Fundamental Study of Waste Oil Potential as Base Oil Alternative in Grease Formulation

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Abstract—Large consumption of crude oil in lubrication industry might adversely affected by the reduction of crude oil production due to the decline of petroleum reserves. Environmental pollution caused by the improper disposal of waste oils and the recyclability of waste oils has brought interest to study the potential use of the waste oils. The main purposes of the current research were to formulate grease using different types of base oils from waste oils and to study the grease structure formation ability. Waste lubricating oil (WLO), spent hydraulic oil (WHO) and used brake oil (WBO) were used as base oils. Sodium hydroxide and molybdenum disulfide were used as thickener and additive. The formulated greases were studied by observing the grease's appearance and measuring the oil separation during storage. The overall results show that the formulated greases have achieved the desired grease structure of semisolid form using WLO and WHO as base oil with oil separation up to 10%.

Keywords— Grease; Waste Oil; Waste Lubricating Oil; Spent Hydraulic Oil; Used Brake Oil

1. INTRODUCTION

The use of grease has been implemented since ancient time. Today, there are many different types of greases, but the basic structure of these grease is similar [1].American Society for Testing and Materials (ASTM) defined lubricating grease as a solid or semi-fluid lubricant consisting of a thickening agent in a liquid lubricant or other ingredients imparting special properties may be included [2]. As rule of thumbs, the formulations to make grease were consisting of three components base oil (70-90%), thickener (20-10%) and additive (10-5%).

Base oil of greases are commonly mineral oils, synthetic hydrocarbons and other synthetic compounds Most greases produced today are using mineral oil as their base fluid. The thickener is a material that, when disperse in the base oil, it will form a semisolid structure of grease. The primary type of thickener used in current grease is metallic soap of lithium, aluminum, clay, polyurea, sodium and calcium. Lately, complex thickener-type greases are gaining popularity due to their high dropping points and excellent load-carrying abilities. Non-soap thickeners are also gaining popularity in special applications such as high temperature environments. Additives can play several roles in lubricating grease such as 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, anti-wear, and friction reducing agents [3].

In modern industrial years, grease had been modified to achieve the variety of difficult lubrication problems, particularly those where the fluid lubricant is no practicable. Over the last decades, grease making technology throughout the world, has undergone rapid change to meet the growing demands of the sophisticated industrial environment. Unfortunately, the increase in demand lead to the increase of waste oil generation. Waste oil is categorized as schedule waste for which it can threatens public health and the environment if it is disposed improperly. In Malaysia, approximately 150 million of waste lubricating oil being disposed annually [4].

Other than that, the world petroleum resources have been decreasing and had led to the limited sources of oil available. The decline of crude oil production worldwide has adverse effect in lubricant market because almost 97 – 99 percent of the lubricant base fluid is obtained from the petroleum resources (mineral oil) [5,6]. Consequently, the limited petroleum reserves and unpredictable oil prices have led to the interest in finding the alternative base oil. Interestingly, waste oil is known to be recyclable into new product and the government worldwide had been encouraging in recycling these oils to reduce the volume of waste oil disposed [7,8]. Other study related to the used of waste oil in grease formulation have been conducted to study the potential of the waste oil as grease base oil's replacement [9–11].

In this study, the idea on reusing waste oils, the limited petroleum reserves, unpredictable oil prices and environmental concern have brought an interest in the use of waste oil as the potential grease's base oil in lubricating grease production. Therefore, the waste oil such as waste lubricating oil, spent hydraulic oil and used brake oil, are utilized in this study as base fluid in the grease formulation. In this study, it was aimed to formulate grease from waste oil and to analyse the properties of grease formulated based on different ration of waste oil by using the American Society of Testing and Materials (ASTM) grease testing methods.

2. EXPERIMENTAL WORK

A. Materials

Different types of base oils were used which are waste lubricating oil, spent hydraulic oil and used brake oil. These oils were collected from workshop nearby area of Universiti Malaysia Pahang, Gambang Campus. Sodium hydroxide (NaOH) was chosen as thickening agent, for which it was reacted with fatty acid found in waste cooking oil (WTO) and form sodium stearate (soap thickener). Sodium soap greases have higher dropping points about 175°C, inherent rust protection properties but, they are not water resistant and emulsify in the present of water [12]. Molybdenum disulphide (MoS2) was used as additive to enhance the properties of grease formulation. It has the durability to withstand heat and pressure [13].

B. Preparation of sodium soap thickener

The saponification process is a must to formulate soap grease. It is a process of alkali hydrolysis of fatty matters to form soap. In this study, the soap is prepared by mixing thoroughly 6M of NaOH solution with WCO in the ratio of 1:2 and heated to 37°C [14]. The mixture was stirred continuously until the smooth paste of soap is obtained. The soap formed was then be heated to 120°C to remove water by evaporation.

