UDC 665.6

T.V. Yarmola, P.I. Topilnytskyy, V.J. Skorokhoda, B.O. Korchak

PROCESSING OF HEAVY HIGH-VISCOSITY OIL MIXTURES FROM THE EASTERN REGION OF UKRAINE: TECHNOLOGICAL ASPECTS

Lviv Polytechnic National University, Lviv, Ukraine

The article presents an analysis of reserves and processing of heavy high-viscosity crude oils in Ukraine and the world. A study of the physicochemical properties of heavy high-viscosity oils from the Yablunivske field, Poltava region of Ukraine, taken from various wells was conducted. For further research in order to develop a basic manufacturing scheme for the processing of heavy high-viscosity oils, a mixture of heavy high-viscosity oils from the Yablunivske field was used in certain ratios and its physicochemical properties were determined. As a result of the vacuum distillation of a mixture of heavy high-viscosity oils, the following products were obtained: broad gasoline fraction (fraction boiled up to 200^{0}C), broad diesel fraction (fraction 200–360^{0}C) and the rest of the process (fraction >360^{0}C). An analysis of the physicochemical properties of the prepared fractions was also carried out. It was established that the products obtained from the mixture of heavy high-viscosity oils of the Yablunivske field can be used as raw materials for the production of commercial gasoline and diesel fuels. The rest of the process can serve as raw materials for the production of road bitumen. According to the analysis of the physicochemical properties of the products obtained by vacuum distillation of a mixture of heavy high-viscosity oils, the basics of the processing technology of a mixture of heavy high-viscosity oils of the Yablunivske field were developed. In particular, a manufacturing scheme and a flow chart of the process were proposed, and the material balance was calculated.

Keywords: high viscosity oil, heavy oil, gasoline fraction, diesel fraction, viscosity, bitumen.

DOI: 10.32434/0321-4095-2023-146-1-40-49

Introduction

Heavy high-viscosity oil (HH-VO) is a hydrocarbon liquid having the density of 920–1000 kg/m^3 and the viscosity of 10 to 100 mPa·s. Heavy oil deposits are found at all depths from 300 m to more than 1500 m. Heavy oils contain a fairly high content of aromatic hydrocarbons, tar-asphaltene substances, and high concentrations of metal and sulfur compounds; they also show high density and viscosity values, and increased coking [1–4]. As a result, this causes an increase in the production cost, as well as an increase in the cost of transportation through existing oil pipelines and complicated oil refining according to classical manufacturing scheme.

More than 30 countries have recoverable heavy oil reserves. The world's largest oil fields are as follows: the supergiant Al-Burkan in Kuwait, Kirkuk in Iraq, Abu Safah in Saudi Arabia, and the Bolivar Coastal field in Venezuela. They contain very large amounts of heavy oil in addition to conventional oils. There are also other giant heavy oil fields like Zubair in Iraq; Duri in Indonesia; Gudao and Karamai in China; Seria in Brunei; Bacab, Chac, and Ebano-Panuco in Mexico; Belayim Land in Egypt; Maydan Mahzam in Qatar; and Uzen and Zhetybay in Kazakhstan [5]. The amount of heavy oil reserves in the world (Fig. 1), as estimated by scientists of the U.S. Geological Survey, is 434 billion barrels [6].

Ukraine has about 2% of the world's heavy oil reserves, but there are practically no publications on their research due to the complexity of oil sampling, insufficient production of such oils. A fairly large number of heavy oil deposits were found in the oil and gas condensate fields of the Dnipro-Donetsk depression. As an example, one of the largest is the Yablunivske gas condensate field, located in the Poltava region. The successful development of this field indicates the feasibility of «connecting» these additional hydrocarbon sources during oil, gas, and condensate production. Currently, the explored oil reserves of the Moscow and Bashkir deposits of the Yablunivske field amount to about 50 million tons [7]. Figure 2 shows reserves of HH-VO (%) located in Eurasian countries.

