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Full Length Research Paper

Lubricating grease from spent bleaching earth and waste cooking oil: Tribology properties

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The recovery of waste from many industrial production plants and its applicability in product development may be an incentive to industry, since the use of such squander could represents a cheaper source of raw material for many of the important processes utilized in further manufacturing. This paper presents the incorporated of wastes in industries particularly palm oil industries for new multi-purpose grease. Spent bleaching earth (SBE) from local palm oil refinery is used as thickener for this newly formulated grease while waste cooking oil is used as base oil. The properties of the produced grease are studied deeply in this article. Since SBE is found to be an effective thickener to newly multi-purpose formulated grease while fumed silica act as rheology modifier. So this novel idea can bring the most effective solution to convert the industrial wastage to the usable form.

Key words: Grease, spent bleaching earth, lubricants, vegetable oil.

INTRODUCTION

Greases are semi-solid lubricants used to reduce friction between two solid surfaces (Barriga, 2006; Akpan et al., 2011; Udonne, 2011). Lubricating grease is defined by American Society of Testing and Materials as semi fluid to solid product of a dispersion of a thickener in a liquid lubricant. Greases are made by dispersing thickening agent into carrying lubricant (oil) in a controlled mixing temperature. Generally, grease can be divided into several types depending on the applications; that is, clay greases, asphaltic-type greases, extreme-pressure greases, soap-thickened mineral oils, multi-purpose greases and many more. Recently, researches worldwide are focusing on developing lubricating grease by utilized environmental friendly and green sources for lubricating grease development. Some of the researchers could develop bio grease formulated from sunflower oil with polymer thickener (Barriga, 2006).

Lubricating grease has been used for plenty of application, involving machinery and moving part for efficiency and to prolong the life-time of the machinery (Pogosian and Martirosyan, 2007). Grease can perform additionally, more than lubricant oil do for the reason that grease can act as a seal, provide protection against corrosion and at the same time being able to reduce noise and shock.

Environmental friendly basis of lubricating grease will gradually find it way as materials for grease formulation. Currently practised greases formulation is made from petroleum and it derivatives. Somehow this trend has created environmental pollution due to the nature of non-biodegradability of this base oil (Gow, 2010; Ebewele et al., 2010). In addition, the application of grease from natural sources is more sought-after. The utilization of wastes from natural resources will increase efficiency of these natural resources. Furthermore, environmental friendly lubricant from natural resources are expected to expand for the next century (Cao et al., 2000) and slowly substitute conventional lubricating greases that will secure the environment from contamination that is hard to combat once escape into the surroundings.

Spent bleaching earth (SBE) is derived from natural clay and possesses suitable characteristics to be used as a thickener in grease application. Meanwhile waste cooking oil also has good characteristics as bio-degradable, cheap, possesses inherent viscosity, higher flash and fire points than mineral oil and provides environmental friendly solution for grease application.

Clay is a valuable source as a thickening agent for

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Table 1. Base oil properties.

Characterization	Properties	Analysis equipment
Appearance	Dark yellow	
Specific gravity	0.9126	
Viscosity @ 40˚C [cSt]	12cSt	Viscometer
Viscosity @ 100˚C [cSt]	8cSt	Viscometer
Density	0.9126 g/cm³	Gas pycnometer
Acid value	0.12 mgKOH	Metrohm® Titrino® Model 798
Free fatty acid (%)	0.22	Metrohm® Titrino® Model 798
Moisture	0.3%-1.5%	787 KF Titrino

Table 2. General composition of bleaching earth (Taiko, 1998).

Chemical composition	Percentage
SiO_2	55-80
Al_2O_3	5-20
Fe_2O_3	2-10
MgO	0-8
CaO	0-5
Na_2O	0-2
K_2O	0-2

lubricating grease due to its dispersible lamellar-type structure and capability to form hydrogen bond. Furthermore, chemical reaction is not required to form lubricating grease from a clay thickener. This type of lubricating grease can be easier to produce and require less energy to manufacture than soap-based lubricating grease. Clay is suitable for thickening hydrocarbon, polyglycols and some silicones (Braza, 2006). Gow (2010) wrote in a book that hectorite and bentonite clay which is insoluble in base oil can be used as a thickener, non-melting and does not drop at high temperature.

