APPLICATION OF THE HYDROCRACKING PROCESS OF DISTILLATE OBTAINED FROM LOW-PARAFFIN OILS

S.Yu. Rashidova[1], G.A. Huseynova[1], N.K. Andryushchenko[1], I.A. Khalafova[2], I.A. Hajiyeva[1]

[1]Institute of Petrochemical Processes named after acad. Y.H. Mammadaliyev
Ministry of Science and Education of Azerbaijan Republic, Baku
[2]Azerbaijan State University of Oil and Industry,
Ministry of Science and Education of Azerbaijan Republic, Baku
e-mail: nandryushenko@protonmail.com

Received 04.11.2025
Accepted 17.03.2026

Abstract: *One of the promising technological processes in the production of oils is the hydrocracking process. It is radical in destructive hydrogenation and change in the structure of raw material molecules to obtain oil products with new qualities that are absent in the original raw material.*

The hydrocracking process in the processing of oil fractions and residues of Baku oils is especially necessary due to their high resin content. Therefore, the solution to this issue is of a topical nature.

In this paper, the possibility of using oil fractions – distillate D-11 – a mixture of Baku low-paraffin oils as a raw material for obtaining base oils, including high-index ones, was investigated.

Distillate D-11 from Azerbaijani oils was subjected to hydrocracking on an industrial catalyst GKD-205 under a pressure of 4-5 MPa, at volume rate of 0.5-1.0 h^{-1} and at a temperature of 420 °C. The optimal process mode for the conclusion was determined in order to obtain the base of high-index oils: pressure of 5 MPa, temperature of 420 °C, volume rate of 0.5 h^{-1} and amount of hydrogen of 1000 l/l of raw material.

The oil fractions obtained during the work (300-400 °C) do not require dewaxing, as a result of which the costs of oil production were reduced by half.

Without dewaxing, along with base oils VI-4 and VI-6, all-season motor oils M-4z/6V1 and M-6z/10V, turbine oils of the T-22, T-30, T-46, T-51 brands, and light cylinder oils 11, 24, AK-15, etc. were obtained. After dewaxing the oil fractions of hydrogenates, high-viscosity oils were obtained - vapors, which significantly surpass the quality of oils from unique Baku oils.

Keywords*: low-paraffin oil, D-11 distillate, hydrocracking, hydrogenisate*

Introduction

In modern world oil refining, the most urgent and complex problem is increasing the depth of oil refining, which can be solved by using heavy oil residues – tars and fuel oils. The hydrocracking process is used as the main process for their processing [1-12].

The wide possibilities of the hydrocracking process, which provides a deep change in raw materials, make it possible to process residual oil fractions along with distillate fractions, which makes it possible to obtain not only motor fuels, raw materials for catalytic cracking, but also lubricating oil bases [13-23].

As is known, the efficiency of the hydrocracking process largely depends on the operating pressure. The lower the pressure, the higher the economic efficiency of using the hydrogenation process [18, 24-33]. In view of the large resources of heavy oil residues from Azerbaijani oils, which do not find qualified application, a technology has been developed for obtaining a wide range of oils from them, including high-index ones, using an environmentally friendly process - hydrocracking under a pressure of 5-10 MPa [31-35].

It is known that one of the promising technological processes in the production of oils is the hydrocracking process. This process is radical for rational processing (destructive hydrogenation) and changing the structure of raw material molecules in order to obtain oil products with new qualities that are absent in the original raw material.

The introduction of the hydrocracking process for processing oil fractions and residues of currently processed Baku oils is especially necessary due to their high resin content. With the existing

technical base of the Baku Oil Refinery, where there are sufficient capacities for hydrogenation purification, the solution to this issue is of particular importance [31-36]. Taking this into account, a study was conducted to examine the possibility of using oil fractions (D-11 distillate) of a mixture of Baku low-paraffin oils as raw materials for obtaining base oils, including high-index oils, components of fuels and liquids at various pressures and speeds [37-39].

Experimental part

The raw material used was industrial distillate (vacuum distillate type) obtained from a mixture of low-paraffin oils (fields of Oil Rocks, Guneshli, and Mud Sopka), boiling in the range of 320-560 °C [40-42].

Fractional composition of distillate D-11 according to Bogdanov:

s.b.-320 °C	40 % – 450 °C	75 % – 510 °C
5 % – 394 °C	50 % – 460 °C	80 % – 514 °C
10 % – 416 °C	55 % – 477 °C	85 % – 520 °C
15 % – 430 °C	60 % – 489 °C	90 % – 526 °C
20 % – 437 °C	65 % – 497 °C	99 % – 560 °C
30 % – 447 °C	70 % – 503 °C	

Physicochemical properties of distillate:

Density at 20 °C, кg/m^3	916,7
Kinematic viscosity, mm^2/s, at:	
100 °C	11,74
50 °C	75,3
Viscosity index	72
Temperature, °C:	
flashes	208
pour point	-8
Color in NPA marks	8
Refractive index n_D^{20}	1,5072

Distillate D-11 from the Heydar Aliyev Oil Refinery was subjected to hydrocracking at the continuously operating pilot Shuykin unit of the ANAS OPP, on the industrial catalyst GKD-205 at a temperature of 420 °C, a pressure of 4-5 MPa, a feedstock volumetric feed rate of 0.5-1.0 h^{-1} and a hydrogen flow of 1000 *l/l* of feed, the scheme of which is shown in Fig. 1 [43, 44].

