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# RE-REFINING AND RECYCLING OF USED LUBRICATING OIL: AN OPTION FOR FOREIGN EXCHANGE AND NATURAL RESOURCE CONSERVATION IN GHANA

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**ABSTRACT**

The paper reviews the re-refining of used automotive engine lubricating oils to obtain lube stock with the right characteristics and additives' response suitable for blending automotive engine lubricating oil. The caustic treatment and subsequent vacuum distillation method for re-refining of used automotive gasoline engine lubricating oils was used in this investigation. A lube stock with the appropriate properties and characteristics including additive response for the formulation of SAE 40 grade lubricating oil suitable for an automotive gasoline engine was obtained from a blend of re-refined used lubricating oil and virgin bright lube stock in the ratio 3:1. The lube stock had a viscosity index (VI) of 105.

**Keywords:** lubricating oil, viscosity index, neutralization number, vacuum distillation, oxidation stability test.

## 1. INTRODUCTION

Ghana consumes large amounts of lubricating oils and these include lubricating oils for automotive engines (gasoline and diesel engines), industrial lubricating oils, heat transfer oils, etc. The lubricating oils for various categories of vehicles, machines and equipment are imported either as finished products or semi-finished products for the Ghanaian market. Ghana currently does not have a refinery with a vacuum distillation unit to produce virgin lube oil stock for further processing into finished lubricating oils for automotive engines and other lubricating needs. The Tema Lube Oil Company Limited, (TLOC) currently imports virgin lube stocks and blends and packages them into finished lubricating oils according to the specifications for the various Oil Marketing Companies (OMCs) including Shell Ghana Limited, Total Ghana Limited, GOIL, etc. The OMCs also import finished lubricating oils of various grades, including synthetic lubricating oils; to augment what is produced by TLOC to meet their individual marketing demands. Statistics from the National Petroleum Authority of Ghana and the Tema Lube Oil Company Limited indicate that the total domestic consumption of lubricating oils in 2013 was about 45 million liters which amounts to about US$750 million at current exchange rate of US$1.00 = GHC3.00 (4/10/2014). This constitutes a huge chunk of the foreign exchange requirement of the country with a nominal Gross Domestic Product (GDP) of US$48.678 billion for 2013 [1].

Lubricating oils are partially consumed during their service in a machine or equipment or an automotive (gasoline or diesel) engine, while their quality is degraded by oxidation and decomposition of the mineral oil and/or additives and by contamination by such components as water, gasoline, dirt, metallic particles and carbon as soot [2, 3]. A high proportion of the used oil consists of high quality hydrocarbons contained in the original oil and recovering these hydrocarbons provides an opportunity to reduce significantly the need for the production of virgin lube stock thus conserving virgin crude oil for lube stocks by re-refining and in the case of Ghana conserving the environment and scarce foreign exchange.

Presently in Ghana however, virtually all of the used automotive lubricating oils are either dumped in municipal drains or in streams and rivers especially in the cities and towns where a large number of the service stations and garages are located. Waste oils contain large amounts of contaminants like calcium, magnesium, copper, lead, iron, etc; with lead being the most hazardous environmentally. Environmental and present economic considerations demand that it is worthwhile to explore the possibilities of reclaiming used lubricating oils to produce lube blending stock. Waste oils constitute a large potential petroleum reserve and interestingly enough, yields from re-refining of used oils are higher than yields from refining of virgin crude oil for lube stock.

About 60 to 80% of base lubricating oil stock can be produced from a ton of used lubricating oil compared to 20% yield from the same quantity of virgin crude oil [4]. Re-refining of automotive engine waste oil is a relatively cheap process producing high yield and good quality lubricating oil base stock comparable to virgin lube oil base stock [4]. Reclaiming of used lubricating oil started as a simple technology of settling, centrifuging and heating around 1915 and has developed to more sophisticated processes like solvent extraction, acid-clay treatment, distillation with hydro-treating, etc. Each of these processes has its own advantages and disadvantages depending on the economics and environmental considerations [5, 6].