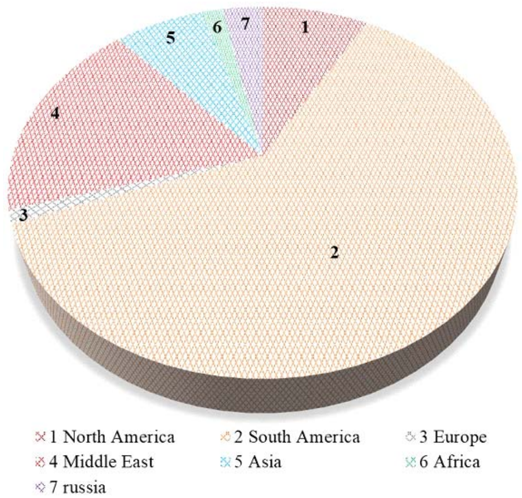

Fig. 1. Estimate of heavy oil reserves in the world

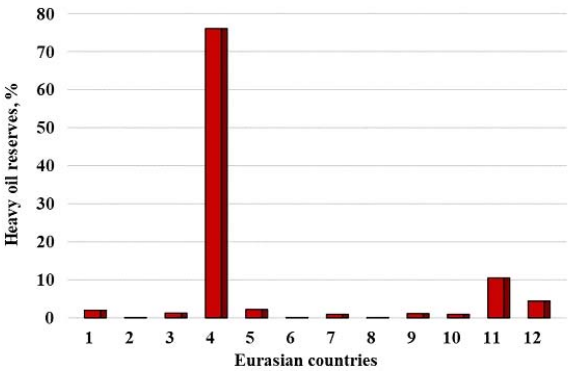

Fig. 2. Heavy oil reserves in Eurasian countries: 1 – Ukraine; 2 – Italy; 3 – Belarus; 4 – russia; 5 – Azerbaijan; 6 – Austria; 7 – Uzbekistan; 8 – Turkey; 9 – Turkmenistan; 10 – Tajikistan; 11 – Kazakhstan; 12 – other

Ukrainian refineries are not designed to process heavy oils. Some oils can be traditionally processed as a blend with conventional light oil, but some require specialized plants that produce a limited range of petroleum products. Solving this problem is complicated by incomplete, highly contradictory and scattered data on the properties and composition of heavy oils. The lack of information makes attracting new investors difficult [8].

It is believed that a reduction in the viscosity of oils and petroleum products is achieved by dispersing asphaltenes when a dispersant (toluene, xylenes, furan, etc.) is added to the oil in the amount of 0.1–25 wt.%, which leads to a decrease in the viscosity and aggregative stability of the dispersed oil system. In addition to a high content of asphalt-resin substances, high-viscosity oils can be characterized by a low content of light fractions, which also leads to increased density and viscosity. The main requirements for petroleum solvents are affinity (lyophilicity) to the asphalt-resin part of the raw material to ensure the stability of the colloidal medium; heat resistance in the given working range of time and temperature; staying in the liquid phase under working conditions and ensuring the maximum dissolution effect [9–11].

In addition to problems with production and transportation of heavy oil, there are problems with its processing due to the complexity of its preparation, namely dehydration and desalting [7].

Depending on the physico-chemical properties of oils, the direction and technology of HH-VO processing and the range of obtained petroleum products are determined. To fulfill the task, it is necessary to conduct a study of the physico-chemical properties of the oil mixtures from the Yablunivske field, which will be processed.

The purpose of this work was to develop the basics of the HH-VO processing technology, namely, the justification and creation of a basic technological scheme of the installation, as well as the preparation of technological recommendations for conducting the HH-VO processing process. These recommendations should be based on the results of experimental studies. To achieve the task, it is necessary:

– to conduct an analysis of the HH-VO mixture of the Yablunivske field;

– to propose a basic technological scheme of the HH-VO processing process;

– to make a material balance of the process;

– to make a technological map of the process.

Experimental

Crude oils from 4 wells of the Yablunivske field was used for the research. Physicochemical properties of the initial crudes were determined according to the standard methods, the list of which is given in Table 1. The characteristics of the raw materials are presented in Table 1.

Table 1

Characteristics of initial crude oils

Properties	Units	Oil from well 1	Oil from well 2	Oil from well 3	Oil from well 4	Standard or ref.
density at 20^0C	kg/m^3	978	981	973	955	ASTM D1298
kinematic viscosity at 40^0C	mm^2/s	488	2010*	470	28.5**	EN ISO 3104
coking ability	wt.%	9.8	10.2	7.5	6.4	[12]
water content	vol.%	5.1	24.6	5.6	5.4	ASTM D95-13
sulfur content	wt.%	2.8	2.9	3.1	1.68	ASTM D4294
chlorides content	mg/dm^3	2810	5250	7120	1260	ASTM D3230
sulfuric resins content	vol.%	17.2	23.6	15.1	22.8	ASTM D974
pour point without solvent	^{0}C	32	42	7	5	ASTM D97
pour point with solvent	^{0}C	–19	–14	–13	–24	ASTM D97
fractional composition, %	wt.%					ASTM D2887, ASTM D5307 and ASTM D6352
distilled to 200^0C		2.9	3.1	4.1	37.0	
distilled to 360^0C		22.0	23.0	21.0	62.0	
distilled to 500^0C		57.0	53.0	56.0	–	

Notes: * – viscosity is determined at 50^{0}C; ** – indices for oil with diluent.

The group hydrocarbon composition of the fractions obtained by the distillation process of the HH-VO mixture was studied by the chromatographic method. It is a non-standardized method using silica gel of ASK grade as an adsorbent. Hydrocarbon fractions were washed with petroleum ether and benzene, and asphalt-resinous substances were desorbed with an alcohol-benzene mixture.

Results and discussion

The HH-VO mixture for further analysis was prepared by mixing oils from different wells of the Yablunivske field in a certain percentage ratio as follows: well No. 88 – 30%; well No. 94 – 20%; well No. 152 – 15%; well No. 153 – 15%; and well No. 337 – 20%. The main physicochemical and technological properties of the studied oil mixtures of the Yablunivske field are given in Table 2.

