FORMULATION OF MULTIPURPOSE GREASE USING WASTE OF PALM OIL MANUFACTURING

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ABSTRACT

Waste palm oil manufacturing has significant potential as a base fluid and thickener agent for grease formulation. Vegetable oils are promising candidates as base fluid for eco-friendly lubricants because of their excellent lubricity, biodegradability, viscosity-temperature characteristic and low volatility. Spent bleaching earth is suitable for the substitute for thickener agent in grease formulation. This paper presents the effective and ability of grease by using natural material. Performance characteristics of greases used for industrial and automotive application are largely depending on the hardness. Grease hardness was determined using standard test methods. Results indicate that the percent combining spent bleaching earth with fume silica in formulated grease are directly proportional with temperature weight loss but it has indirectly proportional to the penetration value and percent ash content (wt%). Therefore, developed greases can be a good substitute for mineral oil-based greases in industrial, agriculture, forestry and marine application.

ABSTRAK

Hasil buangan kilang minyak sawit mempunyai potensi untuk menggantikan minyak asas dan agent pelekat untuk pembentukan gris. Minyak sayuran menjanjikan pengguna sebagai pelincir yang mesra alam kerana tahap pelinciran yang tinggi, biodegradasi, tahap kualiti kelikatan-suhu dan sukar meruap. 'Spent Bleaching Earth' adalah sesuai untuk digunakan sebagai agen pelekat dalam pembentukan gris. Kajian ini membentangkan keberkesanan and kebolehan gris dengan menggunakan bahan semula jadi. Kebiasaanyer, gris yang digunakan didalam industri dan bidang automotif adalah bergantung kepada kekuatan gris trsebut. Kekuatan gris boleh ditentukan dengan kaedah ujian piawai. Keputusan menunjukkan, peratus campuran 'Spent Bleaching Earth' dengan 'fume silica' didalam pengahasilan gris adalah berkadar langsung dengan suhu kehilangan berat tetapi tidak berkadar lansung dengan nilai kelikatan dan peratus kandungan abu. Oleh itu, kemajuan gris ini adalah sangat bersesuain bagi menggantikan minyak galian gris didalam industri, pertanian, penghutanan dan marin.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

The search for environmentally friendly materials that have the potential to substitute for mineral oil in various industrial applications is currently being considered a top priority in the fuel and energy sector. This emphasis is largely due to the rapid depletion of world fossil fuel reserves and increasing concern for environmental pollution from excessive mineral oil use and its disposal. Renewable resources such as seed oils and spent bleaching earth are being considered as potential replacement for mineral oil base stock and thickener agent in certain lubricant application where immediate contact with the environment is anticipated. The nontoxic and readily biodegradable characteristics of vegetable oil-based lubricant pose less danger to soil, water, flora and fauna in the case of accidental spillage or during disposal. (Atanu Adhvaryu *et al.*, 2004)

Grease is a semi fluid to solid mixture of a fluid lubricant, a thickener, and additives. The fluid lubricant that performs the actual lubrication can be petroleum (mineral) oil, synthetic oil, or vegetable oil. The thickener gives grease its characteristic consistency and holds the oill in place. Common thickeners are soaps and organic or inorganic non soap thickeners.

Multi-purpose grease is lubricating grease for general applications, where no specific requirements are asked. Multi-purpose greases combine the properties of two or more specialized greases. It is possible to replace as many as specialized types of grease with single multi-purpose grease and get better results all at the same time. Most of the multi-purpose greases have a soap base of barium, lithium, or calcium complex. (Earle, 1942)

Good multi-purpose lubricating grease has to perform well in a number of applications. It should have a high melting point, and operate well at continuous temperatures of 250ºF or more. Such grease should also have good resistance to water, and exceptional stability.

The majority of greases on the market are composed of mineral oil blended with a soap thickener. Additives enhance performance and protect the grease and lubricated surface. Grease has been described as a temperature-regulated feeding device, when the lubricant film between wearing surface thins, the resulting heat softens the adjacent grease, which expands and release oil to restore film thickness.