C. Formulation of grease samples

In this stage, waste oil was heated to 100°C for 30 minutes and the soap was dispersed in the base oil by gradual addition and continuous homogenization for at least 1 hour until smooth paste of grease was formed. The amount of base oil and thickener added was as in Table 1. The additive of fixed amount of 3% of the total composition was then added slowly and homogenized for another 1 hour and the grease was allowed to cool to room temperature for 2 days and observed.

Table 1: Grease composition.

Type of base oil	Sample identification	Composition (%wt)		
		Base oil	Soap thickener	MoS_2
Waste lubricating oil	WLO_1	80	17	3
	WLO_2	70	27	
Spent hydraulic oil	WHO_1	80	17	
	WHO_2	70	27	
Used brake oil	WBO_1	80	17	
	WBO_2	70	27	

D. Oil separation of grease

The test was done as complied with the Standard Test Method for Oil Separation from Lubricating Grease during Storage (ASTM-D1742). It is known as oil separation test in which it determines the stability of the grease formulated. All grease samples were stored in enclosed container and the initial level of the grease is observed and recorded. In this study, the formulated greases were left for 2 months at room temperature. The amount of oil separated was measured using the measuring cylinder and weighed. Theoretically, the lesser the oil separated, the better the stability or quality of the grease. The sample is considered stable if and only if the amount of the oil separated less than 4% [15].

3. RESULT AND DISCUSSION

A. Formation of grease structure

Table 2 shows the observation of the formulated grease structure by using three different type of waste oils. Both formulation using WLO shows better result for which the grease structure is obtained. Grease structure also was obtained by using base oil of WHO. However, the amount of oil need to be reduce in order to reduce the number of oil separated from the grease and to achieve better grease structure. Unfortunately, greases formulated using WBO were unable to form any grease structure at which, it is believed that the thickener was unable to hold the oil in its thickener system. This is might be due to the different oil base in brake oil for which it is not mineral-based oil as WLO and WHO [16]. Moreover, greases are often formulated either using mineral oil and synthetic oil.

Table 2: Grease structure observation.

Grease sample	Observation
WLO_1	Semi-solid structure of grease is formed with butter-like consistency but, some oil is separated on the surface.
WLO_2	Semi-solid structure of grease is formed with viscous liquid-like consistency. Some oil is separated on the surface
WHO_1	Half of the volume formed grease structure and another half is oil separated from grease.
WHO_2	Semi-solid structure of grease is formed with viscous liquid-like consistency. Some oil is separated on the surface
WBO_1	There is small amount of grease structure formed at which most likely all the product remained as precipitate at the bottom.
WBO_2	

B. Oil separation during storage

Greases tends to release their base oils during storage (static bleeding) [17]. Static oil bleeding can be affected by storage conditions and is more pronounced if the grease is soft in consistency (NLGI grades 00, 0 and 1) [18]. Oil separation often relates to the base oil and thickener combination with kinematic viscosity of the base oil [19]. Table 3 shows the actual amount of oil separated from the formulated grease.

Table 3: Oil separation from grease.

Grease samples	Amount of oils separated, g	Oil separation, %
WLO_1	30	6
WLO_2	6	0.12
WHO_1	250	50
WHO_2	50	10
WBO_1	450 (base oil and thickener mixture)	90
WBO_2		

Base on Table 3, it is shown that the best base oil candidate for grease formulation using waste oil is waste lubricating oil (WLO). This is due to the small amount of oil separated from 500g of grease sample. The formulated grease of WLO_2 shows excellent stability with the amount of oil separated less than 4%. By comparing the greases formulated as per tabulated in Table 1 and 2, it was inferred that the structure and amount of oil separation of formulated greases using WLO and WHO can be improved by decreasing the oil-to-thickener ratio [20]. Unfortunately, WBO is not practical to be used as base oil in grease formulation due to the inability of grease structure to form as the thickener is unable to hold the oil in its matrix.

4. CONCLUSION

Waste oils can be used as base oil. However, not all type of waste oils can be utilized in the formulation of grease. Based on the result obtained, waste lubricating oil and waste hydraulic oil can be the base oil alternative to replace the fresh mineral oil in grease formulation due to the ability of thickener and the oil to form grease structure. The waste oil-based greases were successfully formulated but the greases oil-to-thickener ratio need to be reduced or proper selection of additive were required to reduce the amount of oil separated of the formulated grease. Further study on these greases still need to be done to study the properties such as consistency and dropping point, and the performance of these formulated grease.

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