

FORMULATION OF HIGH PERFORMANCE GREASE FROM WASTE OILS AND RED GYPSUM

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Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Chemical Engineering

**Faculty of Chemical Engineering and Natural Resources
UNIVERSITI MALAYSIA PAHANG**

JULY 2014

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ABSTRACT

This thesis describes a formulation of high performance grease from waste oils and red gypsum. The objectives for this study are to develop high performance grease from different types of waste oils and red gypsum and also to determine the best quality of grease based on different ratio of red gypsum and fumed silica. Grease is a semi-solid lubricant that the composition comprising of three major components, a lubricating base oil, a thickener and an additive. The grease formulated using four different waste oils as base oil which is recovered oil from waste emulsions, waste cooking oil, used oil and silicone oil, while fumed silica and red gypsum are used as thickener, molybdenum disulphide as additive and iron octoate as anti-oxidant agent. Different ratios of fumed silica and red gypsum were tested in this research to determine which ratio will formulate the best grade of grease based on National Lubricating Grease Institute (NLGI) number grade grease. The proportions of fumed silica and red gypsum involves are (100% red gypsum), (80% red gypsum, 20% fumed silica), (60% red gypsum, 40% fumed silica) and (50% red gypsum and 50% fumed silica). Evaluation is carried out using American Society for Testing and Materials (ASTM) to characterise the new formulation of grease in term of penetration test, dropping point test, type of thickener and amount of oil separated. This test is important to find the best formulation of grease from waste oils and red gypsum, by comparing it with greases that available in markets. It was discovered that the formulated grease has no dropping point even after 240°C of heating which proves that the grease has a stable structure at higher temperature. When the amount of fumed silica and red gypsum increases, oil separation decreases while the consistency of the grease increases. Grease properties are not only dependent on the composition of the base oil but also on the size and configuration of particles of the thickening agent. The more fumed silica contains in the grease, better the grease's quality. Greases with a higher grade number are firmer, tend to stay in place and are a good choice when leakage is concern. From the result of the experiment, grease was well made using base oil from silicone oil, following by waste emulsion. Smooth grease was made by using waste cooking oil, while grease cannot form when using used oil.

ABSTRAK

Tesis ini menerangkan formulasi gris prestasi tinggi daripada minyak sisa buangan dan gipsum merah. Objektif bagi kajian ini adalah untuk membuat gris prestasi tinggi daripada sisa buangan minyak dan gipsum merah dengan menentukan gris yang berkualiti terbaik berdasarkan nisbah yang berbeza antara gipsum merah dan fumed silika. Gris adalah pelincir separa pepejal dimana komposisinya terdiri daripada tiga komponen utama iaitu sisa buangan minyak sebagai asas pelincir, pemekat dan bahan tambahan. Gris dirumuskan menggunakan empat sisa buangan minyak yang berbeza sebagai minyak asas dimana minyak bersih daripada sisa emulsi, sisa minyak masak, minyak yang telah digunakan dan minyak silikon, manakala fumed silika dan gipsum merah digunakan sebagai pemekat, molibdenum disulfida sebagai bahan tambah dan asid octoate sebagai agen anti oksida. Nisbah yang berbeza daripada fumed silica dan gipsum merah telah diuji dalam kajian ini untuk menentukan nisbah yang akan memberikan gred yang terbaik berdasarkan Institusi pelincir gris antarabangsa (NLGI). Nisbah fumed silika dan gipsum merah merangkumi (100% gipsum merah), (80% gipsum merah, 20% fumed silika), (60% gipsum merah, 40% fumed silika) dan (50% gipsum merah, 50% fumed silika). Penilaian yang dijalankan bagi menentukan formulasi gris yang baru dari segi ujian penembusan, menjatuhkan ujian mata, jenis pemekat dan jumlah minyak yang dipisahkan. Ujian ini penting untuk mencari formulasi gris terbaik daripada sisa buangan minyak dan gipsum merah, dengan membandingkan gris yang terdapat di pasaran. Didapati bahawa gris tersebut tidak mempunyai titik jatuh walaupun dipanaskan selepas 240 darjah yang telah membuktikan bahawa gris itu mempunyai struktur yang stabil walaupun pada suhu yang lebih tinggi. Apabila jumlah fumed silika dan gipsum merah menaik, pemisahan minyak berkurangan manakala konsistensi gris menaik. Ciri-ciri gris bukan sahaja bergantung kepada komposisi minyak asas tetapi juga kepada size dan konfigurasi zarah ejen penebalan. Semakin banyak jumlah fumed silika dalam gris, lebih baik kualiti minyak itu. Gris dengan bilangan gred yang lebih tinggi adalah lebih kukuh dan adalah pilihan yang baik apabila ada kebocoran. Menurut pemerhatian yang telah dibuat sepanjang eksperimen, gris yang dibuat daripada minyak silicon adalah lebih baik strukturnya, diikuti dengan sisa emulsi. Manakala, gris licin terbentuk daripada sisa minyak masak, dan gris tidak dapat dibentuk apabila menggunakan minyak yang telah digunakan.