Hydrocracking of the feedstock, preheated in heat exchangers 1 and 2 and mixed with H_2 gas is carried out in a multi-zone reactor 3 with a descending flow of the feed mixture. The liquid separated from the gas in separators 4 and 5 is heated in heat exchanger 6 and fed to distillation column 10 for the separation of light gasoline (b.s.-180 °C). Water vapor VI is introduced into the bottom of column 10. The fraction boiling above 180 °C is heated in the coils of furnace 11 and separated in vacuum column 12 into fractions (180-300 °C), a light oil fraction (300-400 °C) and a heavy oil fraction (above 400 °C). In amine treatment unit 17, hydrogen sulfide is removed from the recirculating gas. The unit makes extensive use of air-cooled units – condensers and refrigerators. Between units 1 and 13, water is injected into the hydrocracking product stream to flush out deposits. The resulting fractions are collected in receiver 20.

The qualities of the D-11 distillate from a mixture of low-paraffin oils and it's hydrogenates, obtained at a temperature of 420 °C, various pressures, and volume rates, are given in Table 1.

As can be seen from Table 1, increasing the process pressure leads to an improvement in the color, density, and other parameters of the hydrogenation product.

The color of the hydrogenation products improves from 8 to 5 NPA grades. Reducing the process volumetric flow rate from 1 to 0.5 h^{-1} at the same temperature (420 °C) leads to intensive destruction of

the feedstock, and the viscosity, flash point, density, and other parameters of the hydrogenation products decrease sharply [27, 45, 46].

