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Intensification of production and preparation of high-viscosity oil from the Kokhanivske field for the purpose of bitumen production

Intensyfikacja wydobycia i przygotowania ropy naftowej o wysokiej lepkości ze złoża Kokhanivka do produkcji bituminu

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ABSTRACT: The existing problems of production, collection and preparation of high-viscosity oils need to be solved by further research and search for effective technologies. The oil of the Kokhanivske field is unique among the fields of Prykarpattia region, which is characterized by a high density of ≈1000 kg/m^3, a significant content of asphaltenes, resins up to (45–60% by weight) and sulphur (7%), which is most suitable for the production of the highest quality bitumen. According to the physico-chemical characteristics and composition of the oil of the Kokhanivske field, an analysis of the conformity of this oil to the bituminous group according to the international classification was carried out. It is emphasized that this oil can be an analogue of the raw material from which high-quality bitumen of the Swedish company Nynas are produced. In connection with the above-mentioned physical and chemical properties of the oil from the Kokhanivske field (high density, viscosity asphaltene and resin content, etc.), significant complications arise during its collection and preparation. In order to solve the problem of preparing this type of oil, a technological solution for its preparation with a wave field of different intensity is proposed. In accordance with this technological solution, a laboratory setup was developed to study the effect of a wave field of different intensity on high-viscosity oil of the Kokhanivske field based on the Yutkin effect.

Key words: Kokhanivske field, high-viscosity oil, asphaltenes, high quality bitumen, Yutkin effect.

STRESZCZENIE: Obecne problemy związane z produkcją, magazynowaniem i przetwarzaniem ropy naftowej o wysokiej lepkości wymagają znalezienia rozwiązań poprzez dalsze badania i poszukiwanie skutecznych technologii. Ropa naftowa ze złoża Kokhanivka jest unikalna wśród złóż Podkarpacia, gdyż charakteryzuje się wysoką gęstością ≈1000 kg/m^3, znaczną zawartością asfaltenów, a także żywic (do 45–60% wagowo) i siarki (7%), co czyni ją najbardziej odpowiednią do produkcji bituminu o wysokiej jakości. Biorąc pod uwagę właściwości fizykochemiczne i skład ropy naftowej ze złoża Kokhanivka, przeprowadzono analizę kompatybilności tej ropy z grupą bitumiczną zgodnie z międzynarodową klasyfikacją. Podkreślono, że ropa ta może być zamiennikiem surowca, z którego produkowane są wysokiej jakości asfalty szwedzkiej firmy Nynas. W związku z wyżej wymienionymi właściwościami fizykochemicznymi ropy naftowej ze złoża Kokhanivka (wysoka gęstość, lepkość, zawartość asfaltenów, żywic itp.), podczas jej wydobycia i przetwarzania pojawiają się dosyć znaczne trudności. Aby rozwiązać problemy związane z przetwarzaniem tego typu ropy naftowej, zaproponowano rozwiązanie technologiczne do jej przetwarzania za pomocą pola falowego o różnej intensywności. Zgodnie z tym rozwiązaniem technologicznym opracowano stanowisko laboratoryjne do badania wpływu pola falowego o różnej intensywności na ropę o wysokiej lepkości ze złoża Kokhanivka w oparciu o efekt Yutkina.

Słowa kluczowe: złoże Kokhanivka, ropa naftowa o wysokiej lepkości, asfalteny, wysokiej jakości asfalt, efekt Yutkina.

Introduction

The Kokhanivske oil field, located in the Yavoriv district of the Lviv region in Western Ukraine, was discovered in 1958 with the drilling of a 1-Kh well. Geographically, the field is located in the northwestern part of the Kosiv-Uhersk subzone, which is part of the Bilche-Volytsia tectonic zone of the Carpathian Foredeep. The Kokhanivske field is associated with the eponymous uplift, the geological structure of which is complicated by the presence of faulting. Structurally, the Kokhanivske field is divided into two main blocks: Pivdenno-Kokhanivskyi and Kokhanivskyi (Kokhanivske oil field).

The research and industrial development of the oil deposits of the Kokhanivske field were carried out in two main stages at

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different time intervals. During the first stage, in 1958–1961, oil production was carried out using only one well (Special permission for...). The second stage of field development, which began in 1987, was characterized by the use of eight wells for oil production according to Malskaya and Pishnenko (1985).

From 1988 to the 2020s, specialists developed and approved projects for the further development of the Kokhanivske oil field (Rudakova et al., 1961; Trebin et al., 1980; Malskaya and Pishnenko, 1985; Pelinichka, 1988; Popovich, 1993; Ilyushenko and Listkova, 1996; Sheremet, 2018).

