DECOLOURIZATION OF RECOVERED BASE OIL FROM USED LUBRICANT OIL: A STUDY ON THE PERFORMANCE OF COMPOSITE ADSORBENTS

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ABSTRACT

The process of decolourizing used oil is usually done by adsorption to remove the darkish colour and lighten the oil for further purification [1]. This paper discusses the results of a study carried out to determine the performance of composite adsorbents comprising a mixture of activated carbon and activated clay in decolourizing recovered base oil. The recovered base oil is contacted with a certain percentage of the chosen adsorbents where the colour of this oil is compared to new virgin oil by using a spectrophotometer. Based on the results from the factorial design analysis, an adsorbent mixture of 12 grams containing 80% activated clay and 20% activated carbon added to 100 ml of base oil at 60°C produced the best decolourized base oil. Besides that, from four parameters studied in this case, which are the ratio of adsorbents, operating temperature, the ratio of adsorbents/oil and number of contact stages, the most influential parameter affecting the adsorption process was the ratio of adsorbents added to the base oil while the interaction between the operating temperature and the number of contact stages was the most significant of all interactions under study.

Keywords: Adsorption, Base Oil, Used Lubricant Oil, Decolourization

INTRODUCTION

Base oil is defined as the base stock which refers to the mineral oil content in lubricant oils. From the overall content of lubricant oils, about 70-90% is contributed by this mineral oil and the remaining portion consists of chemical additives added to increase the quality of the oil [2]. Recycling base oil from used lubricant oil (re-refining) has been carried out to remove contaminants and spent additives, thereby allowing the base oil to be used repeatedly. This is usually done by solvent extraction, a method involving the addition of a single/composite solvent to extract the base oil from used lubricant oil where spent additives and impurities are flocculated and allowed for sedimentation. Although the viscosity of the recovered oil is identical to the virgin oil, the oil still maintains its darkish colour and some odor [3].

Decolourization of recovered oils can be carried out by few processes including adsorption, ozonation and chemical precipitation [4]. Adsorption, a process which is still under the development stage, offers an attractive alternative for decolourizing recovered oil [5]. This method involves the addition of adsorbents; a mixture of activated carbon and activated clay in this case into the recovered base oil to allow adsorption of the colour and odor. The objective of this study was set to investigate the impact of certain ratios of activated carbon and activated clay used in the adsorption process for decolourizing the recovered oil.

EXPERIMENTAL METHODS : PROCEDURE AND ANALYSIS

Solvent Extraction and Membrane Filtration

The used oil is mixed with the solvent (n-hexane and 2-propanol mixture) and a flocculating agent, potassium hydroxide (KOH) in a beaker and is subjected to strong agitation for 15 minutes. The mixture is then left at room temperature for 24 hours to allow gravitational settling of the sediments. This is where extraction-flocculation occurs. Subsequently, the oil is introduced to membrane filtration to separate the extracted phase which is base oil from the oil sludge. The recovered base oil which maintains its darkish colour is collected and kept in a closed drum to ensure that the oil is in a homogeneous phase throughout the experiment.

Decolourization Process

An adsorbent mixture of activated carbon and activated clay is added into a beaker containing the recovered base oil and is oven-heated at a temperature of 60/120°C. The heated mixture is then subjected to intense agitation for 10 minutes. It is then left at room temperature for half an hour to allow gravity settling. After that, the recovered oil is separated from the adsorbent mixture by using filter paper. The adsorption process is repeated for second, third and fourth stage adsorption.

Colour Measurement

The colour of the recovered base oil is measured by using a spectrophotometer where the amount of colour absorbed by the spectrophotometer, A is recorded at a wavelength, λ of 850 nm. The amount of colour absorbed from new virgin oil is also recorded and this value is fixed as a basis where the comparison between this value and the amount of colour absorbed from the recovered base oil samples are made to determine which sample represents the best colour removal from the recovered base oil.

Factorial Design Analysis

It is a good practice at early stage of investigation to determine the main effect and interacting effects of variables involved. Two-level factorial design method is employed to statistically compare the average effects of various variables, thus enabling the study to look at a large number of factors superficially rather than smaller numbers thoroughly. There are four quantitative variables involved in this study, namely ratio of adsorbents, operating temperature, the ratio of adsorbents to oil and number of contact stages. The response for this study is the amount of colour absorbed from the recovered base oil samples and its colour. For a two-level factorial design with four variables, sixteen runs ($2^4=16$) of experiment needed to be conducted. A design matrix that provides a display of levels to be run is shown in Table 1. The following equation describes how the main effect of variables involved was determined:

$$\text{Main effect} = \hat{y}_+ - \hat{y}_- \qquad (1)$$

Where : $\hat{y}_+$ = average response for (+) stage variables
             $\hat{y}_-$ = average response for (−) stage variables

From equation (1), the variable which showed the highest response value is the most influential parameter that effects the change of colour in the oil and vice versa. This same method is also applied for the analysis on the interacting effects studied. The designated experiments under the specific conditions are carried out according to the experiment procedure mentioned to the response data required for factorial analysis [6].