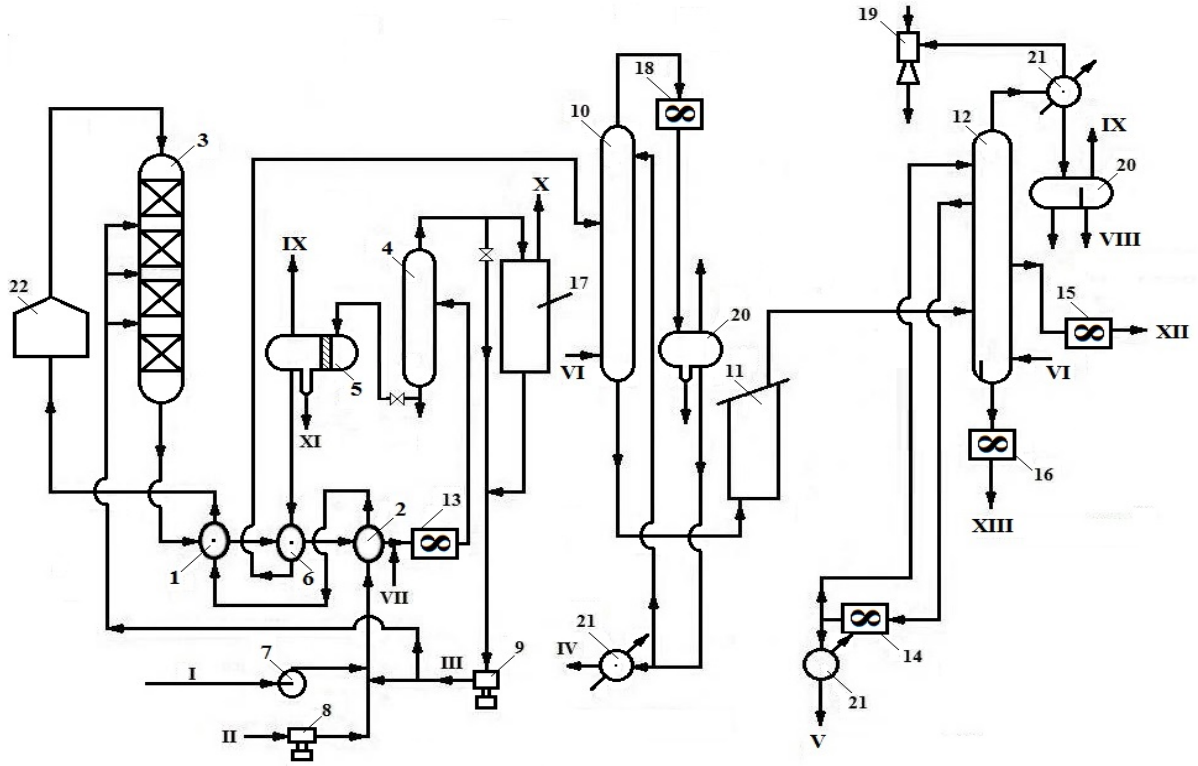

Fig. 1. Scheme of the unit for hydrocracking of distillates for the production of oils. 1, 2 – heat exchangers for heating purified oil; 3 – reactor; 4, 5 – separators; 6 – heat exchanger; 7 – raw material pump; 8 – fresh gas compressor; 9 – compressor of circulating hydrogen-containing gas; 10 – atmospheric column; 11 – tubular furnace in the fractionation section; 12 – vacuum column; 13-16 – air coolers; 17 – unit for cleaning circulating gas from hydrogen sulfide; 18 – condenser-refrigerator; 19 – ejector; 20 – receiver; 21 – refrigerator; 22 – tubular furnace. I – feedstock – distillate; II – fresh hydrogen-containing gas; III – circulating hydrogen-containing gas; IV – fraction b.s.-180 °C; V – liquid hydrocarbons; VI – water vapor; VII – water; VIII – fr. 180-300 °C; IX – gas to flare; X – hydrogen sulfide; XI – aqueous solution; XII – fr. 300-400 °C; XIII – fr. above 400 °C

Table 1. Qualities of distillate D-11 from a mixture of low-paraffin oils and its hydrogenates obtained at a temperature of 420 °C, various pressures and volume rates

Indices		Distillate D-11	Hydrogenisate	Hydrogenisate	Hydrogenisate
Pressure, MPa		–	4	4	5
Volume rate, h^{-1}		–	1,0	0,5	0,5
Density at 20 °C, кg/m^3		916,7	909,3	904,2	902,1
Kinematic viscosity, mm^2/s	100 °C	11,74	8,47	5,02	6,26
	50 °C	75,3	47,0	20,62	25,73
	40 °C	–	77,58	30,9	39,58
Viscosity index VI		72,0	74,0	82,0	110,0
Temperature, °C	flashes	208	178	104	104
	pour point	-8	-12	-17	-12
Color in NPA marks		8	6	6	5
Refractive index n_D^{20}		1,5072	1,5050	1,4998	1,5010

Results and discussion

Oil fractions boiling at different temperatures were isolated and analyzed from the hydrogenation products obtained at different pressures and volumetric flow rates by atmospheric-vacuum distillation (Table 2).

In order to obtain a base for high-index oils, it is advisable to carry out the hydrocracking process under relatively low pressure (5 MPa), a temperature of 420 °C, a volume rate of 0.5 h^{-1}, and a hydrogen amount of 1000 *l/l* of feedstock.

Table 2. Qualities of oil fractions of hydrogenates obtained at a temperature of 420 °C, various pressures and volume rates

Indices	Fraction, °C											
	320-400			400-420			420-450			> 450		
Pressure, MPa	4	–	5	4	–	5	4	–	5	4	–	5
Volume rate, h^{-1}	1,0	0,5	–	1,0	0,5	–	1,0	0,5	–	1,0	0,5	–
Density at 20 °C, кg/m^3	907,7	906,8	905,0	912,2	908,3	907,9	915,2	908,7	908,3	918,6	909,2	908,7
Kinematic viscosity, mm^2/c, at:												
100 °C	4,14	3,75	3,24	8,06	7,18	6,66	11,48	9,72	9,42	23,54	17,2	16,5
50 °C	15,99	13,84	11,02	46,43	38,52	33,99	88,87	62,95	60,12	194,4	131,94	119,51
40 °C	23,75	20,08	15,93	79,06	63,88	56,05	150,8	110,45	104,51	369,7	238,49	221,47
Viscosity index VI	70	71	73	58	60	63	45	53	55	82,5	70,0	78,0
Temperature, °C:												
flashes	184	180	173	229	226	220	249	248	242	293	285	292
pour point	-16	-20	-20	-8	-8	-4	-2	-6	-4	-2	-2	-4
Color in NPA marks	4½	2½ -	3½	8-	3½ -	4	8-	4	4½ +	dark	dark	dark
Refractive index n_D^{20}	1,5064	1,5037	1,5040	1,5074	1,506	1,505	1,508	1,5068	1,506	1,5083	1,5082	1,5064
Yield, % to process	23,77	27,36	18,83	18,72	15,14	20,13	28,57	20,69	22,22	22,01	25,03	31,86

Oil fractions with boiling ranges of 300-350 °C and 300-400 °C were isolated and studied from the hydrogenated distillate D-11.

It was shown that they are low-viscosity oils with a high viscosity index (100) and meet the requirements of the standard GOST 33111-2014 for high-index industrial oils of the VI-4 and VI-6 types (Table 3).

