Determining an Efficient Solvent Extraction Parameters for Re-Refining of Waste Lubricating Oils

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ABSTRACT

Re-refining of vehicle waste lubricating oil by solvent extraction is one of the efficient and cheapest methods. Three extracting solvents MEK ((Methyl-Ethyl-Ketone), 1-butanol, 2-propanol were determined experimentally for their performance based on the parameters i.e. solvent type, solvent oil ratio and extraction temperature. From the experimental results it was observed the MEK performance was highest based on the lowest oil percent losses and highest sludge removal. Further, when temperature of extraction increased the oil losses percent also decreased. This is due to the solvent ability that dissolves the base oil in waste lubricating oil and determines the best SOR (Solvent Oil Ratio) and extraction temperatures.

Key Words: **Waste Lubricating Oil Recycling, Solvent Extraction Parameters.**

1. INTRODUCTION

In re-refining waste lubricating oils, different methods have been used. In recent years the solvent extraction processes have been proposed as an alternative process being a simple process [1-6]. The usual acid-clay treatment successfully generates poisonous acidic sludge [7-8]; the solvent extraction replaces the common acid-clay treatment successfully [9-10]. In this process solvent has to mix with waste lubricant oil in proper proportion and fully miscible with the base oil and reject impurities (carbonaceous and additives) generally found in waste oils that flocculates and settled down due to gravity action, then recover the used solvent for recycle purpose during distillation. Among the alternative processes, solvent extraction re-refining remained efficient way for separating sludge particles from waste oil received considerable attention. It also reduces base oil losses from sludge phase around 10-14% quantity approximately that is more or less equal to impurities and addictiveness in the waste lubricating oil [11]. Fig. 1 shows schematic diagram solvent extraction experimental setups for re-refining of waste lubricating oil. The designing step is more difficult for development of suitable solvent extraction technique consists of solvent(s) type, extraction factors (SOR, pressure, temperature, etc). This process has capability of removing sludge particles from waste lubricating oil in maximum capacity and losing base oil amount minimum in sludge phase. For an optimum extraction, many processes have been demonstrated for hydrocarbons as solvents, ketones and alcohols [12]. Theses methods were used for solvent performance for optimization extraction that depend on solvent ability to remove sludge from waste lubricating oil and use physical properties, experimental data (polymer in waste lubricating oil additives and solubility of solvent) as indicator. Solvent's solubility

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parameters difference depend on the sludge removal in percent from waste lubricating oil and the polymer found normally in waste oils additives, Concluded that as difference in the solubility parameters increase, the solvent capability increases to remove the impurities and additives from the waste lubricating oil [13]. In the experimental work effective parameters of solvent extraction has been studied i.e. solvent type, solvent to oil ratio and temperature of extraction, based on the experimental results of oil losses and sludge removal aim to know about different in solubility among oil and solvent that decreases in the light of well-known hypothesis of Elias that oil decreases due to increases in miscibility of solvent in oil, as a result oil losses decreases experimentally determined at various extraction conditions [14].

2. EXPERIMENTAL WORK

A laboratory scale (glassware) setup was made in the Petroleum Refinery Laboratory, Institute of Petroleum & Natural Gas Engineering, MUET (Mehran University of Engineering & Technology), Jamshoro, Pakistan as shown in Fig. 1. The waste oil samples of different crankcase lubricating oil from internal combustion engines were collected from service stations and garages of different areas from Hyderabad and Karachi, mixed in a container to represent a mix feed stock to a re-refinery plant for recycling, it was kept in a closed drum to homogenize before to any testing. Used oil 30gm (W_{oil}) mixed with the commercial grade solvent (W_{sol}) of commercial grade solvents, MEK, 1-Butanol, 2- Propanol at a specified ratios in conical flask to evaluate the extraction performance at extraction temperatures, 20, 30 and 50^{o}C. The sample was stirred at 275-300 rpm for 30 min in the flask with no oil losses and ensured sufficient mixing. The temperature of bath was maintained and for gravity settlement it was left for 24 hours where in the bottom of the flask, sludge particles in black color were clearly observed and from the experiment work, following parameters were studied.

