FORMULATION OF BIOGREASE FROM CASTOR WASTE

NURATIQAH BINTI ISMAIL

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ABSTRACT

Grease is a mixture of a fluid lubricant usually petroleum oil and a thickener (soap) dispersed in the oil. The base oil (petroleum) can be changed by using the castor waste. Other than base oil, thickener may play an important role in the mixture. Soap thickeners are formed by reacting metallic hydroxide, or alkali, with a fat, fatty acid, or ester. Since the petroleum prices were increase each year, using castor waste as base oil is the best solution to produce grease in the low cost at the same time it will decrease the water pollution. The objective of this research is to produce special lubricant grease from castor waste with bentonite. In this research, preparation and formulation of bio-based grease and quality and performances of grease were studied. The characteristics of produced grease were analyzed in order to evaluate the performance of the grease. The testing (type of thickener, dropping point test, viscosity test and Fourier Transform Infrared Spectroscopy, FTIR analysis) have been done on the formulated greases to determine the properties. It was discovered that formulated grease has no dropping point which proves that the greases has stable structure at higher temperature. Therefore, the formulated greases has high potential to be used in wide range of industries such as the cars, ships, aircrafts and most of the industries that deals with heavy duty equipments.

ABSTRAK

Gris ialah campuran cecair pelincir kebiasaannya minyak petroleum dan agen pengental (sabun) kemudian dilarutkan ke dalam minyak. Minyak petroleum boleh digantikan dengan minyak pelincir terpakai. Selain daripada minyak petroleum, agen pengental memainkan peranan yang penting di dalam campuran tersebut. Agen pengental dihasilkan melalui tidakbalas logam hidroksida, atau alkali dengan lemak, asid lemak atau ester. Memandangkan harge petroleum meningkat sejak kebelakangan ini, pilihan terbaik adalah dengan menggunakan minyak pelincir terpakai sebagai pengganti kepada minyak petroleum, ia bukan sahaja dapat mengurangkan kos pengeluaran gris malahan dapat mengurangkan pencemaran air yang berpunca daripada pembuangan minyak pelincir terpakai ke dalam sungai. Objektif eksperimen ini adalah untuk menghasilkan gris istimewa daripada kastor terpakai dengan bentonit. Eksperimen ini meliputi pembuatan bio-gris untuk memformulasi bio-gris supaya kualiti dan prestasi bio-gris lebih baik. Ciri-ciri minyak yang dihasilkan telah dianalisis untuk menilai prestasi gris. Beberapa eksperimen (jenis agen pemekatan, ujian menentukan suhu dimana gris berubah menjadi cecair dan ujian kelikatan dan analisis Spektroskopi inframerah transformasi Fourier, FTIR) telah dilakukan pada gris yang dihasilkan untuk menentukan ciri-cirinya. Ia telah dibuktikan bahawa gris yang dihasilkan tidak berubah menjadi cecair yang membuktikan gris ini mempunyai struktur stabil pada suhu yang tinggi. Oleh itu, gris yang dihasilkan mempunyai potensi yang tinggi untuk digunakan dalam pelbagai sektor seperti kereta, kapal layar, kapal terbang dan juga industri yang menggunakan alat-alat yang bertenaga tinggi.

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LIST OF SYMBOLS

cP	Centi Poise
cSt	CentiStokes
◦C	Degree Celsius
◦F	Degree Fahrenheit
ρ	Density
η	Dynamic Viscosity
g	Gram
Kg	Kilogram
kPa	Kilo Pascals
ν	Kinematic Viscosity
mm	Milimetre
%	Percent
cm^{-1}	Per centimetre
lb	Pound
psi	Pound per square inch
rpm	Revolutions per minute
τ	Shear Stress
wt	Weight

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
Ca	Calcium
FKKSA	Faculty of Chemical & Natural Resources Engineering
FTIR	Fourier Transform Infrared Spectroscopy
ISO	International Organization for Standardization
IR	Infrared Spectroscopy
Li	Lithium
NLGI	National Lubricating Grease Institute
PTFE	Polytetrafluoroethylene
SAE	Society of Automotive Engineers
SBO	Soybean Oil
TEM	Transmission Electron Microscopy