Following review of the various technologies for re-refining of used lubricating oils this study adopted the caustic treatment with subsequent vacuum distillation process for the re-refining of used lubricating oils drained from the automotive engine crankcase of salon cars after they had travelled 6, 000 kilometers. As noted earlier the objectives of the investigation among others is to explore the possibility of using the caustic treatment with subsequent vacuum distillation to re-refine used lubricating oil and characterize the used oil, determine the physical properties of the re-refined used oil and blend them to obtain lube blending stock with the right properties for the production of lubricating oil for automotive gasoline engines.

## 2. EXPERIMENTAL WORK

### 2.1 Materials and Methods

The samples of used lubricating oil used in the study were drained from the crankcase of salon cars with an average age of 100,000 kilometers and had travelled 6000 kilometers using SAE 20W-50 grade automobile lubricating oil. The used crankcase lubricating oil collected was re-refined using the caustic treatment and vacuum distillation method to obtain a lube oil base stock. The lube oil base stock was subjected to physical and chemical analysis to determine its suitability for use as a base stock for formulation of a single grade (SAE 40) automotive engine lubricating oil. An optimal additive package developed using Response Surface Methodology techniques detailed elsewhere [7, 8] was used to formulate a single grade (SAE 40) automotive engine lubricating oil.

The experimental procedure followed included among others: the characterization of the used oil and re-refined oil, re-refining of the used oil, treatment of the blended lube stock with additives, and oxidation stability test of additive treated blended lube stock. The test and methods of characterization were American Society for Testing and Materials (ASTM) and /or Institute of Petroleum (IP) Standard Test Methods.

### 2.2 Viscosity determination

Viscosity is a measure of the resistance to flow and may be regarded as the internal or fluid friction of the lubricating oil. It is a single most important property of a lubricant and must be known when formulating lubricants. It is a key measurement for detecting a number of used oil conditions including fuel dilution, oxidation and contamination. Oxidation products and contaminants such as soot, dirt, glycol and water cause viscosity increase while fuel dilution and shearing of viscosity index improver in multi-grade oils cause viscosity decrease.

Kinematic viscosities of the used and re-refined oil samples were measured at 37.8ºC (100ºF) and 98.9ºC (210ºF) with Canon-Fenske Routine viscometers or Canon-Fenske Opaque viscometers according to ASTM D445-12 [9], standard test methods for transparent and opaque liquids respectively.

### 2.3 Viscosity index determination

Viscosity index (VI) is the viscosity-temperature relationship and is an arbitrary number indicating the degree of change of viscosity of petroleum oil with change in temperature. It is one of the most critical factors to consider for selecting lubricating oil for use in an internal combustion engine since the oil must function over a wide range of temperature. Arbitrarily, naphthenic and paraffinic oils are assigned VI values of 0 and 100 respectively [3, 10]. Viscosity index was determined from kinematic viscosities at 37.8ºC (100ºF) and 98.9ºC (210ºF) and ASTM D2270-10 recommended monographs [11].

### 2.4 Water content

Water content of the used oil drained from the engine crankcase was determined to assess the amount of water contamination resulting from condensation and combustion chamber blow-by gases into the crankcase. ASTM D95 standard test method was used for water content determination [12].

### 2.5 Fuel dilution

This is the test for determining the quantity of gasoline in used crankcase oils of gasoline engine. The standard ASTM D322-97 [13] and IP 23/66 test method was used in this investigation.

### 2.6 Neutralization number

Oxidation is the primary cause of oil deterioration and forms acidic products which increase the acidity of used oils. Hence, the neutralization number gives an indication of the extent of oxidation and for that matter oil deterioration [14]. Neutralization number is defined as the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. The recommended IP 136/65 - ASTM D974-12 standard test method for acid and base number by color indicator titration was used for the determination of neutralization number [15].

