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DEVELOPMENT OF A PILOT PLANT FOR THE RECYCLING OF USED LUBRICATING OIL.

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ABSTRACT

Various processes involved in the recycling of used lubricating oils were investigated. These processes were combined together to develop a pilot plant for the recycling of used lubricating oils, which was tested to evaluate the quality of the recovered oil. The composition analysis of the used oil shows that the major contaminants are sludge, water and sand. The optimum temperature of sludge extraction was determined to be 29 ^{o}C. The viscosity and the flash point of the recovered oil are higher than that of the used oil but slightly lower than the virgin oil. The results show that the pilot plant is to a large extent effective in removing contaminants from the used lubricating oil.

Keywords: Recycling, used oil, lubricating oil, contaminants and pilot plant.

1.0 INTRODUCTION

Lubrication implies the introduction of lubricants e.g. grease or oil between two surfaces moving relatively to each other. In human body, the bones holding the ankles, the wrists, the knees, e.t.c are moving on each other, and rub against themselves just as the moving parts of the engines move on each other. Synovia fluid in human body lubricates the bone joints in man (Hill and Holman, 1995), likewise, lubricants are needed to lubricate machine surfaces moving relatively to each other in order to reduce or control friction, reduce wear, reduce the amount of deposit of dirt and often to prevent overheating in engines and machines.

In the early nineteen-century, vegetable oil from olives; grape seeds, castor seeds and animal oils are used as lubricants. However, the breakthrough in petroleum, distillation and refining in the late nineteen century replaced the grapes and castor seeds oils with mineral oils, while some of the viscous bye-products were investigated as better substitutes for vegetable and animal oils previously used for lubrication of engine parts (Capillary, 1974).

Crude oil is normally used to make lubricating oils. They differ widely in composition from source to source. They are either paraffin based (Nigeria crude) containing high proportion of low boiling temperature minerals and naphthalene based (Venezuela crude) contains asphaltic material with small proportion of low boiling temperature components, which is most suitable for making lubricating oils. Mixed-based crude (Middle East crude) classified as paraffinic contains appreciable quantity of aromatics and naphthalenes (Frank, 1994; Schilling, 2000).

According to Reidel (1994), the regeneration of used oils has long been practiced in Italy, the first plants they built for reclamation of used lubricating oil is date back to 1930. And even in terms of legislation there have been specific regulations governing the collection and regeneration of used oils in Italy, which makes the collection of used oils obligatory and then regeneration a matter of priority.

Lube oils, in contrast to fuels, are not consumed during lubricating services in engine and machine, but they deteriorate because both the base oils and additives breakdown chemically. The processes leading to degradation according to (Reidel, 1994) are:

(i) ***Oxidation*:** This is the process whereby oxygen molecules are introduced into the base oil molecules, converting the hydrocarbon molecules into aldehydes and then into acids which further attacks the metal parts.

(ii) ***Contamination with fuel*:** This occurs in internal combustion engines whereby the combustion system of fuel is poor resulting in fuel mixing with the lube oil in cylinder.

(iii) ***Contamination by solid*:** This includes contaminant due to wear debris, combustion products such as soot and external dust or dirt injected into the engines.

(iv) ***Contamination by water*:** Engine oils may be contaminated with water from the burning of fuel in cold engines or from condensation if the temperature of the system rises and falls in humid temperature. This water combines with other dirt to form sludge blocking the holes and filters.

(v) ***Breakdown due to shear*:** This happens when lube oil is trapped between two sliding surfaces in the engine. The sliding surfaces are subjected to shear and large molecules of lube oils move or shear apart by mechanical forces involved. This resulted to increase in viscosity of the oil.

(vi) ***Other miscellaneous*:** These are spent additives, corrosive products from the attack of metal components of the engines by oil or water and unburned fuel etc.