Table 3. Physicochemical indices of fractions of 300-350 °C and 300-400 °C obtained from the hydrogenated distillate in order to obtain the base of VI oils

Indices	Fraction 300-350 °C	GOST R 59107-2020 for base oils of the VI-4 series	Fraction 300-400 °C	GOST R 59107-2020 for base oils of the VI-6 series
Density at 20 °C, кg/m^3	892,9	-	902,9	-
Kinematic viscosity, mm^2/c, at:				
100 °C	1,78	-	2,59	-
50 °C	4,37	3,5-4,5	7,29	5,5-7,5
40 °C	5,44	4,3-6,0	10,16	7,2-10,1
20 °C	10,39	-	22,27	-
Viscosity index VI	~150	-	99	95
Temperature, °C:				
pour point	-32	not higher -8	-28	not higher -10
flashes	140	not lower 125	150	not lower 145

Refractive index n_D^{20}	1,4994	-	1,5045	-
Color in NPA marks	2-	1,0	2	1,5
Acidity number, мg KOH/g	0,01	no more 0,05	0,02	no more 0,05
Ash content, %	absent	no more 0,05	отс.	no more 0,05
Coking ability, %	0,02	no more 0,05	0,03	no more 0,05
Yield, % to process	6,61	-	20,00	-

It should be noted that the specified oil fractions do not require dewaxing, and, as a result, the production costs of such oils can be halved [20]. They can be used to obtain alloyed oils of the IGP series [47].

In order to obtain the base of high-index all-season oil of type M-4, the hydrogenation product of industrial distillate D-11, obtained at 420 °C, a feed volumetric feed rate of 0.5 h^{-1} and a hydrogen supply of 1000 *l/l* of feed, was fractionated [29, 31, 35].

Fuel (up to 320 °C) and oil fractions boiling at 320-400 °C were isolated from the hydrogenation product, which was thickened with 2.48-4 % viscosity (T-2-670) additive (PMA with olefin copolymer) [48-53].

At the same time, a high level of viscosity-temperature properties of thickened oils is ensured, which meet the requirements of GOST 10541-2020 for oil M-4z/6B1 and oil M-6z/10V (Table 4).

Table 4. Characteristics of the base of thickened motor oils

Indices	Fraction 320-400 °C		GOST 10541-2020 for oil M-4z/6V1	GOST 10541-2020 for oil M-6z/10V
	+2,48 % T-2-670	+4 % T-2-670		
Density at 20 °C, кg/m^3	906,3	907,5	-	890,0
Kinematic viscosity, mm^2/c, at:				
100 °C	6,24	9,5	5,5-6,5	9,5-10,5
50 °C	23,81	32,28	-	-
40 °C	31,86	47,73	-	-
-18 °C	2091	7809	1100-2600	≤9000
-30 °C	10392	-	≤11000	
Viscosity index VI, not less than	133	145	125	115
Temperature, °C:				
pour point	173	183	no more 165	no more 190
flashes	-42	-37	no higher - 42	no higher - 40/-30
Color in NPA marks	4-	4	-	-
Refractive index n_D^{20}	1,5041	1,5041	-	-
Yield, % to process	18,83	18,83	-	-

The advantage of the hydrocracking process is that from the D-11 distillate under relatively easy conditions, it is possible to obtain the base of all-season oil with a yield of 18.83% by weight, calculated on the distillate (Table 4), and by compounding the oil fractions, it is possible to obtain various base oils with low solidification (Table 5).

Evaluation of the quality of fractions boiling at s.b.-180 °C, 180-320 °C, s.b.-240 °C, and 240-300 °C, obtained from hydrogenates, showed that they can be used as a solvent-liquid RZh-3 according to TU 38.101964-83, a component of jet fuel according to GOST 10227-2013, and a component of winter diesel fuel according to GOST 305-2013 [54-56].

Table 5. Qualities of oil fractions of hydrogenates obtained at a temperature of 420 °C, various pressures and volume rates

Fraction, °C	Pressure, MPa	Volume rate, h^{-1}	Density at 20 °C, кg/m^3	Kinematic viscosity, mm^2/s, at:		Viscosity index VI	Temperature, °C:		Refractive index n_D^{20}	Yield, % to process
				100 °C	40 °C		flashes	pour		