### 2.7 N-Pentane and benzene insolubles

These tests determine the insoluble matter in used oil samples drained from automotive engine crankcases. The insoluble matter includes solids and contaminants which get into the oil from external sources such as dust, dirt, metal particles and combustion blow-by products (lead, soot, fuel, resins formed from thermal decomposition and oxidation of fuel heavy ends). The recommended ASTM D893-12 standard test method for insolubles in used lubricating oils was used [16]. Total insolubles were represented by n-pentane insolubles while benzene insolubles represented extrinsic insolubles.

### 2.8 Re-refining of used lubricating oil

A vacuum distillation technique similar to the recommended ASTMD 1160-13 standard method for distillation of petroleum products at reduced pressured was used [17]. The sample was treated with 1% by weight sodium hydroxide (NaOH) at about 150ºC to dehydrate, remove fuel dilution and to neutralize all acids. The sample was then vacuum- distilled at about 65 millimeters mercury and over a temperature range of 272 to 400ºC.

### 2.9 Blending of lube stocks

Kinematic viscosities of the distillates were measured at 37.8ºC and 98.9ºC to determine the viscosity index and SAE grade. ASTM viscosity blending chart and actual viscosity determinations were used throughout the experimentation to blend the lube stock. Virgin bright lube stock forming 25% of total blend to which a 0.4 % (v/v) viscosity index improver had been added was used to obtain a SAE 40 lube stock.

**2.10 Oxidation stability test**

The recommended IP 48/67 standard test method for testing oxidation stability of lubricating oils was adopted and STANHOPE-SETA series 1600 apparatus for testing oxidation stability of lubricating oils was used.

**2.11 Metal content of used lubricating oil**

The recommended ASTMD 3237-12 Standard test method for the determination of metal content of lubricating oils [18] was adopted for the used oil samples. A Perkin Elmer model 503 Atomic absorption spectrophotometer was used.

**3. RESULTS AND DISCUSSIONS**

Table-1 gives the characteristics of both a composite of used drained from the crankcases of cars and re-refined lubricating oils. The samples were collected from properly maintained cars which had travelled an average distance of about 100, 000 kilometers and the cars were generally used for long distance journeys. Thus, they do not have problems usually associated with “stop-and-go” vehicles (such as taxis) and that the used oil had very low values of fuel dilution, water content, and resins as reported in Table-1. The water content of 0.1% (v/v) was much lower than the generally observed average value of between 1.2-1.6% (v/v) [4] for lubricating oils drained from crankcase engines after 6000-8000 kilometers. The metal content of the used oil was reduced considerably to negligible levels through re-refining. Particularly, lead and calcium contents in the used oil were reduced from 2813 to 1.86 ppm and 606 to 9.6 ppm respectively. It is worthy of note that the metal contents of the used oil sample were generally far below the general range for used oil.

Table-2 gives details of the vacuum distillation re-refining process used in this investigation. A recovery of 73.3 weight percent was achieved which is comparable to recoveries in the range 60 - 80 weight percent achieved in most re-refining processes [4]. Table-3 gives the kinematic viscosities at 37.8ºC and 98.9ºC, viscosity index and Society of Automotive Engineers (SAE) classification of used oil, re-refined used oil and blended lube stocks. Re-refined used oil blended with 25% virgin lube stock and 0.4% viscosity improver (additive) has a viscosity index of 110 and SAE classification of SAE 40 which is comparable with unused SAE 40 and SAE 20W-50 lubricating oil purchased on the market.

**4. CONCLUSIONS**

The caustic treatment followed by vacuum distillation process used for re-refining of the used SAE 20W-50 oil gave a recovery of 73.3% (weight percent) of re-refined neutral lubricating oil base stock with viscometric properties (viscosity @ 37.8ºC = 87.5 cSt and VI = 98). The re-refined oil was blended with virgin bright stock in the ratio 3:1 to a viscosity index of 103 and kinematic viscosity of 134.58 cSt at 37.8ºC (SAE 40). The blend proved a good lube stock for producing automotive engine lubricating oil with SAE classification of SAE 40 from re-refined used lubricating oils.