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LIST OF ABBREVIATIONS

$^{\circ}\text{C}$	degree Celsius
<i>cm</i>	centimetre
<i>g</i>	gram
<i>K</i>	kelvin
<i>Kg</i>	kilogram
<i>m</i>	mass
<i>m</i>	meter
<i>ml</i>	millilitre
<i>mm</i>	millimetre
<i>N</i>	newton
<i>nm</i>	nanometre
<i>sg</i>	specific gravity
<i>V</i>	volume
<i>wt</i>	weight

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
CNC	Computer numerical control machine
DI	Deionized water
DOE	Department of Environmental
EQA	Environmental Quality Act
FS	Fumed Silica
ISO	International Organization of Standardization
NLGI	National Lubricating Grease Institute
RG	Red Gypsum
SW	Scheduled waste

1 INTRODUCTION

1.1 Motivation and brief review

Grease may be defined as a solid to semi-solid material consists of three major components that form lubricating grease. These components are base oil, thickener and additives. Most grease produced today use mineral oil as their fluid components. The thickener gives grease its characteristic as a sponge that holds the lubricant in place. Additives mostly are oxidation and rust inhibitors, extreme pressure, antiwear and friction-reducing agents (Jeremy, 2008). There a few of common greases which are calcium grease or lime grease, aluminium grease, lithium grease, sodium grease, silicone grease and others (Boehringer, 1992).

Grease is a viscous semi fluid, which adhere strongly to the packing material (Adhvaryu *et al.*, 2005). The base oil and thickener package are the major components in grease formulations that exert considerable influence on the behaviour of grease. Many types and combination of thickener and base fluids, along with the supplemental structure modifiers and performance additives, give final grease formulation their specialty.

The use of liquid lubricant generally requires sealing of bearing against loss of lubricants. This sealing problem can often be simplified if lubricants are employed which resist the deforming effect of gravity. Grease functions as a sealant to minimize leakage, to keep out contaminants and also acts to keep deteriorated seals effective. Other than that, grease is easier to contain than oil. In comparison, grease, is easily confined with simplified, less costly retention devices (Jeremy, 2008). Grease also can resist change in structure or consistency during service, maintain mobility under conditions of application and provide corrosion protection (Boucher and Jones). In daily applications, it has become increasingly important that a grease composition is able to provide adequate lubrication at high temperature and it retain its properties under shear. Besides that, grease can be used for machinery that runs intermittently or is in storage for an extended period of time and also can be used for machinery operating under extreme conditions such as high temperatures and pressures, shock loads or slow speed under heavy loads. Under these conditions, grease provides thicker film cushions that

are required to protect and adequately lubricate (NLGI Lubricating Grease Guide, 1996).

