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The Basics of Lubricants and lubrication

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Abstract

This article is about the basics of lubricants and lubrication. This article covers brief knowledge about lubricant, their nomenclature, properties and additives in the lubricant.

About the Author

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Intended Readers

Introduction

The Basics of Lubricants and lubrication

How Industrial Oils functions?

A lubricant for modern machinery must do much more than live up to its classic definition- A substance capable of reducing friction, heat and wear when introduced as a film between two solid surfaces. It must

- Lubricate- form a fluid film between highly loaded parts.
- Act as a coolant to remove heat.
- Receive and carry away contaminates arising from both internal and external sources.
- Act as a hydraulic medium in many applications.
- Protect against wear of highly loaded parts when the fluid film is very thin.
- Protect against rust and corrosion of precision parts made of various metals.
- Protect against accumulation of deposits in the lubrication system.
- Resist aeration and foaming which can cause malfunction
- Resist or aid emulsion formation in wet system

Note: The first four functions can be performed by any properly refined mineral oil as the substance most commonly used as base of lubricant. But the other functions involve properties not normally possessed by mineral oil. They can be achieved by use oil soluble chemicals called lube *oil additives*

Description

Meaning of lubrication

Friction - is created when there is relative motion between two surfaces.Resistance to motion is defined as friction

Lubrication is use of a material between surfaces to reduce friction, any material used is called a lubricant

Two main methods

- ✓ Hydrodynamic lubrication
- ✓ Boundary lubrication

Hydrodynamic lubrication

- Also called complete or full flow.
- Occurs when two surfaces are completed separated by a fluid film

Boundary lubrication

- Occurs when Hydrodynamic lubrication fails.

- By adsorption or chemical reaction.

Types of Lubricant – Physical

- Liquid
- Solid
- Semi solid
- Gases

Liquid-Typical lubricants are liquid/fluids Ex-Mineral oil or synthetic oils
Solid-Graphite, MoS_2
Semi solid-Greases
Gases-Atomised 2 stroke oils

Typical lubricants - Application

- Engine oils
- Gear Oils
- Turbine Oils
- Hydraulic Oils
- Metal working oils
  - Cutting oils
  - Forming Oils
- Rust preventives
- Heat Transfer Oils
- Heat Treatment Oils
- Quenching Oils
- Tempering Oils
- Refrigeration Oils
- Rubber Process Oils
- Ink process Oils
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Lubricant – Components

Base Oils-

1. Mineral by-products of crude oil refining process.
2. Base oils are polymerized or synthesized further and called synthetic

Additives

1. Natural
2. Synthetic

A lubricating oil is composed of a base stock blended with various performance enhancing additives. The base stock may be petroleum oil, synthetic oil or in rare specialized instances vegetable oil. Petroleum oils are usually classified as either paraffinic or naphthenic. Paraffinic oils, as name implies contains paraffin wax and are the most widely used type of lubricating oil stock. In comparison to naphthenic, paraffinic oils are more resistant to oxidation, have lower volatility, a higher viscosity index and generally a better lubricant. Since naphthenic oils are essentially wax free, they have low pour point.
Synthetic based lubricants, that are lubricant produced from man-made products rather than from

vegetable or refined petroleum oils, are generally superior to petroleum lubricant in most circumstances. Despite of the superior performance of synthetic lubricants, their use is usually limited to severe or unusual applications due to their cost which can be many times more than a similar petroleum product.

Function of a lubricant

Lubricate - Reduce friction
Cooling - Heat transfer
Cleaning - Detergency
Noise pollution - dampening
Sealing – prevent leakage
Protection – prevent wear

Lubricate – reduce friction

- ✓ **The effects of friction**
  - **Metal to metal contact**
  - **Leads to wear and tear**
  - **Generates heat**
  - **Results in Power loss**
- ✓ **Lubricant reduces friction by forming a film**
  - **Reduces ill effect of friction**

Cooling

- ✓ **When fuel is burnt in an engine**
  - **33% is useful power**
  - **33% removed by cooling water**
  - **33% by lube oil and radiation**
- ✓ **Lube oil removes heat from all areas and brings it to the engine sump.**
- ✓ **Improper cooling can lead to overheating, lead to wear, distortion and failure.**

Cleaning

- ✓ **Cleans carbon and varnish deposits**
- ✓ **Flushes the entire system removing**
  - **Soot**
  - **Deposits**
  - **Acids**
  - **Wear products**
  - **Moisture**
- ✓ **Removes external contaminants dust, moisture (external)**

Noise reduction

- **Reduce noise, By preventing metal to metal contact**
- **Dampens noise, As between camshaft and tappet**

Sealing

- **Oil film Between piston ring and liner**
- **Helps in creating a gas tight seal**

Protection

- **Protection against acids and moisture**
- **Very important to increase life of component and equipment**

Why might a lubricant fail to lubricate?

