Chem. Chem. Technol., 2023,
Vol. 17, No. 2, pp. 460–468

Chemical Technology

STUDY ON THE PURIFICATION PROCESS OF USED MOTOR OILS IN THE PRESENCE OF CRYSTALLINE UREA

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https://doi.org/10.23939/chcht17.02.460

Abstract. The paper deals with the results of the study on the purification process of used mineral and semi-synthetic motor oils in the presence of crystalline urea. The effect of the process main factors (the amount of the main reagent, time, and temperature) on the performance indicators of purified motor oils was studied. Used mineral and semi-synthetic motor oils for gasoline and diesel engines were purified under the established optimal conditions. The results of X-ray-fluorescence and IR-spectroscopic studies on the chemical composition of motor oils purified in the presence of urea are presented.

Keywords: mineral motor oil, semi-synthetic motor oil, used oil, urea, oil aging, X-ray fluorescence analysis, IR spectra.

1. Introduction

Ukraine has a long history of extraction and processing of oil, natural gas, and coal.[1-7] The above-mentioned raw materials serve for obtaining products of organic synthesis. Moreover, oil is a source of commercial oils that are used in the operation of various mechanisms.

Over the last decade, Ukraine has increased its consumption of commercial oils and nowadays there are more than 500,000 tons/year of used oil products. This is similar to the resource of Germany, for example, which annually accumulates more than 600,000 tons/year of used lubricants. Since Ukraine imports the most of lubricants, it is important to collect and recycle used oils. Moreover, considerable volumes of used lubricants accumulated annually in Ukraine, are one of the most acute environmental problems[8,9] caused by insufficiently developed collection systems and almost undeveloped facilities for their regeneration or disposal.[9]

It is known that used motor oils are highly toxic, complex multicomponent systems formed during an internal combustion engine operation. Numerous studies have identified more than 140 types of carcinogenic polycyclic hydrocarbons in used motor oils (UMO), the number of which increases in direct proportion to the increase of UMO operating life.[10-12] That is why UMO is classified as the hazardous substance of the 4th class according to its toxicity.

In Ukraine and many developed countries of the world, decisions of the Stockholm and Basel Conventions are in force, according to which it is necessary to control the disposal of UMO. They impose obligations on participating countries to minimize the production of hazardous waste, ensure adequate disposal facilities, as well as ensure environmentally safe management of waste containing hazardous carcinogenic substances.[8]

As a result of the operation of motor vehicles with gasoline or diesel internal combustion engines (ICE), motor oil is continuously exposed to high temperatures, action of metals, the influence of chemical reactions (oxidation, thermal decomposition, polymerization, polycondensation, sealing, *etc.*), external pollutants, catalysts (wear products of metal surfaces), *etc.*[12] As a result of this, oil accumulates products of additives decomposition, oxidation, incomplete combustion, ICE parts wear, sealing of the hydrocarbon part, and asphalt-resinous substances, which causes irreversible changes in its qualitative chemical composition. Numerous studies by leading scientists and scientific organizations have established that the chemical composition of motor oils during their operation in ICE changes slightly, the products of physicochemical transformations of oil components, as well as impurities that enter from the outside and make oils unsuitable for further operation, make up ~20–25 % of their total mass, while 75–80 % of the hydrocarbon component of motor oil remain unchanged. Owing to the extraction of aging products from UMO, the operational properties of used oils are similar to those of virgin oil produced from petroleum crude. Therefore, the urgent problem is to develop regeneration technologies, which would provide a high yield of regenerated oil and could be implemented in domestic enterprises without significant modernization of existing equipment.[13]

In the oil refining industry, to improve the low-temperature properties of fuels and oils the dewaxing

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process applying urea is widely used. The process is characterized by significant amounts of urea (~100 wt.% relative to raw material) and solvent (50-100 wt.% relative to raw material); the process time is 30 minutes and the process temperature is 303–323 K. As a result of the process, urea complexes with paraffin hydrocarbons are formed, which are removed by filtration. The obtained deparaffinizate is characterized by a significant decrease in freezing point and a slight decrease in the acid number.[14]

The complex-forming ability of urea has inspired researchers and scientists on the possibility of its use in the technology of UMO purification.

