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Re-Refining of Used Lube Oils and Sustainability

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Abstract: *As petroleum products continue to be an inseparable part of our lives, so does the waste that is generated from these products, the prominent among them being the used lubricating oil. However, research shows that more than half of the used lube oil can be converted back to usable lubricant through the process of re-refining. This can certainly reduce the amount of waste oil in the environment and the need of crude oil extraction to a certain extent. As there are various different methods of re-refining, this work focused specifically on the method used widely in India, i.e., Vacuum distillation with Clay treatment. In this paper, the sustainability of the re-refining process was checked using the green chemistry principles and overall material balance of the process. Based on the assumptions made for the material balance, nearly 69.92% of lube oil base stock was obtained along with 11.13% fuel by - product and 12.14% residue, both of which have varied uses in the industry, thus producing additional profit.*

Keywords: Petroleum, Used lubricating oil, Re-refining, Vacuum distillation, Sustainability

I. INTRODUCTION

Lubricating oil is used to reduce the friction, heat, and wear and tear between mechanical components when they are in contact with each other[1]. It is extracted in the form of lube oil base stock from crude oil, which undergoes a series of unit operations, mostly distillation, to produce it. The lube oil base stock is then combined with additives, depending upon its end use, and we obtain the lubricating oil[2]. However, when this lubricating oil gets degraded and becomes unfit for further use, it becomes the used lube oil, which needs to be disposed off properly as even small amount of lubricant can contaminate large amount of water[3]. The used oil can be disposed off in three ways: re-refining, thermal cracking and incineration. Though thermal cracking produces valuable fuel, it is an energy intensive process.

Whereas incineration of used lube oil produces large amount of ash and the heavy metals are also not incinerated completely, thus polluting the environment. Hence the most viable and efficient option is re-refining.

Re-refining of used lube oils is being done since the past four decades, as the lube oil doesn't wear out, it just gets dirty. The used lube oil consists of majorly the lube oil base stock, which can be obtained back using the re-refining process, and with the addition of additives, can be re-used as a lubricant.

The core steps of re-refining include dehydration/defueling, re-refining and finishing. Dehydration/defueling involves the removal of water and lighter ends in the used lube oil, while re-refining gives us the lube oil base stock, which is purified through the finishing step[4].

The unit operations for these steps vary, depending upon the choices of the manufacturers and the facilities available in the plant. As a result, there are many proprietary processes available in and around the world.

In this study, we have taken into account the "vacuum distillation with clay treatment" technology, which is widely used in India and has been approved by the central pollution control board (CPCB)[5]. This study focuses on sustainability which is the need of the hour. With the help of green technology principles and the overall material balance, this paper is able to assess the sustainability of the vacuum distillation with clay treatment technology for re-refining of used lube oils.

II. METHODS OF RE-REFINING

In India, re-refining of used lube oils is carried out using the environmentally sound technologies (ESTs), which have been approved by the Guidelines for Environmentally Sound Recycling of Hazardous Wastes As per Schedule IV of HW Rules, 2008. These guidelines have been published by the Central Pollution Control Board in January 2010, with the support of the Ministry of Environment & Forests.

The ESTs are: vacuum distillation with clay treatment, vacuum distillation with hydro treatment, thin film distillation and any other technology approved by the Ministry of Environment & Forests. Among these, Vacuum distillation with clay treatment is the widely used one[5]. The block diagram of the process is shown in Fig.1.

