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EFFECT OF DESLUDGING AND ADSORPTION RATIOS ON RECOVERY OF LOW POUR FUEL OIL (LPFO) FROM SPENT ENGINE OIL

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Abstract: The study presents the effect of desludging ratio (oil to acid ratio) and adsorption ratio (oil to clay ratio) on the recovery of low pour fuel oil (LPFO) from spent engine oil. Two major unit operations were use to recycle the spent engine oil: the desludging and the adsorption. Concentrated sulfuric acid was used as the reagent to effect the desludging operation while activated clay was used as the adsorbent in the adsorption operation. The result shows that the efficiency of the recycling operation depends on the reagent ratio used (desludging and adsorption ratios) and increases with the ratios. However, a desludging ratio of 20:1 and an adsorption ratio of 10:1 gave the best recovery of 82.9%. Also the specific gravity, API gravity, pour point, flash point and viscosity index of the recycled oil are lower than the fresh and the spent oil.

Keywords: *Desludging Ratio, Adsorption Ratio, Low Pour Fuel Oil, Spent Engine Oil, Recovery*

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1. Introduction

Low pour fuel oil (LPFO) are finely balanced combination of highly refined petroleum oils, made up chiefly of high molecular weights hydrocarbon obtained from the residual fraction of a crude oil distillation unit. Their intrinsic properties, lubricity, viscosity index, chemical and physical stability, make them a very good choice as base stock for lubricating oil production, these properties are frequently fortified by blending with additives [1].

Lubricating oils play a dual role of heat transfer and that of friction reduction that reduces heat generated in internal combustion engine. During usage, lubricating oils undergo changes termed degradation and contamination, which render them ineffective for further application. Lubricating oil goes through normal degradation and about 50% of it is consumed in the process. The rest of the oil picks up number of contaminants from the working environment, such as, residual components of engine fuels, solids from wear processes along with corrosion products and dirt, soot, combustion products etc [2]. Degradation involves changes in the desired viscometic properties of oil as a result of alteration in the lubricating oil molecular structure caused by cracking, isomerization and polymerization reactions prompted by high temperatures in the running engine. The overall effect of this degradation is the formation of low molecular weight compounds and oxidation products which include polymerized or condensed molecules called gum and sludge.

There are basically three options to deal with the waste oil in the world: a) dumping the waste oil on land, garbage heap and sewerage system, b) regeneration of base-oil from waste oil and c) extracting of heat value of waste oil through combustion process [3].

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Waste oil creates enormous problems if is improperly disposed in the environment (land, garbage heap, surface water, sewerage systems). Simply one gallon of waste oil can ruin the taste of a million gallons of drinking water. Films of oils on the surface of water prevent the replenishment of dissolved oxygen thereby hamper aquatic life, impair photosynthetic processes and block sunlight [4]. Studies showed that, significant long-term effects have been observed in freshwater fishes with concentration of oil of 310 ppm and in marine life forms at concentration of oil of only 1 ppm [5].

Waste oil is also used as fuel for industrial furnaces. Combustion of waste oil destroys valuable resources and also represents a significant threat to the environment. All the toxic components present in the waste oil reach to the environment with the flue gas. In extreme cases, these contaminants damage the furnace, leading to increased environmental pollution [2]. Waste oil can be a very valuable resource, if managed properly. It has varying refined fractions of petroleum and its recovery possibilities are extremely high. Average crude oils have 3-8% base-oil, whereas lube crudes typically have 12-16% base-oil. This compares with 65-75% recoverable base-oil content in used automotive oils, which if burnt or dumped would mean the loss of a valuable natural resource [6].

Some major recycling processes in use include; setting centrifuge system, acid-clay process, Philips re-fined oil process, fixed bed sand filtration process to produce relatively clean oil [7]. Limitations of the activated sand filtration processes arises from the fact that the process incorporates only physical separation of contaminants by filtration, as such there is usually no appreciable change in the color of the used oil. This should be expected because most of the chemical properties remain relatively un-altered by physical separation. This necessitates the adoption of a different process route to improve and also enhance the chemical properties of the recycled oil. In the recycling process, a number of stages are possible depending on the original source of the used oil, the level of contamination, and the sophistication of the technology utilized [8]. Studies on the ageing characteristics of automotive oils [9], recycling of used engine oil [7], rheological properties of used engine oil [10], regeneration of used engine oil [1], an analysis of biodiesel fuel from waste edible oil [11], gasoline-like fuel from waste engine oil via catalytic pyrolysis [12] and the effect of operating variable on the regeneration of base-oil from waste oil by conventional acid-clay method [3] have been reported. However, this study presents the effect of desludging and adsorption ratios on the recovery of low pour fuel oil (LPFO) from spent engine oil.