Used lubricating oil is usually contaminated by water emanating from fuel combustion in the engine and accidental contamination by rain, light hydrocarbons from incompletely burnt gasoline and diesel oil, carbonaceous particles produced by motor wear. Effective refining of used lubricating oil will removes contaminants from and returns the oil to a quality comparable to that of oil obtained from virgin crude oils (Hymore and Enaigbe, 1999). Refining of used engine oil is thus a good means of conserving this valuable resource. Other reasons for refining used lubricating engine oils include:

- the need for more efficient use of lubricating oil;
- the need to curtail importation of oil and thus conserve foreign exchange; and
- the need to eliminate environmental pollution and prevent health hazard as would occur through the indiscriminate dumping and burning of the used lubricating oil.

Many refining processes are in use today but the acid-clay process is the most widely used (El-din *et al.*, 1998). The extent of removal of sludge in this process determines the final quality of regenerated oil. The more sludge produced and removed from the used oil the better the colour and consistency of the regenerated oil. The yield of sludge however, is constrained by the equilibrium nature of the dislodging reaction and the poly-functional nature of the dislodging agent, H_2SO_4. This necessitate that competing reactions such as oxidation and solubilization of the nascent sludge also occur side by side with the sludge forming reactions (Njieribeako and Orga, 2005; Garilov, 1999). Maximum sludge yield and removal occur at an oil/acid ratio 5:1, reaction temperature of 50^0C and mixing time of one hour in used engine oil regeneration (Onukwuli *et al.*, 1998). The major shortcoming of the acid-clay process is that the acid sludge is a greater environmental pollutant than the used oil itself as the sludge is very difficult to incinerate, very difficult to separate from used oil and almost impossible to mix with other fuels (O'Connor and Boyd, 1998).

In this paper, various processes involved in the recycling of used oils were investigated. These processes were combined together to form a pilot plant, which was constructed and tested to evaluate the quality of the recovered oil.

2.0 MATERIALS AND METHODS

2.1 Used Oil Recycling Processes

The method of Beather and Kochin (1993) on how to recycle used lubricating oil was employed. This method involves the following processes: heating, settling, decantation, magnetization and filtration.

(i) ***Heating*:** Sample of used oil was poured into the beaker up to about 500 ml and it was heated on the heating mantle to lower the oil viscosity and thereby accelerate the settling process. The oil in the beaker was continually stirred to allow equal distribution of temperature and allow for easy settlement of sludge. The thermometer is used to monitor the temperature of the heated used oil and at temperature of 100 ^{o}C the temperature was kept stable for some minutes after which the heated oil is allowed to cool (Fig. 1).

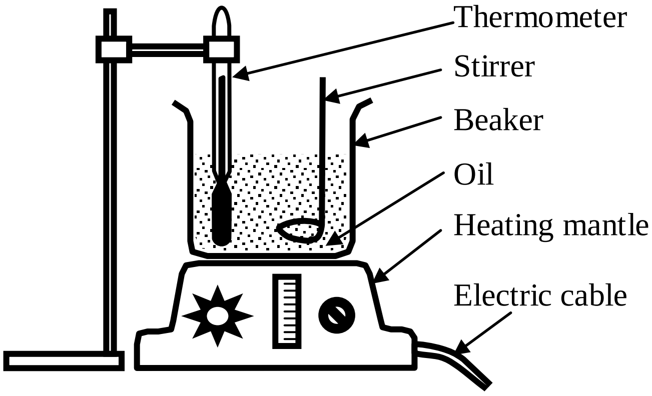

Fig. 1: Heating process.

(ii) ***Settling***: The used-oil after it has been heated is allowed to cool down for about 3 hours. During this period, water and heavy solid contaminants (sludge) were separated by gravity and settled down at the bottom of the beaker (Fig. 2).

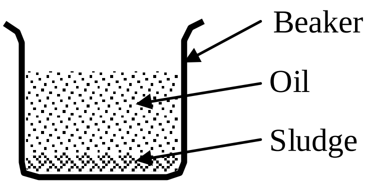

Fig. 2: Settling process.

(iii) ***Decantation***: The oil is then poured from the beaker that contained both oil and sludge into another empty beaker slowly so as not to disturb the sediment (sludge). The decantation process separates the recovered oil from sludge (Fig. 3).