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Grease is a semi-solid mixture of a fluid lubricant, a thickener, and additives used to reduce friction between two solid surfaces. By controlling the mixing temperature, greases are made by dispersing thickening agent into carrying lubricant (oil). The actual lubrication can be petroleum (mineral) oil, synthetic oil, or vegetable oil. Common thickeners are soaps and an organic or inorganic non soap thickener which gives greases its characteristic consistency and holds the oil in place.

Recently, many researchers have been carried out to search for environmental friendly materials that have the potential to substitute mineral oil in various industrial applications. This is extensively due to the swift depletion of world fossil fuel reserves and also increasing in understanding of environmental pollution from limitless mineral oil usage and its disposal. In certain lubricant applications, a renewable resource such as castor oil is being considered as potential replacements for mineral oil base stocks where immediate contact with the environment is expected. In case of accidental spillage or during disposal of the material, the nontoxic and biodegradable characteristic of castor oil-based lubricants will cause less danger to environment. (A. Adhvaryu et al., 2005).

Instead of using mineral oil as based, castor oil is believed to be a potential source to meet the purposes which are more economic and abundantly available. When it come in contact with soil or water, these products are very desirable in total loss lubricant since their release will not cause any harm to the environment. In our study, we are concern about the properties and the suitability of this oil.

1.2 Problem Statement

Crude oil or mineral oil is one of the most important mixtures in the world. Lubricant oil is one of the application products from crude oil. Nowadays the petroleum price was increase each year due to the decreasing of oil reserve and the increasing of demand. As the increasing of raw material price, we need to find the solution to produce grease in the low cost.

Most current lubricants contain petroleum base stocks, which are harmful to environment and difficult to dispose. Environmental concern continues to increase of pollution from exaggerated lubricant use and disposal, especially total loss lubricants. In the United States, over 60% of the lubricants used are lost to the environment (S.Z. Erhan et al., 2006).

Castor oils have a capability to contribute towards the goal of energy independence and sustainable since they are a renewable resource. The aim of this research is to find the solution that can reduce the environmental problems and at the same time can use the waste to produce grease. This project will benefit not only to the environment, but also the entrepreneur and society. It is known that, the advantages of using bio-based grease are biodegradable, environmental friendly, green energy, sustainable energy and cheaper. Besides, by utilizing waste castor oil, the cost will be cheaper compared to virgin castor oil. In this research grease will be produce by using used castor oil based on suitable method.

1.3 Research Objectives

The objectives as followed:

i. To formulate special lubricant grease using natural substitution
ii. To characterize the formulated grease

1.4 Scopes of Study

The study will look for a better substitute for petroleum and crude oil in order to achieve sustainable energy. This research will focus on using castor oil as the alternative to crude oil and petroleum. Areas of study are limited to the following:

i. Performing batch reaction on castor waste using bentonite as thickener in a closed flanged flask.
ii. Characteristics of formulated grease were analyzed based on the effect of castor oil and bentonite's amount by performing conventional ASTM (American Society of Testing and Materials) methods.
iii. The performed tests were penetration test, dropping point test, Oxidation Stability Test, Roll Stability Test, Copper Corrosion Test.
iv. Analysing the properties of the biogrease produced and comparing it to standard, ASTM D128, ASTM D566, and ASTM D445.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The important formulation for the special lubricating grease is the lubricating as the base and the gelling agent or thickener to improve the properties of the lubricant grease. The improvement is kept on track by the researches all over the world to produce quality products especially on mechanical devices such ball bearing. The tested had been done to ensure and study the characteristic of each lubricant grease produce. Certain biodegradable greases consist of vegetable oil, synthetic esters or glycols as base fluids; metal soaps or polyureas as thickeners, and additives to improve the behaviour of the final material in specific conditions. Grease is oil suspended in a base or carrier, and when these bases are exposed to moisture or heat, they can turn into soap or carbon ash. Therefore, it may be necessary to use synthetic additives to prevent deterioration of the base. There are factors to consider certain greases to use include hardness, stability and water resistance.