Greases are employed where heavy pressures exist, where oil drip from the bearing is undesirable, and/or where the motions of the contacting surface are discontinuous so that it is difficult to maintain a separating lubricant film in the bearing. Grease-lubricated bearings have greater frictional characteristics at the beginning of operation. Under shear, the viscosity drops to give the effect of an oil-lubricated bearing of approximately the same viscosity as the base oil used in the grease.

1.2 Problem statement

Grease is a mixture from fluid lubricant (usually petroleum oil) and thickener soap. Nowadays the petroleum price were increase each year, one of the factors because the decreasing of oil reserve and the increasing of demand. Because of the increasing of raw material price, we need to find the solution to produce grease in the low cost.

Malaysia currently accounts for 41 % of world palm oil production and 47% of world exports, and therefore also for 11% and 25% of the worlds total production and exports of oils and fats (Malaysia Palm Oil Berhad, 2009). As the biggest producer and exporter of palm oil and palm oil products, Malaysia in the countries where the palm oil industry produces large amount of waste in the refining of crude palm oil process. To manage the waste, in some countries it is generally a practice to dispose of the waste in landfills where else in some other countries it is treated as hazardous and is disposed off accordingly as hazardous waste.

The aim of this research is to find the solution that can reuse the waste of palm oil manufacturing. This project will benefit not only to the environment, but also the entrepreneur and society.

In this research multipurpose grease will be produce by using waste of palm oil manufacturing based on suitable method. The product will be testing weight loss analysis and the consistency of the grease.

1.3 Scope of study

There are some important tasks to be carried out in order to achieve the objective of this study. The important scopes have been identified for this research in achieving the objective:

I. In this study, Spent Bleaching earth is a waste from palm oil manufacturing. Spent Bleaching earth will be use as a thickening agent in formulating multipurpose grease.

II. In this research, additive will be use to give extra special properties for the grease for example antioxidant, anti corrosion, anti wear, extreme pressure and solid lubricants

III. In this research, analysis would be done to measures the mass of a substance in relationship to temperature and is used to determine the loss of material with increasing temperature and consistency of the grease. Manual Penetrometer will use for the Cone Penetration of Lubricating Grease test and TGA analysis for estimating changes in the consistency of used grease.

1.4 Objective

The objective of this project is:

I. To formulate multipurpose grease using waste of palm oil manufacturing.

II. To test and compare the physical properties of the formulated grease with the standards.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Lubricating greases are semisolid colloid dispersions of a thickening agent in a liquid lubricant matrix. They owe their consistency to a gel forming network where the thickening agent is dispersed in the lubricating base fluid. Grease may include various chemical additives for specific property enhancement. A typical grease composition contains 60-95% base fluid (mineral, synthetic, or vegetable oil), 5-25% thickener (fatty acid soaps of alkali or alkaline metals), and 0-10% additives (antioxidants, corrosion inhibitors, anti-wear/ extreme pressure, antifoam, tackiness agents, etc.). The base fluid imparts lubricating properties to the grease, whereas the thickener, essentially the gelling agent, holds the matrix together. (Atanu Adhvaryu *et al*., 2004)

Grease is the preferred form of lubrication in hard-to-reach places in a mechanically rubbing or dynamic systems. Grease acts as reservoir for lubricant-based fluids and additive molecules. Much of its functional properties are dependent on their ability to flow under force, have shear stability, resist viscosity changes with temperature and pressure, water stable, seal out contaminants, decrease dripping and spattering, etc. The dependability of lubricating grease depends on their physical properties that are structurally related, which is obtained by the proper selection of ingredients and processing. Thus, it is pertinent to understand the grease microstructure as it contributes significantly to various functional properties of grease. (A. Adhvaryu *et el*., 2003)

Renewable raw materials are going to play a very noteworthy role in the development of sustainable green chemistry. They offer a large number of possibilities for applications which can be rarely met by petrochemistry (H. Baumann, *et al*. 1988). Oils and fats of vegetable and animal origin share the greatest proportion of the current consumption of renewable raw materials in chemical industry (U. Biermann, *et al*. 2000).

