The Effect of Extraction Conditions on Oil Yield from Waste Lubricating Grease

Motshumi Diphare, and Edison Muzenda

***Abstract*—**Solvent extraction is one of the cheapest and more efficient processes for waste lubricants recycling. In this short paper, the effect of extraction temperature, agitation speed and extraction time was studied. Oil recovery was enhanced by an increase in extraction temperature, time and agitation speed. The optimum extraction time and overall recovery were 12 minutes and 74% respectively.

***Keywords*—**Extraction Temperature, Waste Grease, Oil Yield, Solvent Extraction, Agitation.

I. Introduction

LARGE and increasing volumes of used lubricating oil and grease are produced each year and are considered as hazardous wastes. This is because waste lubricants typically consist of a mixture of undegraded base oil and additives with high concentrations of metals, varnish, gums, and other asphaltic compounds coming from bearing surfaces and degradation of the fresh lubricant components [1]. This waste source may be eliminated by recycling the oil in the lubricant.

Currently, natural gas and oil resources are extensively used and will not last indefinitely, hence it is necessary to seek other energy alternatives [2]. A lot of effort and studies [3] have focused on shale oil, whose world reserves are 50 times than those of petroleum oil [4], although the presence of mineral matter complicates its use as an energy source.

Recycling of waste oil is receiving lot of attention. Studies [5] have been undertaken on methods of extracting oil from waste oil sludges. Most of them focused on the yield of extraction and the quality of the extracted oils.

Solvent extraction is the preferred method as it is cost-effective and requires no further purification of the product [6]. Solvent extraction is the ability of a solute to distribute itself between an aqueous solution and an immiscible organic solvent. The organic solvent separates and purifies the solutes by extracting into the organic phase, leaving undesirable substances in the aqueous phase [7].

Hexane is the most extensively used solvent for oil extraction because of its high stability, high ability to dissolve oil, low greasy residual effects as well as low boiling point and corrosiveness [8]. The properties of the organic solvent require that the dissolved species be electrically neutral. Species that prefer the organic phase particularly organic compounds are lipophilic. Optimization of separation processes to produce the purest product at the highest yield and lowest possible cost, and under the most favourable environmental conditions, requires detailed knowledge about the solute reactions in the aqueous and organic phases [9].

Temperature, agitation, extraction time, reagents concentration and their mixing ratios are important factors that influence decomposition rate and oil recovery. Temperature adds synergetic effect on the yield of oils due to extended oil-bearing bodies fragmentations which in most studies increase with increase in temperature [10]. Average temperatures usually yield higher amounts of oil. Influence of temperature on the yield of liquefaction products is sequential. Initially the rise in temperature triggers oil yield until optimum and the further increase inhibits liquefaction [11]. Very high temperature is not usually suitable for production of liquid oils both in terms of operational cost and liquid oil yield.

Many researchers have investigated the effect of residence times on thermo-chemical liquefaction [12]. Reaction times define the composition of products and overall conversion of oil-bearing bodies into its constituent. Optimization of residence times is necessary for the effective decomposition of organic compounds in oil bodies [13]. During thermo-chemical treatment of organic mass, longer residence times are usually preferred. Different studies have reported results for oil yield as a function of residence time. According to Boocock and Sherman [14], longer residence time favoured oil yield while Yan et al. [15] observed negligible increase in oil yield with increasing residence times.

The objective of this study was to evaluate the oil recovery through degradation-flocculation and solvent extraction processes. The influence of various extraction parameters were investigated and optimized, these included agitation speed (200–1000 rpm), extraction temperature (30–80 ^{o}C), and extraction time (2–12 min). The results provide a sound basis for developing an environmentally friendly and economically competitive method for waste lubricating grease treatment.

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II. Materials and Methods

A. Materials

Technical grade n-hexane (95%) and analytical grade potassium hydroxide (KOH) pellets (99.9%) were supplied by Laboratory Equipment Supplies (Pty) Ltd. (Germiston, South Africa). The contaminated high temperature metal bearing grease was supplied by Engine Petroleum (Pty) Ltd.

B. Methods

Effect of temperature – Temperature affects the solubility of both base oil and waste oil impurities in organic solvents [16]. The experiments were conducted to determine the optimum temperature. Temperature was varied from 30 to 80^{o}C. Higher temperatures were not tested as they enhance solvent vaporization. Temperatures lower than atmospheric were also not investigated as it was observed at ambient temperature no oil is recovered, hence the lower limit was set to be 30^{o}C.

Effect of agitation – Extraction was performed at various agitation speeds ranging from 200 to 1200 rpm. Agitation speed or mixing strength plays an important role in the decomposition of waste sludges as it increases molecular surface area and the energy required to break down intermolecular bonds [6, 17].

Effect of extraction time – Extraction was performed at various times ranging from 2 to 18 minutes. Extraction time influences separation of undesirable impurities from the base oil extracted in two ways. It should be long enough to allow the solvent to dissolve the base oil contained in the waste oil and also it should also allow rejection from the solution of the additives and impurities by permitting their aggregation to particle sizes big enough to separate from the liquid phase by sedimentation [18].

