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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

REGENERATION OF UTILIZED ENGINE OILS AND THE CREATION OF NEW LIQUID COMPOSITIONS FOR DIESEL ENGINES FOR DIFFERENT PURPOSES ON THEIR BASIS

Specialty: **2314.01- Petrochemistry**

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GENERAL DESCRIPTION OF WORK

Relevance of the topic and the degree of elaboration. Rising energy consumption in the world is accompanied by the rapid depletion of major energy resources, primarily oil and gas. The inevitability of depletion of traditional energy resources accelerates the search for new sources of raw materials for fuel and energy production.

In the 50s of the last century, when simple diesel engines used non-additive lubricants, later and now, high-quality lubricants with additive composition are used in diesel engines of complex construction, operating in heavy conditions, high-strength, blowing and non-blowing conditions.

Lubricants used in various fields of technology lose their basic quality after a certain period of operation.

With the widespread use of lubricants in large quantities, large amounts of used oils pose a threat to the environment.

The problem of re-use of used oils after use of large amounts of lubricants used in various fields of technology can be substantially solved.

The use of lubricants increases every year, and therefore the volume of used oils also increases. Used petroleum products are toxic and hazardous waste with a very low biodegradation rate (10-30%). Their collection and reuse is an urgent problem.

In this regard, at the current level of development of Azerbaijani industry, it is important and relevant to involve the production of secondary raw materials, especially the production of various petroleum products from the processing of used lubricants as raw materials.

Object and subject of research. It is important and relevant to conduct research on the reuse of used oils collected during the operation of large volumes of used motor oils. In the developed countries of the world, there are production facilities operating with different regeneration methods for the recycling of used oils. The research subject of the dissertation is the process of regeneration of used samples of Mysella-40 motor oil used in generators of modular

power plants in this field, ie in various regions of the republic, including in Baku and all regions of the country.

As a result, a new lubricant composition of Mysella-40 commercial oil was created, new areas of application of regeneration products were identified: using them as a base oil, new lubricating compositions of M-16IKhP-3, M-10G_2 and M-10G_2k, M-14B_2 motor oils were created.

Goals and objectives of the study. Research of used motor oils used in various engines, development of their regeneration process, creation of various motor oils based on regeneration products.

For this purpose, research work was carried out in the following areas:

– study of changes in important physicochemical and operational properties of Mysella-40 oil used in the engines of modular power plants during 1000-6000 hours of operation;
– development of used oil regeneration technology after 6000 hours of operation of Mysella-40 motor oil;
– study of the use of regeneration products as a base oil based on a number of important quality indicators;
– development of an analogue of Mysella-40 motor oil and new lubricant compositions for diesel engines for various purposes on the basis of regeneration products and the relevant additive package.

Research methods: Since the researches in the dissertation work are related to the creation and organization of production of different types of lubricants, the determination of their quality indicators evaluated by GOST and ASTM, ie kinematic viscosity, viscosity index, alkali number, sulfate ash, mechanical mixture and water quantity, etc. At the same time, methods were used to determine the performance of oxidation, corrosion, lubrication, detergent-dispersion, which determine the performance properties of oil samples.

The main provisions of the defense:

- development of new regeneration technology for re-application of used samples of lubricating oils used in various machines and

mechanisms;

- development of new lubricant compositions for transport diesels, autotractor and stationary diesel engines, diesel locomotives, industrial engines, heavy-duty, self-unloading industrial and ship diesels based on regeneration products and relevant additives.

Scientific novelty of the research:

– the optimal operating time in real conditions was determined by determining the important physical, chemical and operational properties of Mysella-40 motor oil used in high voltage electric generators;
– for the first time in the process of regeneration of used motor oil, the technology of regeneration of the used sample of Mysella-40 oil was created using the cavitation method;
– the effect of various factors on the regeneration process - catalyst, adsorbent, temperature, pressure, ratio of components was studied;
– taking into account the quality indicators of the regeneration product, the possibility of using them as a base oil in the field of creating modern motor oils for various purposes has been identified;
– an analogue of Mysella-40 motor oil was created on the basis of the regeneration product of used Mysella-40 motor oil and the appropriate additive composition;
– M-16IKhP-3 (SAE 40 API CB) for diesel vehicles based on regeneration products, M-10G_2 (SAE 30 API CC) and M-10G_2k (SAE 30 API CC) for autotractor and stationary diesel engines operating in amplified and non-blown conditions, new lubricating compositions of M-14B_2 (SAE 40 API CB) motor oils for diesel locomotives, self-unloading, industrial, ship diesels have been created;
– microbiological continuity of the new composition created on the basis of regeneration products was studied.

Theoretical and practical significance of the research: Research work has been carried out to ensure the reuse of used lubricants, in particular, a new regeneration technology has been developed to determine the physicochemical and other important operational properties of a sample of Mysella-40 motor oil used for 6,000 hours.

