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# The Effect of Extraction Temperature and Solvent to Oil Ratio on Viscosity Index of Mixed-medium Lubricating Oil Fraction by Using Solvents Extraction

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## Abstract

*In this study two types of extraction solvents were used to extract the undesirable polyaromatics, the first solvent was furfural which was used today in the Iraqi refineries and the second was NMP (N-methyl-2-pyrrolidone).*
*The studied effecting variables of extraction are extraction temperature ranged from 70 to 110°C and solvent to oil ratio in the range from 1:1 to 4:1.*
*The results of this investigation show that the viscosity index of mixed-medium lubricating oil fraction increases with increasing extraction temperature and reaches 107.82 for NMP extraction at extraction temperature 110°C and solvent to oil ratio 4:1, while the viscosity index reaches to 101 for furfural extraction at the same extraction temperature and same solvent to oil ratio. The increase in solvent to oil ratio has a higher effect on increasing the viscosity index of lubricating oil fraction compared with extraction temperature in furfural and NMP extraction.*
*Further more, the results show that the percentage yield of raffinate was decreased as the extraction temperature and solvent to oil ratio increases for furfural and NMP extraction.*

## Introduction

The NMP and furfural extraction processes uses as the solvents to remove the condensed ring aromatics and polar components from the lubricating oil distillates and bright stocks. This process was developed as a replacement for phenol extraction because of the safety, health, and environmental problems associated with the use of phenol. Several differences between the characteristics of NMP,furfural and phenol make furfural and NMP need to modify the phenol plant design. These differences include a 22 °C higher boiling point for NMP, a 64 °C lower in freezing point, complete miscibility of NMP with water, no azeotrope formation of NMP with water while the differences with furfural include 21°C lower boiling point for furfural, a 76.5°C lower in freezing point and high miscibility of furfural with water [1].

The non – toxic nature, high solvent power, good selectivity and excellent thermal and chemical stabilities of NMP, as well as its applicability to extraction of both paraffinic and naphthenic feed stocks, make it an attractive solvent for the extraction of lubricating oil stocks [2].

While lubricating oils (lube oils) include a large number of liquid petroleum products which have been developed for lubricating various types of machinery [3].
The lube oil base stocks are prepared from selected crude oils by distillation and special processing to meet the desired qualifications. Generally, lubes have a boiling point above 350°C and these are obtained as the main products from vacuum distillation units. Liquid lubricants find the greatest favor in engineering applications because they readily provide separation of surface when correctly applied, and have a high cooling ability when circulated through the bearing area. Also, they characterize by availability in suitable viscosities, low volatility, inertness (resistance to deterioration of the lubricant), corrosion protection (resistance to deterioration of the sliding surfaces) and low cost [4].
The liquids available for use as lubricating media can be classified into three types: animal or vegetable oils;

mineral oils; and synthetic oils. Mineral oils are the most popular lubricants because of their relatively low cost which results from two factors. Firstly, they are produced from the residue obtained from the distillation of crude oil which is otherwise used as fuel oil and is consequently cheap. Secondly, the advanced processing and blending techniques make possible a large of different types of oils in the same processing equipment [5].

The aim of the present work is to obtain lubricating oil with high viscosity index by extracting poor quality components like (polycyclic aromatic and naphthene-aromatic hydrocarbons with short side chains, and unsaturated) which naturally presented in raw lubricating oil fraction by using furfural and NMP solvents.

The study include Studying the effect of operating variables (extraction temperature and solvent to oil ratio) viscosity index and raffinate yield making a comparison between the performance of furfural and NMP solvents.

## Experimental Work

**Mixed-medium lubricating oil properties.**

In this work a mixed lube oil medium distillate fraction obtained from vacuum distillation unit of lube oil plant in Daura Refinery was used. The feedstock for vacuum distillation unit was atmospheric residue produced from mixed Iraqi crude oils (60 % of Basrah, 30 % of Kirkuk, 10 % of Sharki-Baghdad). Table 1 shows the properties of the mixed-medium-lube oil fraction used in this investigation.

Table 1 Properties of the mixed-medium lubricating oil.

| No. | Specification | Values |
|---|---|---|
| 1 | Specific gravity@ 60/60 °F | 0.89 |
| 2 | Viscosity, cSt, @ 40°C | 78.75 |
| 3 | Viscosity, cSt, @ 100°C | 21.25 |
| 4 | Viscosity index | 49 |
| 5 | COC flash point, °C | 141 |
| 6 | Pour point, °C | 21 |
| 7 | Sulfur content, % Wt | 2.975 |
| 8 | Color, ASTM-D1500, at 25°C | 5.26 |
| 9 | Refractive index | 1.4915 |

**Solvents**

The solvents used in this work are furfural and N-methyl-2-pyrrolidone. Table 2 shows the properties of these solvents.