There are two basic reasons

- It loses some of the lubricating properties provided by additives during service.
- It becomes contaminated from internal and external sources.

Properties of lubricants

A. Viscosity
B. Viscosity index
C. Pour Point
D. Flash Point
E. Neutralization Number

A. Viscosity

It is the single most important characteristics of a lubricant. Viscosity is a measure of fluids internal friction or resistance to flow. The higher viscosity a fluid has , the greater the internal resistance and greater its load capacity. Oil with correct viscosity for a particular application will be thick enough to support the load while not being so thick to cause excessive fluid friction and a corresponding increase in operating temperature.

Dynamic or absolute viscosity is defined as the ratio of shear stress to shear rate and most commonly measured in poise or centipoise (cP)

Kinematic viscosity is the dynamic viscosity divided by the density of the lubricant and is the most commonly measured in centistokes. The kinematic viscosity is related to the time required for a fixed volume of lubricant to flow through a capillary tube under the influence of gravity. The kinematic viscosity is the most common method of expressing a lubricants viscosity.

Kinematic viscosity

- Measure of internal resistance to flow
- "Thickness" of fluid (in laymen terms)
- Decreases with increase in temperature
- Important in lubricant selection
- Increase in used oil indicates oxidation
- Specified at 40˚C and 100˚C
- Measured in Centi Stokes (CSt)

Example: Oil Specifications ... Ex. ISO VG 460 means **Average kinematics viscosity** of oil at 40 deg C (Min: 414, Max ; 506 and Average : 460) , SERVO MESH SP 150 (Viscosity range 135 to 165); SERVO MESH SP 220 (Viscosity range 198 to 242)

Kinematic Viscosity – Recommendations

- Low Viscosity oils used
  - High speeds
  - Low pressure
  - Low temperature
- High Viscosity oils used
  - Low speeds
  - High pressure
  - High temperature

B) Viscosity index(VI)

- Measure of fluids change of viscosity with temperature.
- Empirical number
- Higher the VI lower will be the change of viscosity with temperature
- Indicator of temperature range of operations

C) Pour Point

A lubricant's pour point is the lowest temperature at which fluid will flow. In paraffinic oils the pour point is the result of the crystallization of waxy particles. In naphthenic oils pour point is the result of the decrease in viscosity caused by decrease in temperature. This property is important in choosing a lubricant for cold weather

- Lowest temperature at which the fluid will flow
- Indicates lowest operating temperature
- Measured in ˚C

D) Flash Point

- Lowest temperature at which the vapor above the liquid will ignite under flame
- Indicated safe maximum temperature of operation.
- Indicator of volatility
- Test method - COC and PMCC
- Measured in ˚C.

E) Neutralization Number

The neutralization number is a measure of the acidity of an oil and is the amount, in milligram of potassium hydroxide (KOH) required to neutralize one gram of oil. A relative increase in the neutralization number indicates oxidation of oil. TBN is total base number and TAN is total acid number. TBN is a measure of the reserve alkalinity or reserve acid neutralization remaining in the oil. TAN measure the increase of oil oxidation and build-up of corrosive acidic compounds. Total Base Number (TBN)

- Measured the acid neutralizing reserve in oil.
- Important for deciding discard of oil
- Decreases due to Oxidation of oil , Water contamination &Fuel contamination
- Measured in Mg KOH/gm of oil
-

Lab Tests - for lubricants

- Kinematic viscosity - ASTM D 445
- Viscosity index - ASTM D 2250
- Pour Point - ASTM D 97
- Flash Point - ASTM D 92 (COC)/ASTM D 93 (PMCC)
- Total Base Number (TBN) - ASTM D 664

What are additives?

Lubricant additives used includes

- Extreme pressure (EP) anti-wear additives to provide the necessary load carrying capacity and

prevent scuffing of moving parts under boundary lubrication.

- Inhibitor additives to control oil oxidation, rust and corrosion.
- Dispersant and detergent additives to control deposit formation throughout the system.
- Special purpose additives such as pour point depressants, bactericides, emulsifiers, demulsifiers, tackiness agents, friction reducers, foam inhibitors, mist suppressors, viscosity index improvers.

The amount and types of additives used depend upon the performance characteristics to be met. Oil must be designed for a wide variety of services and it is extremely important that the correct oil should be used in given machine at all times.

Additives are:

- ✓ Classified on their functional capability
- ✓ Enhance existing property
- ✓ Suppress undesirable property
- ✓ Impart new property

What additives do in Engine Oils?