Current development of lubricating grease normally involved the use of petroleum or synthetic mineral oil, but nowadays environmental awareness has lead to more strict policies on the use of non-environmental friendly sources. Due to this reason, the invention and the use of environmental friendly lubricating grease start to gain importance. Somehow some of the eco-friendly base oil such as biodegradable synthetics ester lubricating is costly and not economically wise. To cope with this problem, vegetable oils are set as the alternative in term of their economical aspect other than significant environmental advantages of being renewable, non-toxic and satisfactory performance in a wide range of application (Sukirno et al., 2009). Plenty of research mainly involved edible oil sources of vegetable oil such as rapeseed, canola and soybean oils for lubricating use. These natural oils are good option for total loss, because they pass through applications like chainsaw lubricating and railroad grease where stability is not an issue and ready biodegradability is a requirement (Boyde, 2002).

Vegetable oil is well known for its biodegradability. Somehow most of the production of vegetable oil commercially is for food purposes. It is not desirable to use this source into lubricants formulation since it could adversely affect the food market price and demand. Waste cooking oil is set to be alternative for these edible vegetable oils. The properties and the suitability of this oil in being the subject of our study and the comparison are made between this waste oil and edible vegetable oil. The waste cooking oil is no longer suitable for food use due to toxic build up after being heated (Clark and Serbia, 1991). The change in color and smell also make it not suitable to be used any longer for food industries.

METHODOLOGY

Grease formulation from SBE and () WCO

In this formulation it is desirable to formulate lubricant grease which has special ability for machinery and other type of application. Grease is usually employed in the area where a continuous distribution of oil can not be maintained, such as open gears or bearings.

Cooking oil undergo several changes after being used in cooking process. Particularly this oil will undergo degradation due to thermal and also react with water to produced polymer and other type of impurities. Solid particles were removed from WCO by filtration and the acidity, moisture content and fatty acid profile of the filtered oil was determined. Filtered oil was kept in sealed bottle prior to use to avoid contaminant and reaction with air. In this research, the properties of waste cooking oil used for lubricating grease base oil are described in Table 1.

Spent bleaching earth was obtained from local palm oil refinery plant "FELDA Vegetable Oil Product Sdn Bhd" and it is being used without any further treatment. The SBE is natural clay within bentonite family and commonly used as bleacher in bleaching process due to its special properties. SBE commonly disposed in dumpsite or mixed with feedstock for animal food. Particle sized of SBE was determined to study its characterization. Prior to the chemical composition of SBE, this formulation was determined due to the variation of the natural clay that existed in the composition. Table 2 show the general composition of bleaching earth. In general bleaching earth comprised of SiO_2, Al_2O_3, Fe_2O_3 and few trace elements.

Formulation of grease from WCO and SBE involved simple but

Table 3. NLGI consistency number.

NLGI consistency number	Worked penetration range, 25°C (77°F)
000	445 to 475
00	400 to 430
0	355 to 385
1	310 to 340
2	265 to 295
3	220 to 250
4	175 to 205
5	130 to 160
6	85 to 115

Table 4. Percentage of WCO and SBE in base grease formulation.

Formulation number	Base formulation (WCO/SBE %)
Formulation 1	50% WCO / 50% SBE
Formulation 2	40% WCO / 60% SBE
Formulation 3	35% WCO / 65% SBE
Formulation 4	30% WCO / 70% SBE
Formulation 5	25% WCO/ 75% SBE
Formulation 6	20% WCO / 80% SBE

vigorous mixing of the compounds at room temperature by an overhead stirrer. The mixing of WCO and SBE was based on weight over weight percent (w/w %) of the base oil and thickener. The mixing process of the WCO and SBE is simple mixing process and was done at room temperature (21°C) until homogenise structure was obtained.

In general, clay has been used for grease formulation commonly having swelling ability and required more base oil to form a grease, but SBE does not possess swelling ability; therefore, less base oil is required for the formulation of grease as SBE is able to hold less oil (around 5 to 10% of its weight). Therefore, within this formulation, thickener is the dominant composition for this type of grease. The tribology properties grease produced was tested to determine it ability, either it is suitable for further application or vice versa. Unlike soap based grease, clay type grease generally does not involve any chemical reaction therefore the energy and time could be save as no heating particularly is needed to complete the process. The formulated base grease's consistency is determined by measuring the penetration of cone into the grease by penetrometer and comparing the result to the standard established by National Lubricating Grease Institute (NLGI) as shown in table 3. The formulation is based on Table 4. Further testing of the grease is based on penetration test. Grease that is having NLGI grade 2 and 3 will be selected for friction co-efficient and wear scar diameter.