The oil contained in the Kokhanivske field is quite specific and unique to the entire Prykarpattia region in terms of its physical and chemical properties. It is a viscous and at the same time heavy oil with a significant content of resins and sulphur – up to 7% according to some estimates. In addition, the oil of this field is characterised by a small amount of dissolved gas (Yutkin, 1986).

In this respect, the development of the Kokhanivske field requires special methods and the latest technologies. One of them is the electrohydraulic effect technology, discovered by Yutkin in 1953 (Yutkin, 1955, 1986). The essence of this method is that when a specially formed impulse electrical discharge (spark, brush and other forms) is carried out in the middle of a liquid volume, ultra-high hydraulic pressures arise around the zone of its action, capable of performing useful mechanical work and accompanied by a complex of physical and chemical phenomena. This effect is rarely used in the oil industry and is mainly employed today to stimulate production and clean pipelines.

Currently, oil from the Kokhanivske field is transported by tankers to the Sambir-3 oil gathering point, about 70 km away, where it is mixed in a ratio of 1 : 5 with light oil from the Starosambirske field. This mixing worsens the conditions for the preparation of light oil from the Starosambirske field and contributes to the low oil production at the Kokhanivske field.

Another important feature of the Kokhanivske field is its border location in Western Ukraine, close to the border with Poland. This proximity creates opportunities for organizing intergovernmental cooperation with the Republic of Poland to jointly develop both the Kokhanivske field in Ukraine and the adjacent Lubaczów field in Poland. Additionally, the Kokhanivske field could be used to build a modern modular oil refinery to produce high-quality bitumen.

Characterization of the research problem

Recently, interest in heavy, high-viscosity oils has grown significantly. This is due not only to the rise in the price of conventional oil but also to the gradual depletion of light oil deposits around the world and the growing share of hard-to-recover high-viscosity oils. Heavy crude oil is another type of oil that differs from conventional oil in that it is much more difficult to extract from the deposit, and most of these oils cannot be produced using existing methods.

The physical properties that distinguish heavy crude oils include higher viscosity and specific gravity, resulting from heavier molecular composition.

Thus, all of the above conditions are not conducive to the development of heavy oil production at fields such as Kokhanivske. This is evidenced by the current oil recovery factor and the time of wells' operation (idle time). Given the cost of drilling one well, the significant total number of wells already drilled, well idle time, operating conditions, and well production preparation, the field development is neither rational nor efficient. Nevertheless, such fields can become a valuable source of new products – high-quality bitumen.

One way to improve the efficiency of the Kokhanivske field development is to introduce a bitumen production unit at the field. This unit requires improvement of the oil preparation process at the field, taking into account the physical and chemical characteristics of oil, the water cut of well products, and field development conditions. One possible method to improve oil preparation at the field is the technology of wave action of varying intensity based on the Yutkin effect. This technology is innovative, poorly understood, and requires determination of the main parameters and characteristics. The study of the application of this technology will be carried out in order to destroy the emulsion and heating it for efficient separation of mechanical impurities. To determine these parameters and characteristics, a scheme and setup was developed that will allow both laboratory and industrial research based on the Yutkin effect.

Analysis of publications and possible solutions of the problem

The properties of the reservoir oil of the Kokhanivske field were first determined in 1958 from a sample taken at a depth of 925 meters from well 1 (Rudakova et al., 1961). The oil sample contained up to 14 percent of formation water. Based on the results of laboratory tests, the initial values of reservoir oil parameters were determined (Rudakova et al., 1961; Trebin et al., 1980) – Table 1. The physical and chemical properties of oil from the studied well 1-Kokhanivka are shown in Table 2 (Trebin et al., 1980).

Studies of separated oil samples from the Upper Jurassic deposits of the Kokhanivske field were conducted in research institutions of Western Ukraine, the results of which are pre-

Table 1. Initially determined basic values of oil parameters from Kokhanivske field (Rudakova et al., 1961; Trebin et al., 1980)

Tabela 1. Określone początkowo podstawowe wartości parametrów ropy naftowej ze złoża Kokhanivka (Rudakova et al., 1961; Trebin et al., 1980)

Parameters	Units of measurement	Values
Formation pressure	[MPa]	11.1
Layer temperature	[°C]	60
Saturation pressure	[MPa]	4.89
Gas content	[m^3/m^3]	24.8
Volume coefficient		1.11
Density of oil in reservoir conditions	[kg/m^3]	915
Viscosity of separated oil	[mPa · s]	200
Coefficient of compressibility	[MPa^{-1}]	$1.32 \cdot 10^{-3}$
Coefficient of solubility	[$m^3/m^3 \cdot MPa$]	5.06