The main purpose of this study is to develop grease from different types of waste oils as the base oil and red gypsum as one of the thickener that use to formulate the grease, which is something new to be discovered by using different types of waste materials as the raw material for this research. This new generation formulation of greases was tested by using an ASTM (American Society for Testing and Materials) testing to determine the grade classifications for the grease based on NLGI (National Lubricating Grease Institute) grade (Salvatore, 2003).

There are three problems need to be considered in this project. The main problem is actually waste emulsion. In industrial situations, an emulsion is formed that can seriously endangers the environment. With varieties of oil pollution and miscellaneous characters of the pollution sources, largeness of discharge and high requirements for treatment, control of such wastewater is faced with huge difficulties and pressure (Xin and Wan, 2013). Another main problem is environmental pollution by red gypsum waste from industries. Disposal of red gypsum by land filling or storage of massive amounts of gypsum in large pieces of land due to the high cost of the waste's treatment, gives the negative effects to the environment. Not only that, cost also one of the main problems that need to consider. Even though, formulation of grease from red gypsum and waste oils are subjected because they are wastes and easily to get, but the formulation of grease from raw materials are very expensive.

1.2 Problem statement

There are three major problems in this project. The main problem is waste emulsion. Oils and greases bind in certain ways with water and may produce a phase known as emulsion. Generally in industrial situations, an emulsion is formed by some type of oil, animal fat, vegetable oil or organic oil becomes coated by a protein or carbohydrate polymer thus allowing the oil to remain in suspension. As the pollution of waste emulsion, seriously endangers the environment, environmental protectors have carried out many researches on the treatment technology during past years and have developed many treatment technologies. But for the varieties of oil pollution, miscellaneous

characters of the pollution sources, largeness of discharge and high requirements for treatment, control of such wastewater is faced with huge difficulties and pressure (Xin and Wan, 2013).

Another main problem that needs to be considered is environmental pollution. Disposal of red gypsum by land filling or storage of massive amounts of gypsum in large pieces of land due to the high cost of the waste's treatment, will give the negative effects to the environment (Rose Aini Kamarudin, 2007). Similarly, for the waste oils, we can save our environmental pollution by using it for another uses instead of by dumping it into the water, lakes or river. In addition of this, we can preserve our drinking source from being polluted.

Lastly, cost also considered as one of the problems. Even though, formulation of grease from red gypsum and waste oils are subjected because they are wastes and easily to get, but the formulation of grease from raw materials such as silicone oil are expensive. In Malaysia, red gypsum waste was classified as a scheduled waste. It represents the largest quantity of waste generated as to be compared to other waste produced. According to Rose Aini Kamarudin (2007), these wastes are dump in a substantial amount, where the wastes are exactly valuable and can be recycled before they are being sold. In this research, we are using red gypsum as a thickener to formulate grease by reducing the amount of fumed silica to be used. With this, we can save cost of production and at the same time we also can reduce the amount of red gypsum waste dumped into land filling. However, red gypsum from industrial waste play as the most important role as the source for this formulation of grease.

1.3 Objectives

The objectives of this research are:

- i) To formulate high performance grease from waste oils and red gypsum
- ii) To determine the best quality of grease based on different ratio of red gypsum and fumed silica.

1.4 Scope of this research

The scopes of this research are:

- i) To compare the new formulation of grease with four types of base oils which are silicone oil, recovered oil from waste emulsion, waste cooking oil and used oil.
- ii) To characterise the new formulation of grease in term of penetration test, dropping point test, type of thickener and amount of oil separated.
- iii) To find the best formulation of grease from waste oils and red gypsum.