Previously,[15] we established the basic possibility of purifying used oil mixtures in the presence of urea and determined the change in the operational characteristics of the purified oils. The proposed method cannot be used independently, but only as an intermediate stage of the combined process of mineral oil purification. However, this method has not been studied for used mineral and semi-synthetic motor oils, which to date are one of the most massive groups of oils used in internal combustion engines of regional and international transport (commercial use class).

Therefore, it is important to establish the possibility of using crystalline urea in the purification technology for used mineral and semi-synthetic motor oils. This will make it possible to create a new method of purification, which would be characterized by the absence of alcohol, aqueous or ammonia solutions of urea and provide purified oils with a low acid value, the absence of water, and a higher value of viscosity-temperature properties.

2. Experimental

The most available and most widely used motor oils were chosen as the initial objects of research. NORMAL 15W-40 oil for gasoline engines and M-10DM for diesel engines were chosen as used mineral motor oils. Castrol 10W-40 oil for diesel engines in trucks and ELF Evolution 700 STI for gasoline engines in passenger cars were chosen as used semi-synthetic motor oils. The above-mentioned oils were removed from the crankcases of gasoline and diesel engines after the end of their standard operating life.

The densities of the investigated oils were determined by the pycnometric method, the viscosity – by the viscometric method; the refractive index was determined by a refractometer, the flash point – in an open-type device; the acid number (AC) was determined by potentiometric titration, the water content and ash content – according to the procedures described in the literature.[16]

X-ray fluorescence was used to determine the elemental composition of oils and was carried out using a mobile precision analyzer EXPERT 3L, the assignment of which is to determine the mass fraction of chemical elements in monolithic and homogeneous powder objects. For the analysis, we prepared oil samples, which were burned at 723 K for 4 h, cooled in a desiccator and ground.[17]

IR spectroscopy was performed on Spectrum Two FT-IR spectrometer of PerkinElmer firm in the cell made of zinc selenide with 0.1036 mm of thickness. The program Spectrum v.10.03.06 was used.

Purification of UMO with crystalline urea was carried out in a laboratory setup. Used engine oil is loaded into a container equipped with mechanical stirring, a thermometer, and a dispenser for supplying the reagent. The sample is heated to the process temperature, and after reaching it crystalline urea is added through the dispenser in equal portions at certain equal intervals of time under continuous stirring. After adding the last portion of urea, the process is carried out at the previously determined temperature and time. At the end of the process, the reaction mixture is cooled and transferred to a separating funnel for settling, after which the lower layer is removed, and the upper layer of purified oil is filtrated.

3. Results and Discussion

A unique feature of urea is its ability to form urea complexes due to its hexagonal structure. This determines its ability to form complexes with *n*-alkanes, organic acids, ketones, aldehydes, ethers, esters due to their penetration into the hollow channels of the urea complex. The obtained complexes are so-called clathrates, which are formed due to the fact that normal alkanes and their derivatives penetrate into the thinnest hollow channels present in the crystal lattice of urea, while compounds with a branched hydrocarbon chain do not form complexes with urea, since their molecules cannot fit into the channels crystal lattice of urea.[16]

To develop a procedure of UMO chemical regeneration in the presence of crystalline urea, it is necessary to study the influence of the process main factors (the reagent amount, temperature and time of the process, and the UMO nature) on the main performance indicators of purified motor oils. The obtained experimental results are presented in Tables 1-6.

Tables 1 and 2 show that with an increase in the urea amount there is a decrease in the value of acid number (AN), a slight increase in the kinematic viscosity and viscosity index (VI). A significant reduction of the AN is achieved when using 5 wt.% of urea. At the same time, a further increase in the reagent amount from 5 to 12 wt.% almost do not change the AN value. An increase in the urea amount has a positive effect on the reduction of ash content and the amount of mechanical impurities. Water is absent in the presence of urea.

Table 1. Effect of the urea amount on the performance indicators of purified mineral motor oil M-10DM

Urea amount, wt.%	Acid number, mg KOH/g	Water content, %	Viscosity, mm^2/s		Viscosity index	Ash content, %	Mechanical impurities, %	Yield, wt.%
			ν_{50}	ν_{100}				
0	2.71	0.14	51.65	10.22	88	0.940	0.062	-
1	1.45		51.81	10.57	92	0.900	0.055	98.50
3	0.55		52.30	10.77	93	0.850	0.049	97.70
5	0.32	–	52.60	10.97	94	0.765	0.039	97.00
7	0.32		52.91	10.97	94	0.700	0.030	96.25
9	0.32		53.44	10.97	95	0.670	0.028	95.78
12	0.32		53.75	11.24	96	0.650	0.025	95.00

Note: the process time is 80 minutes, the temperature is 413 K.

