RECYCLING OF USED ENGINE OIL USING SOLVENT EXTRACTION AND DISTILLATION

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ABSTRACT

A solvent extraction process has been used to recycle the used engine oil. The solvent used for the treatment of used engine oil is a mixture of ethanol, 1- butanol and toluene. The effect of operating parameters on the recycling process has been investigated for optimal conditions. The process parameters considered were agitator speed for blending, boiler temperature and solvent to used oil ratio. The maximum recovery for refined oil was 72% using solvent to used oil ratio of 9:1 at a boiler temperature 120° C and agitator speed of 600 rpm. The maximum solvent recovery of 98% was also obtained at the same process conditions.

KEYWORDS: *Used engine oil; Solvent extraction; recycling process; optimal operating conditions*

INTRODUCTION

Used lubricant oils are replaced in machinery and vehicles for the safe operation. Mostly the used oil is directly disposed to the environment rather than proper treatment, while sometime it is illegally dumped in land or ground water and causes environmental pollution[1]. If this used oil is properly recycled, it can preserve the precious resources and reduces the environmental pollution.

The lubricant oil is used for different purposes such as; it reduces the friction between the moving parts of the machine and enhances the efficiency. Other application of lubricating oil includes maintaining the equipment cleaning, removing heat and preventing corrosion[2]. The exhausted lubricating oil (used oil) is also known as waste lubricating oil, transmission oil, hydraulic oil or engine oil. The used engine oil consists of different contaminates such as carbon residue, gums, metal, varnish, ash, water and other asphaltic compounds[3]. The molecules of lubricant oils are not degrading during its use but the concentration of contaminates are increased, due to which the quality of oil are detoriated and demands for replacement[4]. If this engine oil is disposed to water, land or burnt as a fuel, it will liberate detrimental metals and other pollutants into the environment[5].

The lubricating oil is mainly composed of Zn, S, Ca and P elements. The concentrations of these elements are similar in both used and unused oil. The lubricating oil molecules are consisting of paraffinic, naphthenic and aromatic. The paraffinic is waxy type having high pour point and temperature stability. The concentration of alkanes in used oil is more than unused oil[6].

A number of methods have been used for the refining of used oil. In acid clay process sulfuric acid was used to remove the asphaltenic materials from used oil. This process can produces highly polluted acid tar which is deflect to discharge that is why it cannot be adopted nowadays[7]. In another process the natural polymers were used to remove carbon sludge from the used oil. This process is known as acid free clay process. In this process the used oil is initially preheated and after preheating it undergoes vacuum distillation and clay treatment, but the color of used oil can be recovered after using high percentage of clay[8]. The above two processes are using only in UAE[9]. In another method, propane extraction process, the base oil was recovered from the waste oil by using liquefied propane[10]. However this process is expensive because it needs propane in liquefied form[9], furthermore as propane is flammable and hazardous material therefore, the process is considered as potentially dangerous[11]. Martins[12] extracted the base oil from used oil by means of polar solvents in the presences of potassium hydroxide. Nabil et al[13]. have used different absorbents for the recycling of waste lubricating oil by means of absorption process. Araujo and Telles[14] studied the recycling of used lubricating oil and suggested neutralization and decolorization as final step for the purification of used oil. The supercritical carbon dioxide was employed for the treatment of lubricating oil and was proved to be a sustainable process[15]. Brinkman et al[16]. have reported the physical methods such as thin film evaporation and distillation for the refining of lubricating oil, but the main disadvantage of this process is the high

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investment cost[17,18]. Membrane technology was also used for regeneration of engine oil. The polymer hollow fiber membranes were used to remove dust and meta particles from used engine oil. But the main disadvantages of this process is that the large particles fouled and detoriated the expensive membrane[19].

Other treatment methods which are used for used oil refining are incinerations, ultrasonic treatment, chemical treatment, solidifications, photocatalysis, biodegradation, pyrolysis and solvent extraction[20]. The environmental impacts and concentrations of hazardous components of used oil can be reduced by applying theses technologies[21]. In incinerations process the fly ash and hazardous gas are emitted, while this process requires costly equipment and can not treat the heavy metal in the used oil[22]. In ultrasonic treatment method the unrecoverable solids and wastewater are produced, and has a small capacity for treatment of used oil[23]. The chemical treatment process is unfriendly to environment and needs large amount of chemicals[24]. The solidifications treatment method has low efficiency and needs high energy for freezing. The unrecoverable slurry and wastewater are produced during this method[25]. The photocatalysis process needs special type of equipment having high capital and operating costs. The volatile organic compound, unrecoverable solids and wastewater are produced during this process while it is unable to treat heavy metal and has small capacity[26]. The biodegradation treatment method requires skilled operations and proper management for maintenance, monitoring and slurry residence time[27]. The pyrolysis treatment method is not suitable for high moisture content oily sludge and demands for large amount of energy[28]. As compared to these processes the solvent extraction process is efficient and fast while this process is easy to apply for the treatment of a large quantity of used oil[29].

