ANNOTATION

of the dissertation for the degree of Doctor of Philosophy (PhD) on the specialty 6D070800 - Oil and Gas Business

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«Improving the technology of enhanced oil recovery by pulse impact methods»

The sustainable economic development of the Republic of Kazakhstan and the growth of the well-being of the population largely depend on the level of development of the oil industry. Problems of the development of processes affecting the efficiency of oil production enterprises are relevant for the modernization of the national economy.

Kazakhstan is the largest resource base supplying millions of tons of metals, liquid and gaseous raw materials abroad. As the Republic of Kazakhstan moves to an innovative path of development, refining industries will develop, which will require an additional volume of raw materials for petrochemicals. At the same time, significant reserves of hydrocarbons are extracted without taking into account the additional volume. So in the recent past, the total volume of oil production in the country (2018) was planned at the level of 1.698 million barrels per day (0.232 million tons / day) or about 620 million barrels per year (84.5 million tons / year). In October of the same year, the giant Kashagan field resumed production after several years of delays. Kashagan is expected to produce 0.37 million barrels per day (more than 50 thousand tons per day), and in July 2018, the Tengizchevroil consortium decided to continue expansion plans, which should increase oil production in the Tengiz project by about 0.26 mln bbl / d, starting in 2022.

Deterioration of wells and equipment, a decrease in the stock of production wells, a drop in oil production, insufficient investment in R&D are the main negative characteristics of the oil industry in modern conditions. Obviously, during the exploitation of depleted oil fields, the problem of increasing the efficiency of oil production acquires great economic importance.

The current stage of development of the oil industry is distinguished by the fact that the possibilities of implementing extensive growth factors have been largely exhausted, a significant part of the fields is at a late stage of development; the resource base is formed by residual and hard-to-recover oil resources.

Hard-to-recover reserves include oil reserves concentrated primarily in low-permeability, deep-seated formations and reservoirs with high oil viscosity.

Viscosity is a major obstacle in oil recovery. Although thermal and other treatments are generally considered to be the most effective viscosity reduction methods, for some formations, heat input using commonly used thermal methods is not recommended. Electromagnetic treatment is recommended for these types of tanks. Electromagnetic effects target a portion of the reservoir rather than the main body, which means that the targeted area can be treated more efficiently and with less heat loss than other methods. Electromagnetic exposure is still relatively new and is not widely used as an alternative or addition to traditional heat recovery methods. However, research is underway and new technologies are being proposed that may help expand its use. Thus, the purpose of this study is to study the application of electromagnetic wave action on the bottomhole zone of an oil reservoir.

It is no exaggeration to say that today electromagnetic stimulation of oil wells is a modern, high-tech, reagent-free geophysical method of controlled and selective stimulation of the reservoir and the bottomhole zone to stimulate inflows and increase oil recovery. It is applicable in a wide range of geological and technological conditions, with a sufficiently long (up to 2 years or more) and significant (often multiple) effect, moreover, it is practically defect-free for the reservoir and oil well and environmentally friendly, and can also be easily combined with other well-known methods of stimulation and enhanced oil recovery.

The basis and initial data for development of themes.

Thus, practice shows that the use of existing methods of reducing the viscosity of oil during production, preparation and transportation leads to large, as is known, losses. In this regard, the search for scientific and technical foundations for reducing the viscosity of Kazakhstani oils, providing a significant increase (up to 60 - 80%) oil recovery is an urgent scientific problem of the modern oil and gas industry in Kazakhstan.

The solution to this problem is possible by establishing the basic laws of the interaction of oil emulsions with external influences and using them to reduce the viscosity by at least 2 times.

The dissertation work was carried out within the framework of State funding No AP05130483 «Scientific and technical basis for reducing the viscosity of Kazakhstani oils, providing a significant increase in oil recovery» - 2018-2020 yy. Scientific director – Doctor of Technical Sciences, Professor Moldabayeva G.Zh. And also, the doctoral student participated in the contractual research work on the topic No 4.926.16 «Scientific support of services for nitrogen injection and seismic wave impact on reservoirs for enhanced oil recovery», Customer: JSC PetroKazakhstan Kumkol Resources, Agreement No. 1609053 dated September 23, 2016, Deadlines: from 01.10.2016 to 30.09.2017. Scientific director – Doctor of Technical Sciences, Professor - Abdeli D.J.

Justification of the need for this research work

Previous research results have shown the possibility of changing the properties of oil, allowing to reduce the viscosity.

In the "action-response" system, special attention is paid to the study of the activated state of water as a supplier of hydrogen and oxygen for the processes of synthesis of components of an oil-water emulsion. The study of the state of the interface is of leading importance for obtaining the specified properties of the oil under study.

The significance of the work lies in the establishment of the main regularities of changes in the rheological and physicochemical properties of oils, which will allow, using this scientific knowledge, to increase the recovery factor from 30-40% to at least 60% and more.

Thus, in the national plan, the implementation of the study will allow the development of new energy-saving technologies for oil production, which will ensure an increase in the recovery of high-viscosity Kazakhstani oil. Consequently, the competitiveness of the industry will be increased, since these technologies can be applied both in new and in mothballed fields.

