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# Re-refining of used lubricant oil by solvent extraction using central composite design method

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**Abstract**–The primary aim of this study was to recover base oil from used oil using solvent extraction followed by the adsorption method. Many effective variables were examined within the solvent extraction method, including using different solvents, solvent/used oil, temperature and speed of blending. Central composite design (CCD) was applied as the statistical method. Response surface methodology was then used to find the optimum conditions in the process of extraction: ratio of solvent/used oil 2.4 and 3.12 vol/vol, temperature=54 and 18 °C, and speed of mixing=569 and 739 rpm for 1-butanol and methyl ethyl ketone (MEK), respectively. Various flocculation agents were used with the solvent, such as Sodium hydroxide (NaOH), Potassium hydroxide (KOH) and Monoethylamine (MEA); they provided an increase in the separation efficiency. The best result was obtained when using 2 grams of MEA/kg solvent; this amount of MEA increases sludge removal from 12.6% to 14.7%. In the process of clay adsorption, the variables that were tested included the ratio of clay/extract oil, temperature and time of contact. The best conditions in the process of adsorption by activated bentonite were a ratio of clay/extract oil=15 wt/vol%, temperature=120 °C, and time of contact=150 minutes. The recovered base oil was analyzed by Fourier transform infrared spectroscopy (FTIR) and compared to Iraqi specifications of base oils. The recovered base oil specifications were analyzed, including, viscosity @100 °C 8.32, 9.22 cSt, pour point −17.35, −22.23 °C, flash point 210.12, 223.04 °C, total acid number (TAN) 0.25, nill, total base number (TBN) nill, nill, ash 0.031, 0.0019 wt% and color 3.0, 2.5 for two types of base oil recovered using MEK, 1-butanol with activated bentonite, respectively.

Keywords: CCD, Optimization, Re-refining, Used Lubricant Oil

## INTRODUCTION

Within our modern society of advanced technology, the rise in the number of systems pertaining to power generation, for several services, requires an increasing amount of lubricants [1]. When utilized in machines and equipment, the lubricating oils are exposed to severe conditions and excessive temperatures that lead to the formation of a complex mixture called sludge; this usually contains additives causing degradation. The sludge can include heavy metals from engine wear and poly aromatic hydrocarbons (PAHs) from additive degradation, both of which are considered hazardous materials [1,2].

The disposal of used lubricating oil creates an environmental risk because it contains numerous amounts of impurities that have a negative impact on the environment if they are not treated. Furthermore, the used lubricating oil contains a high percentage of the base oil that can be recycled [3]. In general, lubricating oil contains ~71-96 wt% base oil and an additive ~29-4 wt% [4]. The primary reason for re-refining waste is usually to recover the lubricating oil base oil from the waste lubricating oil [5,6].

Solvent extraction is the preferred method in the re-refining of used lubricating oils since it does not require complex processes, it produces acceptable properties of recovered base oil, does not require large energy, and the expense is less compared to other methods [7].

The solvent extraction process includes constructing a model based on the central composite design (CCD) for simulating the sludge outlet yield of waste lubricating oil, and to find the optimum condition [5,6]. The CCD approach represents a method of investigating the response surface methodology, which includes a simulation of the relationship between quantitative variables as well as the process variables and the response variable locking combination process which offers an optimum expected response [8,9].

The present work describes the structure models based on the statistical and mathematical methods of CCD to simulate the sludge yield during the extraction process of used lubricant oil and optimization of its conditions, such as solvent/used oil ratio, temperature, and speeds of mixing.

## MATERIALS AND METHODS

### 1. Materials Used

The selected lubricating oil for this study with specifications as shown in Table 1 was obtained from Shell Co. after it was used in the electrical power generator type 350 KVA Perkins for a period of time. The used oil was first filtered and then subjected to a de-

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