In this research a mixture of ethanol, 1-butanol and toluene has used for the recycling of used engine oil. The process has low cost and high recovery compared to other conventional processes for the recycling of used engine oil. The solvent can be recovered in a maximum quantity at moderate conditions of the process. The oil recovered by this method has potential for reuse as an engine lubricant.

MATERIAL AND METHODS

Sample Preparation

Different samples of used engine oil i.e. Shell Rimula-C SAE 50, PSO DEO 3000 SAE 40 and PSO DEO 3000 SAE 50 has used for recycling. All samples were analyzed before and after treatment. Physical properties such as pour point, flash point, density and viscosity were analyzed. The pour point and flash point were measured by means of Flash point Phenskey Marten apparatus. The density was analyzed by density bottle while viscosity was measured by Viscometer.

Experimental Setup

The experimental set up consists of three main parts: mixer, boiler and condenser as shown in Figure 1. The mixer is made from pyrex glass of cyclone shape with 4 liter capacity in cylindrical portion and 1 liter capacity in conical portion. The mixer is connected at the top with the used oil tank and solvent vessel through flowmeters while it is connected at the bottom to the boiler. A variable speed agitator has installed in the mixer for mixing the solvent and used oil mixture. The speed of agitator can be adjusted by using a regulator. The desired temperature in the boiler can be obtained by changing the power input of the heating element. The condenser condensed the solvent vapor coming from the boiler for reuse.

Experimental Procedure

A known quantity of used engine oil was mixed with specific amount of solvent mixture in a mixer and blended for one hour. The quantities of oil and solvent mixture were controlled and measured through flow meters before mixing. After blending, the mixture undergoes settling for about 18 to 20 hour in order to produce two different layers. The heavy layer consists of large amount of contaminated oil and the light layer is a mixture of solvent and recovered oil. The conical portion of mixer is used for separation of waste and oily layer. These layers were separated due to gravity difference. The waste layer was disposed and the oily layer was send to the boiler where the solvent mixture is vaporized and then condensed in a condenser to recover the solvent for reuse. After vaporization of solvents, the