A steady increase in the use of eco-friendly consumer products like lubricants has occurred as a result of strict government regulation and increased public awareness for a pollution free environment (I Rhee, 1996). There are wide ranges of lubricant base oils in current use which includes mineral oils, synthetic oils, re-refined oils, and vegetable oils. Among these, mineral oils are the most commonly used. They consist predominantly of hydrocarbons but also contain some sulfur and nitrogen compounds with traces of a number of metals. Due to their inherent toxicity and non-biodegradable nature they pose a constant threat to ecology and vast ground water reserves (A. Adhvaryu, *et al*. 2005).

These concerns have resulted in an increasing interest in vegetable oils with high content of oleic acid, which are considered to be potential substitutes to conventional mineral oil-based products. Vegetable oil lubricants are preferred not only because they are renewable raw materials but also because they are biodegradable and non-toxic (Lathi, P.S. and Mattiason, B. 2006). They also acquire most of the properties required for lubricants such as high index viscosity, low volatility and good lubricity and are also good solvents for fluid additives. However, vegetable oils have poor oxidative and thermal stability, which is due to the presence of unsaturation. This unsaturation restricts their use as a good lubricant.

2.2 Application

The function of grease is to remain in contact with and lubricate moving surfaces without leaking out under the force of gravity, centrifugal action or being squeezed out under pressure. Its major practical requirement is that it retains its properties under shear forces at all temperatures it experiences during use. The others function of greases are keep moving parts apart, reduce friction, transfer heat, carry away contaminants & debris, protect against wear and prevent corrosion.

2.2.1 Applications Suitable for Grease

Grease and oil are not interchangeable. Grease is used when it is not practical or convenient to use oil. The lubricant choice for a specific application is determined by matching the machinery design and operating conditions with desired lubricant characteristics (Jeremy Wright, 2008). Grease is generally used for machinery that runs intermittently or in storage for an extended period of time. Because grease remains in place, a lubricating film can instantly form. Machinery that is not easily accessible for frequent lubrication. High-quality greases can lubricate isolated or relatively inaccessible components for extended periods of time without frequent replenishing. These greases are also used in sealed-for-life applications such as some electrical motors and gearboxes. The other application is in machinery operating under extreme conditions such as high temperatures and pressures, shock loads or slow speed under heavy load because of grease maintains thicker films in clearances enlarged by wear and can extend the life of damaged parts that were previously lubricated by oil.

2.2.2 Functional Properties of Grease

Grease functions as a sealant to minimize leakage and to keep out contaminants. Because of its consistency, grease acts as a sealant to prevent lubricant leakage and also to prevent entrance of corrosive contaminants and foreign materials. It also acts to keep deteriorated seals effective.

Grease is easier to contain than oil. Oil lubrication can require an expensive system of circulating equipment and complex retention devices. In comparison, grease, by virtue of its rigidity, is easily confined with simplified, less costly retention devices.

Grease holds solid lubricants in suspension. Finely ground solid lubricants, such as molybdenum disulfide (moly) and graphite, are mixed with grease in high-temperature service or in extreme high-pressure applications. Grease holds solids in suspension while solids will settle out of oils. (Grandou and Masson, 1996)

2.3 Grease Formulation

The American Society for Testing and Materials (ASTM) defines lubricating grease as: "A solid to semi fluid product of dispersion of a thickening agent in liquid lubricant. Other ingredients imparting special properties may be included" (ASTM D 288, Standard Definitions of Terms Relating to Petroleum). (V. V. Sinitsyn and A. B. Kofman ,2004)

As this definition indicates, there are three components that form lubricating grease. These components are oil, thickener and additives. The base oil and additive package are the major components in grease formulations, and as such, exert considerable influence on the behavior of the grease. The thickener is often referred to as a sponge that holds the lubricant (base oil plus additives).Figure 2.0 shows the general formulation for grease.