Table 2. Physical and chemical properties of the crude oil from well Kokhanivka-1 (Trebin et al., 1980)

Tabela 2. Właściwości fizykochemiczne ropy naftowej z odwiertu Kokhanivka-1 (Trebin et al., 1980)

Parameters	Units of measurement	Values
Density	[kg/m^3]	992
Paraffin content	[%]	0.5
Asphaltene content	[%]	17.3
Resins separated on silica gel	[%]	27.1
Coking	[%]	17.5
Viscosity at 60°C	[mPa · s]	339
Solidification temperature	[°C]	8
Boiling point	[°C]	78
Fractional composition – 185°C	[%]	10
Fractional composition – 260°C	[%]	20
Fractional composition – 350°C	[%]	40

Table 3. Crude oil properties of the Kokhanivske field (Rudakova et al., 1961)

Tabela 3. Właściwości ropy naftowej ze złoża Kokhanivka (Rudakova et al., 1961)

Parameters	Units of measurement	Values
Specific gravity	[kg/m^3]	991.0
Sulfuric acid resin content	[%]	70
Resins separated on silica gel	[%]	40
Asphaltene content	[%]	13.9
Sulphur content	[%]	7.1
Content of mechanical impurities	[%]	0.1
Paraffin content	[%]	0.5
Oil pour point	[°C]	+8
Open crucible flash point	[°C]	120
Gasoline content of a component with a final boiling point of 205°C	[%]	2.94
Fractional composition of gasoline		
Start of boiling	[°C]	37
End of boiling	[°C]	208
Residue in flask	[ml]	2.5
Balance + losses	[ml]	3
Sulphur content in gasoline	[%]	0.55
Fractions of diesel fuel	[%]	10.2
Wide oil fraction 350–500°C	[%]	20.68
Residual bitumen	[%]	62.74
Diesel fuel		
up to 300°C	[%]	60
up to 360°C	[%]	93
Sulphur content	[%]	2.45
Solidification temperature	[°C]	8
Residual bitumen softening point by K and SH	[°C]	61.5
Ductility	[m]	1
Penetration [degrees]	[°]	14

sented. The oil is a heavy, highly viscous, black liquid with an odour of sulphur compounds. The density of oil varies from 966.4 to 995.6 kg/m^3, averaging 981.05 kg/m^3. The asphaltene content ranges from 13% to 21.3%, the silica gel resin content ranges from 20.1% to 79%, and the paraffin content varies from 1.1% to 2.5%. According to its physical and chemical properties, the oil has high density and viscosity, high resin and asphaltene compounds content, high asphaltene-based oil content, and high sulphur content. The high resin and asphaltene content of the oil contributes to the production of large quantities of petroleum bitumen. Table 2 shows the average values of the main parameters of the degassed oil. The characteristics of the dehydrated oil from the Kokhanivske field are shown in Table 3 (Rudakova et al., 1961).

The diagram of the dependence of the dynamic viscosity on the temperature of the degassed well oil according to the studies of UKRDGRI is shown in Figure 1 (Rudakova et al., 1961).

Formation water from the field has been sampled and studied by various organizations. The physicochemical characteristics indicate that the formation water is of the chlor-alkali type.

The term heavy is often applied to oil with a density in API degrees of less than 20 (specific gravity greater than 0.933) and a sulphur content greater than 2% by weight. In addition, heavy oils are predominantly dark in colour compared to conventional crude oils. The production, transportation and refining of heavy oils pose special challenges compared to light crude oils (Chernikin, 1958; Baikov et al., 2009; Kemalov et al., 2010; Vorobyov, 2018).

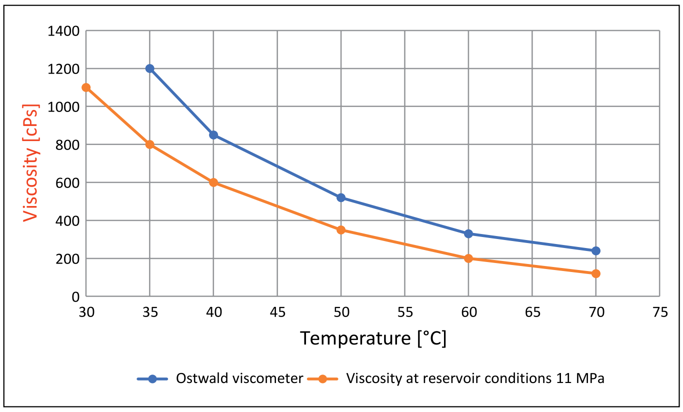

Figure 1. Graph of the dependence of the dynamic viscosity on the temperature of the degassed oil