2.1 Percent Sludge Removal

The PSR (Percent Sludge Removal) indicates the weight of dry sludge (W_{dry}) in gram/kilogram separated from the wet sludge washed with n-hexane and 2-propanol as suggested by [15]. This process was used to remove oil content in the wet sludge expected about 95%. It was soaked in an oven at 100^{o}C for 10 min just to evaporate excess solvent then it was reported as dry sludge (W_{dry}) and the PSR was calculated in Equation (1):

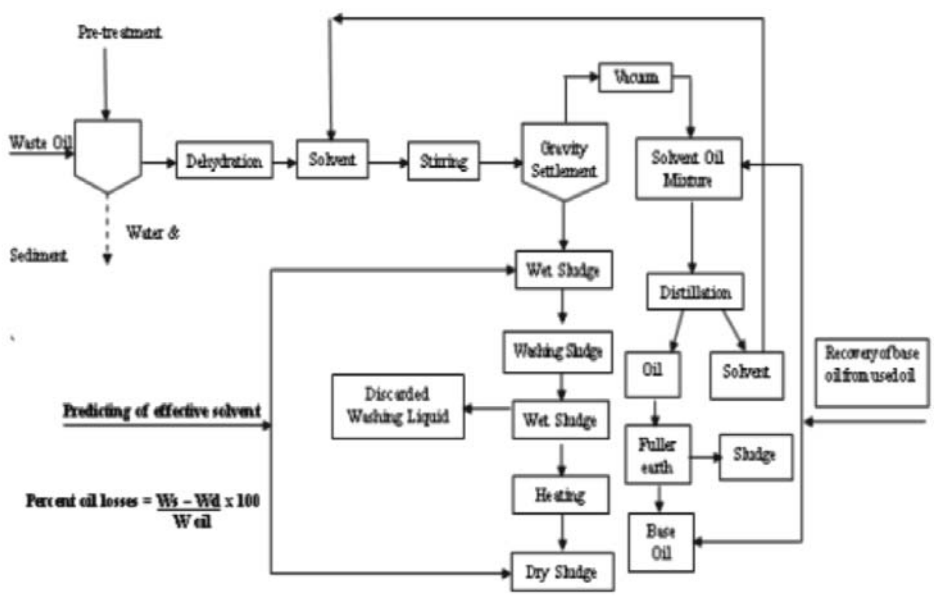

FIG. 1. FLOW DIAGRAM OF WASTE OIL RE-REFINING PROCESS BY SOLVENT EXTRACTION

$$PSR = \left(\frac{W_{dry}}{w_{oil}} \right) \times 100\% \quad (1)$$

2.2 Percentage Oil Loss

POL (Percentage Oil Loss) is defined as the loss of oil to the sludge during SEP process, in mass. Thus, POL was calculated by Equation (2):

$$POL = \left(\frac{W_{wet} - W_{dry}}{W_{oil}} \right) \times 100\% \quad (2)$$

3. RESULTS AND DISCUSSION

The performance of commercial grade hydrocarbon solvents, i.e. 1-Butanol, 2-Propanol, and MEK were investigated, determining the best solvent: oil ratio and temperature of extraction based on the solvents capability to dissolve base oil in waste oil.

Figs. 2-3 show the result of solvent: oil ratio on the oil losses percent and sludge removal for solvent 1-butanol at extraction temperatures of 20, 30 and 50^{o}C. It was observed that at extraction temperature 20^{o}C solvent: oil ratio increases but POL decreased and quick drop in POL amount was found at SOR (1.1 -1. 8) i.e. lower ratio and at SOR (2.0-2.6) oil losses POL found decreases.

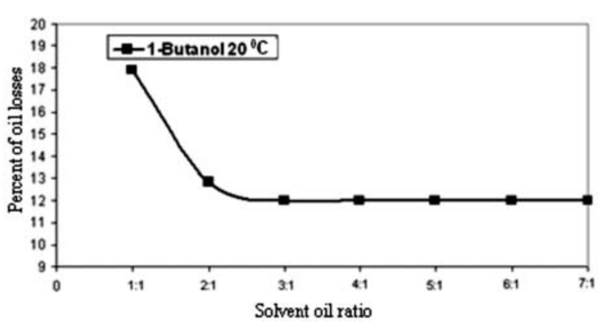

FIG. 2. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF OIL LOSSES FOR 1-BUTANOL AT 20^{O}C

This sector shows the optimum SOL (Solvent Oil Loss) at specified extraction temperature where to get the oil losses minimum in the sludge, the curve shows a retreating effect in the POL instead of further increase in the SOR. This is because of the fact that increasing SOR, oil losses in sludge phase getting reduction and for the other solvents at different extraction temperature, the same trends were found. The curves shown in the Figs. 2-3 for percent oil losses of 1- butanol - oil system, that the oil losses decreases as the extraction temperature increases, so for (SOR) 3:1 at temperature 20^{o}C the maximum oil losses found 12%, at temperature 30^{o}C was 10.8% weight and at temperature 50^{o}C was observed 10.5% and similar trend found at higher temperature. The effect of SOR on the PSR (Percent Sludge Removals) for same solvent at temperature 20, 30, and 50^{o}C is shown in Fig. 4. The rapid sludge removal percent weight found at waste oil ratio (1:1-2:1) and then gradually increasing the sludge removal percent was 15.5 using waste oil ratios (6:1).