Table 2 Properties of Furfural and NMP solvents.

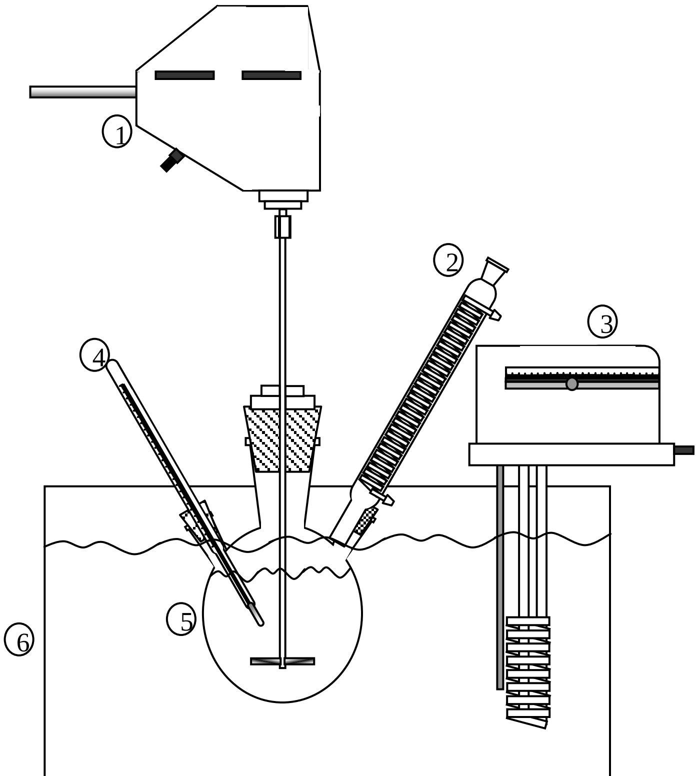
| No. | Specification | Values for NMP | Values for furfural |
|---|---|---|---|
| 1 | Boiling point, °C | 202 | 161 |
| 2 | Freezing point, °C | -24 | -36.5 |
| 3 | Viscosity, cPS, @25°C | 1.65 | 1.49 |
| 4 | Density ($d_4^{25}$), g/cm3 | 1.0270 | 1.1563 |
| 5 | COC flash point, °C | 95 | 68 |
| 6 | Refractive index | 1.4690 | 1.5235 |

**Extraction Experiments**

In the present work a laboratory batch extraction unit was used. Fig. 1 shows the schematic diagram of the laboratory extraction unit. This unit consists of a bench scale 1-liter, 3-necks pyrex flask extraction apparatus. The middle flask neck was connected with the mixer; the second neck was connected with reflux condenser and the third neck was connected with thermometer. Electrical mixer with 45 mm diameter paddle was used to mix the oil with the extraction solvent inside the extractor. The extractor was heated and controlled by using an oil bath (with heater and thermostat) in which the extractor is immersed. The lube oil fraction was mixed with the extraction solvent in the extractor at controlled specified temperature.

Mixing the two materials at the specified temperature was continued for a period of 30 min then the mixture was left at the specified temperature for 30 min to be separated in to two phases. The upper liquid phase is light raffinate solution and the bottom liquid phase is heavier extract solution. After steady state indicated by constant interface level, the two phases were separated by using a separating funnel. The two solutions were weighted to ensure material balance closure [2, 6].

The extraction process studied in the temperature range of 70-110°C and solvent to oil ratio of 1:1 to 4:1.




| | |
|---|---|
| 2 | Condenser |
| 3 | Heater |
| 4 | Thermometer |
| 5 | 3 necks Pyrex Flask |
| 6 | Oil Bath |

Fig. 1 Schematic Diagram of the Laboratory-Extraction.

**Test Methods**

1. **Density and Specific Gravity**
The density and specific gravity of lubricating oil were measured according to ASTM-D1481.
2. **Viscosity**
The viscosity of lubricating oil was measured according to ASTM-D445.
3. **Viscosity Index**
The viscosity indexes of lube oil distillate fraction and raffinate oil were calculated according to ASTM-D2270.
4. **Refractive Index**
The refractive index of lubricating oil was measured according to ASTM-D1218.
The refractive index is measured by the critical angle method with a Bausch and Lomb precision Refractmeter using monochromatic light.
This method is used for hydrocarbons having an ASTM color less than 4 (darkness)and it is limited to measuring refractive indices between 1.33 and 1.50, for temperature between 20 and 30°C [7].