In addition, the implementation of work on a national and international scale will give impetus not only to the creation and application of new energy-saving production technologies, but, which is very important, to the development of new technologies for the preparation and processing of hydrocarbons in natural conditions.

In addition to the economic effect associated with an increase in the recovery factor and a decrease in the cost of production, an important social effect should be expected, since the suspended deposits can be brought into operation, thereby creating new jobs at the city-forming enterprises.

The principal difference from existing analogs is that the recovery is not increased by increasing the pressure. For example, waterflooding or gas injection, and changes in the properties of oil at the interface, providing a decrease in viscosity.

The end result is a change in the chemical composition of the oil-water emulsion, which will lead to an increase in oil recovery of the oil reservoir up to 60% or more when exposed to it in different ways.

Information of metrological support

Experimental studies were carried out on the basis of the laboratory "Physical and technical problems of field development" in D.A. Kunayev Mining Institute, on the basis of the department "Development and operation of oil and gas fields", Russian State University of Oil and Gas (NRU) named after I.M. Gubkina (Moscow, RF) and in the laboratory of Kazakh Research and Design Institute of Oil and Gas. All used standard laboratory equipment and measuring instruments are metrologically verified annually.

Relevance of the topic. The most important component of the raw material base of the oil industry of oil-producing countries are reserves of heavy and bituminous oils. According to experts, their global total volume is estimated at 810 billion tons, which is almost five times higher than the volume of residual recoverable oil reserves of low and medium viscosity, which is only 162.3 billion tons.

The high resource potential of this type of hydrocarbon feedstock determines the fact that oil companies are paying more and more attention to its development. In this regard, the improvement of technologies for the production of heavy oils to enhance oil recovery is becoming increasingly important. According to domestic and foreign experts, the most promising methods of influencing oil are exposure to physical fields (magnetic, pulsed, ultrasonic, vibration, etc.), which lead to the destruction of the structures of oil associates and thereby reduce the viscosity of oil, which makes it possible to increase the oil recovery factor.

The purpose and objectives of the study. The aim of the work is to improve the technology of enhanced oil recovery by means of impulse action.

To solve this goal, the following tasks are solved:

- Analysis of existing technologies in this area;

- To develop a functional diagram and conduct experimental studies of the properties of fluid-containing rocks at the interface during impulse exposure;

- Computer modeling of processes of electrophysical impact;

- On the basis of the data obtained from experimental studies, to develop a pulsed technology for enhancing oil recovery;

- The economic efficiency of the impulse technology has been substantiated.

Object and subject of research

The object of the study is a productive formation of high-viscosity oils, the subject of the study is the processes of changing the rheological properties of oil under electromagnetic influence to enhance oil recovery.

Scientific positions submitted for defense:

- Under impulse action on hydrocarbons at a frequency of 42.8 kHz, water decomposes into H_2 and O_2;

- Hydrogen thus obtained in the atomic state is very active and easily reacts, and combines (hydrogenates) with the components of high-viscosity oil, reducing its viscosity;

- Activated water creates favorable conditions for the synthesis and cleavage of hydrocarbon molecules, in particular, alkanes or peripheral alkyl substituents of condensed aromatic structures.

Scientific novelty of the topic

- At a certain frequency of impulse action, water decomposes into H2 and O2;

- It was found that the produced hydrogen is hydrogenated with the components of high-viscosity oil and reduces its viscosity;

- The conditions for the synthesis and splitting of hydrocarbon molecules are provided when water is activated by impulse action.

Impulse action ensures the course of hydrogenation processes, which is confirmed by the results of IR spectroscopy.

The personal contribution of the author is to carry out work on a literature and patent review and analysis on the topic of dissertation work, setting tasks, developing a research strategy, analytical research to identify theoretical solutions to the proposed technology, conducting experimental research, processing and interpreting the results obtained, computer modeling of the processes under study , as well as calculating the economic efficiency of the proposed technology.

The scientific significance of the work lies in the fact that the surface effects of changes in the chemical and physical properties of water-oil compositions in alternating electromagnetic fields are found. Based on the results of experimental work, the conditions for changing the chemical composition of the components at the interface have been determined, which makes it possible to reduce the viscosity of highly paraffinic oils. The obtained results of the study were confirmed by laboratory tests at the Kumkol field at wells 3103 and 1032. A method for extracting high-viscosity oil without a significant increase in costs at the stage of industrial production has been experimentally substantiated. The developed methodology and physical model can be used in research, design and operational oil production enterprises to increase the recovery factor of heavy oils by changing the chemical composition of fluids using pulsed action.

Practical significance. An effective solution to the problem of increasing the fluidity of heavy oils has been found, which has been confirmed by practical and laboratory results.