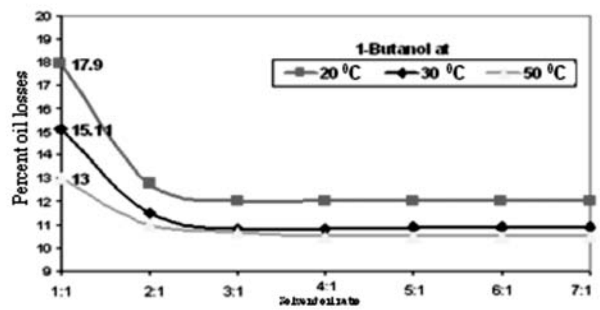

FIG. 3. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF OIL LOSSES FOR 1-BUTANOL AT 20,30 AND 50^{O}C

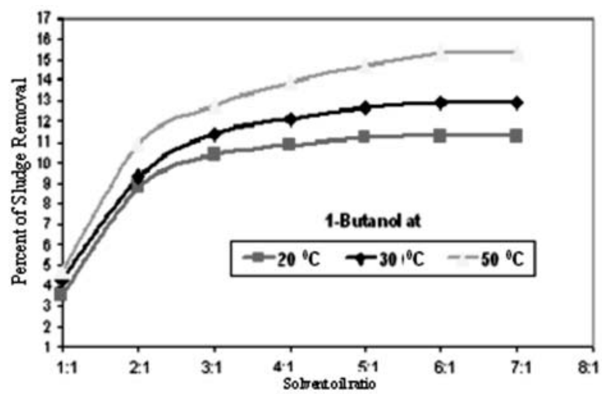

FIG. 4. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF SLUDGE REMOVAL FOR 1-BUTANOL AT 20,30 AND 50^{O}C

The oil losses curve for the 2-propanol solvents at temperature 20, 30 and 50°C is shown in Fig. 5. It was observed that due to the effect of SOR, POL was found as decreasing because of decreasing extraction temperature, the maximum oil losses found 11.3 with SOR 4:1 gave almost similar trends for PSR shown in Fig. 6.

These results are in close agreement with the PSR result reported by [8].This optimum value does not necessary correspond to maximum PSR because an increase of the SOR beyond the optimum point can still lead to an increase in percent sludge removal and minimum oil losses. Nimir, et. al. [16] have also worked on the solvent 2-propanol and concluded that an increase in the SOR leads to an increase of PSR but a decrease in POL. MEK offers the lowest POL and sludge removal shown in Figs. 7-8, when compare to solvents 1-butanol and 2-propanol as shown in Figs. 9-11. As per Elias hypothesis [12], a solvent having

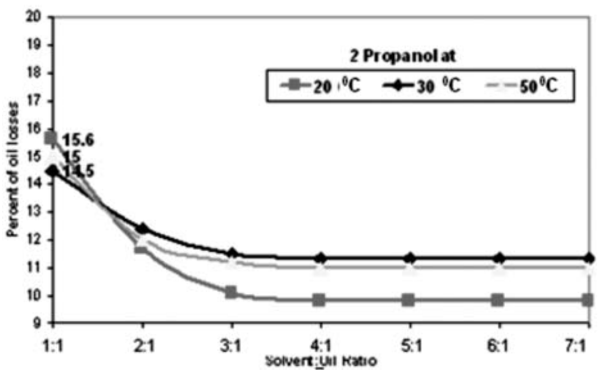

FIG. 5. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF OIL LOSSES FOR 2-PROPANOLAT 20, 30 AND 50^{O}C

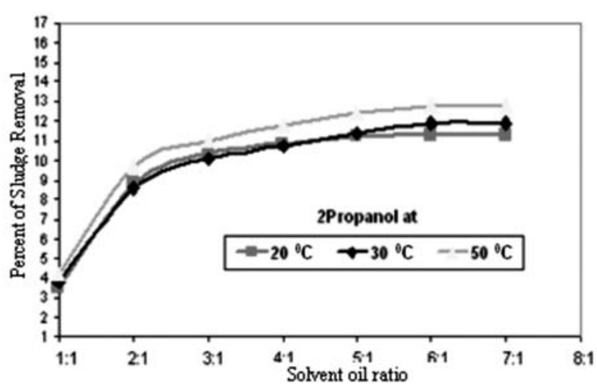

FIG. 6. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF SLUDGE REMOVAL FOR 2-PROPANOLAT 20, 30 AND 50^{O}C

solubility difference minimum from that of oil will have higher miscibility in oil hence lower oil losses percent and among the above solvents the lowest solubility difference i.e. (4(J/cm^3)1/2) has been found in MEK then by 1-butanol (6(J/cm^3)1/2) and 2-propanol (7(J/cm^3)1/2) Elbashir, et. al. [17] and Mutalib, et. al. [18] reported the measuring method for solubility parameters at different extraction temperature.