Table 2. Effect of the urea amount on the performance indicators of purified semi-synthetic motor oil ELF Evolution 700 STI

Urea amount, wt.%	Acid number, mg KOH/g	Water content, %	Viscosity, mm^2/s		Viscosity index	Ash content, %	Mechanical impurities, %	Yield, wt.%
			ν_{50}	ν_{100}				
0	2.43	0.11	50.74	9.58	90	0.458	0.042	–
1	1.34		51.24	10.36	91	0.582	0.040	98.70
3	0.75		51.67	11.11	92	0.563	0.038	98.42
5	0.35	–	52.68	11.42	92	0.369	0.032	97.50
7	0.35		53.24	11.64	92	0.367	0.031	96.83
9	0.35		53.89	12.74	93	0.365	0.030	96.34
12	0.34		54.94	12.82	95	0.363	0.028	96.18

Note: the process time is 80 minutes, the temperature is 413 K.

Table 3. Effect of the process temperature on the performance indicators of the purified M-10DM mineral motor oil

Temperature, K	Acid number, mg KOH/g	Water content, %	Viscosity, mm^2/s		Viscosity index	Ash content, %	Mechanical impurities, %	Yield, wt.%
			ν_{50}	ν_{100}				
–	2.71	0.14	51.65	10.22	88	0.940	0.062	-
353	2.25	0.10	51.75	10.31	89	0.901	0.054	98.00
373	1.89	0.06	51.83	10.65	91	0.823	0.048	97.70
393	1.02		52.01	10.75	92	0.789	0.044	97.40
413	0.32	traces	52.60	10.97	94	0.765	0.039	97.00
433	0.31		52.71	11.13	95	0.745	0.030	96.55

Note: the urea amount is 5 wt.% , and the process time is 80 minutes.

Table 4. Effect of the process temperature on the performance indicators of the purified semi-synthetic motor oil ELF Evolution 700 STI

Temperature, K	Acid number, mg KOH/g	Water content, %	Viscosity, mm^2/s		Viscosity index	Ash content, %	Mechanical impurities, %	Yield, wt.%
			ν_{50}	ν_{100}				
–	2.43	0.11	50.74	9.58	90	0.458	0.042	-
353	1.81	0.09	51.22	10.28	91	0.443	0.040	98.00
373	1.53	0.07	51.75	10.42	91	0.415	0.038	97.73
393	1.15		52.13	11.15	92	0.385	0.033	97.65
413	0.35	traces	52.68	11.42	92	0.369	0.032	97.50
433	0.33		52.93	11.89	93	0.365	0.030	97.30

Note: the urea amount is 5 wt.% , the process time is 80 minutes.

The obtained results can be explained by the fact that, in addition to forming complexes with paraffin hydrocarbons of a normal structure, urea is able to adsorb organic pollutants on its surface and precipitate them.[15] The compounds formed in this way, being in the oil layer, are able to influence the values of kinematic viscosity and

viscosity index. At the same time, the decrease in ash content and content of mechanical impurities, in our opinion, can be explained by the fact that during the reaction of UMO with crystalline urea, UMO exhibits coagulating properties concerning mechanical impurities, which are subsequently removed from the oil by filtration.

The study of the temperature effect on the UMO purification process in the presence of crystalline urea was carried out according to the procedure presented above, and the obtained results are shown in Tables 3 and 4.

With the increase in temperature, the AN value decreases, as well as the content of water, ash, and mechanical impurities (Tables 3 and 4). At the same time, there is an increase in the values of kinematic viscosity and VI, which is also explained by the above-mentioned statement about the adsorption of UMO acid-based aging products on the crystalline complex surface followed by the formation of high molecular compounds. At the temperature of 413 K and higher the values of the examined indicators differ slightly from each other, which allows us to establish the optimal temperature of the UMO purification process with crystalline urea as 413 K.

The study of the effect of the process time on the product characteristics was carried out according to the procedure described above, and the obtained results are presented in Tables 5 and 6.