## Results and Discussion

**Effect of Operating Variables and Solvent Type on Raffinate Viscosity.**

The viscosity of lubricating oil fraction is very important factor in the manufacture of lubricating oils, and the correct operation of the equipment depends upon the appropriate viscosity of the lubricating oil being used.In the present work the effect of extraction temperature on raffinate kinematic viscosity at 100°C was studied. Figures 2 and 3 show the effect of extraction temperature on raffinate viscosity for furfural and NMP extraction respectively.

In general, the viscosity of raffinate produced from furfural or NMP extraction is decreased with increasing the extraction temperature and solvent to oil ratio and that may be due to the extraction of aromatic materials especially polycondensed aromatics from the lubricating oil fraction. The aromatics have the higher viscosity among the hydrocarbons that presented in raw lubricating oils and the extraction of these materials decrease their content in the produced raffinate and increase the paraffins content which has a viscosity relatively lower than that of aromatics as mentioned by Kosters [8].

Figures 2 and 3, clearly indicate that the extraction temperature has slightly effect on the viscosity of raffinate compared with the effect of solvent to oil ratio and the viscosity of the raffinate produced from NMP extraction is slightly lower than that produced from furfural extraction using the same operating variables, because of the higher activity and high solvent power of NMP than furfural [9].

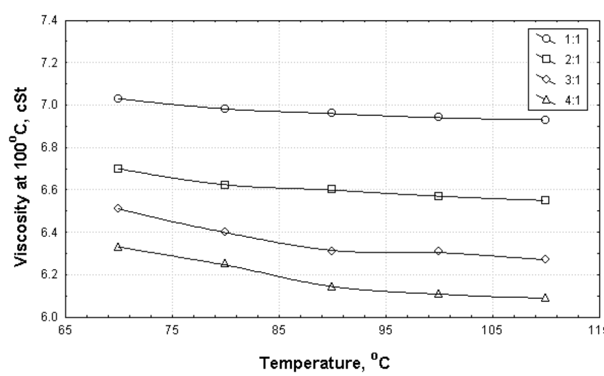



Fig. 2 Effect of extraction temperature on raffinate viscosity at different solvent to oil ratio for furfural extraction

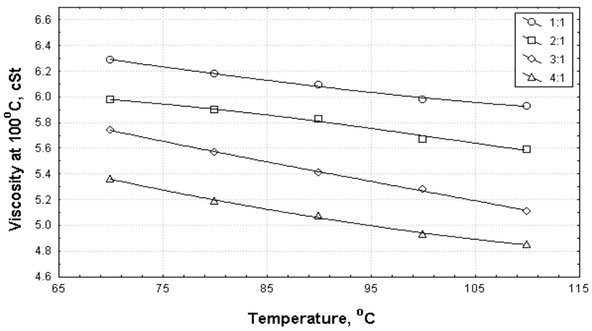



Fig. 3 Effect of extraction temperature on raffinate viscosity at different solvent to oil ratio for NMP extraction.

**Effect of Operating Variables and Solvent Type on Raffinate Viscosity Index**

The viscosity index of lubricating oil reflects the ability of lube oil viscosity to vary with temperature. Figures 4 and 5 show the effect of extraction temperature at different solvent to oil ratio on raffinate viscosity index for furfural and NMP extraction, respectively. The increase in extraction temperature will encourage the solubility of undesirable materials especially polycondensed aromatics (which reduce the viscosity index of lubricating oil) in extraction solvent. It is obvious from figures 4 and 5 that the viscosity index of lubricating oil fraction increases with increasing the extraction temperature and solvent to oil ratio.The increase of extraction temperature 10°C will increase the viscosity index one to three point for a given solvent to oil ratio using furfural and NMP as extraction solvents. The increase in raffinate viscosity index related to the reduction in naphthene – aromatic and polar aromatic content and the increase in saturates content in the produced raffinate [3]. The higher solvent power of NMP compared with furfural gave higher viscosity index using the same operating variables.