Rysunek 1. Wykres zależności lepkości dynamicznej od temperatury odgazowanej ropy naftowej

The world's largest heavy oil reserves are located north of the Orinoco River in Venezuela (4.2 billion tons). Over thirty countries have heavy oil reserves. About 70% of the world's heavy oil reserves are concentrated in Canada and Venezuela. Experts estimate the world's reserves of high-viscosity oils and bitumen at 300–350 billion tons (Wauquier, 1998; Meyer et al., 2007). This is about five times the proven reserves of conventional oil. Heavy oil (Meyer et al., 2007) is closely related to oil sands, the main difference being that oil sands are usually not fluid.

Canada has large oil sands deposits north and northeast of Edmonton, Alberta. Extra-heavy crude oil from the Orinoco region of Venezuela has a viscosity greater than 10,000 centipoise (10 Pa · s) and 10° API. Typically, to extract it, a solvent is added at regular intervals to the pipeline transporting the heavy oil to facilitate its flow. Some petroleum geologists classify oil sands bitumen as extra heavy oil, even though bitumen does not flow under normal conditions. Most geologists agree that crude oil becomes "heavy" as a result of biodegradation, where light fractions are consumed by bacterial activity in the formation, leaving behind heavy fractions. Poor geological sealing of the reservoir exposes the hydrocarbon to surface contaminants, including organic contaminants (e.g., bacteria), contributing to this process.

The share of "light" oil reserves developed by traditional methods tends to decrease, and in the future, the development of hard-to-recover hydrocarbon reserves will play a major role in the supply of raw materials for the petrochemical industry and energy resources.

In terrigenous, carbonate, and unconventional reservoirs, a number of phenomena have been identified related to the peculiarities of the structure of these reservoirs and the specifics of filtration in them, necessitating the search for new technologies for hydrocarbon recovery. The international classification of heavy oils and bitumen is shown in Table 4 (Wauquier, 1998).

Table 4. International classification of heavy oils and bitumens (Wauquier, 1998)

Tabela 4. Międzynarodowa klasyfikacja ciężkich rop naftowych i bituminów (Wauquier, 1998)

Class	Oil (viscosity 10 Pa · s)					Bitumen viscosity (≥10 Pa · s)
	regular	medium	light heavyweight	heavy	extra heavyweight	
Density [kg/m^3]	904	904–934	934–966	966–1000	≥1000	≥1000
Asphaltene content	–	–	2–7	6–15	7–27	

Table 5. Examples od heavy oil fields in the world (Wauquier, 1998; Meyer et al., 2007)

Tabela 5. Przykładowe złoża ciężkiej ropy naftowej na świecie (Wauquier, 1998; Meyer et al., 2007)

Parameters	Oils				
	Boscan (Venezuela)	Jobo (Venezuela)	North Bathulford (Canada)	Lagunillas (Venezuela)	Kaya (Iraq)
°API (Density at 20°C) [kg/ m^3]	10.1 (889)	9.2 (1002)	10.0 (997)	16.8 (951)	16.4 (953)
Viscosity [mm^2/c] – 50°C – 20°C	 5 600 250 000	 34 000 –	 15 000 –	 200 1100	 150 500
S [%]	5,5	4,1	4,05	2,2	7,3
Asphaltenes [%]	15	–	–	4 to 10	–
Faction < Diesel Fuel [% wt.]	14	12	14,4	22,5	15
Distillate [% wt.]	18	28	86,5	77,5	40
Residue [% wt.]	68	60	86,5	77,5	45

According to the American Petroleum Institute classification, heavy oils are classified by density:

- heavy oils with a density of 20–14° API (934–972 kg/m^3);
- ultra-heavy oils with a density of 14–10° API (972–1000 kg/m^3);
- natural bitumen with a density <10° API (>1000 kg/m^3).

The bitumen potential is also calculated by the values of oil density, characterizing factor, shape of the boiling point curve, etc. However, this approach does not allow us to assess the quality of bitumen obtained from a particular raw material.

In particular, the need for oil sorting specifically for bitumen production has been scientifically and practically proven (Baikov et al., 1981). Table 5 shows the characteristics of some foreign heavy oils according to Wauquier (1998) and Meyer et al. (2007).