According to the data presented in Table 1, it can be concluded that in terms of density, the obtained mixture of oils from the Yablunivske field belongs to the category of very heavy oils, since its relative density is 965 kg/m^3. It is worth noting that the heavier oil, the heavier fractions it contains, as a result of which its kinematic viscosity also increases. The kinematic viscosity determined at the temperature of 40^0C is 254.2 mm^2/s, which in turn indicates the presence of a sufficiently large amount of asphalt-resin substances (ARS) in the composition of the HH-VO mixture. As a result, refining such oil is a complex and energy-consuming process. The low solidification temperature of the HH-VO mixture without a solvent also indicates a high content of ARS in its composition. Therefore, difficulties will arise during the transportation of these oils, especially in the period of low temperatures, accordingly, it is necessary to provide additional measures to reduce the solidification temperature. The sulfur content in the HH-VO mixture of the Yablunivske field is 2.4 wt.%. Therefore, to obtain high-quality products, it is necessary to provide the deep hydrogenation processes in the current HH-VO manufacturing scheme at the refinery. At the same time, the high sulfur content in the HH-VO mixture can damage oil refinery equipment (causing equipment corrosion). The mass fraction of water in the HH-VO mixture of the Yablunivske field is 4.2 vol %, but according to the requirements for primary oil processing, the water content in it should be 0.1%. That is why, in the processing scheme of the HH-VO mixture of the Yablunivske field, it is necessary to provide preliminary dehydration, after which the dehydrated HH-VO mixture will be sent to further processing processes.

Therefore, according to the obtained results, it is necessary to develop an optimal current manufacturing scheme for the HH-VO mixture of the Yablunivske field.

Table 2

Physicochemical properties of the blended crude of Yablunivske field

Properties	Units	Values
color	–	black
coking ability	wt.%.	6.9
density	kg/m^3	965
water content	vol.%	4.2
sulfur content	wt.%	2.4
chlorides content	mg/dm^3	9600
sulfuric resins content	wt.%	16.9
asphaltenes content	wt.%	4.2
pour point without solvent	^{0}C	18
pour point with solvent	^{0}C	–12
kinematic viscosity at 40^0C	mm^2/s	254.2
Fractional composition		
distilled to 200^0C	wt.%	14.6
distilled to 360^0C		42.3

To choose the optimal set of technological processes for the treatment of the HH-VO mixture from the Yablunivske field, it is necessary to conduct its separation and analysis of the obtained fractions' physicochemical properties according to the classical research scheme. The separation process of the HH-VO mixture was carried out in the oil refining unit under atmospheric pressure and vacuum. Fractions were taken up to a temperature of 360^0C (with respect to normal conditions), since the thermal decomposition of oil hydrocarbons began at higher distillation temperatures.

As a result of the HH-VO mixture separation, the following fractions were obtained:

- gasoline fraction (b.p.–200^0C);
- broad diesel fraction (200–360^0C);
- residue (>360^0C).

It is worth noting that a characteristic feature of the separation process of the HH-VO mixture of the Yablunivske field is a low yield of light fractions boiling up to a temperature of 360^0C. Therefore, when developing the method of their processing, it is necessary to pay attention to the processing of their dark part (>360^0C).

Generally accepted quality indicators were determined for the broad gasoline fraction b.p.–200, obtained by separating the HH-VO mixture of the Yablunivske field. The results of determination of the physicochemical properties of the broad gasoline fraction are given in Table 3.

As shown in Table 3, the obtained broad gasoline fraction is characterized by the absence of water-soluble alkalis and acids, and it withstands the copper plate test. The sulfur content in the broad gasoline fraction of the HH-VO mixture of the Yablunivske field is 0.11 wt.%, therefore it belongs to the sulfur fractions and requires additional purification processes, for example, hydrotreating.

Figure 3 shows the hydrocarbon composition of the broad gasoline fraction (b.p.–200^0C). The paraffin content in the broad gasoline fraction and aromatic hydrocarbons is 50.61% and 25.36%, respectively, which in turn determines their relatively low detonation resistance. At the same time, the sufficiently high content of naphthenic hydrocarbons (24.03 wt.%) and aromatics (25.36 wt.%) in the broad gasoline fraction suggests that this fraction can be a raw material for the catalytic reforming process to obtain high-octane gasoline. Another factor affecting the quality of the final product is molecular weight and fractional composition. With an increase in the molecular weight of the fraction and, accordingly, its boiling point, the yield of reformate gradually increases. A significant amount of benzene is formed during the reforming of gasoline fractions that boil up to 85^0C. Therefore, the boiling temperature of the fractions sent to reforming the studied oils should be higher.