2 LITERATURE REVIEW

2.1 *Grease*

The basic definition of lubricating grease is a semi-solid product resulting from the fine dispersion of a thickening agent in lubricating oil. Grease consists of two basic structural components: A thickening agent and liquid or base fluid, in which that thickening agent is dispersed. Many types and combination of thickener and base fluids, along with supplemental structure modifiers and performance additives, give final grease formulation their specialty. A grease composition is prepared from isomerized base oil having consecutive numbers of carbon atoms (Micah, 2009). Grease is a semisolid lubricant that consists of a soap emulsified with mineral and vegetable oil. However, it is different with complex grease, because for the complex grease, the thickener contains two dissimilar fatty acids, where one of it is a complexion agent.

As with oil, grease displays its own set of characteristics that must be considered when being chosen for an application. The characteristic that commonly found on product data sheets include pumpability, which is the ability of a grease to be pumped or pushed through a system. 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 while for the dropping point is an indicator of the heat resistance of grease to determine the upper temperature limit at which grease retains its structure, not the maximum temperature at which grease may be used. As grease temperature increases, penetration increases until the grease liquefies and the desired consistency is lost. Not only that, water resistance also one of the characteristics that must be considered for the grease able to withstand the effects of water with no change in its ability to lubricate. High temperatures harm greases more than they harm oils. Grease cannot dissipate heat by convection because without the ability to transfer away heat, excessive temperatures result in accelerated oxidation or even carbonization where grease hardens or forms a crust. If the temperature of grease is lowered enough, it will become so viscous that it can be classified as hard grease. Then, it will influence the pumpability and machinery operation may become impossible due to torque limitations and power requirements (Boner, 1954).

The use of liquid lubricant generally requires sealing of bearing against loss of lubricants. This sealing problem can often be simplified if lubricants are employed which resist the deforming effect of gravity. Such solidified lubricants are usually called grease and are mostly composed of lubricating oil, which would normally have been employed, together with a gelling agent, which lends stiffness to the mixture. The essential property which grease must possess is the ability to form a film between surfaces so that surface-to-surface contact is prevented. This film may be quite thick, where grease is being used as an anti-friction bearing.

Grease functions as a sealant to minimize leakage and to keep out contaminants. For keep its consistency, grease acts as a sealant to prevent leakage and also to prevent entrance of corrosive contaminants. Due to the virtue of its rigidity, easily to confined and less cost retention device, it makes the grease is easier to contain than oil. Not only that, other functions of grease are 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, retain its properties under shear forces at all temperatures it experiences during use and also fluid and also hold solid lubricants in suspension (Pirro,2001).

Fumed silica has a very strong thickening effect that serves as a universal thickening agent and an anticaking agent (free-flow agent) in powders. Fumed silica is an extremely small particle with enormous surface area, high purity, and a tendency to form chains in the chemical manufacturing process, while achieving optimum shear thinning and enhancing the end-use application. Other uses of fumed silica are including as filler in silicone elastomer and viscosity adjustment in paints, coatings, printing inks, adhesives, cosmetics, sealants, toiletries, and unsaturated polyester resins. Moreover, fumed silica particles that act as a thickening agent in grease, hold the fluid by adsorption. The adsorption of fluid by myriad of such particles responsible for holding the fluid when fine silica used for thickening lubricating oil. Grease based that thickened with fume silica is stable on storage and against the effects of heat (Garret, 1992).

During the past few years, several investigators did their work on improving and studying the properties of the greases used in lubrication in the industry. 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 (Scharf and George, 1996).

Additives play several roles in lubricating grease including 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, antiwear, and friction-reducing agents. Boundary lubricants such as molybdenum disulphide 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. Mixing efficiency is important during the whole manufacturing process (Gordon, 1986). The addition of graphite and molybdenum disulphide improves the anti-seize and antifriction properties of greases in sliding friction, but the effectiveness of additives still depends on the composition of grease (Scharf *et al.*, 2001).

An anti-oxidant agent (Iron Octoate) formulated from a mixture of three chemicals, octoic acid, caustic soda and ferrous sulphate is used in this grease formulation. Two processes involved in producing iron octoate are saponification process and precipitation process. Oxidation inhibitor is a natural anti-oxidants among the most important additives used in grease, since, the base oil in grease can oxidize. If the base oil in grease oxidizes, the grease will be darkens and effects on the thickener causing softening, oil bleeding and leakage. Grease cannot conduct heat easily, serious oxidation can begin at a hot point and will spread slowly throughout the grease then it will lead to hardening and forming a crust.