BashSRDI developed a technology for classifying oils in terms of their suitability for the production of road bitumen (Road bitumen). This classification is based on the content of asphaltenes (A), resins (R) and solid paraffins (SP) (Kemalov et al., 2010). Paraffinic high-resinous and paraffinic low-resinous oils are recognized as unsuitable for the production of improved grades of road bitumen using existing technological schemes. Heavy asphalt-resinous oils are considered the most suitable, their composition satisfying the condition

$$A + C - 2.5\,P \geq 8$$

where: A, C, P are respectively the asphaltene, resin and paraffin content [% wt.].

For oil from the Kokhanivske field (Table 2), with $A = 21.7\%$ wt., $C = 8.2\%$ wt., and $P = 2.7\%$ wt.

$$21.7 + 8.2 - (2.5 \cdot 2.7) \geq 8$$

A major disadvantage of this classification is the lack of quality requirements for the raw materials used to produce oxidized bitumen (viscosity and flash point).

Another classification of oils takes into account the rational way of processing their residues into bitumen (Kemalov et al., 2010):

- Group I – high-sulphur, paraffinic oils with a resinous asphaltene substance (RAS) content: 25–36% of resin-asphaltenes, and 3–5% solid paraffinic hydrocarbons. Residues of such oils above 450–480°C correspond to viscous road bitumen of BN type (DSTU 22245-90);
- Group II – resinous, paraffinic oils with a 10–20% RAS oil content and 3–6% solid paraffin content. Vacuum distillation residues of these oils also meet the standard requirements for viscous road bitumen.23.15 ≥ 8;
- Group III – low resinous, low-paraffin oils with a 7–10% RAS content and 0.2–2.5% solid paraffin content. Their resins can be oxidized to obtain the required bitumen grades;
- Group IV – low resinous, with a RAS content and solid paraffin content of 7–10% and 5–7%, respectively. Bitumens with the required stretchability are obtained by oxidation of resins above 500°C in columns;
- Group V – low-resinous, highly paraffinic oils with a 5–10% RAS content and 7–12% solid paraffin content. The most rational way to process them into construction bitumen.

To produce bitumen of the required quality, it is necessary to use raw materials with a combination of hydrocarbon group composition, which determines the choice of bitumen production technology, so the technology must ensure that the group chemical composition of the raw material is changed in the right direction, such as adding additional amounts of asphaltenes, aromatic hydrocarbons and other components to the main raw material.

The world reserves of heavy oil and natural bitumen exceed 810 billion tons, which is much more than the world reserves of light oil. However, their share in production still does not exceed 1%. In order to increase the share of natural bitumen, it is very important to improve the technology of its production, collection, preparation and processing.

In this context, the issue of quality management of bitumen for road pavements remains relevant in various countries. The current global practice of load and traffic intensity on roads emphasizes the importance of using special bitumen-based asphalt pavements that can provide the required physical and mechanical properties of roads and their durability. In order to prolong the service life of road pavements, a polymer-bitumen material is used, which enhances their performance (Baikov et al., 1981).

In this regard, the production of road, construction, and special bitumen in the oil refining industry has grown significantly (road bitumen). Petroleum bitumen is a scarce raw material that has specific properties and qualities that are a key factor in ensuring the durability of roads (road bitumen).

However, ≈70% of bitumen does not meet the requirements of the modern market in terms of range and quality (Baikov et al., 2009). Due to the poor quality of bitumen, road surfaces wear out prematurely, and their repair requires significant capital expenditure and labour-intensive work. This situation is exacerbated by the continuous increase in vehicle carrying capacity and traffic intensity, which results in a significant increase in dynamic loads on the road surface, thereby raising requirements for the bitumen quality (Baikov et al., 1981).

As a result, the bitumen used as a binder in asphalt pavement mixtures is constantly being improved to meet the ever-increasing demands of road builders. Currently, numerous attempts are being made to obtain a solid bituminous composition that meets modern requirements for resistance to cracking (for example, a bituminous composition that has both good performance at low temperatures and good resistance to the formation of potholes at high temperatures).

Problems with the quality of bitumen produced in the industry are related to the lack of perfect technology for refining petroleum products.

Currently, one of the main challenges in the production of road bitumen is the difficulty in controlling the quality of raw materials supplied for processing into bitumen that does not meet the requirements of regulatory documents. It is known that even small fluctuations in the composition of bitumen (content of paraffinic and aromatic hydrocarbons, asphaltenes, and other components) can have a significant impact on the quality of the bitumen produced (Kemalov et al., 2010).