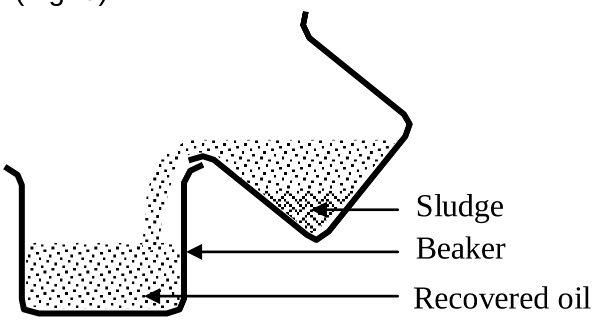

Fig. 3: Decantation process.

(iv) ***Magnetization***: The recovered oil is separated from the metal contaminants by dropping a magnet with the help of a rope tied to it into the beaker contaminating the oil. The magnet magnetizes the metal contaminants in the oil and the stirrer is used to stir the oil in order to move the oil round the magnet for maximum collection of the metal contaminants (Fig. 4).

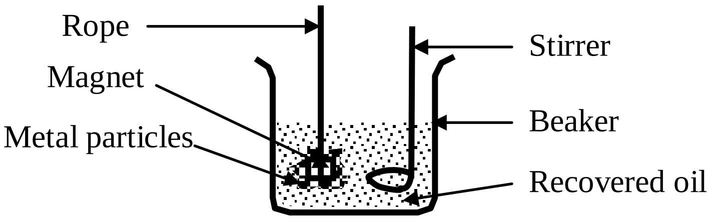

Fig. 4: Magnetization process.

(v) ***Filtration***: The recovered oil is filtered through a filter cloth to remove tiny particles of carbon that remains in the oil (Fig. 5).

2.2 Pilot Plant for Used Oil Recycling.

A pilot plant was constructed which combines the five processes together (Fig. 6). The oil flows from one process to another without manually transferring it from one beaker to the other. The major parts of a typical pilot plant for the recovery of used lubricating oil will at least consist: the pump, piping system, chemical processing vessels, mixing tanks and filters. In this work, the pilot plant is constructed in a way that the flow of oil from one location to another is by gravity, which eliminated the use of pump.

