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Lubricating Grease from Waste Cooking Oil and Waste Motor Sludge

Aseem Rajvanshi, Pankaj Kumar Pandey

***Abstract*—**Increase in population has increased the demand of energy to fulfill all its needs. This will result in burden on fossil fuels especially crude oil. Waste oil due to its disposal problem creates environmental degradation. In this context, this paper studies utilization of waste cooking oil and waste motor sludge for making lubricating grease. Experimental studies have been performed by variation in time and concentration of mixture of waste cooking oil and waste motor sludge. The samples were analyzed using penetration test (ASTM D-217), dropping point (ASTM D-566), work penetration (ASTM D-217) and copper strip test (ASTM D-408). Among 6 samples, sample 6 gives the best results with a good drop point and a fine penetration value. The dropping point and penetration test values were found to be 205 °C and 315, respectively. The penetration value falls under the category of NLGI (National Lubricating Grease Institute) consistency number 1.

***Keywords*—**Crude oil, copper strip corrosion test, dropping point, penetration test.

I. Introduction

CRUDE oil is a vital source of energy of any country due to its different applications as a fuel for transportation and feedstock for industrial and manufacturing processes. Increase in prices of crude oil and environmental concerns have put pressure on the industries and researchers to find the alternatives of mineral oils [1]. The various products from refining of crude oil are petroleum gas, gasoline, naphtha, kerosene, lubricating oil and many more. Grease (Latin word, *Crassus*) is a semi-solid lubricant. Lubricating grease consists of base oil, thickener agents and additives. Its main purpose is to reduce friction and wear between moving parts of machines which helps in improving the efficiency and to reduce the energy consumption [2]. The consumption of lubricants has been increased in the last decades due to increase in the number of vehicles especially the small cars and SUV's. It is expected that the demand for automotive lubricants will experience a steady growth as the vehicle industry rapidly grows. Lubricating greases when used at high temperature and high speed results in loss of thermal, mechanical and lubricating properties. These greases have no further use and regarded as waste [3]. Environmental degradation occurs due to disposal of waste lubricant (burning, land filling, run off from roadways, accidental spillages, pipeline leakages and migration into the surface or ground water). This degradation will pose a threat to human life as well as other living organisms [4], [5]. Therefore, there is a great need for the reutilization of waste lubricating grease/ motor sludge into useful recycled products. Recycling is considered to be beneficial to environment and to economic development since it mitigates resource scarcity, decreases demand for landfill space and generally involves savings in energy. A renewable resource such as vegetable oil is being considered as potential replacement for lubricants made from mineral oil base stocks. The lubricants prepared from vegetable oil cause less harm to the environment in case of accidental spillage or during disposal of the material [6]. Development of vegetable oil based grease has been an area of active research for several decades due to its properties such as biodegradable, non-toxic, low volatility and excellent temperature–viscosity properties. These greases have good lubricating properties due to the polar ester groups which enable them to adhere to metal surfaces. In addition, vegetable oils have high solubilizing power for polar contaminants and additive molecules [7], [8]. Discarded waste vegetable oil from household and different industrial activities can be reutilized along with waste motor sludge for making of lubricating grease [9]. Besides, by utilizing waste vegetable oil, the cost will be cheaper compared to virgin vegetable oil [10]. The objective of this research is to produce lubricating grease from waste cooking oil and waste motor sludge. Also a comparison is made between proposed grease and other greases available in the market in order to determine the quality of produced grease.

Aseem Rajvanshi, Pankaj Kumar Pandey are with the Department of Chemical Eng., Amity University Rajasthan-Jaipur, India, 303002 (e-mail: pkpandey@jpr.amity.edu).

II. Materials and Methods

A. Materials

Waste cooking oil was obtained from the Amity University Rajasthan-Jaipur canteen which is used for making of food and other edible materials for approximate 3000 students every day while waste motor sludge was purchased from local markets near university campus. Hexane 96%, isopropyl alcohol 99.7%, lithium and potassium hydroxide 85% were provided by Ossol Petroleum's Pvt. Ltd., Mumbai, India. The waste motor oil was collected from the closest motor garage in Jaipur. Calcium fluoride was purchased from a local chemical shop. Molybdenum disulphide and 12-HSA were used as thickener and additives, respectively.

B. Sludge Separation from Used Lubricant

About 432 ml of isopropyl alcohol, 1.3 gm of potassium hydroxide and 0.288 mL of hexane were superimposed into a beaker containing 180 mL of waste motor oil. The solution was stirred for about 2 hours to ensure complete mixing in a beaker covered with aluminium foil and set aside for 24 hours for settling filtration system to remove solvent from sludge. The collected sludge was stored in a container until used.