There are a few reasons why greases are more favourable than oil as a lubricant. Due to its consistency, grease acts as a sealant to prevent lubricant leakage and also to prevent entrance of corrosive contaminants whereas oil would simply seep away. Besides that, grease is easier to contain than oil. Oil lubrication can require 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. Another advantage of grease is that it holds solid lubricants in suspension. Finely ground solid lubricants, such as molybdenum disulphide are mixed with grease in high temperature service (over 315°C or 599°F) or in extreme high pressure applications. Grease holds solids in suspension while solids will settle out of oils. Lastly the fluid level of grease does not have to be controlled and monitored.

However, there are some disadvantages when using grease. Due to its consistency, grease cannot dissipate heat by convection like circulating oil. Grease has more resistance to motion at start-up than oil, so it is not appropriate for low torque/high speed operation. It is also more difficult to handle than oil for dispensing, draining and refilling. Also, exact amounts of grease cannot be as easily metered (Engineering Edge, n.d).

2.2 History of Bio-based Grease Production

Grease, as it is looked upon today, is a relatively new science. In 1400 B.C., the first grease that been formulated were bio-based where mutton or beef fat was sometimes mixed with lime to reduce the friction in chariot wheels. Heating lime and fat in oil will form grease under the correct conditions. Modern greases, however, were not commercially available until more than 3,300 years later. From the year of 1859, there was petroleum grease were manufactured. The first grease produced in volume was calcium soap grease. Lithium, barium and calcium complex greases were introduced in the 1930s and 1940s. Aluminium complex greases followed in the early 1950s, but modern lithium complex greases did not enter the market until the early 1960s. (Machinery Lubrication, 2007). An estimation of 98% of the petroleum grease dominated the marketplace in 2004.

As industrial growth rapidly, the grease production industries become wider. Currently, due to increasing in petroleum prices, many researchers have been carried out to search alternative sources for grease production, thus affecting the price of base oil as main component in grease. There were many researchers doing researches in formulating bio based grease. Instead of using commercial oil as based, other potential sources that had been utilized was fresh vegetable oil such as soybean oil, cottonseed oil, canola oil, palm oil and epoxidized vegetable oil.

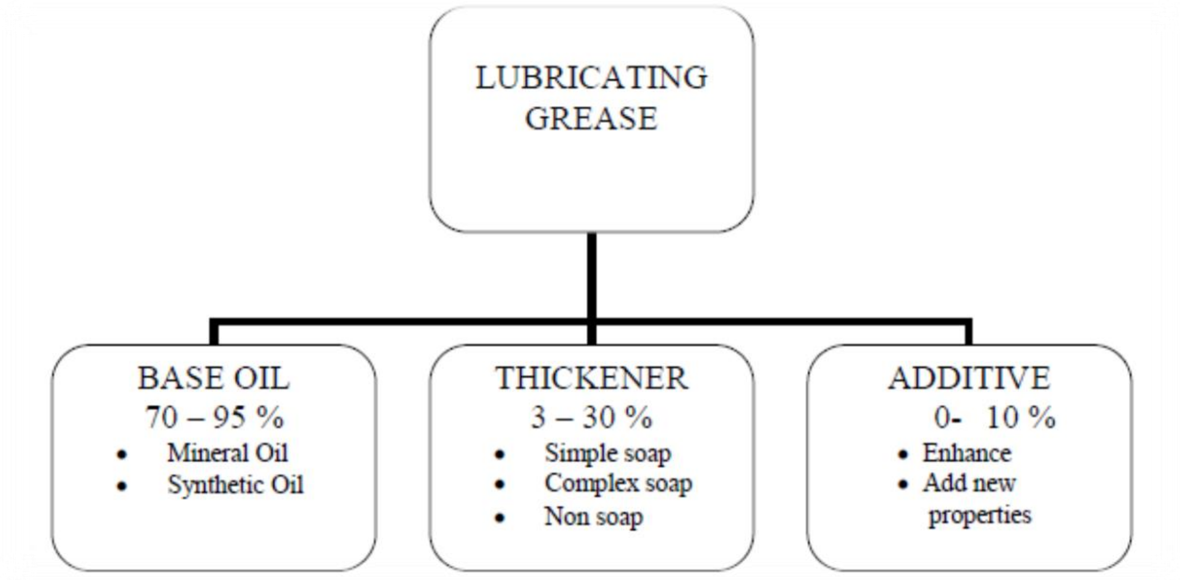
Grease and oil are not interchangeable. Grease is used when it is not practical or convenient to use oil. The lubricant choice for a specific application is determined by matching the machinery design and operating conditions with desired lubricant characteristics. Grease is generally used for machinery that runs intermittently or is 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 also requires grease. 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. Machinery operating under extreme conditions such as high temperatures and pressures, shock loads or slow speed under heavy load prefers the usage of greases compared to oils. Worn components is another suitable application for grease as grease maintains thicker films in clearances enlarged by wear and can extend the life of worn parts that were previously lubricated by oil (Engineering Edge, n.d).