The new lubricant composition of Mysella-40 oil created on the basis of regeneration products was recommended to be applied in “Azenerji” Open Joint-Stock Company.

At present, new lubricant compositions based on regeneration products - M-16IKhP-3 (SAE 40 API CB), M-10G_2 (SAE 30 API CC) and M-10G_2k (SAE 30 API CC), M-14G_2 (SAE 40 API CB) work on application is carried out at the Experimental-Industrial Plant of ANAS.

Personal presence of the author. Problem statement in the dissertation work, development of technological scheme, study of the influence of various factors on the regeneration process, creation of lubricant compositions on the basis of regeneration products, analysis of the obtained results, generalizations were performed by the author herself.

Publication. 35 scientific works on dissertation work, including 6 patents, 10 articles (6 abroad) were published. The results obtained at international and national conferences were discussed, 18 abstracts of reports were published, 3 certificates and diplomas were awarded.

Approbation and application of research. The results of the dissertation were discussed at the following scientific conferences: Contest "The best scientific research of young researchers in the field of chemistry" organized by the State Committee for Family, Women and Children of the Republic of Azerbaijan (Baku, April 26, 2011); Republican scientific conference of young chemists of Azerbaijan (Sumgayit, October 6, 2011); "12th International Scientific-Practical Conference" "Research, development and application of high technologies in industry", (Russia, St. Petersburg, December 8-10, 2011); IV International scientific-technical conference "AIST-2013" (Belarus, Minsk, May 28-30, 2013); Ministry of Education of the Republic of Azerbaijan Ganja State University “Actual problems of modern biology and chemistry” Scientific-practical conference (Ganja, 30.04.2014); “2nd International Conferenence on Energy, Regional Integration and Socio-Economic Development” (Baku, October 1-3, 2014); "XI International Conference of Young Scientists on Petrochemistry" in memory of Academician V.M. Gryaznov; (Moscow, Zvenigorod, September 16-19, 2014); “VI International Scientific and Technical Conference” (Belarus, Minsk, May 30-June 1, 2017), XXII International scientific and technical

conference "Chemical reactives, reagents and processes of low-tonnage chemistry"; Reactive-2018 (Minsk, October 2-4, 2018); 6th International Symposium on Polimers and Advanced Materials ISOP&AM 6 (17-20 July Batumi 2019), Materials of the XXXIII International scientific and technical conference "Chemical reagents, reagents and processes of low-tonnage chemistry" dedicated to the memory of academician of the Academy of Sciences of the Republic of Bashkortostan D. L. Rakhmankulov (1939-2008) (Ufa, November 24-26, 2020).

Volume and structure of the dissertation. The dissertation consists of an introduction, 4 chapters, results, 229 referenced literature sources, 16 pictures, 156 pages of printed material and appendices covering 24 tables, 181936 characters.

The first chapter contains information on the production date, composition, application areas, modern base oils, additives and additive packages of lubricating oils used in various types of machines and mechanisms, especially motor oils.

This chapter contains information on changes in the physical and chemical properties of lubricating oils in the process of exploitation, which are important quality indicators compared to commercial oils and the duration of the change of oils. At the same time, extensive information was provided on the application of used samples of lubricating oils in various fields and finally on the creation of additive compositions in a new composition to achieve re-use by regeneration methods, which are considered important economically and environmentally important.

In the second chapter, methods for determining the physicochemical properties that characterize and determine the use of lubricants, assessment of operational properties - oxidation, corrosion and corrosion, preservatives, detergents and etc. quality indicators, functional properties of additives and additive packages by known standard methods (GOST and ASTM), rules for other tests confirming their suitability for a specific oil group are given.

The third chapter provides information on the important properties of Mysella-40 oil and other modifications used in modular power plants, as well as the physical and chemical properties of the

oil in relation to its operation over different periods (1000-6000 hours) - kinematic viscosity, viscosity index, alkaline number, ignition temperature, density, mechanical properties and performance properties - oxidation, corrosion, corrosion resistance, etc. appointment; sorting of the regeneration method, the effect of various factors - adsorbent, temperature, ratio of components, the possibility of using the cavitation method and the study of suitable ways.

In the fourth chapter, studies were carried out on the use of the Mysella-40 engine oil regeneration product in several directions based on its use as a base oil, taking into account reusable use, quality indicators, especially the viscosity index, oxidation resistance, ignition temperature. The results of studies of new lubricating compositions of motor oils for auto-tractor, stationary, self-discharging diesel engines operating in windproof modes, the development of Technical Specifications for oils recommended for use are reflected.

At the end of the dissertation, the results reflecting the essence of the research, the list of references and appendices are given.

MAIN CONTENT OF THE WORK

Used oil is one of the sources of environmental pollution - soil, water, atmosphere. The regeneration of waste oils, which cause significant environmental damage, will both alleviate environmental tensions and recycle them economically.