The problem of bitumen quality can be addressed by optimizing its group chemical composition, the content of modifying additives (mainly sulphur), as well as by using technologies such as ultrasound and vibration fields (Kemalov et al., 2010).

Optimization of the ratio of dispersed phase to dispersion medium allows bitumen to obtain plastic properties, increased plasticity and softening point, improved adhesion properties, and enhanced fracture resistance.

An example is the high-quality bitumen from Nynas (Nynas bitumen). Nynas bitumen is a distillation bitumen produced from oil with a high content of heavy hydrocarbons (bitumen content up to 70%) from Venezuelan fields. It is obtained through fractional distillation, passing through a distillation column at atmospheric pressure and through a vacuum distillation column (Nynas bitumen). The special design of the vacuum distillation column allows the required fractions to be separated at a relatively lower temperature and with a shorter residence time in the column. This results in a final product – road bitumen with consistently high-quality characteristics. In road construction, Nynas bitumen is widely used as a binder for the production of bitumen emulsions for the latest bitumen-emulsion technologies such as Slurry Seal (thin layers over existing pavement) and micro-surfacing (surface layer formation), among others.

One of the key factors in the production of bitumen is the cost and quality of the final product.

Considering the average physical and chemical data of the Kokhanivske field (Table 1) and the international classification of oils and bitumen (Table 3), the oil of the Kokhanivske field can be classified as heavy and extra-heavy (bituminous) oil by density (988 kg/m^3), viscosity (68 504 mm^2/s) and asphaltene content (18.5%). Given the above, there is ample reason to classify the oil and deposits of the Kokhanivske field as hard-to-recover in terms of density and viscosity under reservoir conditions. Considering the properties of the Kokhanivske field oil, the bitumen yield from this oil can range from 45% to 55%.

The field's oil is highly viscous, highly resinous, and highly sulphurous, which causes several difficulties in its collection, preparation and transportation. The high sulphur content (up to 7%) complicates the refining of the oil supplied to the refinery. Figure 2 shows oil from the Kokhanivske field and crude oil from the Prykarpattia fields.

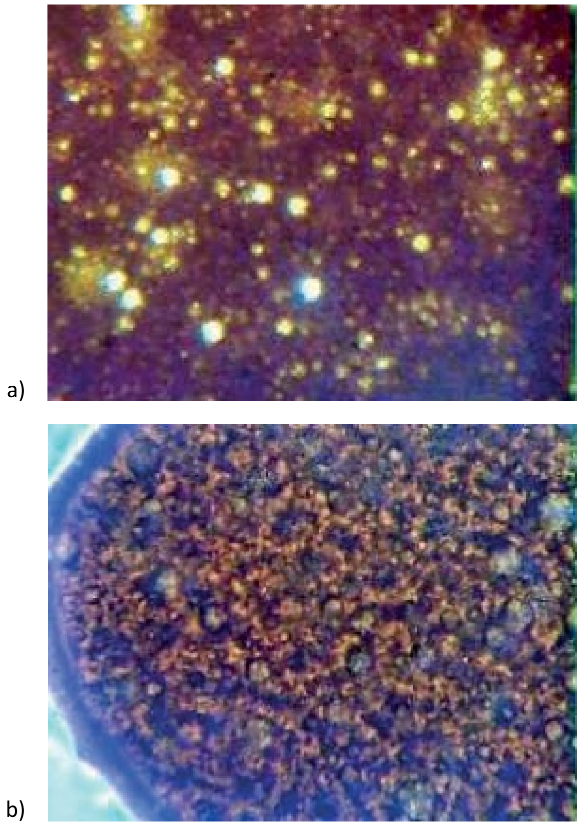

Figure 2. Oil emulsion from the Kokhanivske field and crude oil from the Prykarpattia region fields; a) oil-water emulsion of the Kokhanivske field with a water content of 50%, b) crude oil from the Carpathian region

Rysunek 2. Emulsja ropna ze złoża Kokhanivka i ropa naftowa ze złoża z rejonu Podkarpacia; a) emulsja ropna ze złoża Kokhanivske o zawartości wody 50%, b) ropa naftowa z regionu karpackiego

Ukrainian refineries are not suitable for processing high-sulphur oils, as this process at high temperatures increases corrosion of pipelines and equipment. In addition, sulphurous compounds produced during deep oil refining have a negative impact on the environment. Laboratory studies have established that to demulsify oil from the Kokhanivske field directly at the field, it is necessary to add demulsifier PM grade A at a consumption of 800–1000 g/t and hold it at a temperature of 50–65°C. After 6 hours of settling, oil with maximum water content of up to 10% is obtained (Shumilin, 2011).