Table 3

Physico-chemical properties of the broad gasoline fraction (b.p.-200⁰C)

Properties	Values
yield on the weight of oil, wt.%	14.6
sulfur content, wt.%	0.11
refractive index, n_D^{20}	1.4699
density, kg/m^3	0.755
water soluble acids and alkalis	none
copper plate test	passed
molecular weight	134
actual resins, $mg/100\ cm^3$	23
mass fraction, %	
monocyclic aromatic hydrocarbons	23.99
bicyclic aromatic hydrocarbons	1.46
fractional composition	
initial boiling point, ^0C	48
10%	79
50%	132
90%	189
end boiling point, ^0C	198

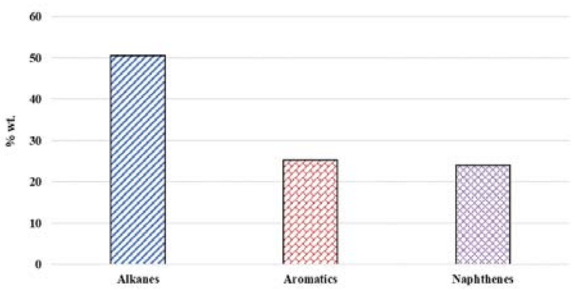

Fig. 3. Group hydrocarbon composition of the broad gasoline fraction (fr. boiled up to 200⁰C)

Generally accepted quality indicators were determined for the broad diesel fraction 200–360⁰C obtained from the HH-VO mixture of the Yablunivske field (Table 4).

As shown in Table 4, the broad diesel fraction of the HH-VO mixture of the Yablunivske field contains 0.81 wt.% of total sulfur. The low-temperature properties of the broad diesel fraction are characterized by a high pour point (+5⁰C). Figure 4 shows the content of aromatic hydrocarbons by a group in the broad diesel fraction (200–360⁰C) determined by the method of UV spectroscopy.

Table 4

Physicochemical properties of the broad diesel fraction (200–360⁰C)

Properties	Values
yield by weight of oil, wt.%	27.7
sulfur content, wt.%	0.81
refractive index, n_D^{20}	1.4835
density, kg/m^3	871
viscosity at 40^0C, cSt	4.72
pour point, ^0C	+5
flash point, ^0C	63
water soluble acids and alkalis	none
copper plate test	passed
molecular weight	214
actual resins, $mg/100\ cm^3$	42
fractional composition	
initial boiling point, ^0C	196
10%	227
50%	291
90%	349
end boiling point, ^0C	363

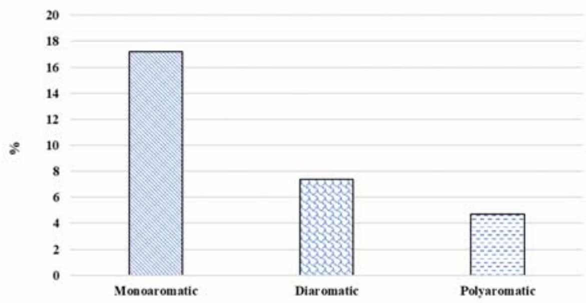

Fig. 4. The content of aromatic hydrocarbons by a group in the broad diesel fraction (fr. 200–360⁰C) determined by the UV spectroscopy method

The studied broad diesel fraction has a high density (871 kg/m^3). Therefore, this broad diesel fraction prepared by the separation of the HH-VO mixture of the Yablunivske field is advisable to be used as a raw material for the hydroisomerization process to obtain a high-quality component of diesel fuel.

The distillation of the blended crudes results in production of a residue, which according to the preliminary estimates may correspond to the distillation (residual) paving bitumen of 100/150 brand. Therefore, according to the standardized methods described earlier in ref. [12], its main quality indicators were determined (Table 5).

The yield of the residue obtained in the process of separation of the HH-VO mixture of the Yablunivske field is about 57 wt.% with respect to the raw material. The purpose of further research is to establish the physicochemical properties of the residue of the separation process of the HH-VO mixture and the selection of further processes for its modification.

Table 5 shows that the produced distillation (residual) bitumen meets all technical requirements. Figure 5 shows the group hydrocarbon composition of the obtained distillation bitumen 100/150.

According to the analysis of hydrocarbon composition (Fig.5), the content of paraffin-naphthenic hydrocarbons is 19.8 wt.% with a low yield of paraffin (3.6 wt.%). The content of group I aromatics is 8.8 wt.%, and there is also a relatively high content of heavy aromatic hydrocarbons (groups 3 and 4) and resins: 35.2 wt.% and 23.6 wt.%, respectively. These groups should further have a positive effect on the low-temperature properties of bitumen (brittleness and ductility) at 0^{0}C. The total content of heavy aromatic hydrocarbons (groups 3 and 4) and resins in bitumen is 58.8 wt.%. Various modifiers were added to bitumen to improve its thermal sensitivity, brittleness, and aging properties. The modification process of the obtained distillation bitumen using synthetic wax was previously studied in the work [12].

Based on the results described above, a manufacturing scheme of the processing of the HH-VO mixture of the Yablunivske field was developed (Fig. 6).

The raw material, a mixture of HH-VO mixture of the Yablunivske field, is mixed by pump P-1 from tank T-1 with the solvent flow of heavy gas condensate (HGC) (or with a broad gasoline fraction, which is fabricated at the proposed installation), which is supplied by pump P-2 from tank T-2 and enters the heat exchanger HE-1 for heating. The heat exchanger in HE-1 is the diesel fuel fraction, which is removed from the vacuum column C-1. Further, the raw material mixture is fed for additional heating in HE-2, where it is heated due to the heat of the residual product (bitumen) of the vacuum column C-1.