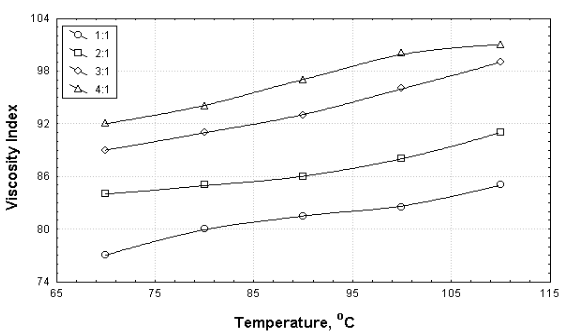



Fig. 4 Effect of extraction temperature on raffinate viscosity index at various solvent to oil ratio for furfural extraction

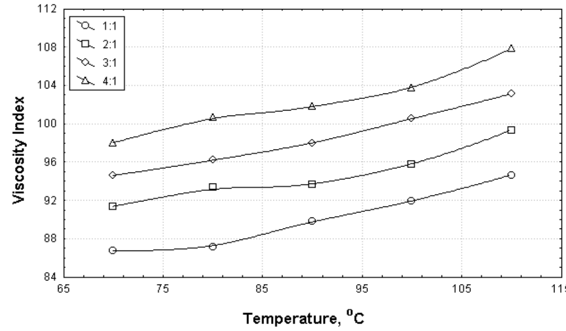



Fig. 5 Effect of extraction temperature on raffinate viscosity index at various solvent to oil ratio for NMP extraction

**Effect of Operating Variables and Solvent Type on Raffinate Yield**

Many factors controlling the operating conditions of solvent extraction. One of these important factors affecting the overall process performance is the lubricating oil yield. Fig. 6 and 7 explain the effect of extraction temperature on raffinate yield at various solvent to oil ratio for furfural and NMP extraction, respectively. It appears from these figures that the yield percentage will decrease as the extraction temperature increase and solvent to oil ratio decrease.

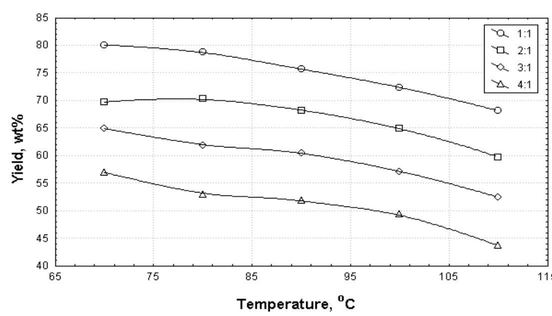



Fig. 6 Effect of extraction temperature on raffinate yield at various solvent to oil ratio for furfural extraction.

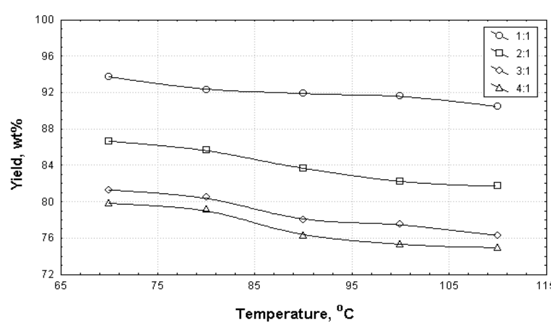



Fig. 7 Effect of extraction temperature on raffinate yield at various solvent to oil ratio for NMP extraction.

**The performance comparison of oil extraction by furfural and NMP**

The comparison was done at extraction temperature of 110°C and solvent to oil ratio in the range 1:1 to 4:1 for furfural and NMP extraction. figure 8 show the effect of increasing the solvent to oil ratio on raffinate viscosity index for furfural and NMP extraction at 110°C, while Fig. 9 shows the effect of increasing solvent to oil ratio on raffinate yield for furfural and NMP extraction at 110°C. Fig.8 indicates that the raffinate viscosity index produced from NMP extraction is higher than that obtained from furfural extraction.The difference in viscosity index at solvent to oil ratio 1:1 is about 10% and decreases to about 6% at solvent to oil ratio 4:1. Fig.9 indicates that the raffinate yield produced from NMP extraction is higher than that obtained from furfural extraction. The difference in the yield at solvent to oil ratio 1:1 is about 25% and increases to about 44% at solvent to oil ratio 4:1.

From the above mentioned discussion it may be concluded that NMP was the most efficient solvent for the extraction of lubricating oil fraction used in this study because low solvent to oil ratio can be used to produce the same raffinate viscosity index, an equivalent or higher raffinate yield obtained from NMP extraction at solvent to oil ratio higher than 1:1, low solvent toxicity, better heat stability (high boiling point).