Table 5. Effect of process time on the performance indicators of the purified M-10DM mineral motor oil

Time, min	Acid number, mg KOH/g	Water content, %	Viscosity, mm^2/s		Viscosity index	Ash content, %	Mechanical impurities, %	Yield, wt.%
			ν_{50}	ν_{100}				
0	2.71	0.14	51.65	10.22	88	0.940	0.062	-
30	1.58	0.08	51.75	10.52	90	0.843	0.051	97.65
60	0.89	traces	51.93	10.75	92	0.793	0.043	97.35
80	0.32		52.60	10.97	94	0.765	0.039	97.00
100	0.31		52.98	11.17	95	0.712	0.037	96.65

Note: the urea amount is 5 wt.% , and the process temperature is 413 K.

Table 6. Effect of process time on the performance indicators of the purified semi-synthetic motor oil ELF Evolution 700 STI

Time, min	Acid number, mg KOH/g	Water content, %	Viscosity, mm^2/s		Viscosity index	Ash content, %	Mechanical impurities, %	Yield, wt.%
			ν_{50}	ν_{100}				
–	2.43	0.11	50.74	9.58	90	0.458	0.042	-
30	1.32	0.09	51.25	10.42	91	0.421	0.039	98.21
60	0.83	traces	51.75	10.79	91	0.393	0.035	97.82
80	0.35		52.68	11.42	92	0.369	0.032	97.50
100	0.34		52.90	11.83	92	0.363	0.030	97.30

Note: the urea amount is 5 wt.% , the process temperature is 413 K.

Table 7. Performance indicators of M-10DM and NORMAL 15W40 mineral and semi-synthetic motor oils purified in the presence of urea under optimal conditions

Indicator	Mineral motor oils				Semi-synthetic motor oils			
	M-10DM		NORMAL 15W-40		Castrol 10W-40		ELF 700 STI	
	Used	Purified	Used	Purified	Used	Purified	Used	Purified
Acid number, mg KOH/g	2.71	0.32	1.96	0.56	2.25	0.38	2.43	0.35
Water content, %	0.14	traces	0.15	traces	0.15	traces	0.11	traces
Viscosity, mm^2/s								
ν_{50}	51.65	52.60	69.81	70.15	84.86	115.50	50.74	52.68
ν_{100}	10.22	10.97	13.96	14.54	11.97	14.72	9.58	11.42
Viscosity index	88	94	110	116	60	60	90	92
Ash content, %	0.940	0.765	0.534	0.428	0.470	0.194	0.458	0.369
Mechanical impurities, %	0.062	0.039	0.039	0.028	1.24	0.51	0.042	0.030
Yield, wt.%	–	97.00	–	97.00	–	97.00	–	97.50

Note: the process temperature is 413 K, the time is 80 min., and the urea amount is 5 wt.%.

Based on the obtained results, we can state that the increase in the process time results in a decrease in the values of AN, water content, ash content, and mechanical impurities. At the same time, there is an increase in the values of kinematic viscosity and VI (Tables 5 and 6). However, in the period from 80 to 100 min. there is no significant change in the above-mentioned performance indicators, which allows us to establish the optimal process time as 80 minutes.

Performance indicators of used mineral and semi-synthetic motor oils purified in the presence of urea under established optimal conditions are represented in Table 7.

The comparative experimental results confirm that the proposed method allows to purify UMO from water, partially from acidic compounds, and to reduce the content of mechanical impurities and ash content.

It is known that all commercial motor oils contain in their composition a significant amount of metal-containing additives to increase or give oils certain properties. During oil action in ICE, additives are destroyed and contaminate the oil with their decomposition products [18-21]. The durability of the engine and the service life of lubricating oils can be determined by the additives wearability. Therefore, by analyzing the content of metals (indicators of mechanical wear of ICE parts) and the changes in the oil elemental composition, it is possible to effectively control the properties of engine oils and diagnose faulty tribological units of the engine.

The composition of the inorganic part of investigated used and purified oils was studied using X-ray fluorescence analysis. The obtained results are represented in Table 8.