								point		
320-400	4	1,0	907,7	4,14	23,75	70	184	-16	1,5064	23,77
–	–	0,5	906,8	3,75	20,08	71	180	-20	1,5037	27,36
–	5	–	905,0	3,24	15,93	73	173	-20	1,5040	18,83
GOST 32-74 for oil T.22	–	–	900,0	–	20,0-23,0	70	180	-15	–	–
320-450	4	1,0	911,7	7,14	62,3	64	207	-6	1,5047	71,06
–	–	0,5	907,9	5,92	43,31	74	201	-12	1,5048	73,19
–	5	–	907,6	5,98	45,28	66	200	-7	1,5033	61,18
GOST 32-74 for oil T-30	–	–	900	–	–	65	180	-10	–	–
> 320 °C	4	1,0	915,0	9,53	95,55	76	213	-10	1,5051	93,07
–	–	0,5	908,5	7,76	68,41	72	208	-5	1,5058	98,22
–	5	–	908,0	8,16	75,12	70	205	-10	1,5053	93,04
GOST 32-74 for oil T-46	–	–	905,0	–	–	60	195	-10	–	–
GOST 32-74 for oil T-51	–	–	900,0	–	–	70	195	–	–	–
> 400 °C	4	1,0	916,0	13,1	179,7	50	254	-8	1,5075	69,3
–	–	0,5	908,7	11,47	131,4	60	250	-2	1,5070	70,86
–	5	–	908,3	9,43	94,65	71	215	-3	1,5050	74,21
GOST 26191-84 on lightweight vaporizers 13	–	–	–	11,4-14,5	–	–	180	-10	–	–
TU 0253-008-58966428-2005 for light cylinder oil 11	–	–	920	9-13	–	65	215	5	–	–
> 450 °C	4	1,0	918,6	23,54	369,7	82,5	293	-2	1,5083	22,02
–	–	0,5	909,2	17,2	238,49	70,0	285	-2	1,5082	25,03
–	5	–	908,7	16,5	221,47	78,0	292	-4	1,5064	31,86
TU 0253-008-58966428-2005 for light cylinder oil 24	–	–	940	22-28	–	35	240	20	–	–
SAE 90 for AK-15 oil	–	–	–	≥ 14,5	–	≤ 65	225	-5	–	–

The consolidated material balance of the process of obtaining fuels, oils, and liquids for industrial distillate D-11 by hydrocracking under optimal conditions (T – 420 °C, P – 5 MPa, v – 0.5 h^{-1}, H_2 – 1000 *l/l* of raw material) is presented below.

Taken, % wt.:		100
Distillate		
Received, % wt.:	I mode	II mode
Fraction to 300 °C	5,8	-
Fraction to 320 °C	-	6,97
including:		
s.b.-180 °C (RJ-3 or component of fuel T-2)	1,4	1,40
180-300 °C (component of diesel fuel «3»)	4,4	-
180-320 °C (component of diesel fuel «3»)	-	5,57
Fraction of lubricating oil		
including:		
300-400 °C (industrial VI-6)	20,0	-

320-400 °C (base of all-season motor oil M-4)	-	18,83
> 400 °C (cylinder light oil 11)	74,2	74,20
Total	100,0	100,0

Conclusion

Taking into account the above, we note that with the existing technical base of the Baku Oil Refinery, which has sufficient capacity for hydrogenation purification, research into the possibility of using oil fractions (D-11 distillate) of a mixture of low-paraffin oils as raw materials for obtaining base oils, including high-index ones, is of particular importance.

During the research into hydrocracking of D-11 distillate on the GKD-205 catalyst, the optimal mode was identified: pressure, 5 MPa; space velocity, 0.5 h^{-1}; temperature 420 °C.

It should be noted that the oil fractions (300-400 °C) obtained from the hydrogenate under the optimal mode do not require dewaxing and, as a result, the costs of oil production are reduced by half.

From the hydrocracking of the D-11 distillate, along with the base oils VI-4, VI-6, all-season motor oils M-4z/6V1 and M-6z/10V are obtained.

Also obtained oils without dewaxing – turbine oils of the T-22, T-30, T-46, T-51 brands and light cylinder oils 11, 24, AK-15, etc.

After dewaxing the oil fractions of hydrogenates boiling above 400 and 500 °C, high-viscosity oils - vapors - are obtained, significantly superior in quality to oils from the unique Baku oil oils.

It should be noted that the scheme proposed in this work ensures waste-free production of environmentally friendly fuels and renewable oils, and it is also significantly simpler than existing ones and can be used as the basis for oil refinery projects.

References

1. Khavkin V.A., Gulyaeva L.A., Chernysheva E.A., Petrov S.M., Lakhova A.I. Conversion of hydrocarbons in the process of hydrocracking. *World of oil products*, 2017, **No. 4**, p. 4-8. (in Russian)
2. Khavkin V.A., Gulyaeva L.A., Nikulshin P.A., Bitiev G.V. Hydrogenation processes for refining oil residues. *Oil refining and petrochemistry*, 2018, **No. 6**, p. 9-11. (in Russian)
3. Kuzmina R. I., Liventsev V. T., Aniskova T. V., Romadenkina S. B. Hydrocracking – a process of deep processing of oil residues. Saratov: Amirit, 2019. 79 p. (in Russian)
4. Prajapati R., Kohli K., Maity S.K. Slurry phase hydrocracking of heavy oil and residue to produce lighter fuels: An experimental review. *Fuel*, 2021, **Vol. 288 (4)**, 199686. DOI: 10.1016/j.fuel.2020.119686
5. Miao P., Zhu X., Guo Y., Miao J., Yu M., Li C. Combined mild hydrocracking and fluid catalytic cracking process for efficient conversion of light cycle oil into high-quality gasoline. *Fuel*, 2021, **Vol. 292**, 120364. DOI: 10.1016/j.fuel.2021.120364
6. Khavkin V.A., Gulyaeva L.A., Chernysheva E.A. Oil residues – raw materials for hydrogenation processes. *Oil refining and petrochemistry*, 2020, **No. 1**, p. 12-18. (in Russian)
7. Khavkin V.A., Gulyaeva L.A., Ovchinnikov K.A., Nikulshin P.A., Shmelkova O.I., Vinogradova N.Ya., Bitiev G.V., Mitusova T.N., Lobashova M.M., Krasilnikova L.A., Yusovsky A.V. Method for processing oil residues. Patent 2613634, Russian Federation, IPC C10G67/04, "VNII NP", No. 2016108785; Claimed 11.03.2016; Published 21.03.2017. (in Russian)
8. Khavkin V.A., Gulyaeva L.A. Prospects for the development of the hydrocracking process at Russian oil refineries. *Oil refining and petrochemistry*, 2016, **No. 2**, p. 8-14. (in Russian)
9. Nguyen T.T., Shevchenko M.A. Improving the process of hydrocracking vacuum gas oil. *Science and Education Today*, 2017, **No. 11**, p. 20-21. (in Russian)
10. Kosyanenko D.S., Anishchenko O.V. Analysis of chemical processes occurring during hydroprocessing of vacuum gas oils. *Bulletin of the Magistracy*, 2021, **No. 5-4 (116)**, p. 10-12. (in Russian)