Accordingly, this demulsifier consumption is 10 times higher than for conventional oils. With additional dosage of oil-soluble demulsifiers and elevated temperatures (70–90°C), after 6–8 hours of settling, an oil is obtained that is classified as commercial oil by water content (up to 1 %). The stabilizers of the oil emulsion at the Kokhanivske field are resins, asphaltenes and mechanical impurities (Shumilin, 2011).

In order to improve the production of high-viscosity oil from the Kokhanivske field, a technological solution was proposed to install a bitumen production unit directly at the field, which will extract a light fraction (distillate) from the oil, part of which will be used directly at the field as a solvent in the field wells and will be fed into the annulus of the production wells to liquefy high-viscosity oil (Shumilin, 2011).

In accordance with the laboratory research and experimental work, special attention was paid to the process of petroleum bitumen production by atmospheric distillation of heavy oil from the Kokhanivske field without oxidation. Bitumen grades (BND-200/300, BND-130/200, BND-90/130, BND-60/90, BND-40/60) were produced in a reactor without air supply when oil was heated from 320°C to 360°C. The preparation of this type of oil is a complex technological process that requires significant costs.

Taking into account all the above, we can conclude that intensification of preparation of high-viscosity oil of the Kokhanivske field for bitumen production is an urgent task. Similar conditions and reasons for inefficient production at this type of fields in Ukraine (Yablunivske, Orkhovytske, Bugrivativske and others) are constantly observed. Therefore, the technology for processing high-viscosity oil at such fields requires detailed research, improvement and optimization.

One of the technologies that may allow the intensification and improvement of the technological processes of high-viscosity oil preparation is the technology of wave action on oils and oil emulsions. This technology will affect both the conditions of oil preparation and further processes of bitumen production from this type of oil.

Wave technology is used in various industries. Various ways of intensifying technological processes using wave technology are being developed and implemented. The use of wave technologies has led to the formation of a new direction in chemical technology – sonochemistry, which makes it possible to use these technologies to intensify technological processes (Voitovich, 1992).

Wave action technology can be implemented using the Yutkin electrohydraulic effect (EHE) (Yutkin, 1986.). This technology is innovative and poorly understood when used with high-viscosity oils, and requires the determination of the main parameters and characteristics.

In order to determine the current parameters and characteristics, a scheme (Figure 3) and an installation were developed that allow both laboratory and industrial research to be conducted based on the well-known Yutkin effect. The scheme consisted of the following elements: 1 – laboratory autotransformer of AOSN-8 (LATR) type, 2 – measuring transformer TOR-10 (Tr-1, Tr-2), 3 – high-voltage diode (V), 4 – capacitor (25 kV, 0.25 µF), 5 – air discharge (FIP-1, FIP-2), 6 – container with dischargers in liquid.

EHE is based on the phenomenon of a sharp increase in hydraulic and hydrodynamic effects and the amplitude of the impact action when a pulsed electric discharge is applied in a liquid, provided that the pulse duration is minimized, the front is as steep as possible and the pulse shape is close to aperiodic.

The mechanism of action of the wave field during EGE can be as follows: under the action of the wave field, the existing structural lattice of the oil emulsion of high-viscosity