2.3 Grease

2.3.1 Elements of Grease

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 behaviour of the grease. The thickener is often referred to as a sponge that holds the lubricant (Machinery Lubrication, 2008). Grease is a semi fluid 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 (Engineering Edge, n.d). Grease consists of two basic structural components: A thickening agent and liquid or base fluid, in which that thickening agent is dispersed. They owe their consistency to a gel-forming network where the thickening agent is dispersed in the lubricating base fluid. The consistency of thickener as mentioned in Engineering Edge (n.d) is a “three-dimensional fibrous network” or “sponge” that holds the oil in place. Greases may include various chemical additives for specific property enhancement and protect the grease and lubricated surfaces. As stated in Figure 2.1, a typical grease composition contains 70-95 wt. % base fluid (mineral, synthetic, or vegetable oil), 3-30 wt. % thickener (simple, complex and non-soap), and 0-10 wt. % additives (antioxidants, corrosion inhibitors, anti-wear/ extreme pressure, antifoam, tackiness agents).

Figure 2.1 Typical composition of Grease



Lubricating greases are generally highly structured suspensions, consisting of a thickener dispersed in mineral or synthetic oil. Fatty acid soaps of lithium, calcium, sodium, aluminum, and barium are most commonly used as thickeners. This component is added to increase the consistency of greases, preventing loss of lubricant under operating conditions and avoiding the penetration of contaminants, such as solid particles and water, without a significant reduction of the lubricating properties, which are mainly supplied by the oil. The thickener forms an entanglement network, which traps the oil and confers the appropriate rheological and tribological behavior to the grease. The performance of lubricating grease depends on the nature of its components and the microstructure achieved during its processing. Consequently, suitable structural and physical properties may be reached from a proper selection of the ingredients but, also, from a process optimization, as was previously reported.

2.3.2 Biodegradable Grease

2.3.2.1 Base Oils

Base fluids make up to 70 to 95% of the total composition of grease. Basically, the base oils can be divided into two types: (i) water miscible, and (ii) non-water miscible. Glycols are completely water soluble; the most regularly used are monopropylene glycol or polyethylene glycol with an average molecular weight of 200–1500. The advantages of these compounds are their resistance to aging and hydrolysis, still the major disadvantages are solubility in water and incompatibility with mineral base oils. Non-water soluble base oils can be subdivided into two categories: (i) vegetable oils, and (ii) synthetic esters (Roehrs and RoBrucker, 1995; Mang T.,1993). This class of compounds usually has the same structure, and hence, identical physical and chemical properties.

There are five specific categories of base oils. These categories define the type of base stock the oil is formulated from. The categories are as follows. (Synthetic Oil, 2013)

1. **Group I - Solvent Freezing**

   Group 1 base oils are the least refined of all the groups. They are usually a mix of different hydrocarbon chains with little or no uniformity. While some automotive oils on the market use Group I stocks, it’s generally used in less demanding applications.