Approbation of work. The dissertation materials were discussed at international conferences:

- East European Science Journal, 4(20), International East European Conference. - 2017. – P. 122-124.
- Russian-Chinese scientific journal "Commonwealth". Monthly scientific journal of the scientific and practical conference No 16, Part 2. – 2017. – P. 4-9.
- Russian-Chinese scientific journal "Commonwealth". Monthly scientific journal of the scientific and practical conference No 16, Part 1. – 2017.- P. 55-59.
- Naukowa Przestrzen Europy-2018: Materials of the XIV International Scientific and Practical Conference (07-15 April 2018). – Valume 10 Przemysl: Nauka I studia.- P. 26-31.
- The 25th World Mining Congress 2018.-Astana.-P. 20-24.
- Naukowa Przestrzen Europy-2018: Materials of the XIV International Scientific and Practical Conference (07-15 April 2018). – Valume 10 Przemysl: Nauka I studia.- P. 31-36.
- «Modern trends in higher education and science in the field of chemical and biochemical engineering» 13-14 September 2018, Almaty, ISBN 978-601-04-3552-0.

The main content of the dissertation was published in 19 printed works, including in three editions from the list of the Committee for the Control of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, in five editions that are included in the Scopus database, in two editions in the Russian Science Citation Index (RSCI) on the Web of Science platform, one invention application filed.

The main content of the work

The introduction substantiates the relevance of the topic of the dissertation work, formulates the goals and objectives of the research, sets out the scientific novelty and practical significance, the personal contribution of the applicant.

The first section provides an overview of existing technologies for enhancing oil recovery of productive formations of fields and an analysis of research works aimed at improving methods of impulse impact on oil formations. The problems in the creation and use of existing technologies in this direction are identified and their shortcomings are revealed. In order to increase the economic efficiency of development, reduce direct capital investments and maximize the extension of the field development period, three main stages are distinguished.

At the first stage, as is known, the natural energy of the field is used as much as possible for oil production (elastic energy, energy of dissolved gas, energy of edge waters, gas cap, potential energy of gravitational forces).

At the second stage, methods of maintaining reservoir pressure by injecting water or gas are implemented. These methods were called secondary.

At the third stage, Enhanced Oil Recovery (EOR) methods are used to improve the efficiency of field development. These methods are also called tertiary. In the United States and in most oil-producing countries of the world, enhanced oil recovery methods are understood as a group of methods that differ in the applied working agents that increase the efficiency of oil displacement.

With the development of EOR technologies, the concept of Improved Oil Recovery was introduced. These methods, which are sometimes also called quaternary, involve a combination of elements of the above EOR groups, as well as such promising technical means of enhanced oil recovery as horizontal wells. It should be emphasized that the use of horizontal wells to improve the method of enhancing oil recovery is associated mainly with the solution of such strategic tasks as the organization of vertical stimulation, increasing the efficiency of the gravity mode of development, and the development of oil reserves not involved in development. This means that the use of horizontal wells cannot be considered as an independent enhanced oil recovery method, which is often promoted in our country. This is all the more important because horizontal wells are often used as a means of stimulating oil production. Such use of horizontal wells does not always lead to increased oil recovery.

There are various ways to develop deposits of heavy oils and natural bitumen, which differ in technological and economic characteristics. The applicability of this or that development technology is determined by the geological structure and conditions of bedding, the physicochemical properties of the reservoir fluid, the state and reserves of hydrocarbons, climatic and geographical conditions, etc. Conditionally they can be divided into three, unequal in terms of the volume of implementation, groups: 1 - quarry and mine development methods; 2 - the so-called "cold" mining methods; 3 - thermal extraction methods. Table 1 below shows a comparative analysis of the choice of stimulation methods according to the criteria of applicability for a productive formation.

In order to increase the economic efficiency of the development of hydrocarbon raw materials and reduce direct investments, as well as create optimal conditions for capital reinvestment, various methods of increasing oil recovery are used throughout the entire period of field development. It should be noted that the technologies and methods used to improve oil recovery (secondary) or enhance (tertiary) are largely complementary. At the same time, there is no clear definition of which methods should be classified as secondary and which should be tertiary. Based on this, different statistical sources contain different factual data on the extent of the use of modern EOR.

The analysis showed (table 1) that the problem of enhanced oil recovery remains relevant at the present time.

Table 1 - Selection of stimulation methods according to the criteria of applicability for a productive formation

Parameters	Average values of geological and physical parameters of the field	Exposure methods and criteria of applicability									
		Hydrodynamic methods	Physicochemical methods			Gas methods			Microbiological methods		
		Flooding	Surfactant injection	Polymer injection	Alkali injection	injection CO_2 (mixed)	Hydrocarbon gas injection (unmixed)	Water-gas impacts	Biopolymer injection	Activation of stratal microflora	Microbial (molasses) flooding
Breed type	Terrigenous	Тер., карб.	Ter., Carb.	Ter., Carb.	Ter., Carb.	Ter.	Ter.	Ter., Carb.	Ter.	Ter.	Carb., Ter.
Collector type	Porous	Porous	Porous	Porous	Porous	Porous	Porous	Porous	Por., fissured.	Porous	Fiss., Por., fiss.,
Depth of occurrence, m	850-1350	NA	NA	NA	NA	900-6000	800-6000	NA	30-1500	30-2000	0-1500
Incidence angle, degrees	25	0-5	0-5	0-5	0-5	0-90	0-90	0-90	NA	NA	0-10
Initial reservoir pressure, MPa	11	NA	NA	NA	NA	8-55	5-55	НП	1-20	1-20	0-15
Initial reservoir temperature, ºC	55	20-100	10-70	10-90	<150	20-200	20-200	<100	0-150	20-80	20-60
Effective oil-saturated thickness, m	7,2	3-100	7-15	NA	NA	6.30	NA	NA	3-20	>1	3-100
Permeability, μm2	0,711	0,1-5,0	0,1-2,0	0,1-2,0	>0,1	0,001-3,0	0,005-3,0	0,004-0,8	0,05-5,0	0,1-5,0	0,1-5,0
Porosity coefficient, unit fraction	0,268	0,1-0,5	0,1-0,35	0,1-0,35	0,1-0,35	0,04-0,35	0,04-0,35	0,1-0,35	0,25-0,4	0,25-0,4	0,1-0,4
Clay content,%	23,3	0-5	0-10	0-10	0-10	NA	NA	0-25	0-10	NA	NA