Table 8. Elemental composition of the inorganic part of motor oils

Element	Metals content, ppm							
	Mineral motor oil				Semi-synthetic motor oil			
	M-10DM		NORMAL 15W-40		Castrol 10W-40		ELF 700 STI	
	Used	Purified	Used	Purified	Used	Purified	Used	Purified
Ca	16006.4	13259.7	1445.7	1197.6	3354.5	1425.9	3266.6	2934.1
Zn	4033.1	3341.0	4360.9	3612.6	1282.2	472.9	1169.2	640.1
Cu	53.8	44.6	74.1	61.3	23.2	11.7	12.2	10.4
Cr	64.2	53.7	52.6	43.6	0.8	0.8	<1.9	<1.9
Fe	307.1	254.4	696.4	576.7	22.6	18.2	10.0	3.1
Mo	1.5	1.2	48.2	39.9	15.9	8.6	111.3	103.6
Pb	26.9	22.3	16.1	13.3	<1.1	1.1	6.0	1.0

Earlier,[20,21] we presented a detailed description of changes in the amount of the metals given in Table 8 in the original and used motor oils of the mentioned brands. However, the proposed method of UMO purification with crystalline urea allows, although not completely, to remove some metals from the chemical composition of purified oils. In particular, this refers to zinc, calcium, iron, lead, *etc.* In our opinion, the removal of the above-mentioned metals occurs as a result of their coagulation with urea, precipitation, and subsequent filtration of oils after the completion of their purification process.

To confirm the decrease in the content of oxygen-containing aging products in samples of purified semi-synthetic motor oils, an IR spectral analysis was carried out, the results of which are shown in Figs. 1 and 2.

Analyzing the IR spectra of the used and purified ELF 700 STI semi-synthetic motor oil (SSMO), we can see some differences. Primary oxygen-containing products of "aging" (aldehydes, ketones, alcohols, ethers, esters, and organic acids) formed as a result of oxidation, polymerization, thermal decomposition, recombination, and condensation processes of engine oil hydrocarbons were found in SSMO (Fig. 1). The presence of these products in the IR spectrum of used oil containing the C=O group is confirmed by absorption bands in the region of 1740–1690 cm^{-1}. However, such bands are observed in the spectrum of purified oil as well, but with lower absorption intensity. Organic acids in the used oil were identified by absorption bands of the carboxyl group in the region of 1720-1680 cm^{-1}. In the IR spectrum of purified semi-synthetic motor oil, the intensity of absorption bands of organic acids is lower (Fig. 2).

Ethers in SSMO were identified in the region of 1125–1025 cm^{-1} by asymmetric stretching vibrations of the C–O–C bond; however, in the IR spectrum of purified oil, these vibrations have lower intensity. The pres-

ence of esters in the IR spectrum of used SSMO is confirmed by absorption bands at 1740–1730 cm^{-1}, which corresponds to the absorption band of the C=O group of aliphatic esters, as well as the absorption band at 1235-1225 cm^{-1}, which is characteristic of stretching vibrations of the C–O bond.[22] At the same time, in the spectrum of purified SSMO, the intensity of the absorption band of esters is lower (Fig. 2).

