Regeneration of Used Engine Oil

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Abstract— **This work presents the result on the regeneration of used engine oil using industrial bleaching earth and activated carbon as the bleaching agents. The used oil undergoes acidification and bleaching steps to remove the aromatic content and to improve the colour and quality of the oil. Analysis carried out showed that when the formulated grades were compared with standard grade (fresh oil). Formulation A showed a better quality of regenerated oil amongst the different grades formulated with a viscosity of 53.16 cP at 40^0C, specific gravity of 0.932 and total acid number of 0.54 using industrial bleaching earth. On the other hand, formulation E gave a fair quality using activated carbon with a viscosity of 40.41 cP at 40^oC, specific gravity of 0.883 and total acid number of 0.59..**

Index Terms— **engine oil, industrial bleaching earth, formulation, activated carbon, viscosity**

I. Introduction

ENGINE or Lubricating oils are viscous liquids that are used for lubricating moving part of engines and machines. These oils are derived from petroleum base feedstock which consists of mainly of complex mixtures of hydrocarbon molecules[1]. According to [2] these hydrocarbon molecules usually range from low viscosity oils to high viscosity oil.

Lubricating oils help to protect rubbing surfaces, reduce friction between moving and connected parts, eliminate build up of temperature on the moving surfaces and keep the engine clean[1,3].

The main service properties of Engine oil are their viscosity, viscosity – temperature properties, fluidity at low temperatures, chemical stability and protective properties. Lubricating oils have viscosities ranging from 10 to 1000 centistokes at 100^oF [4].

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Analysis have shown that lube oil consist of aromatics in the range of 4 to 12 % free, sulphur and other impurities depending on the source of the hydrocarbon crude oil process and the production method [5]. The colour and odour of lubricating oil are largely caused by the nitrogen, sulphur and oxygen (NSO) compound concentrated in the crude oil and residue fraction. Investigation into the aromatic present in the lube base oil show that the aromatics are in homogeneity with the other compounds in the oil. Studies by America petroleum Institute (API) show that most of the aromatics present in lube base oil are polynuclear in nature. The used lubricating oils like the automobile lubricating oils are petroleum derived and originally produced through acid and bleaching treatment, vacuum distillation, solvent extraction dewaxing, multiple refining steps and hydro finishing [6].

However, used lubricating oil are contaminated by contaminants or impurities obtained from undesirable oxidation product of automobile, sediment, metallic wear particles and water, degraded additive and hazardous substances from lead compound. This contaminants or impure lubricant is what is drained off cars and disposed off as used or waste oil [7].

Large quantity of used lubricating oil is generated globally. As at 1996, Nigeria accounted for about 364,166,000 litres of used lubricating oil annually. It is a common practice in Nigeria that used oil is disposed into gutters, water drains, open plots and farms. This leads to pollution of streams, ground water, lakes and oceans. It has been reported that one gallon of used oil has the potential to contaminate million gallons of fresh drinking water (EPA 530-F-94-008). Used oil dump on the ground reduces soil productivity and makes the plants grown on the soil to be unsuitable for food and forage [8]. Regeneration of used lubricating oil simply means the removal of the contaminants or impurities by sulphonating agents such as sulphuric acid, oleum or sulphur trioxide. About 80 % of the aromatics and other impurities are removed in the first circle while the remaining 20 % are removed in the second cycle of the operation [5].

During operation of engine, lubricating oil temperature build up and degrade the oils leading to decline in important properties like: viscosity, specific gravity and flash point.. Aside this dirt particle and worn out metal parts from engine surfaces are deposited into the oils. With the passage of time, these engine oil loses its functional properties and s must be replaced with fresh lubricant. Considering the fact that huge quantity of lubricating are oils used on daily basis, the frequent dumping of lubricating oils has

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now become a source of serious concern . It is on this premises that most countries of the world are presently paying serious attention to the menace of environmental degradation caused by the disposal of waste or used lubricating oils [8].

The rapid depletion of fossil fuel reserve which provide feedstock for the production of lubricating oil in Nigeria, shortage of fresh oil, increasing prices and high demand for lubricating oil have necessitated most industries and private users to seek or adopt ways of regenerating the oil [9].

Hence, this work is aimed at regenerating used engine oil using industrial bleaching earth and activated carbon as the bleaching agent. In this work, acid and bleaching treatment will be highly emphasized.

II. METHODOLOGY

Standard methods of testing and characterization of hydrocarbons were used as recommended by ASTM (Annual book of ASTM, 1987, ASTM test method.

A. Reagents and Raw Materials Used

Sulphuric acid, fresh engine oil (SAE 40), waste used engine oil (mixed), activated carbon (wood charcoal) and Phenolphthalein.

B. Formulations

In this section various formulation were made as shown below:

C. Procedure

Formulation A

1. Acid Treatment:

300 ml of used engine oil was measured in a 500 ml beaker. Also, 30 ml of sulphuric acid was measured in a separate 50 ml beaker. The regulator hot plate was switched on and the measured base oil was placed on top. The temperature of the base oil (used engine oil) was maintained at 40-45^{o}C. At this temperature the sulphuric acid was introduced into the used engine oil simultaneously with stirring of the mixture for 10 minutes.