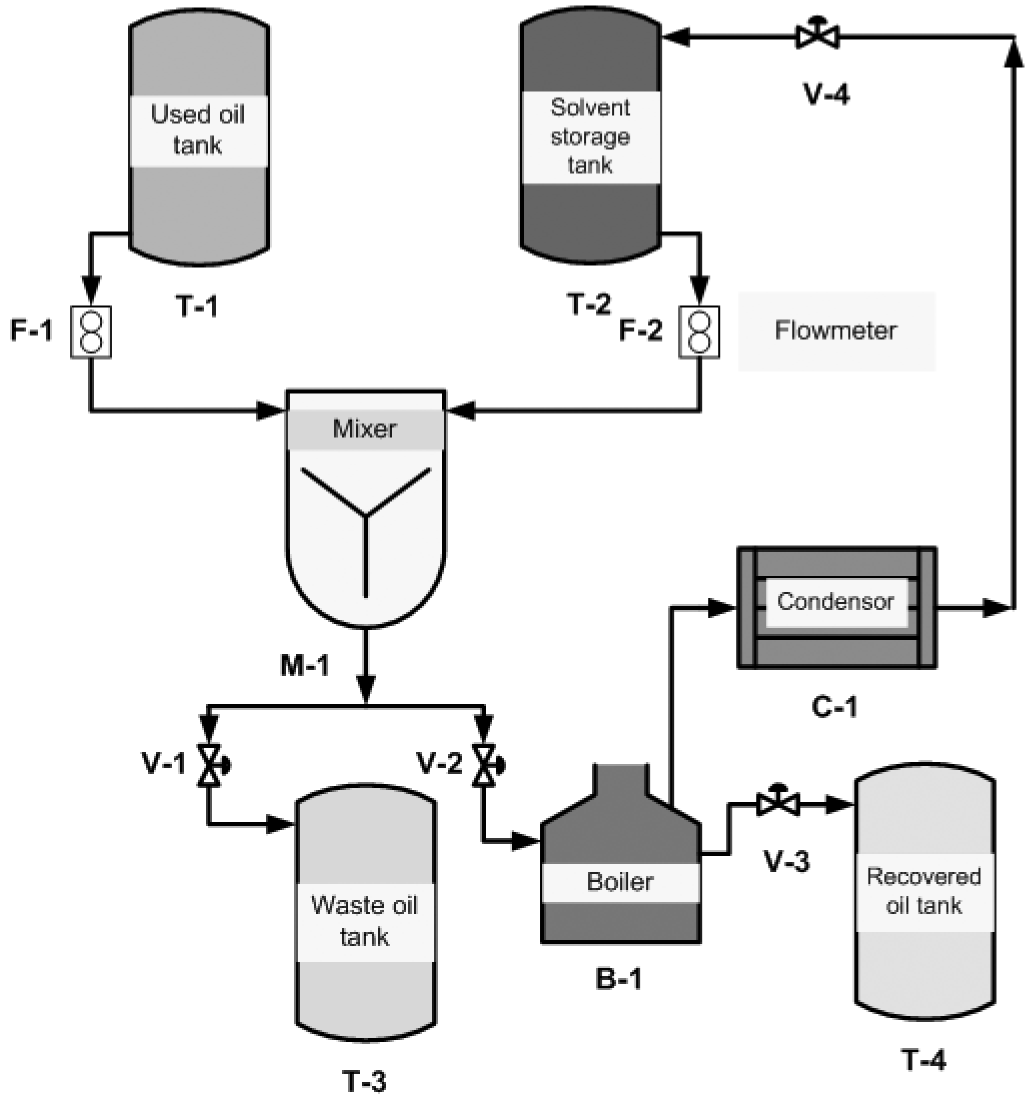

Figure 1: Schematic diagram of experimental setup for recycling of used engine oil

remaining base oil was taken as product. This product is known as refined/recovered engine oil. The product was weighted and collected in the storage tank.

RESULTS AND DISCUSSION

Boiler Temperature optimization

The boiler temperature was set for the different runs of experiments in order to obtain the optimum boiler temperature. The solvent to used oil ratio (S/F=9) remained constant during experiments and controlled through flow meters. The percentage recoveries of recovered oil and solvent at different boiler temperature are shown in Figure 2. It can be seen that as the boiler temperature increases, the percentage recovery of the refined oil also increases till 120° C and then started decrease with further increase in boiler temperature. As the less volatile components gets evaporated when temperature of boiler is increased from 120° C that is why percentage recovery of recovered oil and its quality are decreases. The optimum temperature of the boiler for the maximum recovery of refined oil is 120° C.

In case of percentage solvent recovery, it increases with increase in boiler temperature up to 120^{o} C. The percentage recovery of solvent is more than the refined oil recovery. The maxium percentage recovery for solvent and refined oil at bolier temparature 120° C were 98 percent and 72 percent respectively.

Effect of Solvent to feed ratio

Various solvent to used oil ratios have been tested at a fixed temperature of boiler (120° C) and the results are presented in Figure 3. The plot shows that the optimum solvent to feed ratio is 9 for the maximum percentage recovery of refined oil. After increasing solvent to feed ratio 9 the process becomes unfeasible due to economic point of view and low capacity of solvent extraction.

Effect of Agitator speed

For various agitator speeds the percentage recoveries of recovered oil and solvent are presented in Figure 4. The percentage recovery of refined oil was different for the different agitator speed at optimum boiler temperature (120° C) and optimum solvent to used oil ratio (S/F= 9). The figure shows that the optimum value of agitator speed for the maximum oil recovery was 600 rpm. The percentage recoveries of refined oil and solvent are decreased when the agitator speed is increased from 600 rpm.

As it is cleared that the percentage recovery of solvent mixture is greater than the percentage recovery of refined oil. The optimum percentage recoveries for the solvent and refined oil at 600 rpm are 98 percent and 71.5 percent respectively.