The term "regeneration" means the restoration of used lubricants to bring them to the initial level of quality.

Lubricants used in various fields of technology are motor, industrial, transmission and other existing oils that differ in their purpose. Motor oils are one of the most widely used lubricants.

With a wide range of applications, the use of motor oils in engines of complex design, especially the current requirements for their quality, the creation of lubricant compositions consisting of various functional additives that provide performance properties is an important and topical issue.

Research in the field of regeneration of used lubricants has a special place in developed countries for the last 20 years. Thus, the regeneration processes of used lubricants in Europe and the United States have been studied in depth and in this area there is the activity of modern regeneration plants and the efficiency of the plants continues to grow.

Regeneration and reuse of thousands of tons of used oil collected in modular power plants in Baku and a number of regions of the country is an urgent problem. At present, physical, physicochemical and chemical methods are used in the regeneration processes of used lubricants.

Physical methods: the effect of fields of force (gravity); centrifugal (electric and magnetic cleaners); filtration (from perforated partitions); thermal physical technology (heating, washing with water, atmospheric or vacuum evaporation, etc.); combined technology.

Physicochemical: coagulation; sorption; ion exchange cleaning; extraction.

Chemical: cleaning with sulfuric acid; alkali treatment; hydrogenation; cleaning with metal urea.

Regeneration of used oils with sulfuric acid is the first in the world. There are a number of disadvantages of this widely used method: the process produces sour goudron, which is environmentally hazardous and difficult to dispose of.

The second most widely used method is sorption cleaning. This method uses activated clay as a sorbent.

Sorption treatment is replaced by hydrogenation processes. However, in this case it is necessary to use sorbents. Thus, sorbents are necessary to protect the catalyst used in the hydrogen cleaning process.

The disadvantage of the hydrogenation process is that the process uses large amounts of hydrogen.

Hydrogen purification (hydrogenation) is a widely used process in the processing of used oils. This method creates a wide range of opportunities for the production of high quality oils, and this process is considered environmentally superior without cleaning with

sulfuric acid and adsorption.

2. Regeneration process of the used sample of Mysella-40 motor oil used in modular power plants

Mysella-40 oil is a high-quality low-ash oil from Shell for two- and four-stroke, high-speed engines.

During the operation of Mysella-40 oil, the properties of the samples taken for the analysis of used oils during different hours (1000-6000 hours) were determined, which determine the important physical, chemical and operational properties. Table 1 shows the physicochemical and operational properties of used oil samples.

Analysis of the used oils taken from the engine at different times shows that in a generator operating in the same mode, there is almost no difference in the mechanism of operation of the oils during operation.

As can be seen from the table, a number of indicators of used samples of Mysella-40 oil, which have been working for different periods, have changed dramatically: kinematic viscosity first decreased, then increased kinematic viscosity as a result of evaporation of light oil fractions (14.70-14.83 mm^2/s for 4000 hours, 15.06-15.12 mm^2/s for 6000 hours): primary oil color index from 6.5 CNT units (undiluted), even when diluted, it was above 8.5. The mechanical mixture increased from 0.085 to 0.46. These indicators occur during operation of internal combustion engines.

The performance of the oil is 0.44 mg KOH/g after the last 6000 hours, as the alkaline number decreases from 4.4 mg KOH/g due to the use of detergent-dispersant additives included in the composition of the lubricant to neutralize the resulting acidic products. The corrosion resistance decreases to 118 g/m^2 per 1500 hours and the corrosion resistance increases to 141.2 g/m^2 every 6000 hours after 500 hours of operation. The oil is resistant to oxidation for 30 hours. These figures indicate that the Mysella-40 engine oil has already reached the end of its service life. Thus, the oxidation resistance of commercial oil does not exceed 0.5% of the amount of sediment formed within 40 hours.

Table 1

Physical - chemical characteristics of samples of Mysella-40 motor oil processed during different hours

Indicators	Fresh Mysella -40 oil	Mysella-40 used oil samples, hour							
		1500		2000		4000		6000	
Kinematic viscosity, mm^2/s, 100°C 40°C	14,0 139	14,85 151,9	14,77 152,44	14,11 115,76	14,20 141,38	14.70 147,50	14,83 152,07	15,06 154,47	15,12 157,44
Viscosity index	95	97	96	93	97	98	97	97	96
Alkaline number, mg KOH 1g oil, should be less	4,4	1,87	1,70	1,65	1,62	1,43	1,44	0,86	0,44
Mass content of mechanical mixture, %	0,085	0,13	0,12	0,15	0,15	0,29	0,28	0,46	0,45
Corrosion, on C1 and C2 lead boards according to GOST 377877, g/m^2	9,8	111,5	118,0	128,5	128,97	148,7	146,2	148,2	144,6
Duration based on the induction period of sediment formation, sediment, %, (30 hours)	0,3	0,04	0,09	0,18	0,25	0,41	0,51	0,23	0,39
Color, in CNT colorimeter, CNT unit (diluted 15:85)	6,5	6,8	7,0	7,2	7,5	8,1	8,5	>7,9	>8,5

Due to the introduction of a number of innovations in the development of Mysella-40 motor oil regeneration technology compared to known technologies, which increase the yield of regeneration products and provide high performance qualities such as base oil, the regeneration technology developed by us is protected by the Azerbaijani patent.