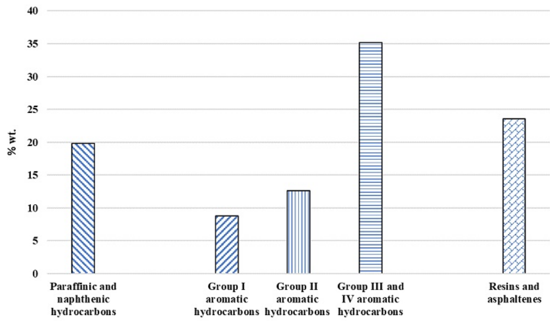

Fig. 5. Hydrocarbon composition of obtained distilled bitumen 100/150

The raw material mixture, heated in H-2, is additionally mixed with water and demulsifier supplied by pumps P-3, and P-4 from tanks T-3, and T-4, respectively, and enters the thermal dehydrator TD. Dehydration and desalination of oil occur in the thermal dehydrator. The temperature in the TD is 90^{0}C, and the working process pressure is 0.6 MPa. The water separated from the bottom of the TD flows into the sewer network and goes to the treatment facilities.

Dehydrated and desalted oil from TD enters the tubular furnace F-1 for heating where it is heated to the temperature of 320–350^{0}C and enters column

Table 5

Main properties of obtained distilled bitumen for conformity with commercial paving bitumen 100/150

Properties	Units	Distilled bitumen produced from blended crudes of Yablunivske field	Standard requirements for 100/150
softening point (R&B)	^{0}C	42	312–320
penetration at 25°C	0.1 mm	128	100–150
ductility at 25°C	cm	157	–
adhesion to gravel	points	2	–
fraas breaking point	^{0}C	–18	≤–15
flash point	^{0}C	231	≥230
solubility in organic solvent	%	99.5	≥99.0
penetration index	–	–0.36	from –1.5 to 0.7

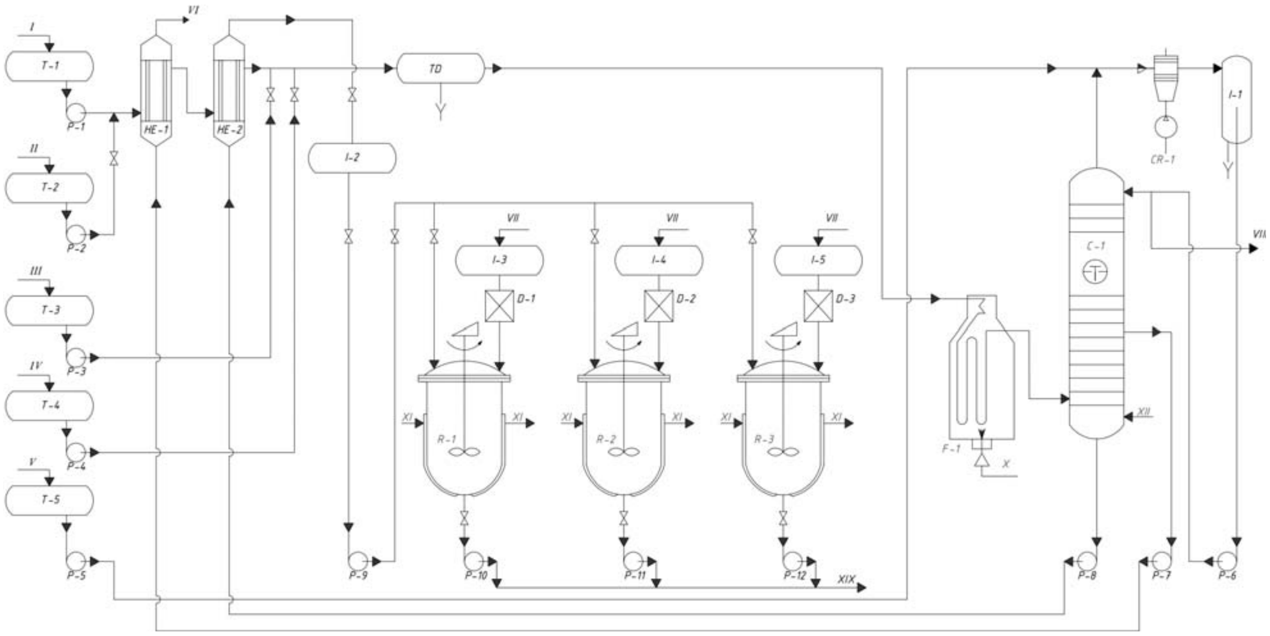

Fig. 6. Manufacturing scheme for the HH-VO mixture separation process of the Yablunivske field: T-1-5 – tanks; P-1-12 – pumps; R-1-3 – reactor; TD – *thermodehydrator;* C-1 – vacuum column; F-1 – furnace; CR-1 – cold reflux; I-1 – intermediate tank; I-2 – intermediate tank for bitumen; I-3-4 – tank for Sasobit modifier; HE-1-2 – heat exchanger; and D-1-3 – dosing device for Sasobit modifier. I – oil; II – solvent (VHC or broad gasoline fraction); III – water; IV – demulsifier; V – corrosion inhibitor; VI – broad diesel fraction for hydroisomerization installation; VII – Sasobit modifier; VIII – broad gasoline fraction for catalytic reforming; XIX – modified bitumen; X – fuel gas; XI – coolant; and XII – water vapor

C-1 for further separation. Uncondensed vapors of the gasoline fraction that come out from the top of column C-1are mixed with a corrosion inhibitor supplied from the tank T-5 using P-5 to prevent corrosion C-1, after which the top product is fed to the cold reflux CR-1 for condensation and intermediate tank I-1.