Friction co-efficient (ASTM D5707)

Friction co-efficient is defined by ASTM D5707 as the dimensionless ratio of the friction force (F) between two bodies to the normal force (N) pressing these bodies together (ASTM, 2008). The friction and wear tests were conducted at a rotating speed 1450 rpm (linear speed) and load 392 N, for test duration of 30 min. The ambient temperature is about 15°C. The method of the friction co-efficient was recorded automatically with a strain gauge equipped with the four-ball tester by the SRV testing machines used. The wear scar diameters on the three lower balls were measured using an optical microscope and the friction coefficients.

Wear scar diameter

Wear scar diameter caused by wear and friction of the steel balls used in four ball test were measured under a microscope having a calibrated grid.

RESULTS AND DISCUSSION

Penetration test (un-worked)

Grease consistency associated to the firmness of the grease. Basically the grease is formulated and design depending on their applications. Grease structure and properties can range from semi fluid consistencies to nearly solid. If the grease is too hard, it may not satisfactorily flow to the areas in need of lubrication. If it is too soft, it may leak away from the desired area.

The un-worked penetration test (Table 5) suggesting that the penetration of grease by penetrometer is proportional with the grease composition. The higher the quantity of the SBE the lower the penetration and the lower the NLGI grade obtained. If the cone submerged deeper into the grease, the lower consistency of the grease it indicate, that is the grease are easier to flow under operation and vice versa. The common grease consistency for most of the commercial lubricating grease lies within grade 2 and 3. Therefore grease composition

Table 5. NLGI grade for formulated greases.

Base formulation (WCO/SBE %)	NLGI hardness grade
50% WCO / 50% SBE	00
40% WCO / 60% SBE	0
35% WCO / 65% SBE	1
30% WCO / 70% SBE	2
25% WCO/ 75% SBE	3
20% WCO / 80% SBE	4

Table 6. Friction co-efficient of formulated grease.

Sample no.	Sample formulation	Friction co-efficient	Average scar diameter (mm)
1	0.75SBE/WCO	0.082	0.743
2	0.69 SBE/WCO	0.095	0.773
3	0.52NCO/0.37SBE/0.11 FS	0.11	0.801

having 70 to 75% of the SBE is desirable.

Among others, the penetration test also shows the consistency of the grease. The grease is made of non soluble thickener whereas heating and pro-longed mixing time would have no significant effect over the grease homogenization. SBE acts as a reservoir for the base oil and absorbs the oil and release the oil when pressure and temperature are increasing. The un-worked penetration does not really suggest the real operation of the grease. From observation, at elevated temperature, the penetration value would be different from the normal room temperature somehow base on the standard method (ASTM), the reading should be taken at room temperature which is 25°C. In another observation, the consistency of the grease would change after the grease stored for more than one month. The differences occur due to migration of the oil from the thickener by oil separation resulting into de-homogenization of the base oil and the thickener after being stored for some period. It is important to ensure the homogenization of the grease by using proper instrument of homogenization. Penetration test is contributed by the particle size of the SBE and also by the base oil viscosity. To achieve formulation as mentioned earlier, the base oil should be unchanged by the temperature changed.

Friction co-efficient: Four ball test

From the result obtained in Table 6, the wear scar diameter measured give us the understanding that friction from the grease would likely cause wear to the contact metal. The result also shows that the wear scar diameter is proportional with the friction co-efficient of a grease. The higher the friction co-efficient the bigger the scar diameter obtained and minimizing friction reduces wear.

Conclusion

Grease composed from spent bleaching earth and waste cooking oil has promising future as reliable lubricating grease for plenty of application. Spent bleaching earth consists of very fine particles of clay, able to absorb oil and hold the oil. This special property is important for any thickener, the ability to hold and to release oil when needed. As conclusion, spent bleaching earth can be used as a novel application for grease formulation even without addition of additives. Somehow due to the ability of WCO which is prone to oxidation, more study is needed to overcome this problem such as structure modification and anti-oxidant addition. The application of wastes in industries is a wise way to decrease pollution from industries as well as to preserve the environment. At the same time this trend is hope to further utilize and give added value of wastes by converting the waste to wealth.

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