2. G**roup II - Hydro processing and Refining**

   Group II base oils are common in mineral based motor oils currently available on the market. It have fair to good performance in lubricating properties such as volatility, oxidative stability and flash/fire points. It gives fair performance in areas such as pour point, cold crank viscosity and extreme pressure wear.

3. **Group III - Hydro processing and Refining**

   Group III base oils are subjected to the highest level of mineral oil refining of the base oil groups. Although it is not chemically engineered, it offers good performance in a wide range of attributes as well as good molecular uniformity and stability. They are commonly mixed with additives and marketed as synthetic or semi-synthetic products. Group III base oils have become more common in America in the last decade.

4. **Group IV - Chemical Reactions**

   Group IV base oils are chemically engineered synthetic base stocks. Polyalphaolefins (PAO's) are a common example of a synthetic base stock. Synthetics, when combined with additives, offer excellent performance over a wide range of lubricating properties. They have very stable chemical compositions and highly uniform molecular chains. Group IV base oils are becoming more common in synthetic and synthetic-blend products for automotive and industrial applications.

5. **Group V**

   Group V base oils are used mainly in the creation of oil additives. Esters and polyolesters are both common Group V base oils used in the formulation of oil additives. Group V oils are generally not used as base oils themselves, but add beneficial properties to other base oils.

Most grease is formulated using Group I and II mineral oil base stocks, which are appropriate for most applications. However, there are applications that might benefit from the use of synthetic base oil. Such applications include high or low operating temperatures, a wide ambient temperature range, or any application where extended relubrication intervals are desired.

2.3.2.2 Castor Oil

In common research nowadays, castor oil being the material used as it is quite reasonable to get. Castor oil consists of triacylglycerol with the major fatty acid component being ricin oleic acid (~89 wt%) (Hurd, P.W., 1996). In the 1960s, both the Stumpf research group at University of California, Davis and the Morris group at Unilever Research in Great Britain, carried out basic research investigating the hydroxylation reaction that converts oleate to ricinoleate (Galliard, T., & Stumpf, P.K., 1966; Morris, L.J., 1967). It is non-drying oil with high viscosity and is quite suitable for various lubricant applications. Phoronic acid derived from castor oil is superior in making greases since it has a higher metal content, delivering long grease life at higher temperatures. The shorter chain of phoronic acid is less subject to shear degradation when used in a grease matrix (Morway, A.J., and Wellman, W.E., 1966).

However, to date, oilseeds transformed to express the gene for oleoyl -12-hydroxylase produce much less than the 90% present in castor oil, with most transgenes producing less than 20% hydroxyl fatty acid content in oil (Broun, P., & Somerville, C., 1997). The alkali is selected based on the type of grease to be formed and alcohol selection controls the viscosity of the lubricant.

Castor oil has also been used to prepare total vegetable oil based grease with sodium and lithium gallants. The alkali is selected based on the type of grease to be formed (Li, Na or Ca) and alcohol selection controls the viscosity of the lubricant. Higher carbon number and molecular weight of the alcohol produces lubricants with higher viscosity (Dwivedi, M.C., & Sapre, S., 2002).The residual hydroxyl group in the ricin oleic acid chain offers an active site for adherence to metal surfaces. It is therefore expected that greases prepared from castor oil will have better extreme pressure characteristics. The castor seed itself contain 50% of oil and it has two parts; kernel and the shell. Kernel reaches around 70-75% of the whole seed weight. The main ingredients of kernel are oil and protein (MBI Green Farm Corp., n,d).