The balance amount of the gasoline fraction serves as acute irrigation for the top of column C-1 to maintain its temperature regime, and the rest is removed from the installation and goes to further processing processes (for example, to the catalytic reforming installation).

The by-product of the column C-1, the diesel fraction, is fed by the pump P-7 to the heat exchanger HE-1, where it gives its heat to the raw material and is removed from the installation for further processing processes (for example, hydroisomerization of diesel fuel).

The residue of the distillation process, which according to preliminary indicators may correspond to the distillation (residual) petroleum road bitumen, is fed from the bottom of C-1 by the pump P-8 as a heat exchanger goes to HE-2, where it gives off part of its heat and enters the intermediate tank I-2, from which it is fed to the bitumen modification unit by the pump P-9.

The bitumen modification installation consists of three reactors R-1-3 operating in parallel, which must ensure uninterrupted operation of the installation, Sasobit modifier storage tanks E-3-5, and dosing devices D-1-3. The bitumen modification process occurs at the temperature of 180^{0}C. Sasobit synthetic wax was used as a bitumen modifier in the amount of 3 wt.% with respect to the initial bitumen. The modification process took 3.0 hours. The produced modified bitumen comes out from the bottom of R-1-3 and is fed to the modified bitumen storage tank by pumps P-10-12.

The flow chart of the separation process for the HH-VO mixture of the Yablunivske field is presented in Table 6. The material balance of the separation process for the HH-VO mixture of the Yablunivske field is given in Table 7.

Conclusions

HH-VO samples obtained from 4 wells of the Yablunivske field were mixed and their physico-chemical properties were determined. According to the research results, it can be concluded that the studied oils have a high density (>950 kg/m^3) and

Table 6

Flow chart of the separation process of the HH-VO mixture of the Yablunivske field

No.	Process parameter	Units	Nominal value
1	oil consumption	kg/h	12254.90
2	solvent consumption	kg/h	1225.49
3	water consumption	kg/h	1225.49
4	demulsifier consumption	kg/h	1.23
5	corrosion inhibitor consumption	kg/h	1.23
6	Sasobit modifier consumption	wt.% with respect to raw material	3.0
7	temperature in TD	^{0}C	90
8	pressure in TD	MPa	0.6
9	temperature of input of raw materials in C-1	^{0}C	320–350
10	pressure in C-1	MPa	0.2–0.3
11	temperature in R	^{0}C	180.0
12	duration of the bitumen modification process	h	3.0
13	amount of diesel fraction	kg/h	3358.51
14	amount of gasoline fraction	kg/h	2377.63
15	amount of modified bitumen	kg/h	7274.76

Table 7

Material balance of the separation process of the HH-VO mixture of the Yablunivske field

Raw material	wt.% with respect to raw material	tons/year	kg/h
Input:			
1. Oil (HH-VO) including	100.00	100000.00	12254.90
water	5.00	5000.00	612.75
2. Solvent	10.00	10000.00	1225.49
3. Water	10.00	10000.00	1225.49
4. Demulsifier	0.01	10.00	1.23
5. Corrosion inhibitor	0.01	10.00	1.23
6. Sasobit modifier	3.00	1692.00	207.35
Total	123.02	121712.00	14915.69
Obtained:			
1. Broad gasoline fraction	19.61	19401.50	2377.63
2. Broad diesel fraction	27.70	27405.48	3358.51
3. Modified bitumen	60.00	59362.05	7274.76
4. Losses (including water in the oil and water for washing)	15.71	15542.96	1904.78
Total	123.02	121712.00	14915.69

belong to very heavy oils. They show a high solidification temperature (5–42^{0}C). The obtained data can serve as initial information for choosing the optimal technology for processing HH-VO at the refinery.

The separation of the HH-VO mixture of the Yablunivske field was carried out, with the production of a broad range of gasoline (b.p.-200^{0}C) and diesel fractions (200–360^{0}C), and the residue (>360^{0}C). Analysis of their physicochemical properties was carried out. The ways of their further application were proposed. It was found that the yield of light fractions from the HH-VO mixture of the Yablunivske field, which boils up to a temperature of 360^{0}C, is low. Therefore, when developing technology for their processing, special attention should be paid to the processing of their dark part (fr. residue >360^{0}C).

According to the above studies, the basics of the processing technology of the HH-VO mixture of the Yablunivske field have been developed. In particular, the manufacturing scheme and flow chart have been proposed, and the material balance of the process has been calculated.

REFERENCES

1. *Physico-chemical* properties of high-sulfuric heavy oils from Yablunivske deposit / Topilnytskyy P., Romanchuk V., Yarmola T., Zinchenko D.V. // Chemistry, Technology and Application of Substances. – 2020. – Vol.3. – No. 1. – P.75-82.