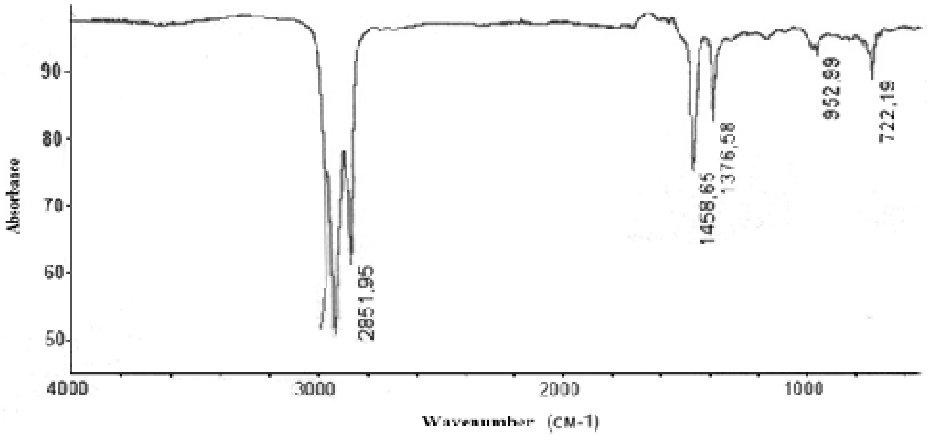

Fig. 1. IR spectrum of used ELF 700 STI

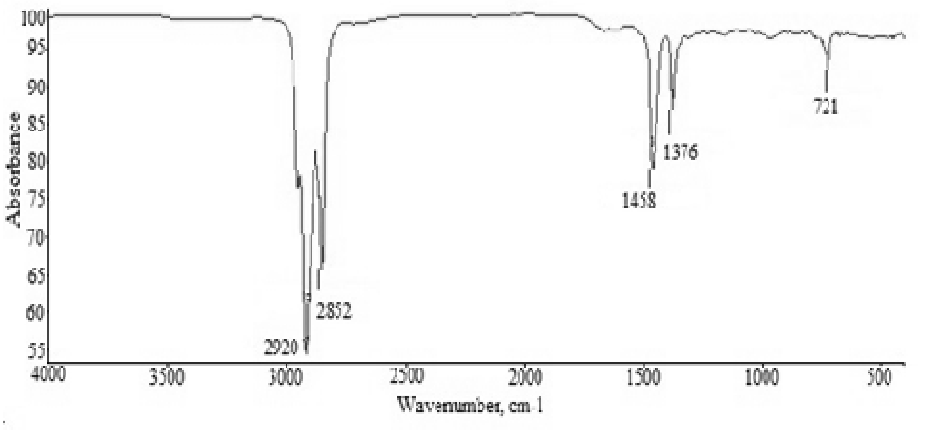

Fig. 2. IR spectrum of purified ELF 700 STI

The C=O carbonyl group, contained in aldehydes, acids, and alcohols, is observed in the IR spectrum of used SSMO and confirmed by absorption bands at 1725–1620 cm^{-1} and 1165–1125 cm^{-1}, typical for deformation vibrations of the C–O group.[22] However, the same absorption bands but with lower intensity are found in the IR spectrum of purified SSMO.

Similarly to ELF 700 STI, an IR spectroscopic study was performed for Castrol 10W-40 SSMO. The recorded spectra of used and purified oils are shown in Figs. 3 and 4.

The presence of products, which contain the C=O group, is confirmed by absorption bands at 1740–1690 cm^{-1} (Fig. 3). The same absorption bands have a somewhat lower intensity for purified oil (Fig. 4). Carboxylic acids in used oil were identified by absorption bands of the carboxyl group in the region of 1720–1680 cm^{-1}. The presence of esters as products of oil aging is confirmed by the bands in the region of 1740–1730 cm^{-1} (Fig. 3), which corresponds to the absorption band of the C=O group in aliphatic ester, as well as the absorption bands at 1235–1225 cm^{-1}, characteristic of stretching vibrations of the C–O bond. We can state a rather low intensity of absorption bands of esters in purified SSMO. The presence of the C=O carbonyl group, contained in aldehydes, acids, and alcohols, is observed in the IR spectrum of used Castrol 10W-40 oil and confirmed by absorption bands at 1725–1620 cm^{-1}.[22] In the IR spectrum of purified Castrol 10W-40, these absorption bands are characterized by a rather lower intensity (Fig. 4).