In connection with the above, we can only describe the stages of the regeneration technology developed by us for the developed Mysella-40 motor oil. They consist of the following.

2.1. Purification of oil from mechanical mixtures and sour goudron

As is well known, the performance properties of diesel oils used in various diesel engines change dramatically as additives are used during operation, resulting in the gradual formation of acidic products.

The first stage of the regeneration process is the release of oil from acid tar and mechanical impurities by acid-contact method. The values of Mysella-40 oil after acid-contact treatment are given in Table 2.

Table 2

Acid-contact performance of a 6000-hour sample of Mysella-40 oil after cleaning

Indicators	Before cleaning	After cleaning
Kinematic viscosity mm^2/s, ^0C 100 40	 15,06 154,47	 12,26 115,19
Viscosity index	97	96
Alkaline number, mg KOH 1g oil	0,86	0,14
The amount of sulfate ash, %	0,05	0,02
The ignition temperature is set on an open tray, ^0C	250	255
Mass quantity of mechanical mixture, %	0,013	0,005
Color in CNT colorimeter, CNT unit (diluted15:85)	>8,0	>8,0
Density 20^0C, kg/m^3	897	884

As can be seen, the alkalinity of mechanically mixed and goudron-free oil samples drops sharply.

2.2. Cleaning of oil from residual resins and acidic products in bleaching and neutralizing adsorbents

The second stage of the 6,000-hour sample of Mysella-40 oil is the process of cleaning residual resins and acid products by neutralizing them with bentonite and M-1 adsorbent.

Bentonites of different composition and quality, existing in different regions of the republic (Sheki, Gazakh) and Iran, were

studied in this process. Depending on the properties of bentonites, color differences are observed between the processed oil and the regeneration products. It also sometimes affects the output.

Table 3

Performance of the processed sample of Mysella-40 oil after cleaning with adsorbents

Indicators	Before cleaning with adsorbent	After cleaning with adsorbent
Kinematic viscosity mm^2/s, ^0C 100 40	 12,26 115,19	 11,15 98,15
Viscosity index	96	99
Alkaline number, mg KOH 1g oil	0,14	0,12
The amount of sulfate ash, %	0,02	0,02
The ignition temperature is set on an open tray, ^0C	255	250
Continuity according to the induction period of sediment formation, hours	Continues 30 hours	Continues 40 hours
Density 20^0C, kg/m^3	884	890
Color in CNT colorimeter, CNT unit (diluted 15:85)	>8,0	3,5

3.3. Application of cavitation in the regeneration process

Cavitation is the formation of gas bubbles in a liquid, followed by condensation of the bubbles in the vapor stream. This condensation is observed by sound and hydraulic shocks. Cavitation occurs when the pressure in a moving fluid drops.

The following processes can occur during cavitation processing of oil and oil products:

– accelerates the diffusion of oil into paraffin pores, intensifies its decomposition process;
– breaks the chain structure, breaks the bonds of the parts of the molecules;
– affects the change of structural viscosity, ie temporarily breaks the Van der Vaals relations;
– C - C bonds in paraffin molecules are broken;

– the physical - chemical composition of oil and oil products changes (molecular weight decreases, etc.).

Given the effect of all this cavitation treatment, we prefer to use cavitation in the regeneration of used oils.

4. Creation of various lubricant compositions based on the regeneration product of used Mysella-40 motor oil

In order to create lubricating compositions based on the regeneration product of used Mysella-40 oil, of course, first of all, the possibility of using this regeneration product as a base oil had to be studied. If the physical - chemical and operational properties of the regeneration product meet the requirements for base oils, it is possible to proceed to the study of the creation of various lubricating compositions based on it.

4.1. Research of used Mysella-40 motor oil regeneration product as a base oil

As noted, the required physicochemical and operational properties of the regenerated product were researched to determine the suitability of the used Mysella-40 engine oil as a base oil for the regeneration product.

Quality indicators of used Mysella-40 motor oil regeneration products

Kinematic viscosity, mm^2/s	40^0C	97,15
	100^0C	10,97
Viscosity index		97
The amount of sulfate ash, %		0,2
Ignition temperature, ^0C		267
Freezing temperature, ^0C		minus 10
Corrosion, on C1 and C2 lead plates according to GOST 377877, g/m^2		258
Duration according to the induction period of sediment formation, sediment,%		0,58 (30 hour)
Mass quantity of mechanical mixture,%		there is not
Mass amount of water, %		there is not
Density, 20^0C, kg/m^3		873

Color in the CNT colorimeter
(diluted 15:85), CNT unit 3,5

Based on the above, it is safe to say that the regeneration product of 6,000 hours of used Mysella-40 motor oil can be used as a base oil in the creation of lubricants for various purposes.