Continuation of table 1

Oil saturation coefficient, unit length	0,792	0,7-1,0	0,7-1,0	0,5-1,0	0,6-1,0	0,25-1,0	0,4-1,0	0,5-1,0	0,7-1,0	0,7-1,0	0,5-1,0
Density of oil, kg / m3	780	650-1000	800-950	820-950	NA	650-880	650-880	650-950	650-850	650-880	650-900
Viscosity of reservoir oil, mPa s	1,2	0,1-25	0,1-60	10-100	0,1-40	0,01-15	0,4-10	0,1-100	0,4-25	0,1-20	0,1-60
Mass content:	20,1 5	NA 0-5,5	15-40 0-2	NA NA	NA NA	0-15 0-30	NA NA	NA NA	NA NA	0-40 0-30	0-40 0-30
ASV,%	7,7	NA	0-25	0-20	0-50	NA	NA	NA	0-150	0-20	0-100
Paraffins,%	0,315	NA	0-5	0-5	0,025	NA	NA	NA	0-10	0-5	NA
Total mineralization of water, g / l	-	Method NA	Method NA	Method NA	Method NA	Method NA	Method is applicable	Method is applica	Method is applica	Method NA	Method is applica

The second section presents the results of theoretical studies of the processes of low-frequency hydraulic impulse and electromagnetic wave impact on the bottomhole zone of the oil reservoir and at the stage of oil preparation. This chapter presents the results of theoretical studies of the parameters and modes of the integrated technology of low-frequency hydraulic impulse action on oil reservoirs in combination with electromagnetic waves, as well as the effect of impulse action on the change in the chemical composition of oil during its preparation.

It follows from the study that the improvement of the technology for the use of hydroimpulse effect methods should be carried out on the basis of the following conditions:

- firstly, the need to reduce power loads is obvious, since maintaining pressures of 10-20 MPa at a working fluid flow rate of up to 500 m3 / day is associated with an increase in energy consumption;

- secondly, some preference should be given to methods using low-frequency oscillations due to their lower absorption in the pore channels of the formation. Effectively use mixed frequency modes of bottomhole formation zone processing;

- thirdly, in order to select a processing mode favorable from the point of view of energy saving, it is necessary to use various methods of optimization of parameters, for example, by means of mathematical modeling. The latter is also important to use due to the lack of a unified methodology for choosing both the treatment method for the bottomhole formation zone and the design of the surface or subsurface impact. Currently, this choice is made in the form of recommendations and is probabilistic in nature, which is an expensive trial and error method.

In this regard, the work proposes technology and equipment that allow for low-frequency hydraulic impulse impact on the bottomhole formation zone. The impact on the reservoir with different frequency and thickness can significantly change the structure of the bottomhole formation zone, increase permeability, and reduce filtration resistance in the reservoir-well system. The combination of low-frequency hydraulic impulse action with electromagnetic waves of treatment of the bottomhole formation zone can be successfully applied in all fields.

Figure 1 shows a technological scheme for the implementation of the technology of low-frequency hydraulic impulse impact on the bottomhole formation zone. The agent can be water, nitrogen (when displacing residual oil from carbonate rock matrices), petroleum solvent - light oil fraction with a benzene group to remove asphalt-resin-paraffin deposits, water to maintain reservoir pressure, acid solution, etc. for bottomhole formation zone treatment.

The agent (or reagent) from the tank 1 is pumped into the well 2 using the pumping unit 3 through the pulsator 4. The pulsator consists of a drive with a crank mechanism, a piston 5 and a cylinder 6 with inlet 7 and outlet 8 nozzles. The pulsator creates an impulse movement for the reagent flow supplied to the well. From the pulsator, the reagent is injected into the bottomhole formation zone through the perforated holes of the tubing 9 and the perforations of the well.

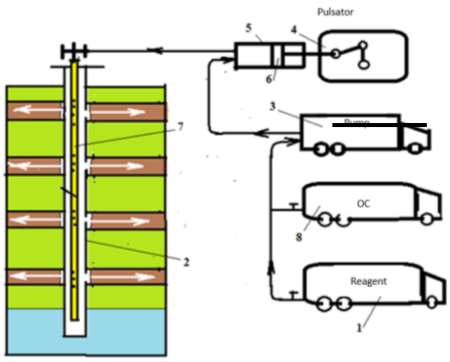


Figure 1 - Technological scheme for the implementation of the technology of low-frequency hydraulic impulse action on the bottomhole formation zone

Then the reagent is pushed from the reservoir by the buffer liquid into the depth of the formation. Due to the impulse movement of the reagent, a more effective treatment of the bottomhole formation zone occurs.