C. Purification of Cooking Oil

The oil undergoes degradation due to heating and it also forms polymer and other types of impurities due to its reaction with water. By filtration, solid particles and the seen impurities were removed from waste cooking oil and the moisture content. Acidity and the fatty acid profile of the waste cooking oil were tested. Filtered oil was kept in sealed bottle to avoid reaction with air, prior to use. The appearance of the cooking oil was dark yellow with a specific gravity of 0.926, acid value of 0.16 mg KOH, viscosity 17 cSt and moisture content of 0.9-1.8%. Many studies reported about the modification of cooking oil [11]-[13]. Through their studies, they concluded about the properties of vegetables oil such as good lubrication properties, viscosity index, flash point and pour point. Blending of oil with other waste materials reported to have better quality [14], [15].

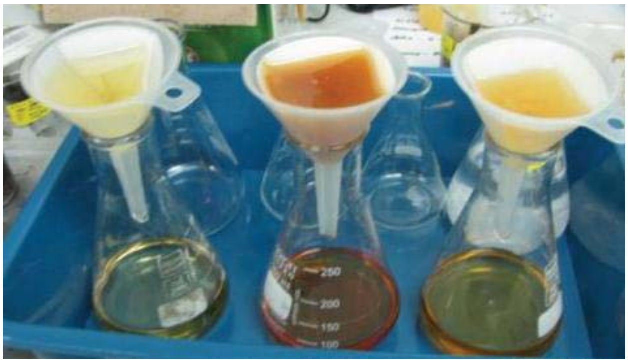

Fig. 1 WCO filtration using filter paper

D. *Steps for Making Grease*

Fig. 2 shows the different steps for making of grease in the laboratory.

Waste collection
↓
Design of formulation
↓
Waste treatment and property determination
↓
Mixing of the ingredient based on the formulation
↓
Grease testing and analysis

Fig. 2 Procedure for making of grease

E. Grease Formulation

Five samples of grease were prepared using different proportions of lithium and waste motor sludge. 50 gm of WCO with a fixed proportion of 12-HSA was heated at 100 °C. Lithium & motor sludge were added according to the different ratios as given in Table I. The mixture was stirred and heated up to a temperature of 180 °C for 15 minutes and cooled to 100 °C. Molybdenum disulphide and calcium fluoride were added with the weight of 0.05 and 2%. The stirring and heating was continued at temperature of 100 °C for next 30 minutes and cooled at room temperature and stored for future analysis.

TABLE I
DIFFERENT COMPOSITION OF LITHIUM TO MOTOR SLUDGE

Sample	Lithium (Wt%)	Motor sludge (Wt%.)
1	0.0	25
2	0.1	25
3	0.2	25
4	0.3	25
5	0.4	25
6	0.5	25

F. Grease Formulation Using Different Mixing Time

Grease formulations were performed using different mixing times varied from 1 to 5 hours. Among them, one of the best samples was selected for analysis of various properties of grease. The same procedure was mentioned in the various research findings.

G. Grease Formulation Using Different Ratios of Waste Motor Sludge and Waste Cooking Oil

Five samples of grease were prepared by using different ratio of lithium and waste motor sludge (20 to 50%) and waste cooking oil from 50 to 80% as given in Table II. The mixing of WCO with lithium and motor sludge was based on (w/w%) of the base oil and the thickener.

TABLE II
PERCENTAGE OF LITHIUM AND MOTOR SLUDGE / WCO

Sample	Lithium & Motor Sludge	WCO
1	50%	50%
2	40%	60%
3	30%	70%
4	20%	80%

H. Analysis

The grease produced using different ratios of lithium to motor sludge was tested for penetration test (ASTM D-217), dropping point (ASTM D-566) in order to determine the best sample produced. Variation of mixing time on grease properties from 1 to 5 hour were also tested for dropping point (ASTM D-566), work penetration (ASTM D-217) and copper strip test (ASTM D-408).

III. RESULTS AND DISCUSSIONS

A. Effects of Lithium to Motor Sludge Ratio on Grease Characteristics

Table III shows the physical appearance and dropping point for grease sample 1-6. The colour varies from black to golden yellow. The variation in the amount of lithium to motor sludge affects the colour of the grease. Since the waste motor sludge which is dark in colour and a little amount of molybdenum disulphide was used, the greases obtained in first sample were dusky in appearance. The dropping point varies with the composition of the lithium in the grease. In grease sample 1-5, the composition of the lithium increases while the composite of the sludge and the waste cooking oil remain same. Sample 1 and 2 were not tested as the physical conditions of both of these greases were inappropriate for testing. Lithium is a commercial grease thickener with a dropping point of around 200 °C with normal lithium grease and 260 °C in lithium complex greases. This means higher the amount of lithium with the motor sludge, higher will be the drop point.