2.3.2.3 Thickener

The thickener is a reaction product of a metal (alkali or alkaline earth metal) based material (oxide, hydroxide, carbonate or bicarbonate) and carboxylic acid or its ester. The most common alkalis used are the hydroxides from earth metals such as aluminium, calcium, lithium, sodium, and titanium. Soap is created when a long-carbon-chain fatty acid reacts with the metal hydroxide. The soap structure is very important to the performance of the grease and will vary in thickness, length and oil solubility, depending on the type of metal hydroxide used. These variations are ultimately displayed in the final properties of the grease. Vegetable oil-based grease thickened with polyurea is environmentally friendly and biodegradable in nature (Hissa, R., 1993).

Polyurea is the most important organic nonsoap thickener and has excellent oxidation resistance due to the absence of metal soaps (which tend to initiate oxidation). Such greases showed good shear stability when subjected to the roll stability test. Organic clay, though readily biodegradable, is a naturally occurring nontoxic material, so its carbon content is not counted in the determination of ready biodegradability (Environmental Protection Agency (EPA, 1982). Thickeners based on organic clay pose the least manufacturing challenges for biodegradable greases. This grease has excellent heat-resistance since clay does not melt and can effectively lubricate up to 260°C. The high temperature application of modern machinery has led to the development of “complex” soap greases. A complex soap is formed by the reaction of a fatty acid and alkali (soap), and the simultaneous reaction of the alkali with a short-chain organic or inorganic acid to form a metallic salt (the complexing agent).

Table 2.1: Common Lubricant Additives (Naval Ships' Technical Manual)

Soap properties	*Lithium*	*Lithium complex*	*Lithium Calcium*	*Calcium*	*Calcium sulphonate complex*	*Calcium complex*	*Aluminium complex*	*Polyurea*	*Bentonite*
Temperature	++	++	+		++	++	++	++	
Resistance to water		+	+	+	+	++	++	+	++
Corrosion						++	++		++
Pumpability		++	+	++	+	++			+
Adhesiveness		++				+	+		
Gen. purpose	++		+			++			
Speed	+	+			++				

Basically, complex grease is made when a complex soap is formed in the presence of base oil. Generally, complex greases have good all-around properties and can be used in multipurpose applications. Base oil and composition of the thickening agent plays an important role in grease consistency.

2.3.2.4 Additives

An additive is added as the coating material to the carrier (base). This additive brings up the characteristic as oxidation stabilizer for the lubricating grease. **Table 2.1** shows several common lubricant additives. Additive works as antifriction for bearings that must be lubricated to prevent metal-to-metal contact between the rolling elements, raceways and retainers.

A good lubricated bearing has the best chance of reaching its maximum service life. In-Sik Rhe (n.d) mentioned that additives behave excellent in water and good storage stability, good shear and oxidation stability, good antiwear and load carrying capacity, and saltwater corrosion properties.

High index of antioxidant work to protect bearing (resistance to oxidation) from being corrode. Water absorption and moisture penetration into a lubricated chamber may lead to a corrosive condition on steel components, via moisture diffusion through the lubricating thin surface film layer (Matco Services Incorporation, n.d). The use of corrosion inhibitors (additives) in grease may be of substantial benefit. **Figure 2.1** below show the effect of corrosion in ball bearing.

Table 2.2: Common Lubricant Additives (Naval Ships' Technical Manual)

Additives Type	Compounds Used	Function
Extreme Pressure (EP)	Sulfur-Phosphorous compounds	Increase load carrying ability
Antioxidant	Hindered phenols Amines	Prolong oil life by slowing oxidation
Antifoam	Silicones	Control foaming in forcefeed systems
Anticorrosion	Zinc dithiophosphates (ZDDP)	Form anticorrosion film
Detergent or Dispersant	Calcium sulfonates	Prevent deposition of carbon
Alkalinity (TBN)	Calcium Carbonates, Magnesium, Sulfonates	Neutralize acidic engines byproducts
Antiwear	Zinc dithiophosphates (ZDDP)	Reduce wear
Pour Point Depressant	Methacrylate polymers	Lower pour point
VI Improvers	Organic polymers	Improve VI

2.4 Manufacture of lubricating grease formulation

Grease is used where it is required to hold the lubricating oil and appropriate additives together to lubricate those applications where oil cannot be contained. Most grease is made in large kettles by mixing oils with various types of base materials called "soaps". As grease is used, the oils in the greases are gradually degraded by temperature and pressure in the work piece being lubricated. This process will continue until the oil becomes carbonized, unless fresh lubricant is applied periodically. As the oil oxidizes in service, it becomes a contaminant and mixes with the collapsing and degrading base to become "Used grease", which will be extruded regularly as fresh grease is added to the bearing or work piece.