2. *Prasad S.K., Kakati A., Sangwai J.S.* Rheology of heavy crude oil and asphaltene-polymer composite blends // Rheology of polymer blends and nanocomposites: theory, modelling and applications. – 2020. – P.161-192.

3. *Chemical–physical* analysis of rheologically different samples of a heavy crude oil / Merola M.C., Carotenuto C., Gargiulo V., Stanzione F., Ciajolo A., Minale M. // Fuel Process. Technol. – 2016. – Vol.148. – P.236-247.

4. *Stebelska H.Ya.* Geological conditions of prospecting and development of high-viscosity oils and natural bitumen // Visn. V.N. Karazin Kharkiv National University, Ser. «Geology. Geography. Ecology». – 2015. – No. 1157. – Vol.42. – P.53-57.

5. *Riva J.P., Atwater G.I.* World distribution of heavy oils and tar sands. – Britannica. Available from: https://www.britannica.com/science/heavy-oil/Tar-sands.

6. *An overview* of heavy oil properties and its recovery and transportation methods / Santos R.G., Loh W., Bannwart A.C., Trevisan O.V. // Braz. J. Chem. Eng. – 2014. – Vol.31. – No. 3. – P.571-590.

7. *Study on* rheological properties of extra-heavy crude oil from fields of Ukraine / Topilnytskyy P., Romanchuk V., Yarmola T., Stebelska H. // Chem. Chem. Technol. – 2020. – Vol.14. – No. 3. – P.412-419.

8. *Technological* features of high-sulfur heavy crude oils processing / Topilnytskyy P., Paiuk S., Stebelska H., Romanchuk V., Yarmola T. // Chem. Chem. Technol. – 2019. – Vol.13. – No. 4. – P.503-509.

9. *Peculiarities* of dewatering technology for heavy high-viscosity crude oils of eastern region of Ukraine / Topilnytskyy P., Yarmola T., Romanchuk V., Kucinska-Lipka J. // Chem. Chem. Technol. – 2021. – Vol.15. – No. 3. – P.423-431.

10. *Dilution* of heavy crude oils for pipeline transportation purposes: the asphaltene instability issue / Orea M., Mujica M.Y., Diaz A., Lizardo G., Bruzual J., Bazdikian G., et al. // *Proc.* Heavy Oil Latin American Conference (HOLA 2015). – Bogota, Colombia, 2015.

11. *Heavy* oil dilution / Gateau P., Henaut I., Barre L., Argillier J. // Oil Gas Sci. Technol. – 2004. – Vol.59. – P.503-509.

12. *Production* of distilled bitumen from high-viscosity crude oils of Ukrainian fields / Yarmola T., Topilnytskyy P., Gunka V., Tertyshna O., Romanchuk V. // Chem. Chem. Technol. – 2022. – Vol.16. – No. 3. – P.461-468.

Received 20.09.2022

ПЕРЕРОБЛЕННЯ СУМІШІ ВАЖКИХ ВИСОКОВ'ЯЗКИХ НАФТ СХІДНОГО РЕГІОНУ УКРАЇНИ: ТЕХНОЛОГІЧНІ АСПЕКТИ

Т.В. Ярмола, П.І. Топільницький, В.Й. Скорохода, Б.О. Корчак

В статті надано аналіз запасів та процесів перероблення важких високов'язких нафт в Україні та світі. Здійснено дослідження фізико-хімічних властивостей важких високов'язких нафт Яблунівського родовища Полтавської області України, взятих із різних свердловин. Для подальших досліджень з метою розроблення принципової технологічної схеми установки перероблення важких високов'язких нафт було використано суміш важких високов'язких нафт Яблунівського родовища у певних пропорціях та встановлено її фізико-хімічні властивості. В результаті виконаної вакуумної перегонки суміші важких високов'язких нафт, було одержано наступні продукти: широку бензинову фракцію (фр. п.к. 200^{0}C), широку дизельну фракцію (фр. 200–360^{0}C) та залишок процесу (фр.>360^{0}C), а також виконано аналіз фізико-хімічних властивостей одержаних фракцій. Встановлено, що одержані продукти з суміші важких високов'язких нафт Яблунівського родовища, можуть використовуватись як сировина для виробництва товарних бензинів і дизельних палив, а залишок процесу може слугувати сировиною для виробництва дорожніх бітумів. На підставі виконаного аналізу фізико-хімічних властивостей продуктів, одержаних в процесі вакуумної перегонки суміші важких високов'язких нафт, розроблено основи технології переробки суміші важких високов'язких нафт Яблунівського родовища, зокрема, запропоновано технологічну схему та технологічну карту процесу, а також виконано розрахунок матеріального балансу.

Ключові слова: високов'язка нафта, важка нафта, бензинова фракція, дизельна фракція, в'язкість, бітум.