- ✓ Protect metal surfaces - (rings, bearings, gears, etc.)
- ✓ Extend the range of lubricant applicability
- ✓ Extend lubricant life

Surface Protective additives

- Anti-wear and EP Agent-
- Corrosion & Rust inhibitor
- Detergent
- Dispersant
- Friction modifier

Additive type- Anti wear & EP Agent

Purpose	Reduce friction & wear. Prevent scoring & seizure
Typical compounds	ZDDP, Organic Phosphates, acid phosphates, organic sulfur and chlorine compounds etc.
Function	✓ Chemical reaction with metal surface and forms a film. ✓ Prevents metal-to-metal contact
Corrosion & Rust inhibitor Purpose	Prevent corrosion and rusting of the metallic parts in contact with lubricant
Typical compounds	ZDDP, Metal phenolates, Basic Metal sulphonates, fatty acid & Amines

Function	✓ Preferential adsorption of polar constituent on metal surface. ✓ Provide protective film ✓ Neutralize corrosive acids

Detergents

Purpose	Keep surface free of deposits
Typical compounds	Metallo organic compounds of Sodium, Calcium and Magnesium phenolates, Phosphonates and sulphonates
Function	Chemical reaction with sludge and varnish precursors to neutralize them and keep them soluble

Dispersant

Purpose	Keep insoluble contaminants dispersed in the lubricant
Typical compounds	Alkyl succinimides, alkyl succinic esters and mannich reaction products
Function	✓ Contaminants are bonded by polar attraction to dispersant molecules. ✓ Prevented from agglomerating ✓ Kept in suspension due to solubility of dispersant

Friction modifier

Purpose	Alters coefficient of friction
Typical compounds	Organic fatty acids and amides. Lard Oil, high molecular weight organic phosphorus. Phosphoric acid esters
Function	Preferential adsorption of surface active materials

Pour Point Depressant

Purpose	Enable lubricant to flow at low temperature
Typical compounds	Alkylated naphthalene Phenolic polymers, Polymethacrylates Maleate/fumerate copolymer esters

Function	Modify wax crystal formation to reduce interlocking

Viscosity modifier

Purpose	Reduce the rate of viscosity change with temperature
Typical compounds	Polymers and copolymers of olefins, methacrylates, dienes
Function	Polymers expand with increasing temperatures This counteract oil thinning

Antifoamant

Purpose	Prevent lubricant from forming a persistent foam
Typical compounds	Silicone polymers Organic copolymers
Function	Reduce Surface tension to speed collapse of foam

Antioxidant

Purpose	Retard oxidative decomposition
Typical compounds	ZDDP, Hindered phenols, Aromatic Amines, sulfurized phenols
Function	Decompose peroxides Terminates free-radical reactions

LUBRICANT - NOMENCLATURE AND SPECIFICATIONS

Nomenclature

- **Crankcase oils - SAE numbers**
- **Viscosity classification – ISO 3448**
- **Grease – NLGI Numbers**

Viscosity Grade Classification Systems

ISO – Industrial Oils	-cSt @ 40°C
AGMA – Industrial Gear Oils	-cSt @ 40°C
SAE – Engine Oils	-cSt @100°C, cP @150°C
	- cP @ -10°C to -40°C
SAE – Gear Oils	-cSt @100°C

-cP @ -12°C to -55°C

Lubricant - Specifications

- Crankcase oils - SAE numbers
- Crankcase oils - Performance levels
- Crankcase oils – OEM Specifications
- Viscosity classification
- Grease specification

Major specifying organizations

- **SAE – Society of Automotive Engineers (USA)**
- **API - American Petroleum Institute**
- **US Military Specs – US - MIL – 2104 -**
- **CCMC – European Specification**
- **ISO – International Standard Organization – ISO 3348**
- **NLGI – National Lubricating Grease Institute**

SAE viscosity grades for engine oils

- **Designated** With corresponding viscosity, For high temperature application, Warmer areas/regions SAE 20,SAE 30,SAE 40,SAE 10,SAE 50,SAE 60.
- Designated With corresponding viscosity, For low temperature application, Colder areas/regions SAE 0 W, SAE 5 W,SAE 10 W,SAE 15 W,SAE 20 W,SAE 25 W
- Can be used either in summer season or in winter seasons. Gradual shift to multi grades. Shift also due to lower oil consumption by multi grades available as Engine oil and Gear Oils. Mono grades are designated with single SAE number SAE 10, 20, 30, 40, 50 SAE 5W,10W, 20W,25W
- Multi grades are designated with two SAE number widely in use todays 10w/30, 15w/30, 25w/50 .SAE 5W/30, 20W/40 Suitable for use in winter and summer months or seasons. Available in Engine oils & Gear oil

GREASE CHARACTERISTICS

a) Consistency

A grease number indicates its consistency. A greases' consistency, or hardness is a measure of its resistance to deformation by an applied force and is in most cases, a grease's most important characteristics. Grease's consistency is dependent on its base oils viscosity and the type and amount of thickening agent used. Consistency measured in terms of depth, in tenth of a millimeter that a standard cone will sink into a grease under prescribed condition and is referred as **penetration number**. The National Lubricating Grease Institute (NLGI) has established consistency number or grades, ranging from 000(soft) to 6(hard), corresponding to specified ranges of penetration numbers.