2. Sedimentation /Decantation

At the end of the acid treatment step, the acidic oil was allowed to settle 4 hours to form sediment at the bottom of the beaker. After this period, the acidic-oil was properly sedimented and was decanted into another 500 ml beaker while the residue i.e acidic sludge at the bottom of the beaker was discarded.

3. Bleaching:

The acidic oil in the beaker was then subjected to bleaching. The oil was placed on a regulator hot plate and the temperature was maintained at a temperature of 110^{o}C. 6 wt % of bleaching earth (industrially produced) was introduced into the oil and the mixture was continuously stirred for 10 minutes. At the end of the bleaching step, the bleached oil was neutralized.

4. Neutralization:

The bleached oil was neutralized to adjust the pH of the oil to neutrality. At this step, 4 wt% of the oil of hydrated lime was introduced into the bleached oil by taken into consideration the pH of the bleached oil at a given point in time. The bleached oil was neutralized with a continuous manual stirring for 10 minutes. At the end of the bleaching and neutralization steps, the oil was allowed to sediment in the beaker for 4 hours and was decanted into the beaker, while the residue at the bottom of beaker was discarded.

5. Bleaching using activated Carbon:

At the end of the acid treatment step, if the acidic oil is to be bleached using activated carbon (charcoal), the same procedure for bleaching using industrial bleaching earth is also used. Except that the temperature was increased and maintained at a range of 130^{o}C–140^{o}C. The same amount of activated carbon as that of the industrial bleaching earth and hydrated lime was used (i.e 6 wt% and 4 wt% of the oil from activated carbon and hydrated lime were used).

6. Sedimentation /Decantation:

During this stage, the oil was allowed to sediment in the beaker for 4 hours and was decanted into another beaker, while the residue at the bottom of the beaker was discarded.

7. Filtration

The sedimented oil was finally filtered using a filter cloth and the filtrate was collected in a filtration flask and was observed to be clear while, the residue (filter cake) was discarded.

Formulation B, C, D, E

The same procedure of formulation A was carried out for formulations B, C, D, E taking appropriate measurement as shown in Table I.

Preparation and Activation of Carbon

The carbon used in this work was obtained from wood (charcoal) because of its availability and relatively low cost. To activate the carbon, the lumps of charcoal were grounded to smaller particles and sieved to remove some impurities such as sand and stones. The sieved carbon was washed with water in order to dissolve some soluble and suspend some impurities.

The suspended carbon was filtered using filtered cloth and was allowed to sediment for two days. The sediment was collected and dried in the sun for about 5 hours.

To activate the carbon particles, the collected mixture of carbon particles was put into an oven and heated between 250^{o}C – 300^{o}C for 1 hour.

D. Measurement of Properties

The properties of used engine oil, unused (fresh) engine oil and the refined or regenerated engine oil were measured. The measurement included viscosity,

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specific gravity, density, API, colour, and the total acid number (TAN).

Viscosity Measurement

Viscometer was used to measure the viscosities of fresh, used and regenerated oils. The viscometer set up consists of silver line test vessel with an agate orifice placed in a casing. 50 ml of each sample was placed in the test vessel and until it attained a required temperature. It was then allowed to flow by gravity and the time of flow was noted.

Generally, viscosity is related to the time of flow of a fixed volume of the test sample through a given capillary viscometer.

The Kinematic viscosity is given by:

$$V = CT \quad (1)$$

Where V is the Kinematic viscosity in mm^2/s, C is a constant (0.08), T is the time taken by the oil to flow through the viscometer.

But the viscosity is given by:

$$U = Ve \quad (2)$$

Where U is the Viscosity, V is the Kinematic viscosity and e is the Density of the substance

Specific Gravity, API and Density Measurement

The specific gravities and densities of the oil were determined with the aid of a 25 ml specific gravity bottle and weighing balance. The mass of the empty specific gravity bottle oil was determined respectively. The difference gives the mass of the oil. The densities of the oils were found by dividing the mass of the oils with the volume of the oils.

Specific gravity was found by dividing the density of water

^{o}API was found from the formular

$$^{o}API = \frac{141.5}{sp.gr} - 131.5 \quad (3)$$

Colour Measurement Determination

The colour was determined arbitrarily by visual inspection of the samples.

Total Acid Number (TAN) Measurement

About 10 grammes of the oil were weighed into a 250 ml conical flask. 50 ml of ethanol was weighed into another conical flask to which a phenolphthalein indicator was added (2 drops) and heated to 40^{o}C. The alcohol was then neutralized with a 0.5 normal potassium hydroxide (KOH) solution. The neutralized alcohol was then added to the weighed oil and heated. This was then stirred to ensure complete extraction of the acid by the alcohol and 2 drops of phenolphthalein solution was then added and allowed to cool for some time and titrated with 0.5 N potassium hydroxide solution.

The total acid number was calculated from:

$$TAN = \frac{56.1 \times NV}{W} \quad (4)$$

Where TAN is the total acid number, N is the normality of alcohol KOH solution, V is the volume of KOH solution used and W is the grammes of sample used.