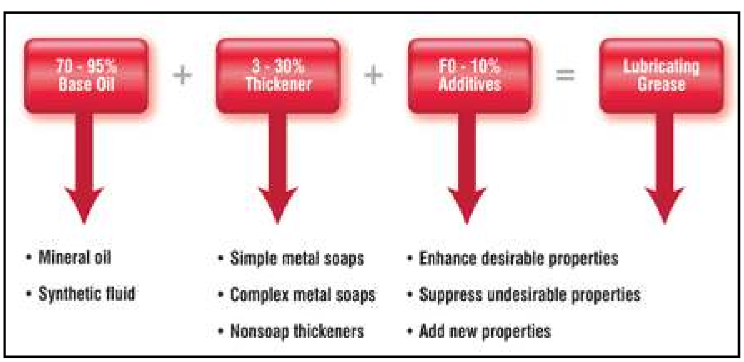

Figure2.0: General formulated grease

2.3.1 Base Oil

Most grease produced today use mineral oil as their fluid components. These mineral oil-based greases typically provide satisfactory performance in most industrial applications. In temperature extremes (low or high), a grease that utilizes a synthetic base oil will provide better stability. (Jeremy Wright, 2008)

Grease is a preferred form of lubrication in certain applications because it gives low friction, is easily confined, and has a long lubricating life at low cost. (Brajendra K. Sharma *et al*., 2006)

2.3.1.1 Palm Oil

The base fluid used in this study is palm oil. The oil is a triacylglycerol molecule with fatty acid chains mainly composed of oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) moieties. Each triacylglycerol molecule has three ester linkages and unsaturations depending on the distribution of fatty acid moieties (Fig. 2.1). The presence of polar group with a long hydrocarbon chain makes vegetable oil amphiphilic allowing them to be used as boundary lubricants. The molecules have strong affinity for and interact strongly with metal surfaces. The long hydrocarbon chain is oriented away from the metal surface to form a monomolecular layer with excellent boundary lubrication properties. When the molecule is adsorbed on the metal surface, two types of interactions occur. The adhesive interaction between the ester group and metal is very sensitive to the type and number of functional groups. The lateral interaction caused by dipole–dipole and dispersive interaction between the hydrocarbon chains is sensitive to structural properties including chain length, unsaturation, and stereochemistry (Jahanmir and Beltzer, 1986a, 1986b).

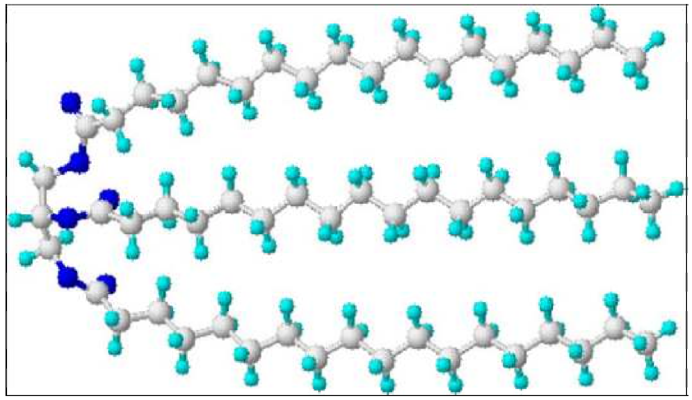

Figure 2.1: Triacylglycerol molecules.

2.3.2 Thickener

The thickener essentially the gelling agent, holds the matrix together. (Atanu Adhvaryu et. el, 2004). 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. (Jeremy Wright, 2008)

Complex greases are made by combining the conventional metallic soap with a complexion 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. Bentonite and silica aerogel are two 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.