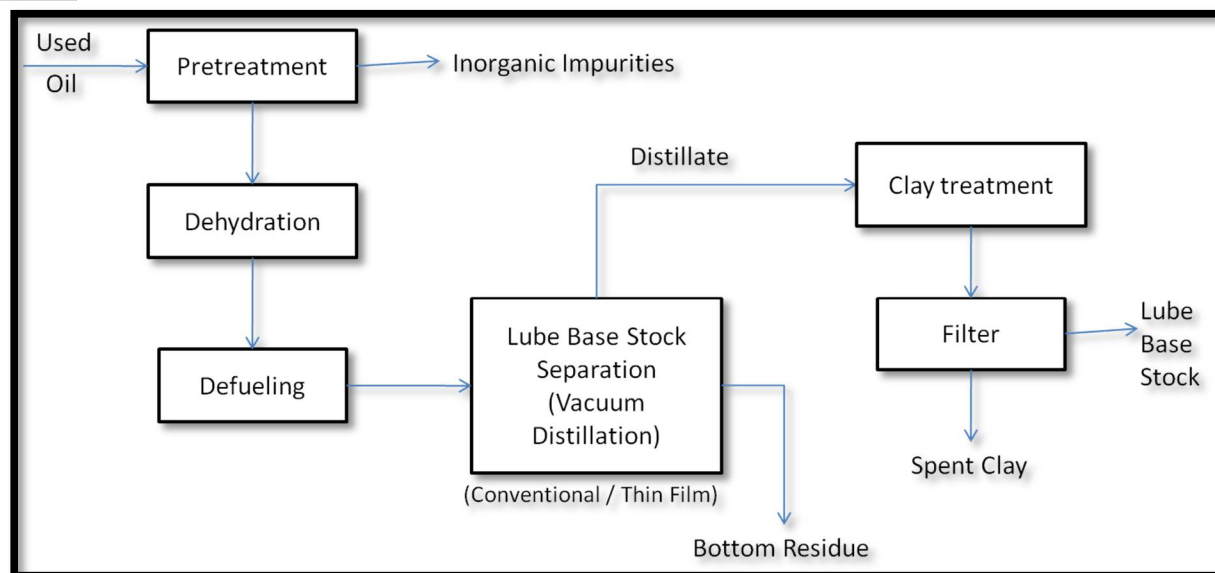


Fig 1 Block diagram of Vacuum distillation with Clay treatment

A. Pre-treatment

This is the first step of the re-refining process. Here the incoming feedstock of used lube is filtered using screens, gravity settling, etc. to remove settle able or suspended materials. This can be done with or without using flocculent. As per authorization granted by SPCBs/PCCs under HW rules, 2008, the materials remaining on the screen as well as the sediments are disposed of as hazardous waste[5].

B. Dehydration

Dehydration refers to the removal of water from the used lube oil. This is carried out mostly through atmospheric distillation. Here along with water, the off gases also get removed as they have quite low boiling points. For the material balance carried out here, it is assumed that 90% of the water is obtained in the distillate and 99% of the fuel by product is obtained in the bottom product. Also the pressure at the top is taken as 101.325 kPa and the pressure drop is assumed to be 50 kPa, which gives the pressure at the bottom of the column as 151.325 kPa. At these pressures, the temperatures at the top and bottom of the column were obtained as 87.52 °C and 453.77 °C.

C. Defueling

In this step, the fuel fraction, which has been formed due to the cracking of lube oil under high temperatures, is removed. This is carried out using vacuum distillation. For the material balance carried out here, it is assumed that 96% of the fuel by product is obtained in the distillate and 99.5 % of the base oil stock is obtained in the bottom product. Also the pressure at the top is taken as 200 mm Hg and the pressure drop is assumed to be 80 mm Hg, thus giving the pressure at the bottom as 280 mm Hg. At these pressures, the temperatures at the top and bottom of the column were obtained as 163.63°C and 486.37°C. Now, according to the choice of the company and the facilities existing in the plant, the dehydration and defueling steps can be carried out either separately or together as a single step. The fuel by product obtained, can either be converted to valuable fuels like kerosene, gasoil, diesel etc. or can be used in the re-refining plant itself for fuelling the boilers and furnaces[5].