III. RESULTS

The result of the experiment was tabulated as shown in Table II.

TABLE I

PROPERTIES OF USED, FRESH AND REGENERATED LUBRICATING OIL

Samples	Viscosity at 40^{o}C (cP)	Specific Gravity	Total Acid Number	Colour
Fresh oil	58.98	0.960	0.52	Yellowish green
Used oil	32.81	0.865	0.66	Very Dark
A	53.16	0.932	0.54	Yellow
B	41.23	0.884	0.64	Pink
C	39.94	0.882	0.62	Pink
D	37.80	0.880	0.61	Brown
E	40.41	0.883	0.59	Light brown

IV. DISCUSSION OF RESULTS

Table II shows the properties of the fresh, used and regenerated engine oils using industrial bleaching earth and activated carbon as the bleaching agents.

The viscosity at 40 ^{0}C, specific gravity and total acid number of the fresh oil (standard grade) are 58.98 cP, 0.960 and 0.52, respectively while that of used oil was 32.81 cP, 0.865 and 0.66, respectively.

Five different formulations were regenerated by treating the oils with chemical (acid treatment) and filtration which raises the viscosity of the oil. Furthermore, treating the oil with industrial bleaching earth or activated carbon improved its viscosity.

From the results of the formulations it was observed that formulation A compared favourably well with the standard grade lubricating oil with a viscosity at 40^{0}C, specific gravity and total acid number of 53.16 cp, 0.932 and 0.54, respectively.

Formulations B and C were carried out to establish the effect of acid concentration on the used oil regeneration using industrial bleaching earth and it was observed that as the acid concentration decreases the functional properties of the regenerated oil donot compare favorably with the standard. Result also show that the properties of the regenerated oil such as viscosity, specific gravity, total acid number of formulation B were 41.23 cP, 0.884, 0.64 and 39.94 cP, 0.882, 0.62 for formulation C, whilst for formulation D had a value of 37.80 cP. 0.880, 0.61, respectively and formulation E were 40.41 cP, 0.883

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and 0.59. Comparing these results with the standard grade (fresh oil) formulation A compared favourably.

The reduction in the viscosity of the used oil may be due to thermal cracking or degradation of the lubricant when used to serve the purpose of lubrication. The product of thermal cracking, fragments of carbon formed caused a fall in the molecular weight of the oil thereby decreasing the viscosity of the oil as a consequence of a rise in temperature.

The regenerated oil was more viscous than the used oil because the molecular arrangements are undisturbed as a result of treatment with chemicals and filtration.

The regenerated oil may retain its viscosity if blended with any oil of higher grade. The density and specific gravity of fresh, used and regenerated oils were determined and the obtained values showed that the specific gravity of the regenerated oil has improved as a result of treating the oil with chemicals as well as bleaching and filtration of the oil.

Also, the lower the acid numbers the greater the stability of the oil. Acidity may be due to the presence of hydrogen sulphide, aliphatic acid and mercaptans. These compounds are present in low quantity after regenerating the lubricating oil.

The acid number of the fresh oil was lower than that of the used and regenerated oil. Treating the used oil with chemical reduces the acid number. The reason is that during the bleaching process industrial bleaching earth or activated carbon were used in conjunction with hydrated lime (CaO). These may have caused the reduction in the acid number to an acceptable value.

The colour of the fresh oil was yellowish green while that of the used oil was very dark. The blackness of the used oil could be due to the formation of small carbon fragments during thermal cracking and also due to the products of thermal oxidation and corrosion. Oil may be contaminated with soot resulting from an incomplete combustion of petrol.

The colour of the regenerated oil from formulation A was good. Industrial bleaching earth was observed to be a better adsorbent than activated carbon. It can be stated that it is quite possible to regenerate used engine oil on a bench scale which could be probably scaled up for industrial level.

CONCLUSIONS

From the result of experiment obtained, used engine oil can be regenerated on a bench scale at controlled conditions.

Formulation A showed a better quality of regenerated oil using industrial bleaching earth with a viscosity at 40^0C, specific gravity and total acid number so close to that of the standard grade. Also, bleaching with industrial bleaching earth exhibit better regenerated used oil than the activated carbon. It can be concluded therefore that the used oil regenerated using formulation A is favorable for automobile application.

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TABLE II

FORMULATIONS OF MATERIALS BY VARYING THE VOLUME OF ACID USED AS WELL AS USING INDUSTRIAL BLEACHING EARTH AND ACTIVATED CARBON FOR BLEACHING FOR THE SAME AND VARIED CONDITIONS

Formulations	Volume of Used Engine oil (ML)	Acid Treatment (Ml of H_2SO_4)	Adsorbent	Hydrated Lime	Bleaching Temperature (°C)
A	300.00	30.00	Industrial Bleaching Earth	4.00	110.00
B	300.00	20.00	Industrial Bleaching Earth	4.00	110.00
C	250.00	30.00	Industrial Bleaching Earth	4.00	110.00
D	300.00	30.00	Activated Clay	4.00	110.00
E	250.00	30.00	Activated Clay	4.00	110.00

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