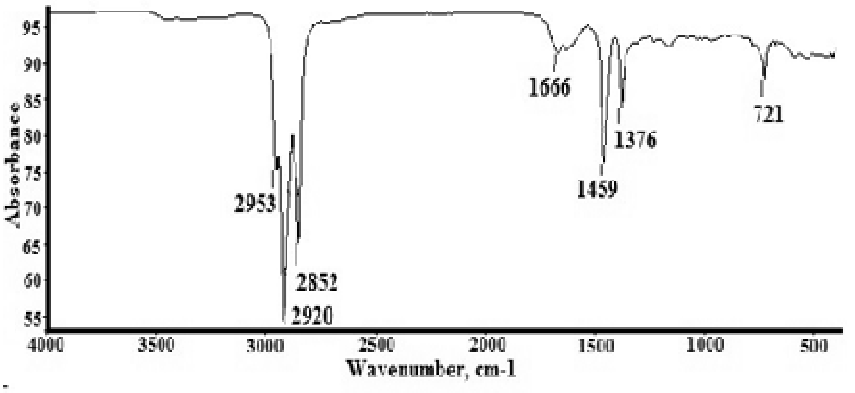

Fig. 3. IR spectrum of used Castrol 10W-40

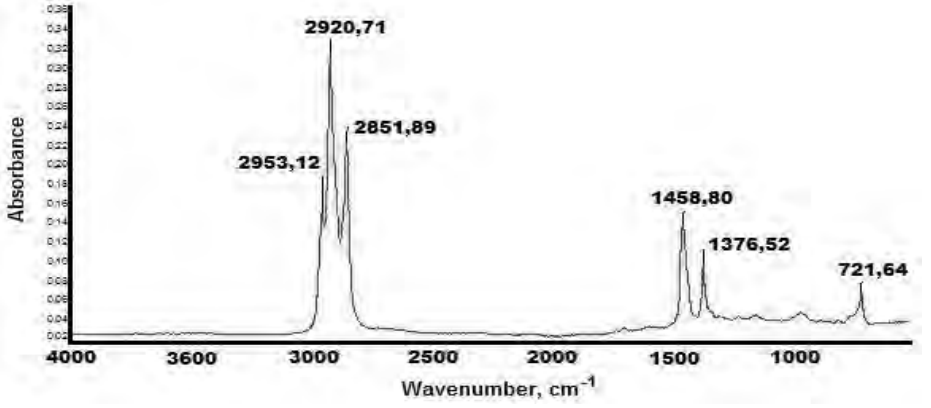

Fig. 4. IR spectrum of purified Castrol 10W-40

The presence of alcohols, as products of oil aging, was detected in used oils in the region of 1725–1695 cm^{-1}, which is confirmed by the absorption band of the C=O group, as well as by the absorption band in the region of 1165–1125 cm^{-1}, characteristic of deformation vibrations of C–O group. There is a rather insignificant presence of alcohols in the purified oil to compare with the used one. Ethers were identified in the used oil in the region of 1125–1025 cm^{-1} by asymmetric stretching vibrations of the C–O–C bond; however, these vibrations have a low intensity in the spectrum of purified oil.

The analogous IR spectroscopic study was carried out for mineral motor oils, and the recorded IR spectra are shown in Figs. 5 and 6.

One can see from Fig. 5 that alcohols, aldehydes, ketones, organic acids, *etc.*, which are products of oil aging, were identified in the used and purified M-10DM mineral oil. Their presence is confirmed by a change in the intensity of absorption bands of C=O stretching vibrations in the region of 1740–1690 cm^{-1} and 1820-1740 cm^{-1}, as well as asymmetric stretching vibrations of the C–O bond in the region of 1260–1150 cm^{-1}.

There is a change in the intensity of the absorption bands of organic acids and their derivatives in the purified oil (Fig. 5), which indicates the possibility of using urea to reduce the content of oxygen-containing aging products of oil.

Similar regularities are observed when purifying NORMAL 15W-40 in the presence of urea (Fig. 6).

Therefore, during a study on the purification process of mineral and semi-synthetic UMO in the presence of crystalline urea a decrease in the values of AN, water content, mechanical impurities, and ash content is observed. At the same time, there is an increase in the values of viscosity-temperature properties. However, the performance indicators of the above-mentioned brands of oils purified in the presence of urea do not correspond to the values of commercial oils, which in turn, requires the involvement of additional purification methods. The use of crystalline urea in the process of UMO purification allows to reduce the content of oxygen-containing aging products. At the same time, undesirable polycyclic aromatic hydrocarbons, ACP, products of additive decomposition and mechanical impurities remain in the purified oil, for the removal of which additional stages of purification are required.