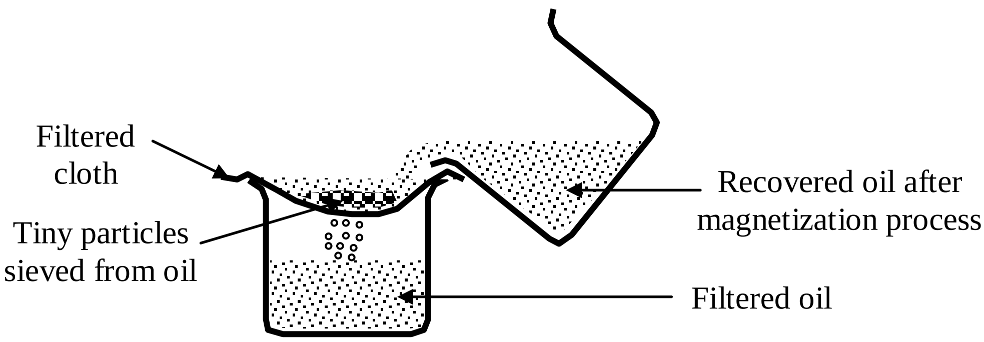

Fig. 5: Filtration process

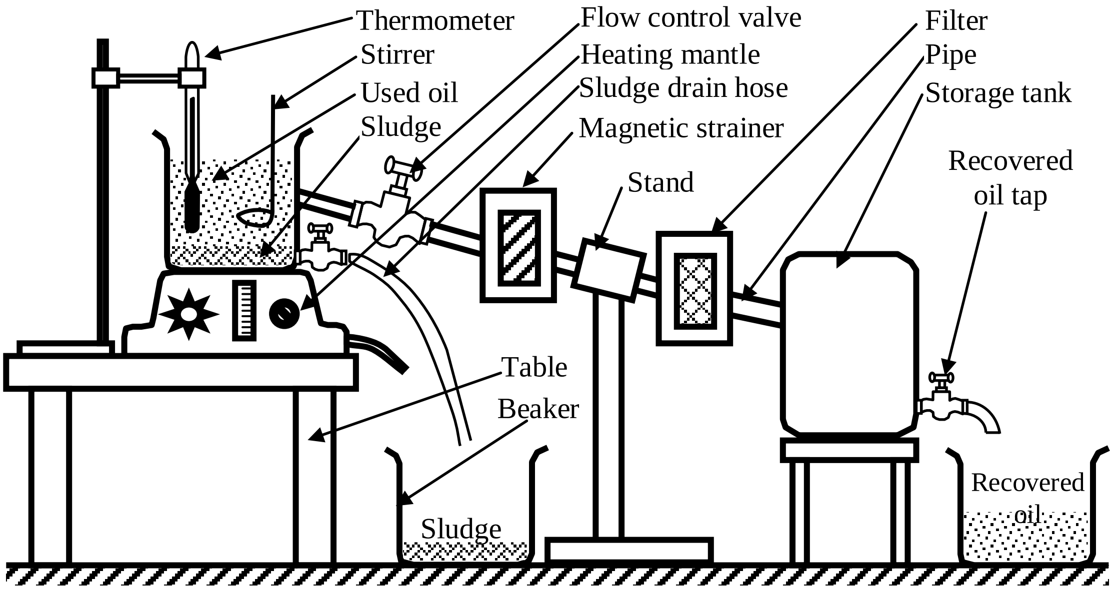

Fig. 6: Pilot plant for used lubricating oil recycling.

3.0 RESULTS AND DISCUSSION

3.1 Results

Samples of virgin (new) oil, used oil and recovered oil were collected and tests were carried out on them to determine their viscosities and flash points. Rotational viscometer and flash point apparatus were used for the tests. The results are shown in Table 1.

Table 1: Viscosity and flash point of virgin, used and recovered oils

Oil sample	Viscosity at Room Temp (cst)	Flash Point (^{o}C)
Virgin oil	170.22	241.5
Used oil	121.12	152.5
Recovered oil	158.68	214.0

Table 2: Percentage of sludge settlement at various cooling temperature

Temperature (^{o}C)	Percentage by volume of sludge settlement (%)
100	0
70	1.8
50	3.7
40	5.2
35	6.4
29	9.6

After heating process, the percentage (by volume) of sludge settlement at various temperatures as the oil being cooled is determined and the results are shown in Table 2. Also after the recovery processes, the composition of the used oil were analysed based on the quantity of the various components extracted from the oil. The results are shown in Table 3.

Table 3: Analysis of composition of used oil

Components	Percentage by volume of quantity extracted (%)
Sludge	8.6
Water	3.4
Sand	52
Recovered oil	82.8

3.2 Discussion

The viscosity of the recovered oil at room temperature as shown in Fig. 7 was higher than that of the used oil but a little lower than that of the virgin oil. The high viscosity of the recovered oil when compared with the used oil shows that the used oil must have been diluted with fuel or any other such liquid. The viscosity of the virgin oil is higher than those of the used oil and the recovered oil. This shows that the polymeric additives (viscosity improvers) in the used oil must have been used up while for recovered oil, some of the polymeric additives and some high viscosity compounds must have been removed along with the sludge during refining.

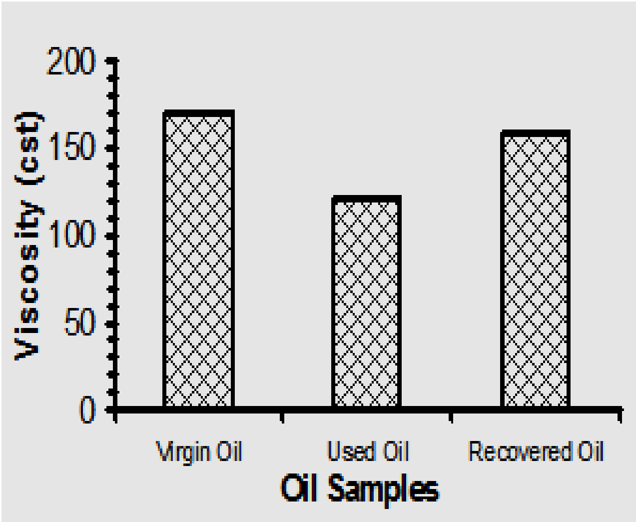

Fig. 7: Viscosity of oil samples at room temperature.