The essence of the pulsator is based on the injection of fluid into the formation in the hydraulic pulse mode. The fact is that there are collectors that are quite efficiently treated with various chemicals. However, as is often the case in practice, the bottomhole formation zone is so clogged that due to the lack of hydrodynamic connection of the well with the formation, it is simply impossible to inject chemicals into it.

To solve this problem, a stake was made on the advantage of fluid movement in a porous reservoir (in the sense of a decrease in hydrodynamic resistance) in a pulsed (oscillatory) mode over conventional movement.

Thus, the study shows that the proposed technology and the concept of the process of low-frequency hydraulic impulse impact on the bottomhole zone of an oil reservoir can be successfully used in the practice of increasing oil recovery in vertical, deviated and horizontal wells by improving the filtration characteristics of the bottomhole formation zone when using the energy of water hammer. which leads to the formation of a series of cracks.

All mechanical vibrations in the medium are ultimately converted into heat. The heat generated in this way due to vibration will increase the temperature with a corresponding decrease in the viscosity of the oil and possibly also a partial phase change (evaporation) of the fluids. Assuming this field to be uniform and neglecting the Coulomb repulsive forces, the motion of electrons can be described by the well-known relation:

$$z = (t - t_2) \cdot v - \frac{a(t-t_2)^2}{2}, \quad (1)$$

z is the current coordinate measured from the plane of the second grid;

t_2 – time of passage of electrons to the second grid;
t – current time;
v – electron velocity in the plane of the second grid;
$a = \frac{k}{m}\frac{V_0+|V_r|}{D}$-yhaste;
D – distance from the second mesh to the reflector.

It follows from the relation that the more time the electrons will be in the field of the reflector, the greater their velocity at the exit from the cavity of the resonator.

The third section describes the experimental setup, the conditions for conducting tests in laboratory conditions, and their results, duration. The created experimental module provides physical modeling of the processes occurring at the interface, which is confirmed by the results obtained. As a result, the regularities of the processes of low-frequency hydropulse and electric wave impacts on the bottomhole zone of the productive formation were established.

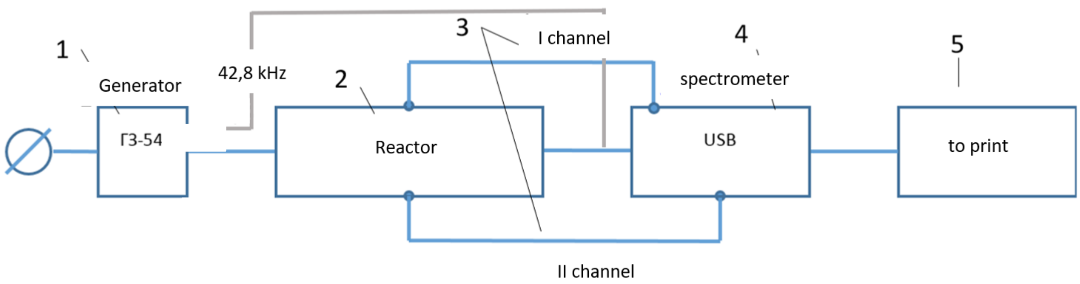


Figure 2 - Functional diagram of the experimental setup for evaluating the response at the interface
(1 - pulse generator G5-54; 2 - quartz cell, reactor; 3 - USB input channel, USB output channel; 4 - USB converter; 5 - exit)

Laboratory tests were carried out on oils from the East Zhetybai, Karabulak, Zhanatan fields, the structural-group composition of which is shown in Table 2.

The oil was processed in reactor 2 at a temperature of 20 ° C, then the oil viscosity was measured. In this case, the generator 1 created a pulse frequency current, which was transmitted to the converter 4 through the cable. The resulting pulsed oscillations were amplified by a waveguide. Impulse generator G - 54 is intended for power supply of converters in various technological installations. The generator creates electrical oscillations of a pulse frequency in the range of up to 60 kHz with a voltage of 100 V (rms value), as well as a constant bias current of up to 20 A with an active load resistance of up to 0.15 Ohm.

Table 2 - Structural-group composition of oil from the East Zhetybai, Karabulak, Zhanatan fields

Oil characteristics	**Oil from the East Zhetybai field**	**Oil of the Zhanatan field**	**Oil from the Karabulak field**
Density at 20 ° C, kg / m³	945	880	920

Content,% mass:			
Asphaltenes	4,0	3,8	3,8
Resins	15,2	19,3	19,3
Paraffin	18,9	28,3	28,3
Dynamic viscosity at 20 ° C, mPas	360	575	575

Oil samples from the East Zhetybai field after impulse exposure with different durations are shown in Figure 3. As shown in Figure 3, after impulse exposure with different durations (12 hours, 24 hours, 2 days), oil demulsification is observed. When exposed for more than 2 days, the greatest effect is observed.