11. Khavkin V.A., Gulyaeva L.A., Vinogradova N.Ya., Chernysheva E.A., Vinokurov B.V., Kapustin V.M. Method of hydrogenation processing of vacuum distillate. Patent 2612133. Russian Federation, IPC C10G65/12 VNII NP NIPI "Neftegaz", No. 2016108784; Declared 11.03.2016; Published 02.03.2017. (in Russian)
12. Tsvetkov O.N. Tribology in oil science. *Friction and lubrication in machines and mechanisms*, 2015, **No. 5**, p. 39-45. (in Russian)
13. Tsvetkov O.N., Maksimov A.L. Trends in the Development of Lubricants in Russia. *World of Oil Products*, 2020, **No. 5**, p. 6-18. (in Russian)
14. Iliev R.L., Vygonyailo A.I., Masalevich V.A., Talanov E.T. Method for fuel oil hydrocracking. Patent for invention. RU 2760454 C1. Russian Federation. November 25, 2021. (in Russian)
15. Tsvetkov O.N., Cheremiskin A.L. Tribological Assessment of the Properties of Lubricating Oils. *World of Oil Products*, 2017, **No. 2**, p. 25-27. (in Russian)
16. Astanovsky D.L., Astanovsky L.Z. Method of Hydrogenation Treatment of Petroleum Feedstock: Patent 2593262. Russian Federation. IPC C10G65 / 12, C10G45 / 22, No. 2015116762/04; Appl. 05.05.2015; Publ. 10.08.2016. (in Russian)
17. Astanovsky D.L., Astanovsky L.Z., Kustov P.V. Deep processing of heavy oil feedstock using fast engineering technology. *Chemical technology*, 2016, **No. 8**, p. 12-15. (in Russian)
18. Astanovsky D.L., Astanovsky L.Z., Kustov P.V. Hydrogenation treatment of oil refining products and heavy oil residues using FAST ENGINEERING technology. *OilGasChem*, 2017, **No. 1**, pp. 27-35. (in Russian)
19. Yuzmukhametova R.F., Boldushevsky R.E., Nikulshin P.A. "Oil Residue Processing: Challenges of Preparing Heavy Raw Materials and Potential for Adsorption-Contact Purification." Oil, Oil Products, and Methods of Their Evaluation, 2025, **No. 6**, p. 12-27. DOI: 10.24412/0233-5727-2025-6-12-27
20. Strugovets G.A., Efanova O.Yu. Replacing the low-temperature dewaxing process with the hydroisomerization process in order to obtain high-index oils with a low pour point / 6th International Scientific and Technical Conference "Problems of Chemmotology: from Experiment to High-Level Mathematical Models", Moscow, October 17-19, 2016, p. 70. (in Russian)
21. Tatzhikov, A.D., Belyakova V.A., Davydov M.V., Rudnikova E.R. Relevance of research and development of the modernization of the hydrogenation process "hydrocracking". *Oil and Gas Technologies and Environmental Safety*, 2024, **No. 2**, p. 60-65. DOI: 10.24143/1812-9498-2024-2-60-65 (in Russian)
22. Dzhuraeva G.Kh. Methods of Processing Petroleum Hydrocarbons. *Economy and Society*, 2024, **Vol. 120(5)**, p. 1212-1216. (in Russian)
23. Budukva S.V., Eletsky P.M., Zaikina O.O., Sosnin G.A., Yakovlev V.A. Middle distillates of secondary origin and their processing (review). *Petroleum Chemistry*, 2019, **Vol. 59(5)**, p. 485-501. DOI: 10.1134/S0028242119050046 (in Russian)
24. Rakhmatulina Yu.A. Technological prospects for processing heavy oil. *StudNet*, 2022, **No. 6**, p. 5629-5637. (in Russian)
25. Krylova M.M., Sosnova N.A., Sotnikova T.A., Kadiev H.M. Development of the design of innovative technology for hydroconversion of heavy oil residues. *World of Oil Products*, 2019, **No. 1**, p. 14 19. (in Russian)
26. Lakhova A.I., Gussamov I.I., Petrova A.N., Ibragimov R.K., Baranov D.V., Petrov S.M., Molodtsov S.D. Study of group composition and physicomechanical properties of oxidation products of heavy residue of super-viscous oil. *Bulletin of the Technological University*, 2015, **Vol. 18(19)**, p. 70-73. (in Russian)
27. Andryushchenko N.K., Yunusov S.G., Khalafova I.A., Babayeva Z.B., Suleymanova E.I., Talybova Kh.I. Oxidative sulfur refining of gasoline fractions in the presence of hydrogen peroxide on a heterogeneous catalyst. *Chemical Problems*, 2026, **Vol. 24(1)**, p. 85-93. DOI: 10.65382/2221-8688-2026-1-85-93
28. Pigoleva I.V., Shabalina T.N., Kitova M.V., Tolmachev S.V. Obtaining base oils from petroleum

