual friction in journal bearings

LUBRICANT HANDLING AND STORAGE

Why special care in lubricant Handling.

1. Since they lubricate precision equipment / components like bearings, seals, valves etc, lubricants used are as critical as these components
2. Lubricants can also be degraded by heat, cold, moisture, chemical attack or solid contaminants just like any metallic item.
3. Lubricants have to be packed to withstand mechanical and physical damage.

LUBRICANT PACKAGING

STORAGE

1. Avoid storing too many types of lubricants
2. Store should have some spare capacities to cope with additional needs
3. Decide on how much of each type to be stored and in what size containers. At least 2 containers of each oil or grease type unless large storage tanks of greater than 150gal are used.
   Size and No of containers depend on
   (a) Purchase and store in large quantities (more economical)
   (b) Small containers – emptied more quickly and less susceptible to contamination
   (c) Small containers are easier to handle.
4. Plan location and layout of stores area. E.g. a corner of an enclosed factory area, basement, or cellar or separate building away from main factory.

5. If combined with storage of solvents and paints, overall fire risk is much higher and should be in a building with adequate fire precautions (leads to less insurance premiums for main factory)
6. Smoking and naked flames should be banned in any lubricant storage area.
7. Access to lubricant stores should be restricted to few people authorised to issue and dispense lubricants.
8. Lubricant store should have floor gratings and drainage channels (for drainage of spilled oil and reduction of floor contamination).
9. In drum storage etc, avoid / prevent moisture accumulating underneath and corroding their bases.
10. Avoid water collecting on drums stored outside. i.e. they should be stored under cover by allowing water to drain off, and also cover with tarpaulin or plastic sheet.
11. Lubricant containers must always be labelled clearly and carefully. (To avoid catastrophic results of wrong usage.)
12. Also date identification should be on lubricant containers. (so as to use containers in same sequence as they are bought.)
13. The store should accommodate dispensing equipment, pumps, charts, cleaning rags etc.
14. Suitable space and facilities should be provided for laundering and disposal of used lubricants.

HEALTH AND SAFETY ASPECTS OF LUBRICANTS

Some basic definitions:

1. Combustion or burning: a form of rapid oxidation in which heat is produced and the burning materials is broken down to smaller molecules of highly oxidised combustion products.
2. Flash: a brief ignition lasting less than a second. Occurs when a vapour is ignited but no more vapour is immediately available to sustain the combustion.
3. A flame: burning gas visible flame occurs when the burning is intensive enough to cause incandescence. i.e. for bright light to be produced.
4. Fire: a self sustaining combustion in which flame is produced. Differs from smouldering which is self sustaining combination without flame. In both, the heat produced by combustion of some part is sufficient to keep the temperature high enough to ignite a further part.
5. A spark: a tiny fragment of a material so hot that it is incandescent. Its temperature is probably greater than 2000^{o}C.
6. An explosion: takes place when pressure builds up to such an extent that it cannot be contained or dispersed slowly. An explosive material is a material which builds up pressure so quickly that even when faster than the speed of sound producing a shockwave.

Important tests carried out on lubricants

1. Flash point
2. Spontaneous nignition
3. Wick ignition
4. Spray ignition
5. dieselling