Analysis of experimental data

The experimental data was statistically extrapolated and the percentage oil recovered from the used oil during extraction process is shown by equation 1 as below:

Percentage oil recovered = $55.0 + 0.00116*S_A + 0.047*R + 0.119\ T_b$

Where S_A is agitator speed, R is solvent to used oil ratio and T_b is boiler temperature.

The residual verses fitted value for the experimental data is shown in Figure 5. The plot shows that all the data are closely lie to each other and there was no outlier in the experimental data. The variability in the data is small indicating that variance and standard deviation is small in the experimental data.

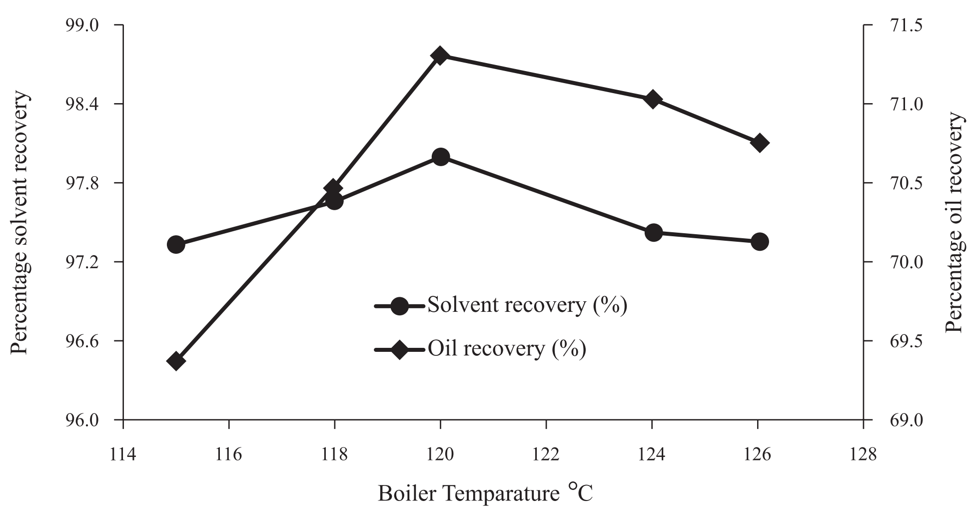

Figure 2: Percentage recoveries of refined oil and solvent for boiler temperature

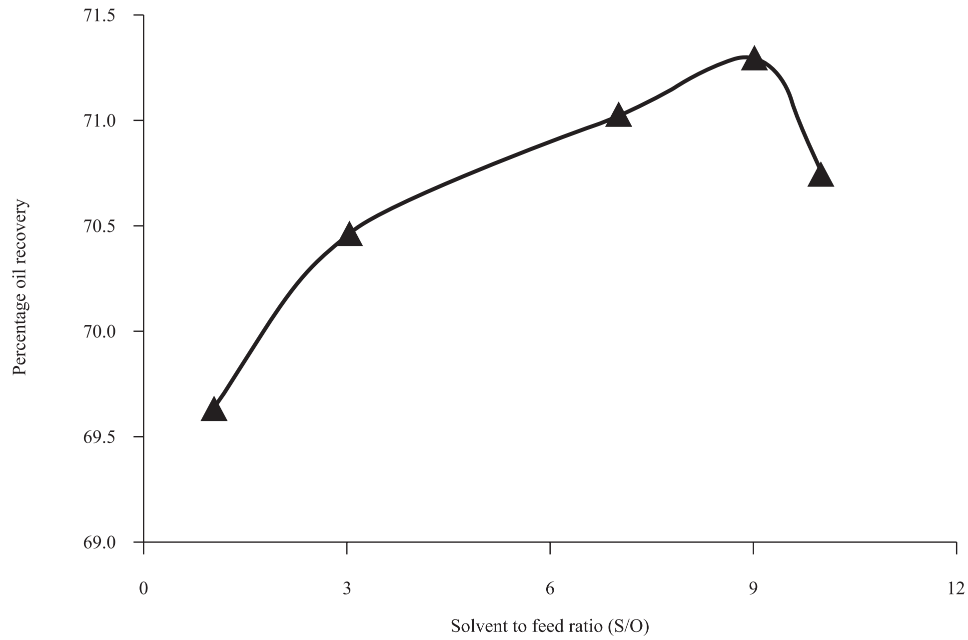

Figure 3: Percentage recovery of refined oil at different solvent to used oil ratio