According to Armstrong (1959), grease can be formulated in either in a batch or continuous process. Batch production is the most common manufacturing method. Grease displays its own set of characteristics that must be considered when being chosen for an application. Batch process offers great advantage over continuous process, which includes manufacturing operation in which flexibility required in either a rate or mixture of products. This process also can adjust the production either operating the flexibility on fewer shifts or manufacturing a different product that is in higher demand. Furthermore, process variables can be subjected to adjustments and multi-product operation can be done. Grease has a demand that changes over time or has

seasonal variability and this type of variability is well suited to batch manufacturing. The most important advantage using batch process is the cost required is less (Ekaterini, 1979).

The NLGI consistency number (sometimes called “NLGI grade”) expresses a measure of the relative hardness of grease used for lubrication, as specified by the standard classification of lubricating grease established by the National Lubricating Grease Institute (NLGI). NLGI's classification is widely used. The NLGI consistency number is also a component of the code specified in standard ISO 6743-9 (Salvatore, 2003). Greases are classified in one of nine grades based on their consistency. NLGI Grade alone is not sufficient for specifying the grease for a particular application but it is a useful qualitative measure. The nine grades are defined by a range of worked penetration test results. NLGI consistency numbers or grades are in range between 000 until 6. Common greases are in the range 1 through 3. Those within NLGI number 000 to 1 are used in low viscosity applications, while for the grade 0, 1 and 2 are used in highly loaded gearing. Grades 1 through 4 are often used in rolling contact bearings. Greases with a higher number are firmer, tend to stay in place and are a good choice when leakage is a concern (Rudnick, 2005).

2.2 Types of greases

2.2.1 Soap based grease

Soap based grease contains organic or inorganic thickeners. It is formed when the fatty acid or ester (from either animals or vegetables) is mixed with an alkali (such as lithium) and then heated under pressure with agitation. The process of this chemical reaction, which takes place, is known as saponification (Jarrod, 2005).

2.2.1.1 Lithium soap grease

Lithium grease is smooth, buttery-textured and by far the most popular when compared to all others. The normal grease contains lithium 12-hydroxystearate soap. It has a dropping point around 205°C and can be used at temperatures up to about 150°C It can also be used at temperatures as low as -35°C. It has good shear stability and a relatively

low coefficient of friction, which permits higher machine operating speeds. It has good water-resistance, but not as well as that of calcium or aluminium base. Pumpability and resistance to oil separation are good to excellent. It does not naturally inhibit rust, but additives can provide rust resistance. Anti-oxidants and extreme pressure additives are also responsive in lithium greases. Lithium complex grease and lithium soap grease have similar properties except the complex grease has superior thermal stability as indicated by a dropping point of 260°C. It is generally considered to be the nearest thing to true multipurpose grease (Jarrod, 2005).

2.2.1.2 Calcium soap grease

Calcium or lime grease, is prepared by reacting mineral oil with fats, fatty acids, small amount of water, and calcium hydroxide. The water modifies the soap structure to absorb mineral oil. Because of water evaporation, calcium grease is sensitive to elevated temperatures. It dehydrates at temperatures around 79°C at which its structure collapses, resulting in softening and, eventually, phase separation. Greases with soft consistencies can dehydrate at lower temperatures while greases with firm consistencies can lubricate satisfactorily to temperatures around 93°C. In spite of the temperature limitations, lime grease does not emulsify in water and is excellent at resisting “wash out.” Also, its manufacturing cost is relatively low. Calcium complex grease is prepared by adding the salt calcium acetate. The salt provides the grease with extreme pressure characteristics without using an additive. Dropping points greater than 260°C can be obtained and the maximum usable temperature increases to approximately 177 °C. With the exception of poor pumpability in high-pressure centralized systems, where caking and hardening sometimes occur calcium complex greases have good all-around characteristics that make them desirable multipurpose greases (Jarrod, 2005).