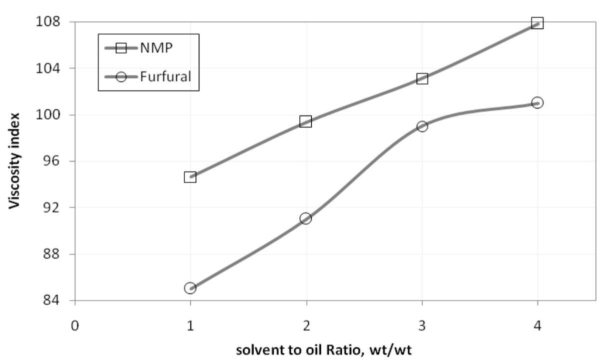



Fig.8 Effect of solvent to oil ratio on raffinate viscosity index for furfural and NMP extraction at 110°C

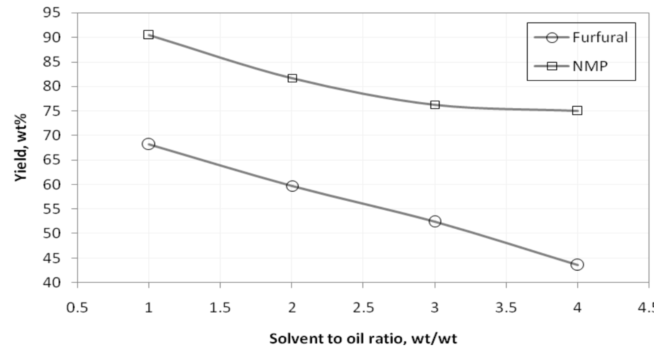



Fig. 9 Effect of solvent to oil ratio on raffinate yield for furfural and NMP extraction at 110°C

## Conclusions

1. The raffinate viscosity index produced from NMP extraction was higher than that produced from furfural extraction at same extraction temperatures and at the same solvent to oil ratio
2. The raffinate yield produced from NMP extraction was higher than that produced from furfural extraction at same extraction temperatures and at the same solvent to oil ratio.

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# تاثير درجة حرارة الاستخلاص ونسبة المذيب الى الزيت على معامل اللزوجة لمقطع متوسط من زيت التزييت باستخدام عملية الاستخلاص بالمذيبات.

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## الخلاصة

تم استخدام نوعين من المذيبات لأستخلاص المواد غير المرغوبة هذه المذيبات هي الفورفورال والمستخدم حاليا في المصافي العراقية والمذيب الاخر NMP (N-Methyl, 2, pyrrolidone).

المتغيرات المؤثرة على عملية الاستخلاص والتي تم دراستها هي درجة حرارة الاستخلاص و تتراوح من 70 الى 110 °م لكل من عمليتي الاستخلاص بالفورفورال و NMP و المتغير الآخر هو نسبة المذيب الى الزيت وتتراوح بين 1:1 الى 4:1 لعملية الاستخلاص بالفورفورال وتتراوح بين 1:1 الى 4:1 لعملية الاستخلاص بـــ NMP.

اظهرت نتائج البحث ان معامل اللزوجة للرافنيت الناتج من عملية استخلاص المقطع الزيتي يزداد بزيادة درجة حرارة الاستخلاص وزيادة نسبة المذيب الى الزيت ليرفع من (49) للمقطع الزيتي الخام ليصل الى (107) لعملية الاستخلاص بـــ NMP عند درجة حرارة الاستخلاص 110 °م ونسبة المذيب الى الزيت 4:1, بينما يصل الى (101) لعملية الاستخلاص بالفورفورال عند نفس الظروف من درجة حرارة الاستخلاص و نسبة المذيب الى الزيت, وهذا يعني انه يمكن الحصول على معامل لزوجة اعلى عند استخدام NMP بدلا من الفورفورال كمذيب في عملية الاستخلاص تحت نفس الظروف من درجة حرارة الاستخلاص ونسبة المذيب.

الزيادة في نسبة المذيب الى الزيت اكثر تاثيرا على زيادة معامل اللزوجة لمقطع زيت التزييت مقارنة مع درجة حرارة الاستخلاص باستخدام مذيب الفورفرال او ال NMP بالاستخلاص.

اكثر تفصيلا, اظهرت النتائج ان نسبة الانتاجية للرافينيت قد قـــلت مع زيادة درجة حرارة الاستخلاص ونسبة المذيب الى الزيت باستخدام مذيب الفورفرال او ال NMP بالاستخلاص.