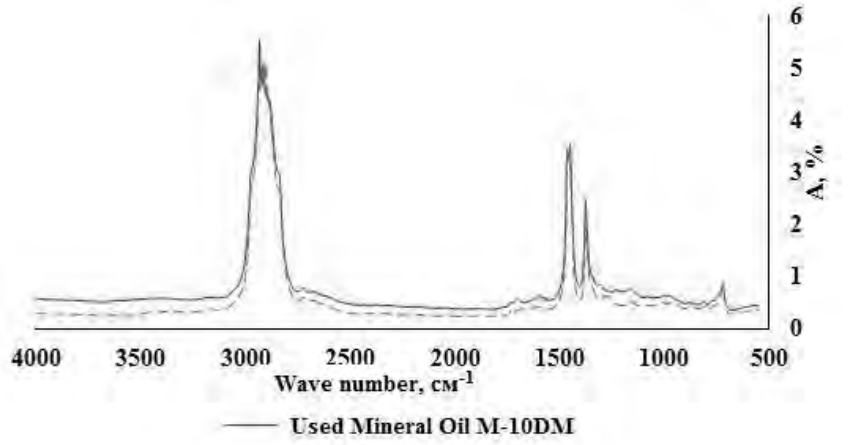

Fig. 5. IR spectra of used and purified mineral oil M-10DM

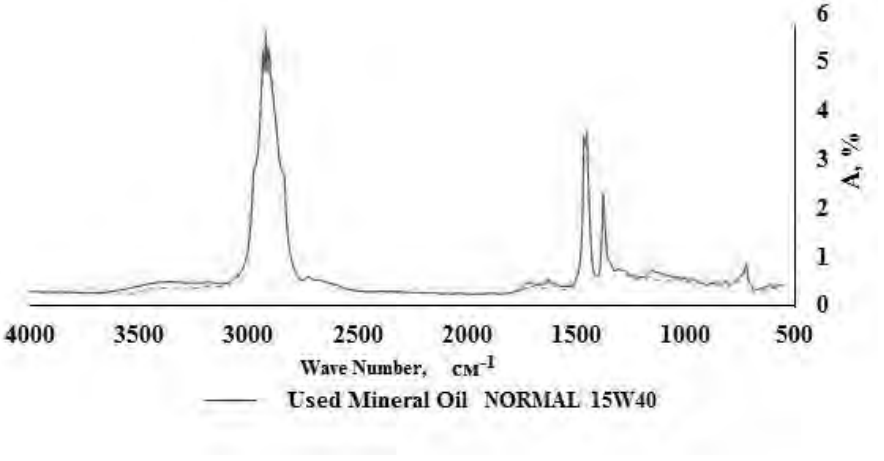

Fig. 6. IR spectra of used and purified mineral oil NORMAL 15W-40

It is advisable to use the proposed method as an intermediate stage of the combined process of UMO purification to restore their performance indicators.

4. Conclusions

The purification process of used mineral and semi-synthetic motor oils for gasoline and diesel internal combustion engines was studied in the presence of crystalline urea.

The process main parameters influencing the performance indicators of purified motor and semi-synthetic motor oils were established: the process time is 80 min., the temperature is 413 K, and the crystalline urea amount is 5 wt.% .

Under the established optimal conditions, the purification process of used mineral and semi-synthetic engine oils was carried out. The purified oils were characterized by a low value of the acid number, the absence of water, a somewhat low value of ash content, and mechanical impurities.

The inorganic part of purified oils was studied using X-ray fluorescence analysis. It has been established that the content of metals in purified oils decreases.

The reduction of the amount of oxygen-containing "aging" products in mineral and semi-synthetic motor oils as a result of their purification with crystalline urea under the established optimal process conditions was confirmed by IR spectroscopy.

The studied purification process of used motor mineral and semi-synthetic oils in the presence of crystalline urea is proposed to be used as an intermediate stage of the combined technological cycle of used motor oils regeneration.

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Received: November 04, 2022 / Revised: November 23, 2022 / Accepted: December 05, 2022

ВИВЧЕННЯ ПРОЦЕСУ ОЧИЩЕННЯ ВІДПРАЦЬОВАНИХ МОТОРНИХ ОЛИВ У ПРИСУТНОСТІ КРИСТАЛІЧНОГО КАРБАМІДУ

Анотація. *У роботі описано результати вивчення очищення відпрацьованих мінеральних і напівсинтетичних моторних олив у присутності кристалічного карбаміду. Вивчено вплив основних чинників керування процесом (кількості основного реагенту, тривалості та температури) на зміну експлуатаційних властивостей очищених моторних олив. За встановлених оптимальних умов очищено відпрацьовані мінеральні та напівсинтетичні моторні оливи для бензинових й дизельних двигунів. Подано результати рентгено-флуоресцентного та ІЧ-спектроскопічного досліджень хімічного складу очищених моторних олив у присутності карбаміду.*

Ключові слова: *мінеральна моторна олива, напівсинтетична моторна олива, відпрацьована олива, карбамід, старіння оливи, рентгено-флуоресцентний аналіз, ІЧ-спектри.*