2.3.2.1 Spent Bleaching Earth

Spent bleaching earth is a solid waste material generated as part of the refining process in the vegetable oil industry worldwide. A typical vegetable oil refining process involved pretreatment of crude vegetable oil such as palm oil with phosphoric acid, followed by bleaching deodorization. The purifying treatment is designed to remove undesired free fatty acids, phophatides, glycerides, sterols, tocopherols, resinous and mucilaginous materials from the crude palm oil. Bleaching is done solely to reduce the colour of the oil and is done using bleaching earth or clay. This process is followed by deodorization, which is intended primarily for the removal of traces of constituents that give rise to flavors and odors (Chanrai, Narain 2004).

2.3.2.2 Fume Silica

Silica fume, also known as micro-silica, is a byproduct of the reduction of high-purity quartz with coal in electric furnaces in the production of silicon and ferrosilicon alloys. Untreated fumed silica is a fumed silicon dioxide, a material which is generally regarded as unique because of its unusual particle characteristics, enormous surface area and high purity. Fume silica are form in powder, fine, white and extremely fluffy. However, when added to liquids and polymers where its index of refraction is a close match, it will appear colorless or clear. Because fumed silica enhances several different properties in formulation, such as thickening liquids or improving flow ability of powders, it is used in a variety of applications including coatings, adhesiveness & sealants, cosmetics, ink & toner, plastics, rubbers, food products and pharmaceuticals.

Fumed silica is an excellent thickener for greases. It produces grease free from the common shortcomings of particulate thickened greases while preserving their benefits. The attractive properties of greases thickened include excellent water resistance, extremely high dropping point and no significant loss of lubricating properties on long-term exposure to heat a series of thickeners were evaluated in a simple formulation yielding National Lubricating Grease Institute (NLGI) #2 grade grease. This simple system emphasizes the response of the thickener. The advantages can also be expected in fully formulated grease.

2.3.3 Additives

Base fluids-mineral oil and also synthetic products-generally cannot satisfy the requirements of high performance lubricants without using the benefit of modern additive technology. Additives are synthetic chemical substances that can improve lots of different parameters of lubricants. They can boost existing properties, suppress undesirable properties and introduce new properties in the base fluids. Table 2.0 shows usual grease additive level in general grease formulation.

Table 2.0 Usual grease additive levels (%)

Additive	**Level (%)**
Antioxidant	0.10 – 1.00
Corrosion inhibitors	0.50 – 3.00
EP/AW additive	0.50 – 5.00
Metal deactivators	0.05 – 0.10
Solid lubricants	1.50 – 3.00
Tackifiers	0.10 – 1.00

Additives function to improve performance of the grease. Additives usually constitute up to 15% of grease. e.g. Teflon is added to some greases to improve their lubricating properties. Nowadays, *biodegrability* of the additives is emphasized. There were many several types of additive used nowadays such as anti-corrosion, anti-wear, anti-oxidant and extreme pressure. According to (A. Adhvaryu, 2005), antimony dithiocarbamate used as an antioxidant and extreme pressure additive. Additive was added at 0-8% by weight of total formulation and under (Manef Chtourou, 2006), the additive that they used are antioxidant, adhesiveness, rust inhibitor and extreme pressure agents.

The most common additives are:

- Anti-corrosion :-

Grease must prevent or reduce processes which lead to rust or corrosion.

- Anti-wear:-

Grease must prevent wear by forming a strong surface film to reduce contact between surfaces to prevent heating as an outcome of extreme pressure.

- Anti-oxidant:-

Grease must prevent oxidation which will lead to damage which in turn will admit impurities or gives rise to acidity.

- Viscosity index improver :-

Additives will retain the viscosity of grease. Grease will break down at high engine temperatures or when the engine has run too long.