feedstock using hydrocatalytic processes. *Oil and Gas Technologies*, 2018, **No. 2**, p. 19-23. (in Russian)
29. Karpov N.V., Vakhromov N.N., Dutlov E.V., Bubnov M.A., Gudkevich I.V., Borisanov D.V. Pat. 2790171 Russian Federation, IPC C10G 67/04, C10G 7/06. Method for producing high-index base oils. No. 2022101486, declared 24.01.2022; published 14.02.2023; Bulletin No. 5. (in Russian)
30. Ryabov V.G., Kudinov A.V., Bakulev P.V., Tsaplina M.E., Pashkin R.E. Determining the possibility of obtaining high-index oil components from unconverted hydrocracking residue. *Industrial service*, 2017, **No. 4**, p. 20-23. (in Russian)
31. Noh Kyung Seok, Kim Yong Woon, Kim Gyung Rok, Jae Wook Ryu, Sun Hyuk Bae, Tae Young Jang, Sun Choi, Seung Hoon Oh. Method for producing high quality lubricating base oil from crude oil. Pat. 8936715 US, МПК C10G69/02, C10M101/02, SK Innovation Co, Ltd. № 13/695070; decl. 08.08.2010; published 20.01.2015.
32. Rashidova S.Yu. Study of deasphalted tar hydrocracking products. *Oil refining and petrochemistry*, 2018, **No. 6**, p. 12-15. (in Russian)
33. Andryushchenko N.K., Khalafova I.A., Abdullayeva S.S. Research on the ıntensıfıcatıon of deasphaltıng and catalytıc crackıng processes ın a magnetıc fıeld. *Processes of Petrochemistry and Oil Refining*, 2024, **Vol. 25(2)**, p. 433-444. DOI: https://doi.org/10.62972/1726-4685.2024.2.433
34. Ongarbaev E.K., Oteuli Sh.A., Muratov D., Tileuberdi E., Nurzhanova S.B., Maldybaev G.K. Demetallization and deasphalting of heavy oil feedstock. *Combustion and Plasma Chemistry*, 2019, **Vol. 17(2)**, p. 140-148. (in Russian)
35. Samedova F.I., Gasanova R.Z., Aliyev B.M., Abdullaeva Yu.A., Logmanova S.B. Results of the development of technology for obtaining base oils from a mixture of Azerbaijani oils. *World of oil products*, 2015, **No. 5**, p. 27-30. (in Russian)
36. Samedova F.I., Gasanova R.Z., Ibragimov H.D., Abdullaev E.Sh., Guseinova G.A., Yusifov Yu.G., Aliev B.M., Abdullaeva Yu.A., Logmanova S.B., Abbasova A.F. Returning the former glory of base oils from Baku oils. *Oil and Gas Technologies and Analytics*, 2016, **No. 6**, p. 66-68. (in Russian)
37. Abbasov V.M., Abdullaev S.E., Samedova F.I., Gasanova R.Z., Nabieva N.D. Collection of research papers 2016-2018 in the field of lubricating oil development. Baku: "Muallim", 2018. 142 p. (in Russian)
38. Abbasov V.M., Abdullaev S.E., Yusifov Yu.G., Aliev B.M., Mamedov F.F., Abbasova A.F., Gasanova R.Z., Logmanova S.B., Nabieva N.D., Abdullaev E.Sh. Quality comparison of engine oils from Baku petroleum with various additive packages. *Azerbaijan Oil Industry*, 2019, **No. 11**, p. 46-50. (in Azerbaijani)
39. Gimatdinov R.R., Fakhrutdinov R.Z. State of production of base oils in Russia. *Bulletin of Kazan Technological University*. 2106, **Vol. 19(11)**, p. 58-62. (in Russian)
40. Abbasov V.M., Samedova F.I., Gasanova R.Z., Abdullaev E.Sh., Yusifov Yu.G., Mamedov F.F., Kasumova L.H., Shashkaeva M.A. Development of Basic Bases of Motor Oils from Baku Oils. *Oil and Gas Technologies and Analytics*, 2016, **No. 6**, p. 69-72. (in Russian)
41. Abbasov V.M., Abdullayev S.E., Abdullayev E.Sh., Gasanova R.Z., Logmanova S.B., Samedova F.I., Kafarova N.F. Production of base oils from Baku oils. *Azerbaijan Oil Industry*, 2018, **No. 5**, p. 47-50. (in Azerbaijani)
42. Abbasov V.M., Samedova F.I., Gasanova R.Z., Abdullayev S.E., Logmanova S.B. Production of base oils from Baku oils using modern processes. *Azerbaijan Oil Industry*, 2018, **No. 11**, p. 40-43. (in Azerbaijani)
43. Chernozhukov N.I. Oil and Gas Processing Technology. Part 3. Purification and Separation of Petroleum Sulfate, Production of Commercial Petroleum Products. Ed. by A.A. Gureev and B.I. Bondarenko. 6th ed., revised and enlarged. Moscow: Chemistry, 1978. 424 p. (in Russian)

