An Overview on Manufacturing of Lubricating Greases and Testing Processes

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Article Info

Article history:
Received 1 January 2014
Received in revised form
10 January 2014
Accepted 20 January 2014
Available online 1 February 2014

Keywords

Grease,
Consistency,
Base Oil,
Additives,
Penetration

Abstract

Lubricating grease is one of the basic needs of Industrial and Automobile sector to upgrade the durability and dependability, serviceability and service efficiency of mechanisms, machines and equipment. Grease is manufactured through various processes with the help of pressure vessels or open cooking kettles under high temperature and pressure. Lubricating greases were manufactured on the basis of application required. Grease-making can be a long, energy-consuming, high-maintenance and multi-step process but new technologies have been developed to reduce as these processes to very much extent. Manufacturing of grease require raw materials such as mineral oils, a thickener and additives to reduce the friction and temperature between moving components. Testing of greases as per ASTM /IP/BIS Standard is a very important aspect to categories grease under NLGI grades. Various testing methods for greases have been described in this study.

1. Introduction

Lubricating grease is defined as a semi-fluid to solid product of a dispersion of a thickener in a mineral oils with special additives to enhance physic-chemical properties of grease. Grease is a lubricant which has been thickened in order that it remains in contact with moving surfaces and not leak out under gravity or centrifugal action.

There has been a need since ancient times for lubricating greases. The Egyptians used mutton fat and beef tallow to reduce axle friction in chariots as far back as 1400 B.C. Good lubricating greases were not available until the development of petroleum based oils in the late 1800's. Today there are many different types of lubricating greases but the basic structure of these greases is similar.

Used as the dispersion medium, which accounts for 75-95% of the grease composition by mass, are petroleum or synthetic oils and other lubricating liquids. The dispersed phase (5-25%) can consist of salts of high molecular weight carboxylic acids (soaps) and additives (0-10%) depending upon the usage of grease. Generally, grease can be divided into several types depending on the applications; that is, clay greases, asphaltic-type greases, extreme-pressure greases, soap-thickened mineral oils, multi-purpose greases and many more.

National Lubricating Grease Institute, USA has classified grease in to various grades which is a measure of the relative hardness of grease used for lubrication. Depending on type of thickening agents' different types of greases like Calcium, Lithium, Sodium, Aluminium Clay Polyurea and others is inexistence.

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2. Material and Methods

2.1 Material

2.1.1 Base Oils

Mineral oils (paraffinic, naphthenic), synthetic hydrocarbons (PAO, Alkylates) and other synthetic compounds (Esters, Polyglycols, etc.) are mostly used for grease manufacturing. Most greases produced today use mineral oil as their fluid components. These mineral oil-based greases typically provide satisfactory performance in most industrial applications. In extreme temperature conditions (low or high), grease that utilizes synthetic base oil provide better stability. When formulating grease the selection of base fluid is not only about product properties, it's also about production costs. And a significant proportion of the production cost is the amount of soap required to achieve a certain NLGI grade. The solvating power of the base fluid affects the amount of soap needed.

2.1.2 Additives

Additives can play several roles in lubricating grease. These primarily include enhancing the existing desirable properties, suppressing the existing undesirable properties, and imparting new properties. The most common additives are oxidation and rust inhibitors, extreme pressure, antiwar, and friction-reducing agents. In addition to these additives, boundary lubricants such as molybdenum disulfide or graphite may be suspended in the grease to reduce friction and wear without adverse chemical reactions to the metal surfaces during heavy loading and slow speeds.

2.1.3 Thickener

The thickener is a material that, in combination with the selected lubricant, will produce the solid to semi fluid structure. The primary type of thickener used in current grease is metallic soap. These soaps include lithium, aluminum, clay, Polyurea, sodium and calcium. Lately, complex thickener-type greases are gaining popularity. They are being selected because of their high dropping points and excellent load-carrying abilities. Complex greases are made by combining the conventional metallic soap with a compelling agent. The most widely used complex grease is lithium based. These are made with a combination of conventional lithium soap and a low-molecular-weight organic acid as the complexion agent. Non-soap thickeners are also gaining popularity in special applications such as high-temperature environments. Smectonite or Bentonite and silica aero gel are examples of thickeners that do not melt at high temperatures. There is a misconception, however, that even though the thickener may be able to withstand the high temperatures, the base oil will oxidize quickly at elevated temperatures, thus requiring a frequent relube interval.

2.2 Grease Manufacturing Process

Manufacturing of grease is carried out either in pressurized vessels or open cooking kettles. Greases can be made in either by Batch Process or In-line/ Continuous Process.

2.2.1 Batch Manufacturing Process

i) Metering and addition of reactants (fatty acids, base oils, water, alkali)
ii) Saponification runs in a reactor/kettle operating at atmospheric pressure or as a pressurized kettle to convert the fatty acid to soap and disperse the soap throughout the mixture.
iii) Dehydration to remove the reaction water
iv) Homogenization or milling to break agglomerated particles, adjust the grease consistency and produce a smooth and stable product
v) Cooling
vi) Inline deaeration to remove air entrapped prior to filling

To add special properties to the grease, other ingredients may be introduced such as oxidation inhibitors, anti-corrosion and anti-wear agents. This additivation step is completed in a fin fishing kettle where the deaeration of the product may be completed.

2.2.2 In-line/ Continuous Manufacturing Process

In the in-line grease manufacturing process, the saponification, dehydration and finishing phases are completed continuously. The in-line process offers:

i) Flexibility
ii) Reduced cycle time
iii) Improved process control

3. Types of Grease

The structure and the performance properties of any grease are determined by the thickener, base oil and additive systems and also by the manufacturing and packaging processes deployed. Grease types are commonly identified in terms of the thickener/ soap involved.