Determination of oil extraction yield - Oil extraction yield was calculated with respect to time for various tests. The oil extraction yield (% w/w) was calculated using (1) [19]:

$$Oil\ Yield\ (\%) = \frac{Oil\ extracted\ (g)}{Waste\ grease\ feed\ (g)} \times 10 \qquad (1)$$

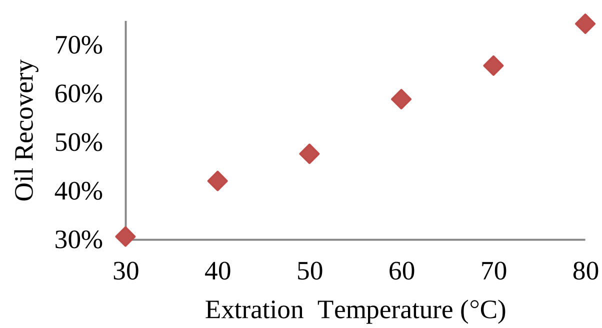
Fig. 1 Formation of various layers during solvent extraction

III. Results and Discussions

The extraction experiments were designed to study the effect of temperature, agitation strength and extraction time on extraction yield. The extraction yield was determined as the weight percentage of oil recovered from the raw waste grease. The accuracy of the experiments was studied by comparing the results from four independent runs carried out under identical conditions. In these experiments the extraction yields were similar (74.1, 73.9, 74.5, and 74.7%) indicating that the reproducibility of the data was good.

A. The effect of extraction temperature

The effect of temperature on the oil extraction yield was studied over the range of 30–80 ^{o}C from waste grease. From Fig. 2 it can be observed that the oil yield was found to be enhanced with the rise in temperature. This is due to the increase in the dissolution capacity of the solvent system.



Karlovic et al, 1992 [20] investigated the effect of temperature on the kinetics of oil extraction from corn germ. Reference [20] reported that increase in the temperature was found to enhance the capacity of solvents to dissolve the oil because of thermal energy that overcomes the cohesive and adhesive interactions. Furthermore, the collision theory states that, two molecules will only react if they have enough activation energy [21]. When the mixture is heated, the energy levels of the molecules increase. When the molecules are in their excited state, there will be more collisions between the molecules as a result the rate of reaction or decomposition increases. Similarly, the energy input in terms of heat or temperature, provides the required energy to break the intermolecular forces of attraction between grease molecules.

However, with temperatures above 80^{o}C the degree of extraction decreased due to solvent evaporation or different reaction being favoured. [22].

B. The effect of agitation speed

The effect of agitator speed on oil extraction is shown in Fig. 3. Agitation increases the eddy diffusion and the transfer of oil from the slurry form of the grease to the solvent mixture [6]. The effect of agitation speed in the range of 200–1200 rpm was evaluated while other variables were constant. The oil extraction yield increased from 48.84% to 74.66% with an increase in agitation speed. The optimum oil extraction yield was 74.66%, at 1000 rpm. However, for agitation speed more than 1000 rpm, there was no significant increase in the oil extraction yield. The dependence of recovery on agitation shows that mass transfer plays a major role during extraction.

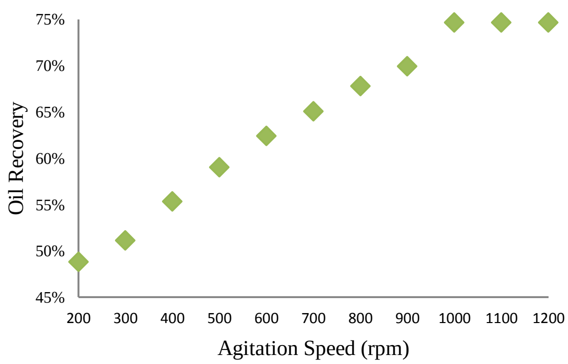


Fig. 3 Effect of agitation speed on oil yield

Pilusa et al, 2013 [17] reported that the role of agitation is to break down the grease molecules in order liberate oil molecules and also increase its active surface area to interact with the solvent. Reference [17] further explained that once the bonds holding the thickener and oil are broken with the aid of agitation and catalyst at optimal temperature, oil floats in the mixture as it is less dense than the thickener and caustic potash solution. Kadi and Fellag, 2001 [23] studied the effect of stirrer speed on oil extraction from olive foot cake using hexane as a solvent. They extracted 6.9% to 7.7% of oil at agitation speed varying from 600 to 1000 rpm.

C. The effect of extraction time

Extraction time is an important parameter in the design and operation of extraction processes particularly in deciding the optimum residence time. The results presented in Fig. 4. show that extraction increases with increase in residence time. Optimum extraction of 74.7% was achieved after 12 minutes at stirrer speed of 1000 rpm, temperature at 80 ^{o}C and solvent-to-solid ratio of 3:1.

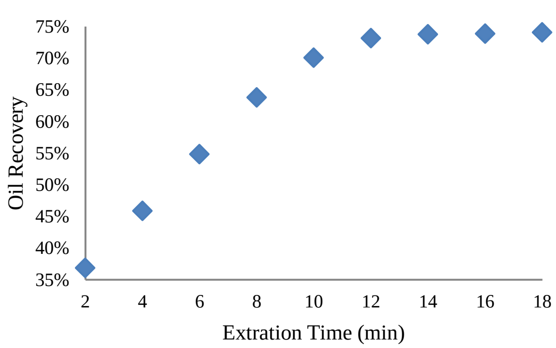


Fig. 4 Effect of agitation speed on oil yield

The increase in extraction time above 12 minutes did not show any improvement in extraction. After 12 minutes the extractable oil was exhausted. Chaiklahan et al., 2008 [24] observed a similar trend when they extracted oil from Cyanobacterium spirulina at residence times varying from 50 to 150 minutes.

IV. Conclusion

The objective of the study was to investigate the effect of experimental parameters on oil recovery. The influence of temperature, agitation speed and extraction time was investigated. An increase in temperature enhanced oil recovery. Agitation speed and extraction time also improved the oil recovery. A recovery of 74.66% was observed when the agitation speed was at a 1000 rpm after 12 minutes at 80^{0}C and solvent-to-solid ratio of 3:1.

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