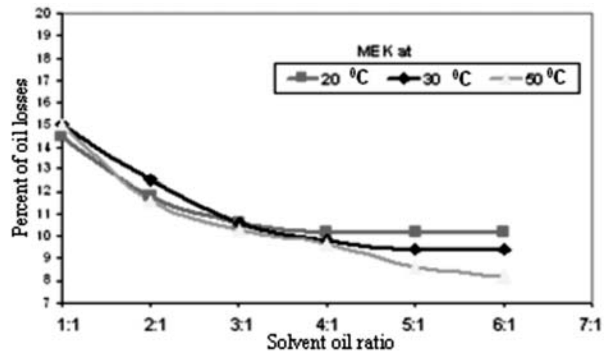

FIG. 7. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF OIL LOSSES FOR MEK AT 20, 30 AND 50^{O}C

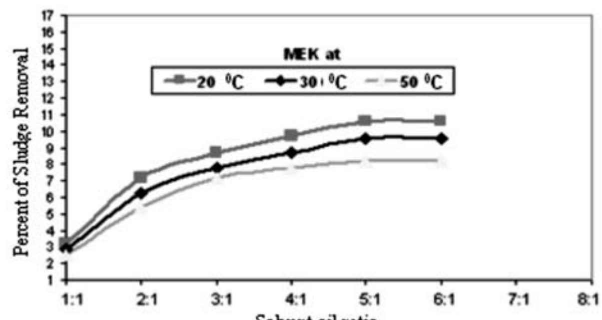

FIG. 8. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF SLUDGE REMOVAL FOR MEK AT 20, 30 AND 50^{O}C

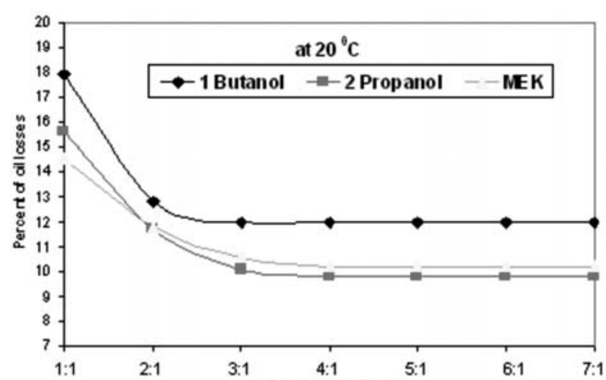

FIG. 9. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF OIL LOSSES FOR 1-BUTANOL, 2-PROPANOL AND MEK AT 20^{O}C

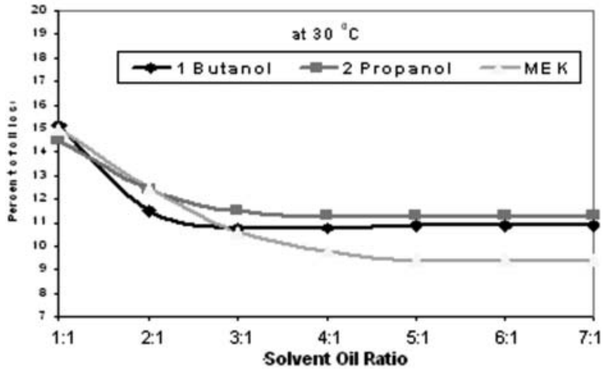

FIG. 10. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THE PERCENT OF OIL LOSSES FOR 1-BUTANOL, 2-PROPANOL AND MEK AT 30^{O}C

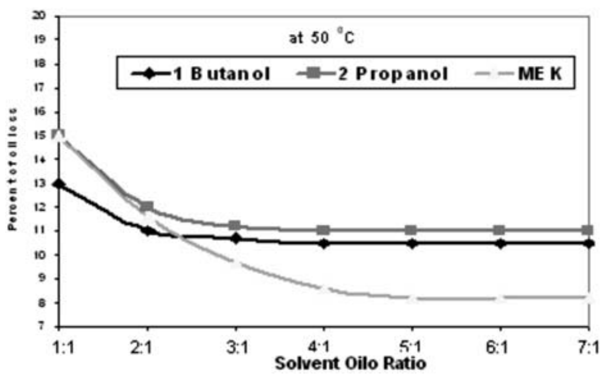

FIG. 11. EFFECT OF SOLVENT: OIL RATIO ON THE EXTRACTION MEASURED BY THEM PERCENT OF OIL LOSSES FOR 1-BUTANOL, 2-PROPANOL AND MEK AT 50^{O}C

4. CONCLUSIONS

The main objective of the study was to determine the efficient solvent extraction parameters i.e. SOR and extraction temperature based on the experimental results (i.e. SRP and POL). The principle investigation shows that the solvent Methyl-Ethyl- Keton gave the best results from that of oil. This research work is the guidance that before to carry out any extensive experimental work, initial determination of the best extraction conditions for particular solvent can be used.

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