3.1 Simple Soaps – Combinations of a fatty acid (derived from animal or vegetable fat) and an active metal. Lithium soap greases are the most commonly used, providing good all-round performance.

3.2 Complex Soaps – Formed by the joint reaction of an active metal with a fatty acid and a non-fatty acid. The main advantage of complex over simple soap based greases is the ability to operate at higher temperatures.

3.3 Non-Soaps – Primarily made up of inorganic thickeners of mineral origin and organic thickeners of polymeric nature – making them best suited for higher temperature applications

Inorganic thickeners include modified clays (bentonite), graphite, carbon black, silica gel and various metallic oxides. Organic thickeners include polyurea, polyethylene polypropylene, poly carbohydrates and polytetrafluoroethylene.

4. Why/When Use Greases For Lubrication?

4.1 Advantages of Greases

i) Greases seal out contaminants
ii) Greases do not need circulation systems
iii) Greases decrease dripping, splattering and leakage
iv) Greases suspend solid additives easily
v) Greases are suitable for intermittent operations
vi) Greases work under extreme operating conditions
vii) Greases seal for life
viii) Greases reduce noise
ix) Greased machinery tends to need less power

4.2 Greases Disadvantages

i) Greases may not reach all places in need of lubrication
ii) Greases do not have any cleaning effect
iii) Greases do not work as cooling agent
iv) Greases cannot be used at as high speeds as liquids

5. Grease Testing Processes

Most of the grease tests that have been standardized define or describe properties that are related to the performance type tests in actual or simulated operating mechanisms. They provide considerable useful information about a grease. On the basis of ASTM Worked Penetrations, NLGI has standardized a numerical scale for classifying the consistency of greases. In order of increasing hardness, the consistency numbers are:

Table: 1. NLGI Grades and ASTM Worked Penetration

NLGI Grades	ASTM Worked Penetration at $25^{O}C$	Appearance	Consistency food analog
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 pate
6	85-115	Very hard	Cheddar cheese

5.1 Cone Penetration (ASTM D 217/IP50)

Consistency is commonly measured by the Cone Penetration. In this test a normalized cone is allowed to sink for 5 sec., under its own weight into a sample of grease held at 25°C. The depth that the cone penetrates into the grease is expressed in tenths of a millimeter and reported as the penetration of the grease. Since the cone will sink further into soft greases, higher penetrations indicate softer greases. Currently you will find on the market as the softest grease a 000 grade (all "0" grades are normally referred to as central lubrication greases) and as the stiffest a 3 or 4 grades (grades 5 and 6 are no longer widely used).

5.2 Mechanical stability ASTM D 217 / IP50)

Sample is worked for 60 strokes or more in a standard grease worker. Often the grease is worked 100,000 strokes, but also 5,000 and 10,000 strokes are used. It is accepted that these result give a basic impression on the grease stability.

5.3 Dropping Point (ASTM 566 /IP 396)

The dropping point is a material specific temperature, at which conventional soap greases pass from a semisolid to a liquid state and start flowing, while certain other non-soap greases (e. g. Bentonite greases) exhibit rapid oil separation. In the laboratory the dropping point is expressed as temperature, at which the first drop of grease/oil is extruded from a sample under prescribed conditions.

5.4 Oxidation Stability (ASTM D 942 / IP 142)

The reaction with oxygen may lead to deterioration of lubricating grease. This test conducted in the Norma-Hoffman oxidation bomb evaluates resistance of lubricating greases in a closed container to oxidation under specific conditions of static exposure

5.5 Roll Stability (ASTM D 1831)

The ability of grease to resist changes in consistency during mechanical working is named its roll stability or shear stability. A variety of laboratory tests are used to evaluate the roll stability of greases, but the two that have been standardized are the change in penetration after prolonged working in the ASTM D 217 grease worker, and the change in penetration after severe rolling in the ASTM D 1831 roll stability worker.

5.6 Oil separation During Storage (ASTM D 1742/ASTM D 6184/ IP 121)

Grease must release oil slowly in service to provide effective lubrication. Some oil release resulting in free oil on the grease surface is normal in storage. However, excessive separation of oil while the grease is in storage may result in loss of the user's confidence in the product.

5.7 Water Washout Test (ASTM D 1264/ IP 125)

The ability of grease to resist washout under conditions where water may splash or impinge directly on a bearing is an important property in the maintenance of a satisfactory lubricating film. Comparative results between different greases under the prescribed test conditions can be obtained with this test, but the results ma not necessarily predict field performance.

5.8 Copper Corrosion (ASTM D 4048/IP 112)

These methods are used to detect substances in lubricating grease which could corrode copper. Since copper and copper alloys are used in bearings it is essential that greases not corrode such materials.

5.9 Four Ball Weld Test (ASTM D 2596)

The grease is tested in a four-ball system consisting of a rotating ball (running ball), sliding with an adjustable test force on three balls identical to it (standing balls). The test load is raised in stages until welding of the four ball system occurs. It predicts the load carrying capacity of lubricating greases.

6 Applications of Greases

General processing industries	High temperature, pressure and shock load conditions	Food processing industries
Mining applications	Automotive industries	Defense purpose, pumps, tanks
Railways, steel industry, nuclear power plant	Aircraft landing wheel bearing	Water pumps
Building equipments	Farm machineries	Ball and roller bearing
Railway antifriction bearing	Lubricant for wire ropes and chains	Lubricant for open gear aircraft industry
Elevators, Paper mills & Textile industries	Steam locomotives	Drilling machine

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