4.2. Creation of various lubricant compositions based on the regeneration product of used Mysella-40 motor oil

Analog of Mysella-40 motor oil on the basis of regeneration product of used Mysella-40 motor oil and relevant additive compositions, M-16IKhP-3 (SAE-40 API CB) for diesel vehicles, M-10G_2 (SAE 30 API CC) and M-10G_2k (SAE 30 API CC) for locomotives and stationary diesel engines operating in amplified and non-blown conditions, diesel locomotive, self-unloading locomotive, M-14B_2 (SAE 40 API CB) for industrial, ship diesels new lubricating compositions of motor oils have been created.

In order to determine the optimal composition of the lubricant compositions, samples of different concentrations of additives were prepared and tested. The abstract gives the specified optimal composition of lubricant compositions.

4.2.1. Creation of a new analogue of Mysella-40 motor oil

Viscoplex-2-670 viscosity additive was used to improve the viscosity and temperature properties of the processed Mysella-40 regeneration product used as a base oil to create an analogue of Mysella-40 motor oil, Viscoplex-5-309 depressant additive was used to reduce the freezing temperature and other functional properties were provided by C-250 and DF-11 additives.

Additives were taken in the following ratio (% by weight)

Viscoplex-2-670	0,5
DF-11	0,6
C-250	1,2
PMS-200A	0,003

Physicochemical and operational properties of the developed Mysella-40 engine oil analogue are given in Table 4.

As can be seen from Table 4, all the indicators of the created

Mysella-40 motor oil analogue correspond to the indicators of the commodity Mysella-40 motor oil.

Table 4.

Comparative characteristics of the newly developed Mysella-40 oil and commercial oil

Indicators	Commodity Mysella-40	Mysella-40 created as a regeneration product
Kinematic viscosity,mm^2/s 40^0C 100^0C	 139 14,0	 123,39 13,56
Viscosity index	97	106
Alkaline number, mg KOH 1g oil	4,4	3,57
Mass quantity of mechanical mixture,%	0,085	There is not
Ignition temperature, ^0C	274	249
Freezing temperature, ^0C	Minus 18	Minus 10
Continuity according to the induction period of sediment formation, 40 hours	Continues	Continues
Density, 15^0C, kg/m^3	882	895

4.2.2. Development of M-16IKhP-3 (SAE 40 API CB) motor oil for diesel vehicles based on regeneration products

Mysella-40 motor oil regeneration product includes a well-known multifunctional additive package Lz-4970, viscosity additive - Shellvis-50, depressant - Viscoplex 5-309 and anti-foaming - PMS-200A, consisting of oxidation, corrosion, anti-corrosion additives and detergent-dispersant additive. and the goal was achieved.

Additives were taken in the following ratio (% by weight):

- polymethacrylate type viscosity additive Shellvis-50 - 0,45-0,55
- multifunctional additive package Lz-4970 - 5,5 – 6,5
- detergent-dispersant additive C-150 - 1,3-1,5
- depressant additive Viscoplex 5-309 - 0,4 – 0,6
- anti-foaming additive PMS-200A - 0,002 – 0,004

Additives in motor oil are industrial products.

Physico-chemical parameters and operational properties of the developed M-16IHP-3 motor oil are given in Table 5:

Table 5

Physico-chemical and operational properties of the developed M-16IKhP-3 motor oil

Indicators	M-16 IKhP-3 GOCT 25770-83	Created M-16 IKhP-3
Kinematic viscosity, 100^0C, mm^2/s	15,5-16,5	16,5
Viscosity index should not be less	90	110
Alkaline number, mg KOH 1g oil, not less	4,0	4,5
Sulfate ash,%, should not be too much	1,25	0,74
The mass of the mechanical mixture, %, should not be too much	0,013	0,005
The ignition temperature should not be lower than ^{0}C, set in an open furnace	225	260
Freezing temperature, ^{0}C, should not be higher	Minus 25	Minus 25
Corrosion, C1 and C2 lead boards according to GOST 377877, g/m^2	9.0	There is not
Washing properties by PZV method, points	0,5	0,5
Density, 20^0C kg/m^3, should not be too much	905	880
Duration according to the induction period of sediment formation, 45 hours	Continues	Continues
Color in CNT colorimeter (diluted 15:85), CNT unit	6,0	4,0
The degree of purity, mg/100g of oil, should not be too much	320	300
Washing potential, 250^0C, %	80	90

As can be seen, the composition of the additive containing 0.5% Shellvis-50, 6.0% Lz-4970, 1.5% C-150, 0.5% Viscoplex 5-309, 0.003% PMS-200A is the best physico-chemical and has operational properties, in other words, it can be assumed that the specified ratios of additives included in the package are the most favorable. It can be assumed that the Lz-4970 additive package, the composition of the optimal concentrations of Shellvis-50, C-150 and Viscoplex 5-309 additives, the oxidation, corrosion, corrosion resistance and detergent properties of the oil sample formed as a

result of synergism of the additives.