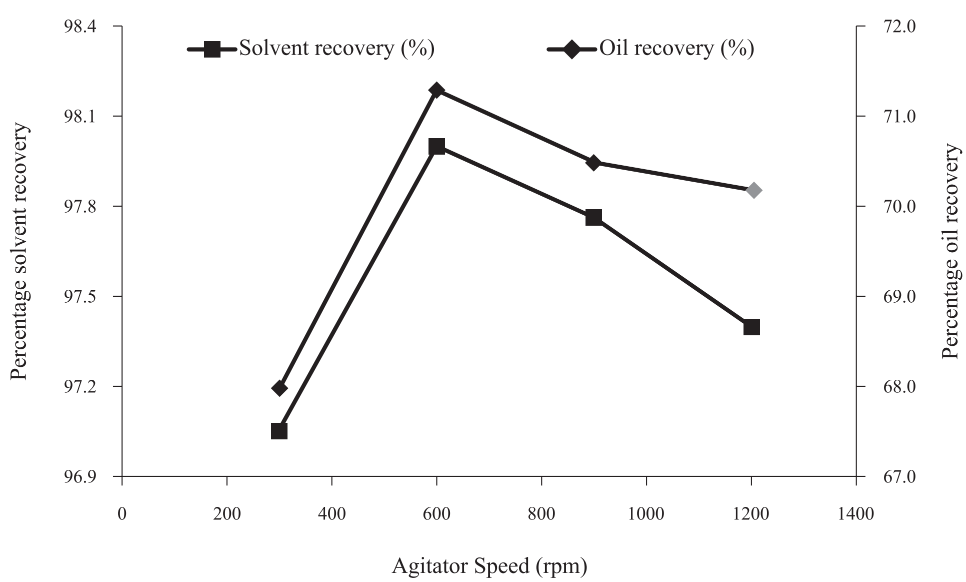

Figure 4: Percentage recovery of refined oil and solvent at different agitator speed

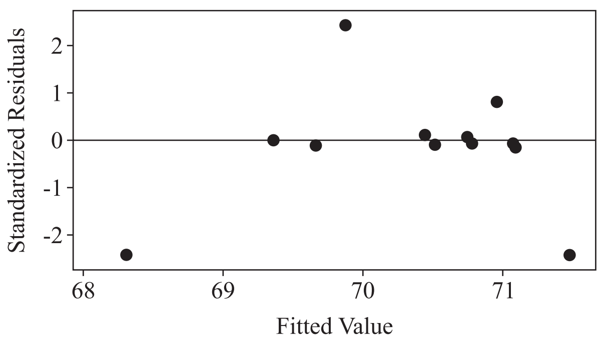

Figure 5: : Plot of Residual verses fitted value

Table 1: Physical properties of used oil, refine oil and standard oil for the different samples of used oil

Sample	Oil type	Pour point (oC)	Density (Kg/m3)	Flash point (oC)	Viscosity (Kg/m.s)
Shell Rimula-C, SAE 50	Used oil	-8	895	186	0.0716
	Refined oil	-9	886	240	0.0868
	Standard	-11	878	241	0.098
PSO DEO 3000 SAE 40	Used oil	-3	894	179	0.0109
	Refined oil	-5	883	227	0.0117
	Standard	-6	875	230	0.0124
PSO DEO 3000 SAE 50	Used oil	-4	892	195	0.0133
	Refined oil	-5	881	238	0.0150
	Standard	-6	874	240	0.0124

Product Analysis

For the analysis of refined and used oil different tests were carried out. These tests are pour point, density, flash point and viscosity. The physical properties of used oil and refine oil according to standard properties for the different oil samples have been shown in Table.1

The pour point, flash point and viscosity of the recovered oil were increased according to the standards while the density of the recovered oil was decreased after removing contaminants from the used oil. The flash point of the refined oil for each sample is quietly improved compared to other physical properties. So the refined oil may be proved has less hazardous and good quality during its reuse compared to the used oil.

CONCLUSION

In this study the effects of process parameters for the recycling of used oil were investigated using solvent extraction method. The process parameters, agitator speeds, solvent to used oil ratio and boiler temperature were optimized for the maximum recovery of refined oil and solvent. The optimum process conditions for the refined oil and solvent recovery were obtained when the agitator speed was 600 rpm at a boiler temperature of 120^0 C and solvent to used oil ratio of 9:1. The physical properties of the refined oil were compared to the standards.

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