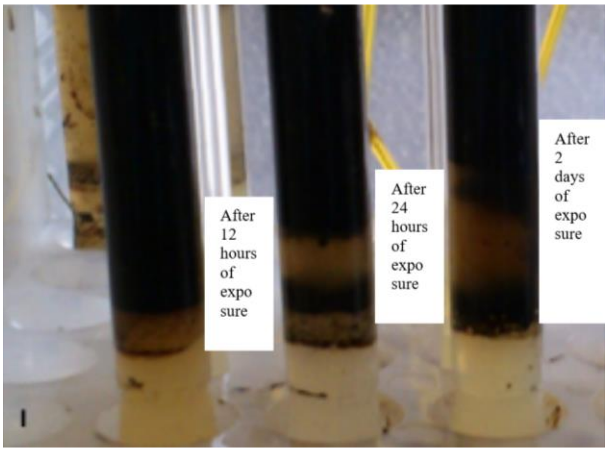
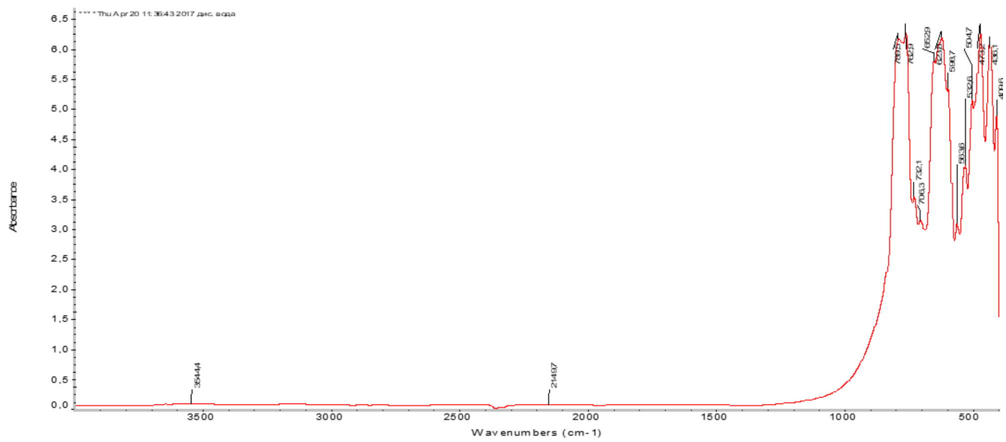
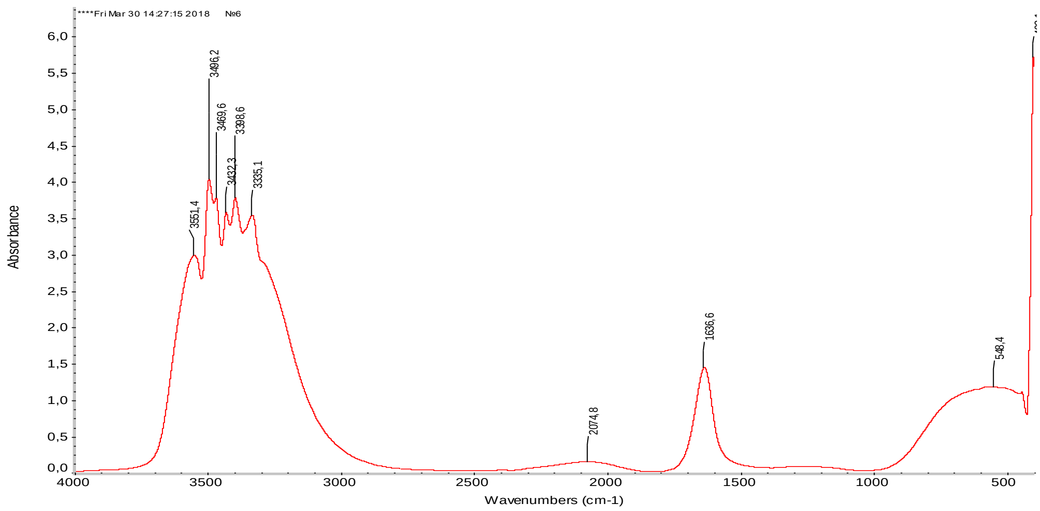


Figure 3 - Samples of oil from the East Zhetybai field after impulse exposure

Oil has the property of thixotropy, that is, it tends to reduce the viscosity from external influences due to the destruction of the structural framework and increase the viscosity at rest. After processing in a pulsed mode, IR spectra were recorded from the obtained samples, since this type of analysis is the most effective in assessing the qualities of organic compounds. The peaks around 3544 indicate HC compounds; Peak 2149 - about the presence of solvents; Peaks from 1000 about different complex connections. The fact of the presence of chemical reactions proceeding by hydrogenation at the interface is confirmed by the data of IR spectroscopy (Figure 4 a, b).



a) before processing



b) after processing

Figure 4 - IR - spectrogram of oil from the East Zhetybai field (after 1.5 hours of processing)

Figure 4 shows that after the treatment in water, responses typical for heavy oil appeared. This is a new effect that shows the correctness of the chosen method of physical modeling.