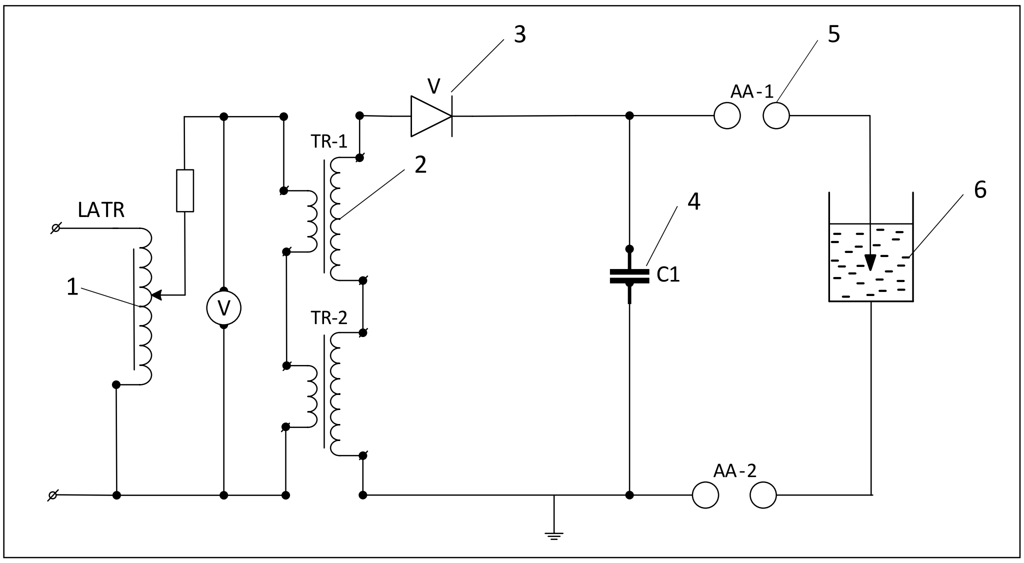

Figure 3. Electrical diagram of EHE study when acting on high-viscosity oil

Rysunek 3. Schemat elektryczny badania efektu elektrohydraulicznego podczas działania na ropę o dużej lepkości oil is destroyed. Consequently, the wave field will affect the change of emulsion viscosity. Additionally, the wave field will change the surface tension of formation water, leading to more efficient destruction of the oil emulsion, reducing the settling time and lowering the temperature required for the oil preparation process.

Based on the analysis of works (Glagoleva, 1992; Voitovich, 1992; Pliss et al., 2007; Yushchishina et al., 2015, 2016; Malyushevskaya and Malyushevsky, 2016; Vasiliev, 2016; Promtov, 2017; Kurochkin et al., 2018), it can also be argued that a wave field of different intensities can lead to an increase in the yield of light distillates from heavy oil. For example, according to Glagoleva (1992) and Pliss et al. (2007), when heavy oil residues were treated at a temperature of 450°C and a pressure of 50 atm, the yield of light products increased by 1.5 times. The effect of EHE on heavy high-viscosity oils will make it possible to simplify the technological scheme of oil preparation and processing, to reduce the temperature of the technological process of preparation and processing, and to increase the yield of light distillates from oil.

Conclusion

Based on the results of the research, it was found that the existing conditions for the development of high-viscosity oil fields in Ukraine do not contribute to the development of such oil production, especially at such a field as Kokhanivske. This is evidenced by the current oil recovery factors (please specify the value) and the field development system using the existing wells at the field. In general, such fields can become a valuable source of new products – high-quality bitumen. This requires the implementation of a comprehensive technology for oil production, gathering, preparation, and processing at the field. This technology requires innovative solutions to improve the oil preparation process at the field, taking into account the physical and chemical properties of the oil, the water cut of the well products, and the field development conditions. To intensify the preparation of high-viscosity oil at the Kokhanivske field for bitumen production, it is proposed to pretreat the oil emulsion of the field with a wave field using electrohydrodischarge technology based on the Yutkin effect. The main innovative solutions in the implementation of the proposed technology in the preparation of high-viscosity oil can be as follows:

1. The wave fields generated during the electrohydraulic preparation can have different effects on the heavy oil, causing new effects that will affect changes in its viscosity, density, pour point, etc., which can be the basis for the development of new technological processes.
2. Depending on the intensity of the wave field action during electrodischarge preparation of hydrocarbon liquids, it is possible to form various carbon materials, the type of which is determined by the hydrocarbon raw material (oil). Works of Yushchishina et al. (2015, 2016) and Malyushevskaya and Malyushevsky (2016) present a possible mechanism for the formation of destruction of hydrocarbon raw material molecules.
3. It is expected that the electric discharge technology of a given adjustable intensity will improve the preparation of high-viscosity oil, which is carried out with the use of a large number of chemicals – demulsifiers, and will also positively affect the quality of bitumen that will be obtained from the treated oil.

   Bitumen production directly at the field will ensure:
   - more intensive development of the field to increase oil production by drilling and commissioning new wells;
   - the need for additional geological exploration of oil and gas deposits in the license area of the field in order to find new raw materials;
   - reduction of costs for oil preparation and transportation;
   - simplification of oil refining processes at refineries;
   - reducing environmental pollution by eliminating sulphur compounds emissions into the atmosphere;
   - targeted combination of on-site oil production, preparation and refining at one technological point;
   - use of light distillates as solvents for heavy oil residues and high-viscosity oils, which will increase oil production;
   - rational use of the natural potential of Ukraine's oil fields;
   - guaranteed market for bitumen as a construction material for roads in the western and eastern regions of Ukraine;
   - creation of new jobs.

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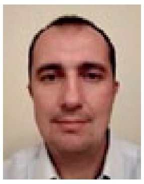

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