D. Lube Oil Base Stock Separation

After the removal of water and fuel fraction, the used lube oil is subjected to vacuum distillation to distil out the lube oil base stock and obtain the residue in the bottom product. For the material balance carried out here, it is assumed that 97% of lube oil base stock is obtained in the distillate and 99.9% of the residue is removed in the bottom product. Also the pressure at the top of this column is taken as 15 mm Hg and the pressure drop is assumed to be 85 mm Hg, which gives the pressure at the bottom as 100 mm Hg. At these pressures, the temperatures at the top and bottom of column are obtained as 366.6 °C and 403.755 °C. The residue obtained in the bottom product is rich in high quality polymers and metal traces due to decomposition of lubricant additives. This residue is used in the blends for paving asphalt or used as fuel in the cement kilns[5].

E. Clay Treatment

After the lube oil base stock is distilled out, it is subjected to a final finishing step, wherein any traces of contaminants present in it are removed. This is done with the help of clay treatment. This treatment also improves the colour and colour stability of lube oil base stock. Here, the 2 to 3% clay is mixed with the lube oil base stock with operating temperatures being around 250 °C. A plate and frame filter press is used to separate the spent clay and lube oil base stock. This spent clay may find uses in cement kilns for co – processing or in brick kilns as fuel[5].

III. COMPOSITION OF USED LUBE OIL

According to the studies carried out in India, nearly five hundred thousand tons of used oil, from the total volume of lubricating oils consumed, can be collected and recycled every year[6]. So that makes for nearly 1370 tons per day. For the sake of material balance calculations, let us assume that the used lube oil contains 72%(w/w) base oil stock, 0.4%(w/w) off gases (C₁ – C₄ gases, inorganic gases, etc.), 10.6%(w/w) fuel by product, 7%(w/w) water and 10%(w/w) residue. The mass flow rate according to the total used oil collected is given in the table I below.

TABLE I
Mass Flow Rate of Components of Used Lube Oil

Components of Used Lube Oil	Composition (%w/w)	Mass Flow Rate (tons/day)
Off gases	0.4	5.48
Water	7.0	95.9
Fuel By-product	10.6	145.22
Lube Oil Base Stock	72.0	986.4
Residue	10.0	137
Total	100	1370

IV. RESULTS AND DISCUSSION

After carrying out the material balance with the assumptions mentioned in the methods section, we obtained the following results, shown in Table II below.

TABLE II
Mass Flow Rate of Components in Re-refined Used Lube Oil

Components of Refined Used Lube Oil	Mass Flow Rate (tons/day)	Composition (wt%)
Off gases	5.48	0.4
Water	87.76	6.41
Fuel By-product	152.54	11.13
Lube Oil Base Stock	957.91	69.92
Residue	166.31	12.14
Total	1370	100

From the table, it can be seen that nearly 69.92% of Lube Oil Base Stock is obtained, along with 11.13% of fuel by product and 12.14% of residue. According to the studies carried out in India, the lube oil demand is nearly 10 lakh tonnes per year[6]. And the lube oil obtained from re-refining is nearly 3.5 lakh tonnes per year. This means that nearly 35% of the lube oil demand can be satisfied per year with re-refining.

A. Sustainability

The sustainability check for the re-refining process was carried out using the green chemistry principles, shown in Fig.2. The second and eighth principles i.e. Maximize atom economy and Avoid chemical derivatives were not account as the re-refining process does not incorporate any chemical reaction, thus rendering the two principles inapplicable to this process.