The fourth section presents the results of computer simulation of ultrasonic action in a porous medium and pipelines in the COMSOL Multiphysics software.

To simulate the processes of ultrasonic action, the following conditions are set:

- Density of oil under normal conditions ρ=850 kg / m3;
- Dynamic viscosity of oil at t=20 C, μ=1980 mPa - s;
- Young's modulus 5,6 mPa (elasticity);
- Poisson's ratio 0,4.

1. The sound wavelength is determined by the formula $\lambda = \frac{\upsilon}{f}$.

υ - wave propagation speed; f - wave frequency.

2. For a plane sound wave, the coupling is determined by Ohm's acoustic law $\frac{p}{y} = \rho \cdot v = R_a$.

p – sound pressure; y – oscillatory speed; ρ – medium density, kg/m3; R_a– acoustic impedance.

3. For a plane sine wave, the ultrasound intensity is determined$I = \frac{pv}{2} = \frac{p^2}{2\rho c} = \frac{v^2 \rho c}{2}$.

p - sound pressure amplitude, Pa, v - particle vibration velocity, m/sec, c - sound speed, m/sec

The change in viscosity on the amplitude of oscillations of the wave action was calculated using the following empirical dependence:

$$\mu_w = \mu_0 * ((0{,}80498 - 0{,}013468) * (\ln(p_w + 5.145 * 10^{-7}))$$

μ_w - fluid viscosity under wave action, μ_0 – initial dynamic viscosity; p_w – amplitude of acoustic vibrations, Pa.

Pore-scale sonication of oil was simulated using COMSOL Multiphysics software using real-world data.

For the pore space, the following conditions were set:

- oil density under normal conditions $\rho = 850$ kg / m^3;
- dynamic viscosity of oil under normal conditions μ=0,025 Pa-c.

Consider the ultrasonic effect on the fluid flow in a pore space of 640 * 320μм.

Figure 5 shows the mesh of the simulated pore space.

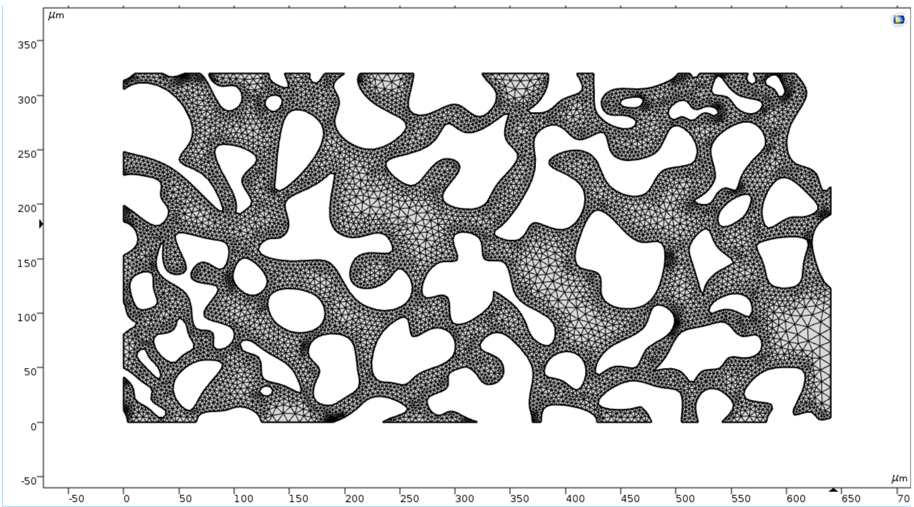


Figure 5 - Mesh of the simulated pore space

If the duration of exposure exceeds the time τ_p, then there is a rupture of intermolecular bonds:

$$\tau_p = \frac{N_p}{\omega}$$

$$N_p = \frac{\sigma_T}{\sigma_0} - \frac{kT}{\gamma\sigma_0}\ln\left\{\frac{\sigma_T}{\sigma_0}\right\}$$

σ_T – the value of the breaking stress of intermolecular bonds of this type; γ – parameter, characterizing this type of intermolecular bonds; K – Boltzmann constant; T – temperature. τ – shear stress, ω – vibration frequency.

Based on the obtained computer simulation data, the dependence of viscosity on the time of exposure to ultrasound was obtained (Figure 6) and the change in temperature during sonication (Figure 7).