2.4 Type of Grease

Grease can be divided into 6 general categories or types; i.e., mixtures of mineral oils and solid materials, heavy, asphaltic-type oils blended with lighter oils, extreme-pressure greases, roll-neck greases, soap-thickened mineral oils and multi-purpose grease (Ron Hughes, 2007)

2.4.1 Mineral of oils mixed solids

These types of greases are very heavy lubricants for specialized applications. Such greases lubricate rough-fitting machine parts operating under heavy pressures or loads at relatively slow speeds. Examples of equipment that will typically use this type of grease include concrete mixers, bearings and rollers on conveyors and heavy construction equipment. (Cline *et al*, 1989)

2.4.2 Heavy-Asphaltic-type oils blended with lighter oils

These types of lubricants are classified as greases but are actually thick, heavy oils used to lubricate open-type gearing and wire rope. A primary advantage of these oils is that they form a heavy protective film when heated or painted on surfaces and then allowed to cool. Lighter oil is typically blended with the heavy oils in order to improve the pour point of the oil. (Ron Hughes, 2007)

2.4.3 Extreme-pressure greases

The unique characteristic of this type of grease is that it contains additives to improve firm strength under various applications. In essence, film strength provides the resistance of the lubricant to being torn apart, thus preventing metal-to-metal contact of the equipment being lubricated. A film is formed by a chemical reaction of the metal to the additives in the grease. The chemical reaction is usually brought about (or accelerated) by pressure exerted on the grease, creating heat. (Theo Mang and Wilfried Dresel, 2001)

A few of the additives used in EP greases include compounds containing parts of chlorine, phosphorus, active and/or passive sulfur, chlorinated waxes and phosphates. Zinc and lead may also be added, as well as asbestos in some lubricants as a filler to cushion the shock loading on gear drives. The specific additive being used will always depend on the application for use. Factors to be considered for types of additives include specific equipment operating conditions such as load, speed, surface condition and inherent design characteristics (Richard L. Nailen, 2002)

2.4.4 Roll Neck Greases

Roll neck greases are specialized lubricants used almost exclusively for lubricating plain bearings in rolling equipment. For example, it's fairly common to use a block of NLGI No. 6 grease, which has the consistency of a bar of soap, carved to mate with the shape needed to accommodate the bearing of heavily loaded equipment. (A. R. Lansdown, 2004)

2.4.5 Soap Thicked Mineral Oils

This is by far the most widely used category of grease in industry today. This type of grease varies by the additive that forms the soap in the lubricants chemical makeup. (D. M. Pirro, 2001)

Sodium-base greases are also general-purpose greases. Because they have a higher dropping point (approximately 300^{o} to 350ºF), they are often used to lubricate machine parts operating near heat. Sodium greases made with lighter oils are used for ball and roller bearing lubrications, as are combinations (mixed base) of calcium and sodium grease. Sodium-soap greases have a spongy or fibrous texture and are yellow or green in color. Because of their working stability and intermediate melting point, they are used for lubricating wheel bearings (other than disc brakes) and for general-purpose industrial applications. Typical examples include rough, heavy bearings operating at low speeds, as well as skids, track curves and heavy-duty conveyors. (A.A. Wessol, 2001)

Barium-soap greases are general-purpose types, valued for their ability to work over a wide temperature range. Their dropping point is approximately 350ºF or higher, although they are not intended to be used in continuous operation at temperatures above 275ºF. Barium-soap greases are chosen for a variety of jobs, especially for nearly all types of bearing lubrications. They have high-soap content. However, this makes this type of lubricant less suitable for use at low temperatures and in very high-speed applications. They have a buttery of fibrous texture and are reddish-yellow or green in color. (Ron Hughes, 2007)