TABLE III
GREASE'S PHYSICAL APPEARANCE, DROPPING POINT AND WORK PENETRATION

Sample	Description	Appearance	Dropping point (°C)	Work penetration
1	Fluid	Black, liquid like	—	—
2	Semi Fluid	Dark brown	—	—
3	Very soft	Pale brown	182.0	390
4	Soft	Pale brown	185.5	328
5	Very Firm	Light Brown	197.0	322
6	Very Firm	Golden Yellow	205.0	315

B. Effects on Grease Characteristics Due to Different Mixing Time

It can be seen by the data achieved in Table IV that the mixing time does not affect the physical appearance of the grease. All the samples with variation in mixing time have the same physical appearance which is golden yellow.

TABLE IV
GREASE PHYSICAL APPEARANCE WITH VARIATION IN MIXING TIME

Sample	Mixing time	Appearance	Food Analogy
A	1hr	Golden Yellow	Tomato Paste
B	2hr	Golden Yellow	Tomato Paste
C	3hr	Golden Yellow	Tomato Paste
D	4hr	Golden Yellow	Tomato Paste
E	5hr	Golden Yellow	Tomato Paste

C. Dropping Point

The dropping point of the grease can be seen in Table V which shows that variation in mixing time of the grease sample does not have a deep impact on the dropping point of the grease samples as there is just slightly increase in the drop point with increased hours of stirring.

TABLE V
GREASE DROP POINT WITH VARIATION IN MIXING TIME

Sample	Mixing time	Drop point(°C)
A	1hr	>200
B	2hr	>200
C	3hr	>200
D	4hr	>200
E	5hr	>200

D. Penetration test

It can be seen in Table VI and Fig. 3 that there is an increase in the worked penetration of the grease sample as the time of mixing increases. This is because; there will be a decrease in the consistency of the grease as the heating hours increases which cause the worked penetration to increase with increase in stirring time. This type of study was also reported by [16], [17].

TABLE VI
WORKED PENETRATION WITH VARIATION IN MIXING TIME

Sample	Mixing time	Work penetration	NLGI consistency no.
A	1hr	310	1
B	2hr	313	1
C	3hr	323	1
D	4hr	340	1
E	5hr	355	0

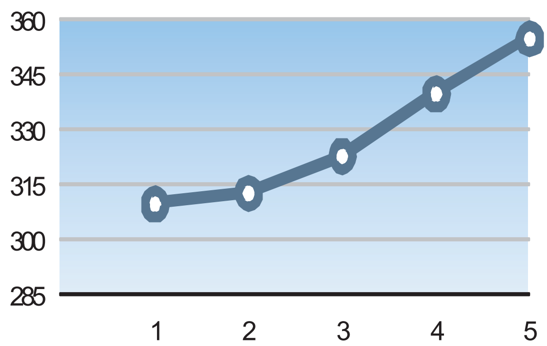

Fig. 3 Variation of work penetration with time

E. Corrosion Test

This test detects the tendency of the grease corrosiveness under specific conditions. It was found that all the grease samples show a very low corrosiveness nature under specific static conditions. In all grease samples copper strip was inserted & all strips were slightly tarnished in appearance which makes them fall in a 1B ASTM rating [18]. The result indicates that the grease produced can be utilized in suitable applications since the presence of corrosive substances was negligible [19].

F. Effects of Different Ratios of Waste Motor Sludge and Lithium to Waste Cooking Oil on Grease Characteristics

It can be observed through Table VII that as the ratio of thickener decreases in the grease formulation and the composition of waste cooking oil increases, the drop point of the grease decreases and penetration number of the grease increases [20].

TABLE VII
DROP POINT AND WORK PENETRATION OF THE GREASE

Sample	(Lithium & motor sludge	Waste cooking oil	Drop point	NLGI Hardness Grade
1	50%	50%	185	1
2	40%	60%	172	1
3	30%	70%	164	0
4	20%	80%	152	0

IV. CONCLUSION

This research was carried out to find the best utilization methods of waste lubricant oil and the cooking oil used in homes and food Industries. This will help in reducing the burden on lithium as it is non-renewable resource which is getting depleted very fast and the prices of lithium tripled in the past year. Also the utilization of the waste lubricating oil and cooking helps in waste management which minimizes the drastic environmental and health related issues in future, related with waste oil. It was found that on using the different composition of lithium to motor sludge, sample 6 gives the best result with a good drop point and a fine penetration value which makes it suitable for its use in industries. The copper strip corrosion test indicates that corrosive nature of the grease samples was low under specific condition. The color of the lubricating oil was shiny black. The results reveal that the lubricating grease manufactured by waste motor sludge and waste lubricating oil have a soft appearance and can be used for general machines where extreme pressure is not required. This shows that wastes (motor sludge and cooking oil) have better potential in the lubricating market and also helpful in reducing the pollution problem as well as to preserve the environment and cost of the grease produced. Also this will helpful in further utilization of wastes into useful products and reduce the burden on the conventional sources.

Abbreviations

ASTM	American Society for Testing and Materials
NLGI	National Lubricating Grease Institute
KOH	Potassium hydroxide
WCO	Waste Cooking Oil
12 HAS	12-Hydroxystearic acid
cSt	centistokes

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