The consistency of a grease should be soft enough to allow easy application and provide acceptable lubrication, but not so soft as to leak out of the area being lubricated. In automatic greasing systems like in Sinter machine and Sinter cooler used in Steel industries, a grease with a consistency softer than is optimum for the lubrication of the equipment may be required so that it can be pumped through the long line & valves.

A grease's consistency may change while in use primarily due to the mechanical shearing of the thickening agent particles. The resistance to this change is referred to as Consistency Stability. EP stands for Extreme Pressure EP 1 & EP 2 grease. And number 1 & 2 indicates consistency of the grease.

b) Consistency stability

A grease's consistency may change while in use primarily due to the mechanical shearing of the thickening agent particles. The resistance to this change is referred to as Consistency stability.

c) Dropping Point

A grease's dropping point is the temperature at which the grease becomes soft enough that a drop of fluid will fall from the grease. At or above the dropping point, grease will act as fluid. It should be noted that the dropping point is not the highest allowable operating temperature for grease, as grease may actually start to break down far below the dropping point. The dropping point should only be used a general indication of a grease temperature limit. For example EP1 & EP2 grease min dropping point temperature is 180 ^{o}C.

A few types of grease have the ability to return to their original consistency after temporary exposer to temperature at or above dropping point. This property is referred as reversibility

National Lubricating Grease Institute - NLGI Numbers

NLGI Grade Number	ASTM worked penetration 77˚F (25˚C)
000	445-475
00	400-430
0	355-385
1	310-340
2	265-295
3	220-250
4	175-205
5	130-160
6	85-115

WHY DOES A LUBRICANT FAIL TO LUBRICATE ?

LUBRICANT PROBLEM	WHY?	WHAT HAPPENS?
A. LOSES PROPERTY OF		
1. Oxidation Control	Inhibitor used up stopping attack on oil and additives	Oil viscosity increases, deposits formed. Acids corrode metals
2. Rust Inhibition	Inhibitor used up	Oil fails to protect against

	protecting iron surfaces	further rusting
3. Load carrying	Additives consumed by reaction with metal surfaces or removed by water	Can't continue to protect against scuffing
4. Dispersancy	Dispersant become overloaded with liquid and solid contaminants	Solids(Varnish & sludge) form
B. BECOMES CONTAMINATED BY SOLIDS		
1. Dirt	Dirt comes from every where	Promotes wear ,deteriorates lubricant properties
2. Wear Metals	A sign of unhealthy machines	Shortened machine life unless corrected
3. Rust	Oxygen, water and iron have interacted	Contributes Wear
4. Carbon	Oil overheated	Deposits clog oil passages
5. Sludge and varnish	Oxidation products have become insoluble	Deposits form on machine parts and control valves
C. BECOMES CONTAMINATED BY LIQUIDS		
1. Water and process fluids	A sign of leaky seals and condensation	Affects lubricant efficiency and promotes oil deterioration.
2. Oxidation products	These will soon be solids	Fore runner of more solid debris
3. Other lubricating oils	Can interfere with the function of the system lubricant	Can alter desirable properties of system lubricant.

TROUBLE SHOOTING.

FIRST STAGE:- Categorize the lubrication system in a particular equipment or systems. They may be one of the following categories.

1. System in which temperatures are low and decomposition of the oil and external contamination are minimal
2. Systems in which bulk or localized temperatures are high. Oxidation becomes a major concern and the oil can become contaminated by its own deterioration products. There is little external contamination.
3. System where temperatures are high and so external contamination. Oxidation takes place and its products contaminate the oil from inside. Dust, water, process fluids, metal particulate, stray oils can contaminate the oil from outside.

SECOND STAGE:- Preliminary sensory analysis of the lubricating oil

1. Is the oil clear, or is it cloudy-contaminated with water or particulate matter.
2. Is it as light in color as make up oil? Dark color could indicate contamination with foreign oil or

oxidation.

3. Does any unusual kind or amount of solid debris are somewhere in the system?
4. Smell okay? A burned or sour odor suggests excessive oxidation an odd smell the possibility of foreign oil.

If all is not well we should go for replacement of the oil if the lubricant quantity is less or go additional tests to pinpoint the problem if lubricant quantity is substantial.

Acknowledgement

References

References

- SAE – Society of Automotive Engineers (USA)
- API - American Petroleum Institute
- ISO – International Standard Organization – ISO 3348
- NLGI – National Lubricating Grease Institute
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