With a recovery of 73.3% (weight percent), used lubricating oils can be as a source of lube stock for producing automotive engine lubricating oil using the method of caustic treatment of used oil and subsequent vacuum distillation at 65 mmHg over a temperature range of 272 to 400ºC. The study has given credence to the fact that used lubricating oils can be recycled to yield lube stock that can be used to produce lubricating oils and thus conserve crude petroleum of lubricating oil grade and scarce foreign exchange in Ghana for importation of automotive engine lubricating oils. Again, the re-refining of used lubricating oil will help prevent dumping of waste oils in our drains, streams and rivers and thus save the environment from pollution and degradation.

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**Table-1.** Characteristics of Used and re-refined lubricating oils.

| Test | Sample | | | General range for used oil |
|---|---|---|---|---|
| | New SAE 40 oil | Used oil | Re-refined oil | |
| Water content (%, v/v) | 0.0 | 0.1 | 0.0 | 1.2 – 1.6 |
| Fuel dilution (%, v/v) | 0.0 | 2.9 | 0.0 | - |
| Pour point, $^{o}C$ | -20 | -20 | -20 | - |
| n-Pentane Insolubles (weight, %) | 0.0 | 1.69 | 0.0 | |
| Benzene Insolubles (weight, %) | 0.0 | 0.911 | 0.0 | 1.17 – 3.33 |
| Neutralization Number (mg KOH/g) | 0.40 | 1.645 | 0.06 | 4.0 – 14.26 |
| **Metal content (ppm)** | | | | |
| Lead | 0.0 | 2813 | 1.86 | 5000 – 12000 |
| Calcium | 543.2 | 606.5 | 9.56 | 784 – 2243 |
| Sodium | 0.0 | 9.5 | 0.0 | 27 – 368 |
| Copper | 0.0 | 21.25 | 2.17 | 15 – 38 |
| Iron | 0.0 | 89.5 | 0.0 | 24 – 434 |
| Potassium | 0.0 | 19.0 | 0.0 | - |
| Nickel | 0.0 | 2.0 | 0 | - |

**Table-2.** Vacuum distillation of used lubricating oil at 64.5 mm Hg.

| Distillate | True Boiling point (TBP) ºC at atmospheric pressure | Average weight of distillate (grams) | Weight percent | Cumulative weight percent | Kinematic viscosity (cSt at 37.8ºC |
|---|---|---|---|---|---|
| 1 | < 272 | 13.22 | 7.43 | 7.43 | 8.29 |
| 2 | 272 – 350 | 55.20 | 31.01 | 38.44 | 61.13 |
| 3 | 350 – 388 | 52.92 | 29.73 | 68.17 | 118.9 |
| 4 | 388 – 400 | 9.06 | 5.10 | 73.27 | 121.3 |
| Residue | > 400 | 35.00 | 19.66 | 92.92 | - |
| Loss | - | 12.59 | 7.07 | 100.00 | - |
| Total | | 178.0 | | 100.00 | |

**Table-3.** Viscosities and SAE classification of blended lube stocks.

| SAMPLE | Kinematic viscosity (cSt) at 37.8ºC | Kinematic viscosity (cSt) at 98.9ºC | Viscosity Index (VI) | SAE classification |
|---|---|---|---|---|
| Used oil | 115.2 | 17.36 | 160 | SAE 20W - 50 |
| A: Blend of Re-refined oils | 87.5 | 9.89 | 98 | SAE 30 |
| B: Re-refined oils + 25% (v/v) bright stock | 134.58 | 13.16 | 103 | SAE 40 |
| C: Re-refined oils + 25% (v/v) + 0.4% VI improver | 140.35 | 13.66 | 110 | SAE 40 |
| New oil (Mobil) | 142.5 | 14.42 | 107 | SAE 40 |
| New oil SAE 20W-50 | 192 | 18.3 | 110 | SAE 20W-50 |

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