RESULTS AND DISCUSSION

Factorial Design Analysis

A better understanding of the factorial design analysis can be illustrated as in Table 1. The data response is plotted according to its respective level for each effect under study. Meanwhile, the results of the factorial design analysis on main and interaction effect are tabulated in Table 2 and Table 3 respectively. From Table 1, we have concluded that sample 9, which had undergone adsorption with an adsorbent mixture of 12 grams containing 80% activated clay and 20 % activated carbon added to 100 ml of base oil at 60°C produced the best decolourized base oil than any other samples. This can be seen from the value of the amount of colour absorbed by the spectrophotometer for this sample, 0.034 which is the closest to the amount of colour absorbed from the new virgin oil which is 0.035. This sample produced a colour very similar to the colour of new virgin oil.

In Table 2, the factorial design analysis concludes that the ratio of adsorbents with a value of 0.651 is the most influential parameter affecting the amount of colour absorbed from the oil. This is followed by the operating temperature and number of contact stages, which brought a value of −0.042 and −0.344 respectively. The effect of the ratio of adsorbents to oil was found to be the most uninfluential parameter which showed no significant effect towards the amount of colour absorbed from the oil sample. From the interacting effect analysis, the results showed that the interaction between the operating temperature and the number of contact stages stood out to be the most significant of all interactions involved for the response of amount of colour absorbed which was 0.144.

Effect of the Ratio of Activated Carbon to Activated Clay on the Colour Absorbed

Based on the results of the analysis carried out, the ratio of activated carbon to activated clay used in the experiment turned out to be the most influential parameter effecting the change of colour in the oil. As shown in Table 1, a mixture of adsorbents containing 20% activated carbon and 80% activated clay added to the recovered base oil produced the best decolourized oil compared to using 80% activated carbon and 20% activated clay. From this analysis, it is concluded that a mixture containing 80% activated clay would remove the colour of the oil more efficiently. This shows that activated clay plays

an important role in decolourizing the oil where a mixture containing activated carbon with a higher percentage than activated clay showed no potential in decolourizing the oil to the desired colour.

Run	Adsorbent Ratio	Temp	Stages	Adsorbent Oil	Colour Absorption Code
1	-	-	-	-	0.288
2	+	-	-	-	0.466
3	-	+	-	-	0.074
4	+	+	-	-	0.137
5	-	-	+	-	0.111
6	+	-	+	-	0.138
7	-	+	+	-	0.461
8	+	+	+	-	0.302
9	-	-	-	+	0.034
10	+	-	-	+	0.339
11	-	+	-	+	0.171
12	+	+	-	+	0.150
13	-	-	+	+	0.022
14	+	-	+	+	0.110
15	-	+	+	+	0.000
16	+	+	+	+	0.171
New virgin oil					0.035
	'-' means 20% carbon '+' means 80% carbon	'-' means 60 °C '+'means 120 °C	'-' means 1 stage '+' means 4 stages	'-' means 4 g/100ml '+' means 12 g/100 ml	

TABLE 1: Factorial design results for colour absorption code

Effect of Temperature on the Colour Absorbed

The adsorption of colour from the recovered base oil was analyzed at temperatures of 60°C and 120°C. From the results of the experiment, decolourization of the recovered base oil at an elevated temperature, which is 120°C in this case did not increase the potential of the adsorbents in removing the colour of the oil. This is because at higher temperatures, the adsorbents tend to become less active in adsorbing colour compared to lower temperatures. At low temperatures, the retention of the adsorbed pigment on the bleaching media surface occurs while at higher temperatures, the adsorbed pigment tend to move into the pores where chemisorption is most likely to occur. But in this case, high temperatures must be avoided to prevent isomerization of the unsaturated base oil and the decrease of the adsorption activity of the adsorbents involved.

CONCLUSION

The followings are the main conclusion of this study. (1) The study of the colour absorption code showed that an addition of an adsorbent mixture of 12 grams containing 80% activated clay and 20% activated carbon added to 100 ml of base oil at 60°C produced the best decolourized base oil. (2) From the main effect study, the most influential parameter affecting the adsorption process was the ratio of adsorbents added to the base oil where it is concluded that activated clay plays a more important role in decolourizing base oil. (3) In the interacting effect study, the adsorption of colouring matters has been shown to significantly depend on the operating temperature and the number of contact stages.