44. Echevsky G.V. Study of bifunctional hydrocracking and hydroisodewaxing catalysts based on zeolites and aluminophosphates. *Catalysis in Industry*, 2019. **Vol. 19(3)**, p. 235-239. DOI 10.18412/1816-0387-2019-3-235-239 (in Russian)
45. Abbasov V.M., Abdullayev S.E., Abdullayev E.Sh., Gasanova R.Z., Logmanova S.B., Iskandarov M.G., Kafarova N.F. Results of laboratory tests of motor oil samples taken from Baku oils. *Azerbaijan Oil Industry*, 2019, **No. 12**, p. 52-56. (in Azerbaijani)
46. Abbasov V.M., Abdullaev S.E., Samedova F.I., Gasanova R.Z., Nabieva N.D. Main results of the development of modern motor oils from Baku oils. *Oil and gas technologies and analytics*, 2019, **No. 12**, p. 54-56. (in Russian)
47. Karibov T.T., Azarenkov N.V. Modern hydrocatalytic processes in the production of mineral oils. *Bulletin of the Magistracy*, 2020, **No. 5-5(104)**, p. 21-24. (in Russian)
48. Shchepalov A.A., Kotlova E.S., Novoselov A.S., Shalashova A.A. Current state of white oil production: foreign and domestic technologies. Bulletin of PNIPU. *Chemical technology and biotechnology. Oil and gas processing technology*, 2018, **No. 4**, p. 138-150. DOI: 10.15593/2224-9400/2018.4.11 (in Russian)
49. Rashidova S.Yu. Hydrocracking of deasphalted oil from Sangachal-Deniz paraffinic oil / Proceedings of the XII international conference "Chemistry of Oil and Gas", Russia, Tomsk: 2022, p. 272-273. (in Russian)
50. Yusevich A.I., Grushova E.I., Timoshkina M.A., Prokopchuk N.R. Utilization of heavy oil residues at oil refineries: analysis of the state of the problem. Proceedings of BSTU. *Series 2: Chemical technologies, biotechnology, geoecology*, 2008, **Vol. 1(4)**, p. 52-57. (in Russian)
51. Kart, M.A., Seregin, S.A. "A Method for Continuous Compounding of Oils". Patent for Invention, RU 2734424 C1, Russian Federation, October 16, 2020. (in Russian)
52. Zaglyadova, S.V., Shabalina, T.N., Kitova, M.V. "Prospects for the Production of White Oils Using Hydrocatalytic Processes". *Scientific and Technical Bulletin of Rosneft Oil Company*, 2015, **No. 4**, p. 68-73. (in Russian)
53. Andryushchenko N.K., Khalafova I.A. Study of the process of obtaining alternative motor fuels using vegetable oils. *Chemical problems*, 2022, **Vol. 20(3)**, p. 229-241. DOI: 10.32737/2221-8688-2022-3-229-241
54. Imanbaev E.I., Serikkazinova A.K., Muktaly D., Akkenzheeva A.Sh., Busurmanova A.Ch. Use of Supercritical Fluids in Oil Refining. *Bulletin of Shakarim University. Technical Sciences*, 2025, **No. 2(18)**, p. 521-546. https://doi.org/10.53360/2788-7995-2025-2(18)-63 (in Russian)
55. Valizade L.G. Main Directions for Processing Heavy Oil Residues. *Bulletin of the Bashkir State Pedagogical University named after M. Akmulla*, 2021, **No. 4(61)**, p. 26-33. (in Russian)
56. Samedova F.I., Huseynova Q.A., Rashidova S.Y., Kuliev A.I., Gadzhieva I.A. Semi-synthetic oils obtained on the basis of mineral oils and α-olefin oligomers. *Azerbaijan Oil Industry*, 2015, **№ 6**, p. 48-51. (in Azerbaijani)