According to Lubricating Greases (2012), grease can be formulated in either a batch or continuous process. Batch production is the most common manufacturing method. Bulk ingredients are metered or weighed into the processing reactor. For soap-based greases made by saponification, the fatty ingredient, alkali and a portion of the oil are added to the reactor. Heating and mixing convert the fat to soap, and the soap is dispersed throughout the mixture. Remaining oil is added to the batch after completion of saponification and dehydration to lower the temperature. Next the grease is milled and homogenized which will produce a uniform crystal and gel structure that will not change when the grease is used. The grease is further cooled, deaerated and packaged.

Adhvaryu et al., (2005) discussed the preparation of lithium soap-based soy greases using different fatty acids and the determination of crystallite structure of soap using Transmission Electron Microscopy (TEM). Lithium soaps with palmitic, stearic, oleic and linoleic acids were synthesized and mixed with Soybean Oil (SBO) and additives to obtain different grease compositions. His TEM measurements have revealed that the soap crystallite structure impact grease consistency. Soap fiber length and their cross-linking mechanism in the matrix control grease consistency (National Lubricating Grease Institute (NLGI) hardness, ASTM D-217 method). They showed that Lithium stearate-based soy grease has a relatively more compact fiber structure than Lithium palmitate. Linoleic acid with two sites of C-C in saturation in the chain has a much thinner and more compact fiber network than oleic acid (CI 8). The presence of additive in grease produces soap with looser network and larger fiber structure than similar grease containing no additive.

Machinery Lubrication (2002) evaluated the manufacture of lubricating greases through the mixing rheometry technique, by studying the effect of some processing variables such as rotation speed, intensity and duration of the homogenization treatment and thermal profile applied, in terms of the power-draw characterization and rheological behavior of the final product. With this aim, their lithium lubricating greases were prepared by inducing the saponification reaction between 12-hydroxystearic acid and hydrated lithium hydroxide within a naphtenic lubricating oil medium in an open vessel.

The saponification reaction occurred until neutralization by stirring with a controlled rotational speed mixing rheometer using an anchor impeller. Different rotational speeds were selected. Finally, a highly intensive homogenization treatment was applied using a rotor-stator turbine in order to reduce crystal sizes.

New generation of grease consisting more than one additive in order to increasing the performance of grease was developed. Some of the additive may contain grafted anhydride functional groups being progressively introduced in grease formulations. In this present work, load-carrying and anti-oxidant chemicals were formulated and added as additives to achieve that purpose. Mixing efficiency is important during the whole manufacturing process. The high temperatures achieved during processing may significantly increase the reactivity of repeating unit of polymethylhydrogensiloxane oil.

It was proven that the addition of graphite or MoS_2 (8 in each case) improves the anti-seize and antifriction properties of greases in sliding friction. The effectiveness of such additives depends to a great extent on the chemical composition of the grease (Boner, 1954). Results have been presented previously from determinations of anti-wear and extreme pressure properties of polytetrafluoroethylene lubricating greases (PTFE greases) and dispersion media of various chemical types; in this work, the PTFE thickener was shown to be highly effective in friction.

2.5 Non-soap base greases - Bentonite Base

There are a few advantages by formulating bentonite's soap. The advantages to formulate bentonite base grease are:

I. Low to relatively high thickener content 6-15% by weight
II. Smooth to buttery texture
III. No dropping point
IV. Maximum usable temperature of 350° to 700°F (177°C to 371°C) The maximum usable temperature is dependent upon the quality and type of base oil used in the formulation of the grease and its re-lubrication cycle.