Run	Y_{12}	Y_{13}	Y_{14}	Y_{23}	Y_{24}	Y_{34}	Y_{123}	Y_{124}	Y_{134}	Y_{234}	Y_{1234}
1	+0.288	+0.288	+0.288	+0.288	+0.288	+0.288	-0.288	-0.288	-0.288	-0.288	+0.288
2	+0.466	+0.466	-0.466	+0.466	-0.466	-0.466	-0.466	+0.466	+0.466	+0.466	-0.466
3	+0.074	-0.074	+0.074	-0.074	+0.074	-0.074	+0.074	-0.074	+0.074	+0.074	-0.074
4	+0.137	-0.137	-0.137	-0.137	-0.137	+0.137	+0.137	+0.137	-0.137	-0.137	+0.137
5	-0.111	+0.111	+0.111	-0.111	-0.111	+0.111	+0.111	+0.111	-0.111	+0.111	-0.111
6	-0.138	+0.138	-0.138	-0.138	+0.138	-0.138	+0.138	+0.138	+0.138	-0.138	+0.138
7	-0.461	-0.461	+0.461	+0.461	-0.461	-0.461	-0.461	+0.461	+0.461	-0.461	+0.461
8	-0.302	-0.302	-0.302	+0.302	+0.302	+0.302	-0.302	-0.302	-0.302	+0.302	-0.302
9	-0.034	-0.034	-0.034	+0.034	+0.034	+0.034	+0.034	+0.034	+0.034	-0.034	-0.034
10	-0.339	-0.339	+0.339	+0.339	-0.339	-0.339	+0.339	-0.339	-0.339	+0.339	+0.339
11	-0.171	+0.171	-0.171	-0.171	+0.171	-0.171	-0.171	+0.171	-0.171	+0.171	+0.171
12	-0.150	+0.150	+0.150	-0.150	-0.150	+0.150	-0.150	-0.150	+0.150	-0.150	-0.150
13	+0.022	-0.022	-0.022	-0.022	-0.022	+0.022	-0.022	-0.022	+0.022	+0.022	+0.022
14	+0.110	-0.110	+0.110	-0.110	+0.110	-0.110	-0.110	-0.110	-0.110	-0.110	-0.110
15	+0.000	+0.000	-0.000	+0.000	-0.000	-0.000	+0.000	-0.000	-0.000	-0.000	-0.000
16	+0.171	+0.171	+0.171	+0.171	+0.171	+0.171	+0.171	+0.171	+0.171	+0.171	+0.171
$\frac{\Sigma Y}{8}$	-0.055	0.002	0.054	0.144	-0.050	-0.068	-0.121	0.051	0.007	0.042	0.060

TABLE 3: Summary of design matrix for interacting effect analysis

TABLE 2: Summary of design matrix for main effect analysis

REFERENCES

Run	Adsorbent Ratio	Temp	Stages	Adsorbent Oil	Y_1	Y_2	Y_3	Y_4
1	-	-	-	-	-0.288	-0.288	-0.288	-0.288
2	+	-	-	-	+0.466	-0.466	-0.466	-0.466
3	-	+	-	-	-0.074	+0.074	-0.074	-0.074
4	+	+	-	-	+0.137	+0.137	-0.137	-0.137
5	-	-	+	-	-0.111	-0.111	+0.111	-0.111
6	+	-	+	-	+0.138	-0.138	+0.138	-0.138
7	-	+	+	-	-0.461	+0.461	+0.461	-0.461
8	+	+	+	-	+0.301	+0.301	+0.301	-0.301
9	-	-	-	+	-0.034	-0.034	-0.034	+0.034
10	+	-	-	+	+0.339	-0.339	-0.339	+0.339
11	-	+	-	+	-0.171	+0.171	-0.171	+0.171
12	+	+	-	+	+0.150	+0.150	-0.150	+0.150
13	-	-	+	+	-0.022	-0.022	+0.022	+0.022
14	+	-	+	+	+0.110	-0.110	+0.110	+0.110
15	-	+	+	+	-0.000	+0.000	+0.000	+0.000
16	+	+	+	+	+0.171	+0.171	+0.171	+0.171
$\hat{y}_+ - \hat{y}_-$					0.651	-0.042	-0.344	-0.980

NOTATION

λ	Wavelength (nm)
A	Colour absorption code
Y	Interaction of parameters

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