The test results show that the viscosity index of the new oil is 110, the ignition temperature is 260^0C, the ash content is 0.74%, and the viscosity index of the commercial M-16IKhP-3 oil is 90, the ignition temperature is 225^0C, the ash content is 1.25%.

Thus, M-16IKhP-3 motor oil developed from regenerated Mysella-40 oil fully meets the requirements for motor oils for diesel vehicles.

4.2.3. Creation of M-10G$_2$ and M-14G$_2$k lubricant compositions for autotractor diesels on the basis of regeneration products

To increase the kinematic viscosity and viscosity index of the regeneration product to the required level, the viscoplex-2-670 additive, which is resistant to thermal and mechanical destruction, was used. The above additive was added to the regeneration product in the amount of 0.4-07%, base oil of M-10G$_2$ (SAE 30 API CC) and M-14G$_2$k (SAE 30 API CC) motor oils for autotractor and stationary diesel engines operating in reinforced and high-strength blowing and non-blowing conditions has been developed.

AKI-150 multifunctional additive, calcium salt of the product of condensation of alkylphenol with formaldehyde and amino acetic acid, high alkalinity C-400 additive, oxidation inhibitor DF-11 additive, antifreeze depressant additive Viscoplex-5-309 and additive PMS-200A are included in the composition of the additive.

The additives were taken in the following proportions:

M-10G$_2$ – 0,4%Viscoplex-2-670+4,5%AKI-150+0,7%C-400+ 0,9%DF-11+0,3%Viscoplex -5-309+0,003%PMS-200A

M-14G$_2$k – 0,7%Viscoplex-2-670+5,0%AKI- 150+0,76%C-400+ 1,2%DF-11+0,3%Viscoplex 5-309+0,003%PMS-200A

Physicochemical and operational properties of M-10G$_2$ and M-14G$_2$k engine oils are given in Table 6.

As can be seen from Table 6, the lubricating compositions of M-10G$_2$ and M-14G$_2$k motor oils fully meet the requirements of GOST for all parameters.

Table 6

Comparative properties of the created M-10G$_2$ and M-14G$_2$k motor oils with commercial oils

Indicators	M-10G$_2$		M-14G$_2$k	
	Commodity	Created	Commodity	Created
Kinematic viscosity, 100^{0}C, mm^2/s	11,0±0,5	10,97	13,5-14,5	13,87
Viscosity index should not be less	85	112	90	95
Alkaline number, mg KOH 1g oil, not less	6,0	6,0	7,0	7,16
Sulfate ash,%, should not be too much	1,65	0,7	1,3	1,02
The mass of the mechanical mixture,%, should not be too much	0,015	There is not	0,01	0,003
The ignition temperature should not be lower than ^{0}C, set in an open furnace	205	230	220	250
Freezing temperature, ^{0}C, should not be higher	Minus 15	Minus 15	Minus 12	Minus 15
Corrosion, C1 and C2 lead boards according to GOST 377877, g/m^2	20,0	There is not	There is not	There is not
Washing properties by PZV method, points	1,0	0,5	-	-
Density, 20^{0}C, kg/m^3, not more	905	912	905	902
Duration according to the induction period of sediment formation, hours	Lasts 40 hours	Lasts 40 hours	Lasts 50 hours	Lasts 50 hours
Color in CNT colorimeter (diluted (15:85), CNT unit	5,0	4,5	4,0	3,5

Regeneration products were used as base oil and OLOA-9999, PA-2600, SAP-2055z and SAN-2022A additive packages, M-14G$_2$ (SAE 40 API CC) type lubricant composition for locomotive and industrial engines ChH 26/26, ChH 30/38 was created.

The test results of the created lubricant compositions are given in Table 7. As can be seen from Table 7, the physicochemical and

operational properties of M-14G_2 lubricant compositions created by us on the basis of regeneration products and various additive packages fully meet the requirements of GOST.