2. Experimental

2.1. Materials and Methods

Spent engine oil from automobile workshops within Port Harcourt Metropolis was collected and 98% Concentrated sulfuric acid (analytical grade), thermometer, beakers of different sizes, electric stirrer, electric heater, volumetric flask, funnel, weighing balance and kaolin (Al_2O_3,2 SiO_2.2 H_2O) clay (activated) were used in this experiment. ASTM standard methods were used to determine various properties of the LPFO. ASTM D1298 for specific gravity, ASTM D2270 for viscosity index, ASTM D92 for flash point and ASTM D97 for pour point.

2.2. Desludging

The lubricating oil undergoes degradation during usage leading to the formation of oxidative products/organic acids, unsaturates, condensed aromatics and mercaptans, asphaltenes and petroleum resins.

The removal of these compounds is known as desludging and is accomplished with sulphuric acid (H_2SO_4). Sulphuric acid is a poly functional mineral acid which can act both as a sulphonating and an oxidizing agent. Also it can act as a catalyst for some polymerization reaction of unsaturated hydrocarbons hence treatment of the spent oil with sulphuric acid results in sulphonation and oxidation of the degraded products.

90 g of spent engine oil was weighed in a 250-ml beaker. 30 g of concentrated sulfuric acid (98%) was weighed and mixed with the spent engine oil to give a desludging ratio of 3:1. The mixture was then heated with continuous stirring to a temperature between 40 to 50°C for about 30minutes. Temperatures beyond 50°C would consume some of the hydrocarbons by introduction of sulphonation reaction [13]. The mixture was then allowed to cool. After about 3 hours, the oil (top layer) was decanted, leaving the sludge. Both the oil and sludge were weighed and tabulated. The same procedure was repeated for other desludging ratios.

2.3. Chemisorption

The desludged oil was heated to100°C in a 500-ml flask. Activated kaolin clay was added to the heated oil at a ratio 5:1 by weight. A rapid effervescence and foaming occurred. Heating and stirring were continued for about 45 minutes during which there was no visible effervescence, marking completion of the reaction. The reactor contents were allowed to cool and to separate into two phases: a reddish yellow top layer, and the solid adsorbent laden with the blackish contaminants at the bottom. The oil was decanted and later filtered with a filter paper in a glass funnel. This procedure was repeated for the other oils obtained from the different desludging ratios and subjected to the various adsorption ratios.

The procedure was varied for given weights of desludged oil; the weight of adsorbent was varied to yield different adsorption ratios. The recovered oils were weighed and tabulated.

2.4. Investigation on adsorption ratio

In a different experimental set-up, the desludging operation was carried out for a desludging ratio of 20:1. Three samples each of 30 g was withdrawn from the desludged oil and using adsorption ratios of 3:1, 5:1 and 10:1, chemisorption operation was carried out on the 3 different samples. The recovered oils were weighed and tabulated.

3. Results

The results of the desludging operation are presented in Table 1 while those of the adsorption operation are given in Table 2. Table 3 compares the recoveries obtained for the recycled oil for different adsorption ratios. The results of the tests carried out on the recycled oil are displayed in Table 4 and 5, while Table 6 compares the properties of the recycled oil to that of the fresh and the spent engine oils.

Table 1: Result of desludging operation

Experiment Number	1	2	3	4	5
Wt of spent oil (g)	90	90	90	90	90
Wt of desludging agent (g)	30	18	9	6	4.5
Desludging ratio	3:1	5:1	10:1	15:1	20:1
Wt of decanted oil (g)	75.29	79.59	80.45	81.63	81.82
Wt of sludge (g)	42.7	26.46	18.43	13.4	10.76
Loss in wt (g)	2.01	1.95	0.12	0.97	1.92
Recovery (%)	83.7	88.4	89.4	90.7	90.9

Table 2: Result of adsorption operation

Desludging Ratio	3:01	5:01	10:01	15:01	20:01
Wt of desludging agent (g)	75.29	79.59	80.45	81.63	81.82
Wt of adsorbent (g)	15.06	15.92	16.09	16.33	16.36
Adsorption ratio	5:01	5:01	5:01	5:01	5:01
Wt of recovered oil (g) (after filtration)	53.19	53.39	53.94	59.36	63.88
Loss in wt (g)	22.1	26.2	26.51	22.27	17.94
Recovery (%)	59.1	59.3	59.3	66	70.98

Table 3: Result of adsorption ratio on recovery

Adsorption ratio	3:01	5:01	10:01
Wt of desludging oil (g)	30	30	30
Wt of adsorbent (g)	10	6	3
Wt of recovered oil (g)	18.9	22.44	24.88
Desludging ratio	20:01	20:01	20:01
Loss in wt (g)	11.1	7.56	5.12
Recovery (%)	63	74.8	82.9

Table 4: Result of specific gravity and API gravity

Experiment Number	1	2	3	4	5
Desludging ratio	3:01	5:01	10:01	15:01	20:01
Adsorption ratio	5:01	5:01	5:01	5:01	5:01
Specific gravity at 40°C	0.893	0.871	0.894	0.865	0.865
API gravity	26.95	30.96	26.76	32.08	32.08

Table 5: Result of viscosity, flash point and pour point measurements

Experiment Number	1	2	3	4	5
Desludging ratio	3:01	5:01	10:01	15:01	20:01
Adsorption ratio	5:01	5:01	5:01	5:01	5:01
Viscosity at 40°C	120.54	120.5	110.14	110.3	110.3
Viscosity at 100°C	12.55	12.53	11.82	11.82	11.8
Viscosity index	94.95	94.72	95.08	94.91	94.6
Flash point (°C))	144	144	148	153	152
Pour point (°C)	-11	-14	-13	-18	-16

4. Discussion

Two major unit operations were employed in the regeneration of the spent automobile engine oil. They include desludging and adsorption operations. In the desludging step, most of the oxidative and degraded products were removed. This was accomplished with the use of the sulfuric acid, which proved very effective and efficient because of its poly-functional nature.