PROCESSING OF HEAVY HIGH-VISCOSITY OIL MIXTURES FROM THE EASTERN REGION OF UKRAINE: TECHNOLOGICAL ASPECTS

T.V. Yarmola*, P.I. Topilnytskyy, V.J. Skorokhoda, B.O. Korchak

Lviv Polytechnic National University, Lviv, Ukraine

***e-mail: yarmolatetana@gmail.com**

The article presents an analysis of reserves and processing of heavy high-viscosity crude oils in Ukraine and the world. A study of the physicochemical properties of heavy high-viscosity oils from the Yablunivske field, Poltava region of Ukraine, taken from various wells was conducted. For further research in order to develop a basic manufacturing scheme for the processing of heavy high-viscosity oils, a mixture of heavy high-viscosity oils from the Yablunivske field was used in certain ratios and its physicochemical properties were determined. As a result of the vacuum distillation of a mixture of heavy high-viscosity oils, the following products were obtained: broad gasoline fraction (fraction boiled up to 200^{0}C), broad diesel fraction (fraction 200–360^{0}C) and the rest of the process (fraction >360^{0}C). An analysis of the physicochemical properties of the prepared fractions was also carried out. It was established that the products obtained from the mixture of heavy high-viscosity oils of the Yablunivske field can be used as raw materials for the production of commercial gasoline and diesel fuels. The rest of the process can serve as raw materials for the production of road bitumen. According to the analysis of the physicochemical properties of the products obtained by vacuum distillation of a mixture of heavy high-viscosity oils, the basics of the processing technology of a mixture of heavy high-viscosity oils of the Yablunivske field were developed. In particular, a manufacturing scheme and a flow chart of the process were proposed, and the material balance was calculated.

Keywords: high viscosity oil; heavy oil; gasoline fraction; diesel fraction; viscosity; bitumen.

REFERENCES

1. Topilnytskyy P, Romanchuk V, Yarmola T, Zinchenko D. Fizyko-khimichni vlastyvosti vazhkykh naft Yablunivskoho rodovyshcha z vysokym vmistom sirky [Physico-chemical properties of high-sulfuric heavy oils from Yablunivske deposit]. *Chem Technol Appl Subst*. 2020; 3(1): 75-82. (*in Ukrainian*). doi: 10.23939/ctas2020.01.075.

2. Prasad SK, Kakati A, Sangwai JS. Chapter 8 - Rheology of heavy crude oil and asphaltene-polymer composite blends. In: *Rheology of polymer blends and nanocomposites: theory, modelling and applications*. Elsevier; 2020. p. 161-192. doi: 10.1016/B978-0-12-816957-5.00008-2.

3. Merola MC, Carotenuto C, Gargiulo V, Stanzione F, Ciajolo A, Minale M. Chemical–physical analysis of rheologically different samples of a heavy crude oil. *Fuel Process Technol*. 2016; 148: 236-247. doi: 10.1016/j.fuproc.2016.03.001.

4. Stebelska HYa. Heolohichni peredumovy rozvidky ta rozrobky pokladiv vysokoviazkykh naft ta pryrodnykh bitumiv [Geological prerequisites for exploration and development of deposits of high viscosity oils and natural bitumen]. *Visn Kharkiv Nats Univ VN Karazina Ser Geol Geogr Ekol*. 2015; 1157(42): 53-57. (*in Ukrainian*).

5. Riva JP, Atwater GI. *World distribution of heavy oils and tar sands*. [Internet]. Britannica; [cited 2022 Jan 12]. Available from: https://www.britannica.com/science/heavy-oil/Tar-sands.

6. Santos RG, Loh W, Bannwart AC, Trevisan OV. An overview of heavy oil properties and its recovery and transportation methods. *Braz J Chem Eng*. 2014; 31(3): 571-590. doi: 10.1590/0104-6632.20140313s00001853.

7. Topilnytskyy P, Romanchuk V, Yarmola T, Stebelska H. Study on rheological properties of extra-heavy crude oil from fields of Ukraine. *Chem Chem Technol*. 2020; 14(3): 412-419. doi: 10.23939/chcht14.03.412.

8. Topilnytskyy P, Paiuk S, Stebelska H, Romanchuk V, Yarmola T. Technological features of high-sulfur heavy crude oils processing. *Chem Chem Technol*. 2019; 13(4): 503-509. doi: 10.23939/chcht13.04.503.

9. Topilnytskyy P, Yarmola T, Romanchuk V, Kucinska-Lipka J. Peculiarities of dewatering technology for heavy high-viscosity crude oils of eastern region of Ukraine. *Chem Chem Technol*. 2021; 15(3): 423-431. doi: 10.23939/chcht15.03.423.

10. Orea M, Mujica MY, Diaz A, Lizardo G, Bruzual J, Bazdikian G, et al. Dilution of heavy crude oils for pipeline transportation purposes: the asphaltene instability issue. In: *Proceedings of the Heavy Oil Latin American Conference (HOLA 2015)*; Bogota, Colombia; 2015.

11. Gateau P, Henaut I, Barre L, Argillier JF. Heavy oil dilution. *Oil Gas Sci Technol*. 2004; 59: 503-509. doi: 10.2516/ogst:2004035.

12. Yarmola T, Topilnytskyy P, Gunka V, Tertyshna O, Romanchuk V. Production of distilled bitumen from high-viscosity crude oils of Ukrainian fields. *Chem Chem Technol*. 2022; 16(3): 461-468. doi: 10.23939/chcht16.03.461.