Table 7

Comparative test results of new lubricant compositions of M-14G_2 motor oil based on various additive packages with commercial oil

Indicators	M-14G_2 GOCT 12337-84	Base oil (regeneration product)		
		0,7%Viscoplex 2-670 5,0%AKI-150 0,76%C-150 1,2%DF-11 0,003%PMS-200A	3,3%Viscoplex 4-550 4,5%SAP-2055z 0,5%AMG-3 0,003%PMS-200A	0,8%Viscoplex-2-670 3,5% SAN-2022A 0,6% C-150 0,6% Viscoplex -5-309 0,003%PMS-200A
Kinematic viscosity mm^2/s, 100^0C	13,5-14,5	13,75	14,02	13,87
Viscosity index should not be less	90	90	93	95
Alkaline number, mg KOH 1g oil, not less	7,0	7,68	7,2	7,16
The amount of sulfate ash,%, should not be too much	1,3	1,12	1,2	1,02
The mass of the mechanical mixture, %, should not be too much	0,01	0,007	0,003	There is not
The mass of water should not exceed %	Iz	Iz	Iz	Iz
Ignition temperature, ^0C, should not be lower	220	250	255	250
Freezing temperature, 0C, should not be higher	Minus 12	Minus 15	Minus 15	Minus15
Corrosion, C1 and C2 lead boards according to GOST 377877, g/m^2	There is not	There is not	There is not	There is not
Density, 200C, kg/m^3, not more	905	895	900	902
Continuity based on the period of induction of sediment formation, continues	50 hours	45 hours	50 hours	50 hours

4.2.4. Creation of M-14B_2 (SAE 40 API CB) motor oil on the basis of regeneration product

M-14B_2 motor oil for locomotive, large-capacity, self-unloading, industrial and ship diesels was created as a base oil for the regeneration product of used Mysella-40 oil and using additive packages. In order to bring the viscosity and temperature properties of M-14B_2 motor oil to the required level, the "Viscoplex" series - Viscoplex 2-670, 8-450, 2-600, etc. studies were conducted using additives. The use of Viscoplex 2-670 and 8-450 additives in the creation of compositions was positively analyzed by analyzing the effect of the mentioned viscosity additives on the increase of viscosity and viscosity index in base oils, as well as the results of their mechanical and thermal destruction at UZDN-2T.

SAN-2022A, OLOA-9999, PA-2600 additive packages were used in the creation of M-14B_2 motor oil.

The results of research on the development of M-14B_2 motor oil are given in Tables 8 and 9.

As can be seen from Tables 8 and 9, the M-14B_2 (SAE 40 API CB) engine oil is superior to commercial motor oil in some respects.

Relevant engine tests of a large sample of M-14B2 engine oil designed for ship diesel engines and used in large quantities were carried out on the IKM-40A and recommended for application based on the positive results obtained.

During long-term storage of widely used M-14B_2 motor oil, it is exposed to various types of bacteria and fungi under the influence of a number of external factors - humidity, temperature, oxygen, and loses its original quality and becomes unusable. For this reason, it is necessary and urgent to prevent the process of biodegradation. Therefore, the effect of *Pseudomonas aeruginosa* bacteria and *Aspergillus niger* fungus on M-14B_2 motor oil and prevention of this effect with biocides have been studied.

Biocidal and non-biocidal tests of M-14B_2 motor oil were carried out. Taking into account the obtained results, the "Technical Specifications" of biodegradable M-14B_2 motor oil was developed.

Table 8

Test results of M-14B$_2$ motor oil based on the regeneration product of used Mysella-40 oil and various additive packages

Examples	Indicators						
	Kinematic viscosity, mm^2/s		Viscosity index	Alkaline numberl mg KOH 1g oil	Amount of sulfate ash, %	Continuity according to the induction period of sedimentation, sediment, %	Corrosion resistance on C1 and C2 lead plates according to GOST 377877, g/m$_2$
	40^{0}C	100^{0}C					
Regeneration product + 0,5%Viscoplex2-670	127,08	13,70	103	-	-	0,55 (30 hours)	221,4
R.p.+0,5%Viscoplex2-670+ 3,0%SAN-2022A+ 0,003%PMS-200A	120,70	13,41	105	7,16	1,02	0,33 (40 hours)	11,5
R.p.+0,5%Viscoplex2-670+ 5,0%OLOA-9999+ 0,003%PMS-200A	127,16	14,06	106	7,71	1,11	0,31 (40 hours)	0,5
R.m.+0,5%Viscoplex2-670+ 3,0%PA-2600+ 0,003%PMS-200A	122,92	13,59	105	7,64	1,02	0,40 (40 hours)	0,5
R.m.+0,5%Viscoplex2-670+ 3,8%AKI-150+ 1,2%DF-11+ 1,0%C-250+ 0,003%PMS-200A	121,77	13,53	105	7,68	1,12	0,35 (40 hours)	0,8

Table 9

Comparative exploitation properties of the created new engine oil M-14B$_2$ with commercial oil