Fig. 8 shows a high increase in flash point of the recovered oils when compared with that of the used oils. This explains the relationship between flash point and viscosity; decrease in viscosity decreases flash point and flash point indirectly determines the presence or the degree of fuel dilution.

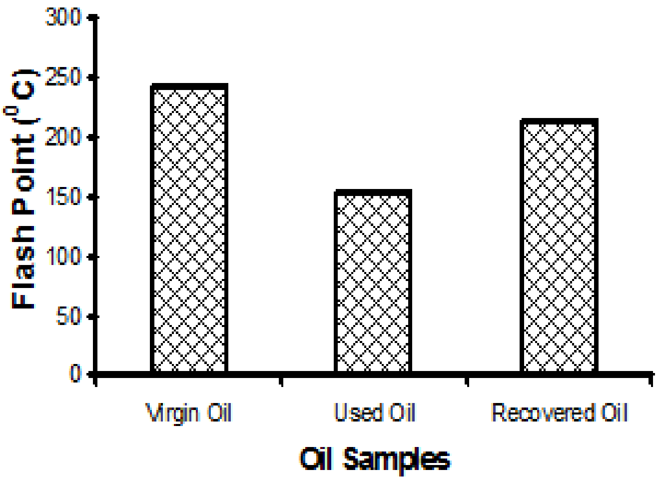

Fig. 8: Flash point of oil samples.

The sludge settling curve at various temperatures is presented in Fig. 9, with a view to determine the optimum temperature of sludge extraction. The results show that as the temperature is decreasing from 100 ^{0}C the percentage of sludge removal is increasing. Of the temperatures investigated, room temperature (29 ^{0}C) is the best temperature for sludge removal. The analysis of the composition of the used oil as shown in Table 3 indicates that the major used oil contaminants are sludge, water and sand, with sludge being the highest in quantity (% by volume) followed by water and then sand.

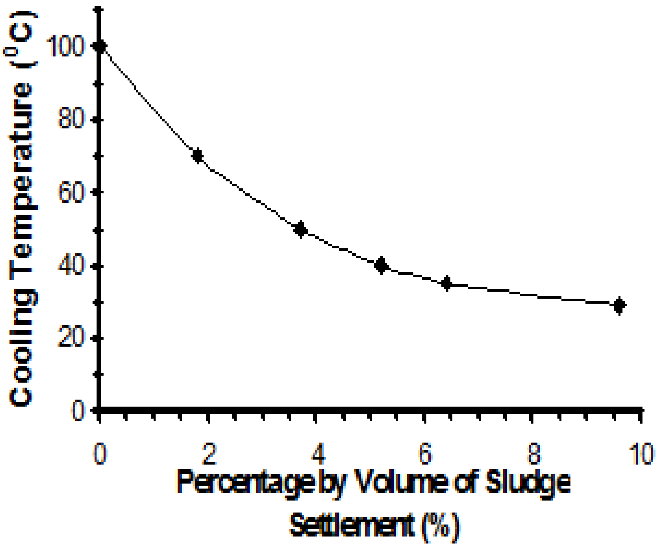

Fig. 9: Sludge settling curve at various temperatures.

4.0 CONCLUSION

The developed pilot plant for recycling used lubricating oil is to a large extent effective in removing contaminants from the used lubricating oil. The optimum temperature of sludge extraction was determined to be 29^{0}C. The viscosity of recovered oil is slightly lower than that of virgin oil but it is much greater than that of used oil. The lower viscosity of the recovered oil, when compared with virgin oil, is due to the fact that some of the additives for property improvement have been depleted and some of the components have been removed during refining. To improve the physico-chemical properties of recovered oil, some lubricating oil additives such as viscosity – index improver, oxidation inhibitors and pour point depressants can be added to replace lost components.

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