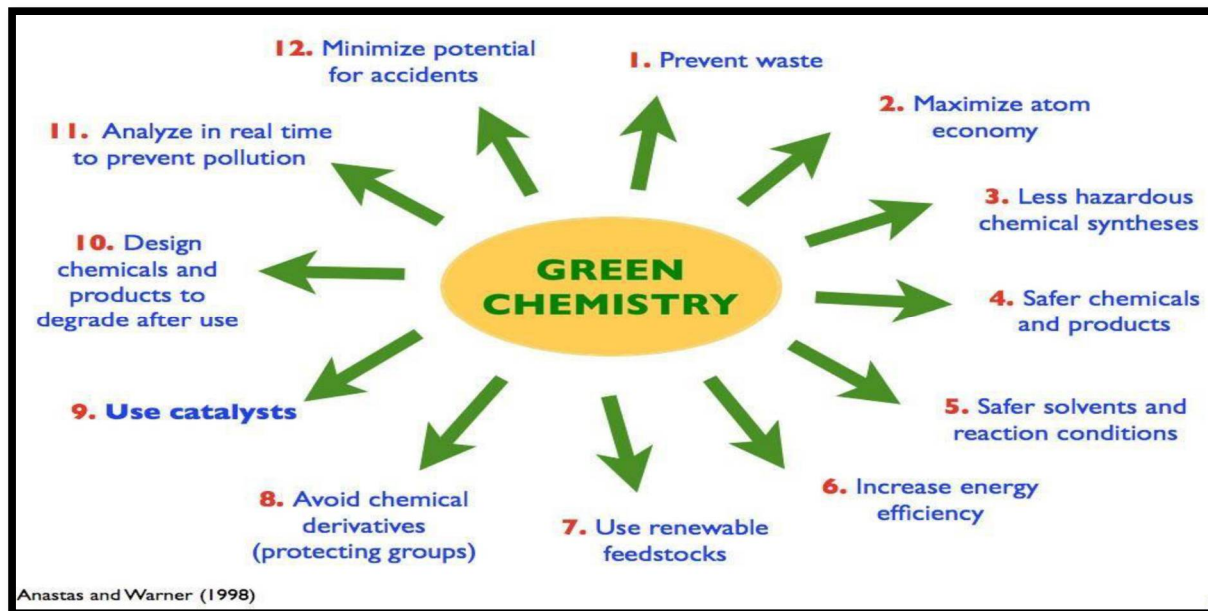


Fig 2 Green Chemistry Principles

From the sustainability check, it has been deduced that the re-refining process reduces the utility costs to a great extent as only one – third amount of energy is required for re-refining used lube oil than that required for refining the crude oil. The raw material i.e. the used lube oil is also reusable and can be re-refined again and again; hence it can be considered as a renewable feed stock. Even the environment is saved, as the used lube oil, instead of being disposed off or incinerated, is used up to produce valuable products and the pollution that could have been caused is prevented.

Our refined product has a higher flash point and lower viscosity value, as compared to the used lube oil, here by achieving a safer chemical product. Here, the auxiliary substance i.e. clay is not only used in very small amounts, but also after use, the spent clay finds many uses in industries like cement or brick kilns.

There are various spectrometric methods that help in the real – time monitoring of the distillation unit operating conditions and feed properties, the most common one being Magnetic Resonance Spectrometry (MRS). It carries out the on-line monitoring of the quality of various products obtained, which indicates the stability of the process and prevents the risks of uncontrolled overshooting when changing the process conditions[7]. Also the presence of vacuum regulators and various kinds of valves at various locations near the distillation units minimizes the potential for accidents.

V. CONCLUSION

A lot of petroleum companies in and around the world are focusing on the process of re-refining, due to the increasing necessity of environmental protection and the more and more strict environmental rules and regulations. However problems like whether the re-refining process is really sustainable and eco friendly and whether the process does add any value to their business, still remain with them. For these very reasons, the sustainability check using the green chemistry principles and the material balance was carried out to give some insight in solving the above mentioned problems. The used lube oil re-refining, as mentioned above, not only prevents pollution and excess energy usage, but also provides profitability by providing additional products like fuel by product and residue which have varied uses. The lube oil base stock itself is, somewhat, at par in properties, with the virgin base oil stock obtained by refining crude oil. And also, from the material balance, it can be said that for India, the re-refining process satisfies nearly 35% of the lube oil demand. Thus, all in all, re-refining is surely one such process which is not only sustainable and eco-friendly but at the same time provides value addition to the business. Hence we need to implement it as much as possible.



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