4.1. Effect of desludging ratio on recovery

The desludging temperature was 50°C to avoid the adverse effect of sulfuric acid oxidation of the oil at higher temperatures. However, at such low temperature the desludging reaction is slow. Hence sufficient time and rigorous agitation was employed to enable the reaction reach completion. Different desludging ratios were used. As shown in Table 1, a recovery of 83.7% was obtained for a ratio of 3:1, 88.40% for a ratio of 5:1 and 89.40% for a ratio of 10:1. This shows that the higher the ratio, the higher the recovery. The observed increase in recovery would depend on the grade of the acid used as well as the original source of the used oil and the level of contamination [8].

4.2. Effect of desludging and adsorption ratios on recovery

In the chemisorption step, the remaining contaminants were removed by adsorption using activated clay as the adsorbing agent. To enhance adsorption, fine particles (-75/+150) of the adsorbent were used coupled with vigorous stirring. Sufficient time was used so as to allow the adsorption reach completion (equilibrium). The oil from the adsorption stage was clear enough.

The adsorption ratio was kept constant at 5:1 and the desludging ratio varied to obtain different recoveries, the result presented in Table 2. This table shows a recovery of 59.1% for a ratio of 3:1, 59.3% for a ratio of 5:1, and 69.9% for the ratio of 10:1. This shows that the higher the ratio the higher the recovery. Next, for a desludging ratio of 20:1, the adsorption ratio was varied. The results show that for adsorption ratio of 3:1, a recovery of 66.7% was obtained; for the ratio of 5:1 a recovery of 74.8% and for a ratio of 10:1 a recovery of 82.9%. This also shows that the recovery increases with adsorption ratio (Table 3). These various recovery values are in agreement with those stated by Graziano and Daniels [6], and Rahman et al [3]; though the 82.9% recovery is slightly higher.

Table 6: Comparison of the properties of the recycle, fresh and spent oils

Oil type	Specific gravity (40°C)	API gravity	Pour point (°C)	Flash point (°C)	Viscosity index
Fresh oil	0.897	26.25	-21	182	98
Spent oil	0.901	25.55	-	185	111.4
Recycled oil	0.865	32.08	-16	152	94.6

4.3. Comparison of the properties of recycled, fresh and spent oils

The results of the tests carried out on the recycled oil showed that the specific gravity, pour point, flash point and viscosity of the recycled oil are all lower than those of the fresh oil and spent oil (Table 6).

The work by Bobmanuel [14] on the spent engine oil recycling, using activated sand as filtering media, gave a value of specific gravity, flash point and viscosity much higher than the values obtained here. This may be due to the fact that only physical separation methods were used to recycle the oil. Physical separation methods will not be expected to improve on the chemical properties. Bobmanuel [14] also reported that there was no appreciable color change in the recycled oil. A very good improvement in color was obtained using desludging and adsorption operations in recycling the oil.

This work shows that a high proportion of good oil can still be recovered from the numerous gallons of ”useless waste” engine oil being thrown away everyday in Port Harcourt and Nigeria in general. Regeneration will not only prove economically profitable [15] but will also minimize pollution problems being posed by the reckless dumping of these spent oils into drainage gutters and sewages. However, the spent engine oil thus recycled could be used as a combustion fuel in cement kilns, since the recycled oil has good combustion characteristics such as low flash and pour points.

5. Conclusion

The effect of desludging and Adsorption ratio was studied on the recovery of Low Pour Fuel Oil (LPFO) from spent engine oil. The result shows that the efficiency of the recycling operation depends on the reagent ratios used i.e on the desludging and adsorption ratios. It was noted that the recovery increases with increase in these ratios. A maximum recovery of 82.9% was obtained with a desludging ratio of 20:1 and adsorption ratio of 10:1.

The characterization of the fresh, spent and recycled oils shows that the specific gravity, API gravity, pour point, flash point and viscosity index of the recycled oil is lower than the fresh and the spent oil. Specific gravity of 0.897, 0.901 and 0.865; flash point of 182, 185 and 152°C; and viscosity index of 98.00, 111.40 and 94.60; were obtained for fresh, spent and recycled oils respectively. However, the spent engine oil thus recycled could be used as a combustion fuel in cement kilns, since the recycled oil has good combustion characteristics such as low flash and pour points.

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