2.2.1.3 Sodium soap grease

Sodium grease was developed for use at higher operating temperatures than the early hydrated calcium greases. Sodium grease can be used at temperatures up to 121°C but it is soluble in water and readily washes out. Sodium is sometimes mixed with other metal soaps, especially calcium, to improve water resistance. Although it has better adhesive

properties than calcium grease, the use of sodium grease is declining due to its lack of versatility. It cannot compete with water-resistant, more heat-resistant multipurpose greases. It is, however, still recommended for certain heavy-duty applications and well-sealed electric motors (Jarrod, 2005).

2.2.1.4 Aluminium soap grease

Aluminium grease is normally clear and has a somewhat stringy texture, more so when produced from high-viscosity oils. When heated above 79°C this stringiness increases and produces a rubber like substance that pulls away from metal surfaces, reducing lubrication and increasing power consumption. Aluminium grease has good water resistance, good adhesive properties, and inhibits rust without additives, but it tends to be short-lived. It has excellent inherent oxidation stability but relatively poor shear stability and pumpability. Aluminium complex grease has a maximum usable temperature of almost 100 °C higher than aluminium-soap greases. It has good water-and-chemical resistance but tends to have shorter life in high-temperature, high-speed applications (Jarrod, 2005).

2.2.2 Non-soap based grease

Non-soap based grease consists of inorganic like molybdenum disulphide and graphite, as well as organic thickeners. The organic thickeners are considered as non-abrasives, which have high capacity to absorb and "hold" the base oil (Jarrod, 2005).

2.2.2.1 Polyurea non-soap grease

Polyurea is the most important organic non soap thickener. It is a low-molecular-weight organic polymer produced by reacting amines with isocyanides, which results in an oil soluble chemical thickener. Polyurea grease has outstanding resistance to oxidation because it contains no metal soaps (which tend to invite oxidation). It effectively lubricates over a wide temperature range of -20 to 177 °C and has long life. Water-resistance is good to excellent, depending on the grade. It works well with many elastomer seal materials. It is used with all types of bearings but has been particularly

effective in ball bearings. Its durability makes it well suited for sealed-for-life bearing applications (Jarrod, 2005).

2.2.2.2 *Organo clay*

Organo clay is the most commonly used inorganic thickener. Its thickener is modified clay, insoluble in oil in its normal form, but through complex chemical processes, converts to platelets that attract and hold oil. Organo clay thickener structures are amorphous and gel-like rather than the fibrous, crystalline structures of soap thickeners. This grease has excellent heat-resistance since clay does not melt. Maximum operating temperature is limited by the evaporation temperature of its mineral oil, which is around 177 °C. However, with frequent grease changes, this multipurpose grease can operate for short periods at temperatures up to its dropping point, which is about 260 °C. A disadvantage is that greases made with higher-viscosity oils for high thermal stability will have poor low temperature performance. Organo clay grease has excellent water-resistance but requires additives for oxidation and rust resistance. Work stability is fair to good. Pumpability and resistance to oil separation are good for this buttery textured grease (Jarrod, 2005).

2.3 *Base Oil*

Base oil comprises the largest component (70-95 %) in development of grease that provides lubricating properties. The selection of the base oil portion will determine the proper viscosity grade in a fluid lubricant. Most grease produced today use mineral oil as the fluid components. But, in this research, there are four different types of oils used in this research, which are recovered oil from waste emulsion, silicone oil, waste cooking oil, and used oil. 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 thickener required to achieve a certain NLGI grade.