Lithium-soap grease handles extremes of temperature quite well, which makes them highly suitable for both high and low temperature application. They have a dropping point of approximately 350ºF, and can be used in continuous temperatures of 300ºF. One reason for their successful low-temperature performance is that they are made with oil having a low pour point. In fact, lithium-soap greases have been used successfully at temperatures of -60ºF. Use of lithium-soap grease at higher temperatures requires a different formula; however the same grease can't be used at both extremes of high and low temperatures because the change would be in the viscosity of the oil used in the grease. Basically, lithium-soap greases have very good stability; good water resistance, and are also readily pumpable. They have a buttery texture and a brownish-red color. (Ron Hughes, 2007)

Calcium-soap, also called lime-soap greases, are probably the best known and most often used of all greases. Depending on the method of manufacture they are usually relatively inexpensive. Uses include axle grease, water pump grease and general machinery applications. Because its water content begins to dry out, and the soap and oil separate, calcium-soap grease isn’t suited to applications where the temperature will get above 160ºF. The major advantage of calcium-soap grease is that they don’t dissolve in water. However, it is not suited to use in lubricating high-speed bearings. Ordinary general-purpose calcium-soap greases have a dropping point of approximately 175^{o} to 200ºF. Calcium-complex grease has unusually high heat resistance making it of considerable value in extreme-pressure applications. The dropping point of this type of grease is 500ºF or even higher. This means that this type of lubricant will maintain its stability while running continuously at high temperatures. However, this type of grease has not replaced lithium-soap greases because they are not as mechanically stable. Calcium-soap greases are yellow or reddish in color, and have a smooth buttery texture. (Ron Hughes, 2007)

Aluminum-soap greases are special-purpose lubricants. Their particular advantage is that they are very sticky making them perfect for applications requiring surface lubrication. (Ron Hughes, 2007)

2.4.6 Multi- Purpose Grease

Multi-purpose grease is lubricating grease for general applications, where no specific requirements are asked. Multi-purpose greases combine the properties of two or more specialized greases. It is possible to replace as many as specialized types of grease with single multi-purpose grease and get better results all at the same time. This permits the use of a single type of grease for a variety of applications. It is possible to replace as many as six specialized greases with single multi-purpose grease and get better results all at the same time. Most of the multi-purpose greases have a soap base of barium, lithium, or calcium complex. For example, the lithium-soap greases discussed earlier. They are not only water-resistant and corrosion inhibiting, but they have very good mechanical and oxidation stability as well.

By reducing the number of lubricants, which a company keeps in stock, the lubricator's job becomes much easier. Another advantage is that it helps reduce the chances of error in application.

Good multi-purpose lubricating grease has to perform well in a number of applications. It should have a high melting point, and operate well at continuous temperatures of 250ºF or more. Such grease should also have good resistance to water, and exceptional stability.

2.5 Characteristic

As with oil, grease displays its own set of characteristics that must be considered when being chosen for an application. The characteristics commonly found on product data sheets include the following: (Jeremy Wright, 2008)

2.5.1 Water resistance.

This is the ability of grease to withstand the effects of water with no change in its ability to lubricate. Soap/water lather may suspend the oil in the grease, forming an emulsion that can wash away or, to a lesser extent, reduce lubricity by diluting and changing grease consistency and texture.

2.5.2 Consistency.

Grease consistency depends on the type and amount of thickener used and the viscosity of its base oil. Grease's consistency is its resistance to deformation by an applied force. The measure of consistency is called penetration. Penetration depends on whether the consistency has been altered by handling or working. ASTM D 217 and D 1403 methods measure penetration of not worked and worked greases. To measure penetration, a cone of given weight is allowed to sink into a grease for five seconds at a standard temperature of 25°C (77°F).

The depth, in tenths of a millimeter, to which the cone sinks into the grease, is the penetration. A penetration of 100 would represent solid grease while a penetration of 450 would be semi fluid. The NLGI has established consistency numbers or grade numbers, ranging from 000 to 6, corresponding to specified ranges of penetration numbers. Table 2.1 lists the NLGI grease classifications along with a description of the consistency of how it relates to common semi fluids.