Indicators	M-14B$_2$ GOCT 12337-84	Regeneration product 0,8% Viscoplex2-670 3,2%PA-2600 0,08%CCK-400 0,5%Viscoplex5-309 0,003%PMS- 200A
Kinematic viscosity, 100^{0}C, mm^2/s	13,0 -14,5	14,30
Viscosity index, should not be less	85	95
Alkaline number, mg KOH 1g oil, not less	4,8	6,86
Sulfate ash,%, should not be too much	1,2	0,91
The mass of the mechanical mixture,%, should not be too much	0,02	There is not
The ignition temperature should not be lower than ^{0}C, set in an open furnace	210	235
Freezing temperature, ^{0}C, should not be higher	Minus 12	Minus 15
Density, 200C kg/m^3, should not be too much	Not normalized. Appointment is mandatory	895
Corrosion, C1 and C2 lead boards according to GOST 377877, g/m^2	There is not	There is not
Continuity according to the induction period of sediment formation, 50 hours	Continues	Continues
Color in CNT colorimeter (diluted (15:85), CNT unit	Not normalized. Appointment is mandatory	4,0
Washing potential, 250^{0}C, %	-	90

CONCLUSIONS

1. As a result of studying the physicochemical and operational properties of samples of Mysella-40 motor oil used in diesel engines of modular power plants during different hours (1000-6000), it was determined that the sample of Mysella-40 oil used after 6000 hours was unfit for operation. [12;13;16;24]
2. Mysella-40 motor oil regeneration technology has been developed as a result of research work on the recovery of used

samples of lubricating oils, especially motor oils, which have a wide range of applications. In the use of regeneration technology - the effect of catalyst, adsorbent, neutralizing reagent, temperature, application of the cavitation process and other factors on the regeneration process was studied. [10]

3. The study of the regeneration product of the developed Mysella-40 motor oil showed that it can be used as a base oil. [11]
4. Using the developed Mysella-40 motor oil as the base oil of the regeneration product, a number of lubricant compositions were created for diesel engines for various purposes: [26;27;30]

– lubricant composition in accordance with the requirements of Mysella-40 commercial motor oil 0.5% Viscoplex2-670, 1,2% C-150, 0,6% DF-11, 0,003% PMS-200A;
– M-16IKhP-3 (SAE 40 API CB) motor oil for diesel vehicles (0,5% Shellvis-50, 6,0% Lz-4970, 1,5% C-150, 0,5% Viscoplex 5-309, 0,003% PMS-200A);
– the developed prototype of M-16IKhP-3 motor oil has higher performance than commercially produced commercial oil and fully meets the requirements for motor oils for diesel vehicles - viscosity index (110 units), oxidation (sediment content <0.5%)), high resistance to corrosion (no), washability (0.5 points) and corrosion (Di 0.45mm) and the production of M-16IKhP-3 motor oil with low ignition temperature (26^0C) and low ash (0.74%) Technical Conditions (TC AKI 3536814-77-2017) have been developed to ensure the consumption; [17]
– lubricants in the composition of of M-10G_2 (SAE 30 API CC) and M-14G_2k SAE 30 API CC motor oils of 0.4% Viscoplex - 2-670, 4.5% AKI-150, 0.7% C-400, 0.9% DF-11, 0.3% Viscoplex -5-309 and 0.003% PMS-200A for autotractor and stationary diesel engines operating in amplified and high-amplified blowing and non-blowing conditions: the use of AKI-150 additive has been identified as an advantage over known detergent-dispersant additives with the same functional properties;
– lubricant compositions with the following composition for M-14G_2 (SAE 40API CC) motor oil for diesel locomotives and

industrial engines ChN 26/26, ChN 30/38; [7;8;23;31]

a. 0,7% Viscoplex-2-670, 5,0% AKI-150, 0,76% C-150 (C-300, C-400), 1,2% DF-11+0,003% PMS-200A
b. 3,3%Viscoplex-4-550, 4,5%SAP-2055z, 0,5%AMG-3, 0,003% PMS-200A
c. 0,8% Viscoplex-2-670, 3,5% SAN-2022A, 0,6% C-150, 0,6% Viscoplex 5-309, 0,003% PMS-200A

– M-14B_2 (SAE 40 API CB) motor oil for diesel locomotives, large-capacity, unloading, industrial and ship diesels were created with lubricant compositions 0,5%Viscoplex-2-670, 3,8% AKI-150, 1,2% DF-11, 1,0% C-250, 3,0% SAN-2022A, 5,0% OLOA-9999, 3,0% PA-2600. [9;23;33;35]

5. Due to the large use of M-14B_2 motor oil, its resistance to the process of microbiological decomposition under the influence of external factors - humidity, temperature, etc. during its transportation and storage provided by the use of the corresponding biocides - α-methyl-βnitroethene, nitrostyrene, α-furyl-βnitroethene and methylene-bis -piperide. Methylene-bis-piperidine biocide has been found to be the most effective of the biocides studied. Technical Specifications (TS AKI 3536814-69-2015) have been developed to ensure the production and consumption of M-14B_2 biodegradable engine oil. [14;18;19;20;21;22;25;28;33]

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