2.3.1 Waste emulsion

Oils and greases bind in certain ways with water and produce a phase known as emulsion. This is a molecule loosely put together by ionic charges that involve the organic molecule and water molecules. An emulsion is not simply oily water though there may be some free oil and grease in the waste stream, which will float at the top of the water and emulsion phases. An emulsion is a mixture of two or more non mixing liquids held in suspension by a small percentage of substances called emulsifiers.

Generally in industrial situations, an emulsion is formed by some type of oil, animal fat, vegetable oil or organic oil becomes coated by a protein or carbohydrate polymer thus allowing the oil to remain in suspension. As the pollution of waste emulsion from mechanical process seriously endangers the environment, environmental protectors have carried out many researches on the treatment technology during past years and have developed many treatment technologies. But for the varieties of oil pollution, miscellaneous characters of the pollution sources, largeness of discharge and high requirements for treatment, control of such wastewater is faced with huge difficulties and pressure (Bezdek, 1984).

At present, treatment methods in common use can be categorized into physical method, chemical method and biological method (Gonzalez and Woods, 1992). The physical method uses physical effect to separate and reclaim suspended oil in the wastewater, such as sedimentation method, air floatation method, screen mesh filtration method, centrifugal separation method, membrane separation method and microwave-assisted treatment, etc., (Jain 1989 and Ibarra-Castanedo, 2004). Chemical method uses demulsification effect to treat emulsifying oil in the water such as coagulation sedimentation method, absorption method, salting-out method, acidification method, electrochemical method, etc., (Antoni Roglski, 2002).

Biological method uses microorganism effect to remove colloidal particle oil drops and dissolved oil such as bio-membrane method, activated sludge method and bio-oxidation pond method (Berthel, 2008). Each treatment method has its own characteristics and application conditions. In practice, as different emulsion has different characters, single method can hardly achieve ideal effects. As a result, only few treatment technologies have been put into actual industrial application. On the basis of sufficient investigations

and researches on the characteristics of waste emulsion produced from aluminium processing enterprises, this (Xin and Wan, 2013).

2.3.2 Waste cooking oil

Cooking oil is plant, animal, or synthetic fat used in frying, baking, and other types of cooking. It is also used in food preparation and flavouring that doesn't involve heat. Cooking oil is typically a liquid, although some oils that contain saturated fat. Proper disposal of used cooking oil is an important waste-management concern. Oil is lighter than water and tends to spread into thin and broad membranes which hinder the oxygenation of water. A single litre of oil can contaminate as much as 1 million litres of water. Also, oil can congeal on pipes provoking blockages. That's why; cooking oil should never be dumped in the kitchen sink or in the toilet bowl. The proper way to dispose of oil is to put it in a sealed non-recyclable container and discard it with regular garbage. Placing the container of oil in the refrigerator to harden also makes disposal easier and less messy (O'Brien, 1998).

Cooking oil can be recycled. It can be used to produce soap and biodiesel. Cooking oil recovered from a waste water plumbing component called a grease trap is called brown grease in the industry. Brown grease is contaminated with rotted food solids and considered unsuitable for re-use in most applications. However there are new technologies to handle brown grease. Yellow grease, also known in industry as recycled vegetable oil (RVO), also termed used vegetable oil (UVO), waste vegetable oil (WVO), used cooking oil, is recovered from businesses and industry that use the cooking oil, typically collected used oil from deep fryers. Yellow is used to feed livestock, and to make soap, make-up, clothes, rubber, detergents, and biodiesel fuel (Potter, 1995).

2.3.3 Used oil

Used oil is defined as petroleum based or synthetic oils that are used as lubricants, hydraulic fluid, heat transfer fluid (coolant), cutting fluid, buoyant or for some other similar purpose and become contaminated with physical and chemical impurities. The

examples of used oil include: engine oils; lubricating oils; brake fluids; transmission fluids; insulating oils; metal cutting fluids; industrial process oils, compressor or refrigerant oils. Used oil does not include petroleum derived solvents used for cleaning or vegetable or animal oils and fats.

Used oil that is not managed safely can pose a threat to humans and the environment. Improperly disposing of used oil can also lead to contamination of drinking water, surface water, ground water and soils. The used oil regulations describe proper used oil management. Used oil is a reusable resource; the regulations also promote used oil recycling. Used oil required proper recycling or disposal to avoid creating an environmental problem. Some examples of types of products that after use, can be labelled as used oil are: hydraulic oil, transmission oil, brake fluids, motor oil, crankcase oil, gear box oil, synthetic oil, and grades 1, 2, 3 and 4 fuel oil.

Used oil can be disposed of in different ways, including sending the used oil off-site (some facilities are permitted to handle the used oil such as your local garages and local waste disposal facilities), burning used oil as a fuel (some used oil is not regulated by burner standards, but others that are off-specification used oil can only be burned in either industrial furnaces, certain boilers, and permitted hazardous waste incinerators), and marketing the used oil. For-site burning of used oil, the oil must be stored in tanks or containers, above or underground. The containers must be in good condition with no leaks, the tanks or containers must be labelled with the words “used oil”, and there must be a spill prevention plan (Department of Energy Office of Environmental Guidance. 1993).

2.3.4 Silicone Oil

One of the base oils that used to formulate grease in this research is silicone oil. Silicone oil is any liquid polymerized siloxane with organic side chains. They are formed with a backbone of alternating silicon-oxygen atoms (...Si-O-Si-O-Si...) – i.e. siloxane, rather than carbon atoms (...C-C-C-C...). Other species attach to the tetravalent silicon atoms, not to the divalent oxygen atoms which are fully committed to forming the siloxane chain. A typical example is Hexamethyldisiloxane, where three methyl groups attach to each silicon atom to form $\text{Si}(\text{CH}_3)_3\text{OSi}(\text{CH}_3)_3$. The carbon analogue would be an

alkylalkane, that is 2,2,4,4-tetramethylpentane $C(CH_3)_3CH_2C(CH_3)_3$. Silicone oils are primarily used as lubricants or hydraulic fluids. They are excellent electrical insulators and, unlike their carbon analogues, are non-flammable. Their temperature-stability and good heat-transfer characteristics make them widely used in laboratories for heating baths ("oil baths") placed on top of hotplate stirrers, as well as in freeze-dryers as refrigerants. In addition, silicone oil is also commonly used as the working fluid in dashpots, wet type transformers, diffusion pumps and in oil-filled heaters (Miyahara, 2006). Figure 2.3.4 shows the structure of trimethylsiloxyl-terminated polydimethyl siloxane whereas table 2.3.4 shows the properties of silicone oil.

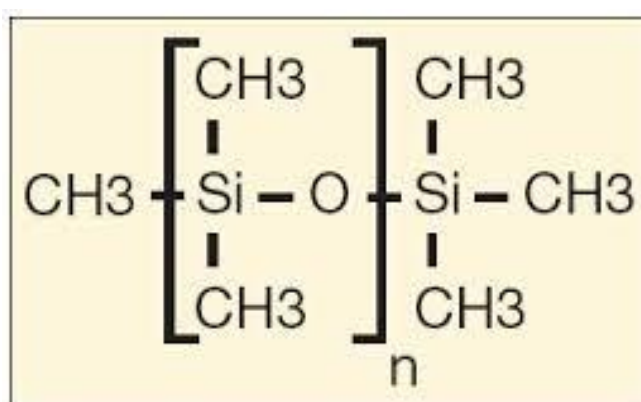


Figure 2.3.4: Structure of trimethylsiloxyl-terminated polydimethyl siloxane

Table 2.3.4: Properties of Silicone Oil

Properties	
Density at 25 °C	Approx. 0.97 g/cm ³
Flash point	> 300 °C
Ignition temperature (liquids)	410 °C
Surface tension at 25 °C	0.021 N/m
Viscosity, kinematic at 25 °C	Approx. 350 mm ² /s