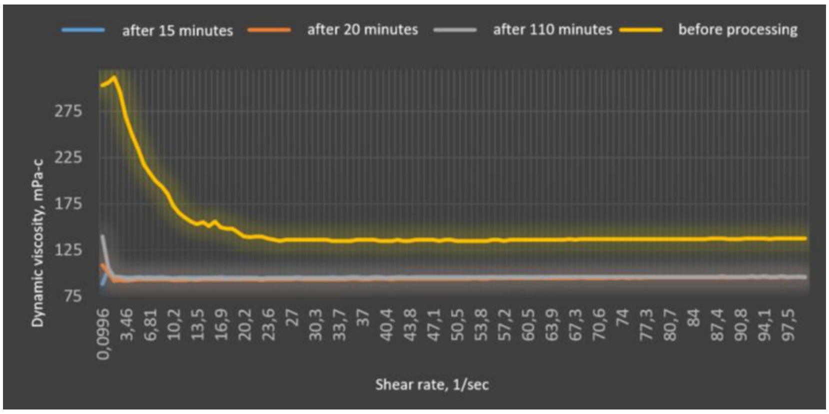


Figure 6 - Dependence of viscosity on the time of exposure to ultrasound

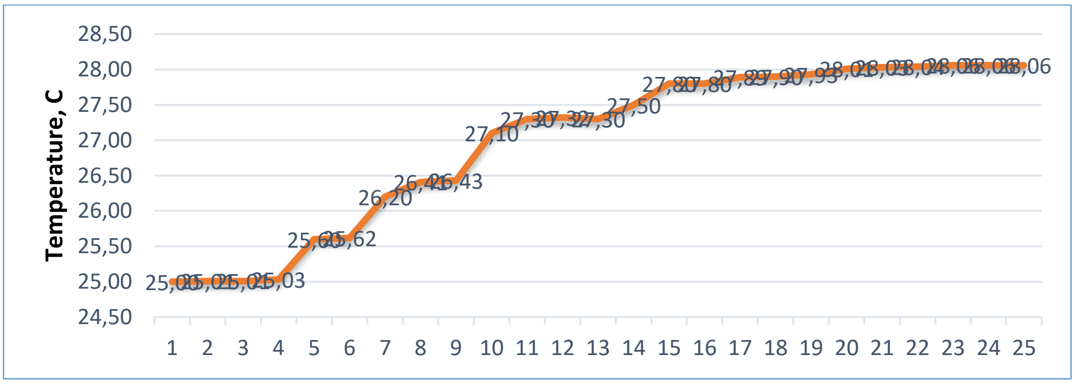


Figure 7 - Change in temperature during sonication

According to the measurements, there was an increase in temperature to 27 ˚C at 15 minutes of treatment, after the changes were insignificant (Figure 7).

The fifth section presents the economic efficiency of research results.

In accordance with the capabilities of the method developed by us, hydrogenation of "heavy" oils can be carried out in two ways:

- to pump water activated according to our method into the wells;

- to carry out an external impulse effect on the phase boundary by placing an electrode in the well, operating at the frequency of exposure.

The calculation of economic indicators of the effectiveness of both methods provides for an assessment of the influence of each component of the technological effect on the economic result. Currently, the indicator of the economic effect from the introduction of enhanced oil recovery methods in operating producing wells is usually calculated by the formula:

$$E = (\Delta Q * (P - C_{var}) - C_{ev}) * (1 - t)$$

E - the economic effect of the introduction of enhanced oil recovery methods at a given well, tenge / well; ΔQ – increase in oil production, tons / well; P – oil sales price, tenge / ton.; C_{var} – conditionally variable costs for the production of 1 ton of oil, tenge / ton.; C_{ev} – costs of carrying out measures to increase oil recovery at this well, tenge / well.; t – income tax, %.

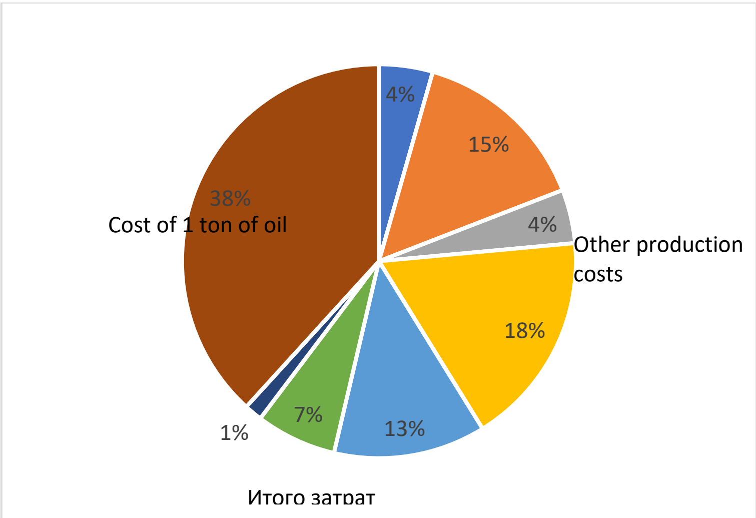


Figure 8 - Diagram of cost change after application of enhanced oil recovery technology using impulse action methods

As can be seen from Figure 8, when this technology is applied (oil viscosity is 1980 mPa * s at a temperature of 20 ° C), the calculations show that the total costs will decrease by 2%, and the oil recovery has increased by 30%. On the national level, the implementation of the project will make it possible to develop new energy-saving technologies for oil production, which will ensure an increase in the extraction of high-viscosity Kazakh oil. Consequently, the competitiveness of the industry will be increased, since these technologies can be applied both in new and in mothballed fields. In addition, the implementation of the project on a national and international scale will give impetus not only to the creation and application of new energy-saving production technologies, but, which is very important, to the development of new technologies for processing hydrocarbon raw materials.

In addition to the economic effect, an extremely important social effect should be expected, since the suspended deposits can be brought into operation, thereby creating new jobs for the city-forming enterprises..

Brief conclusions based on the results of dissertation research

The dissertation provides a solution to the urgent scientific problem of developing an enhanced oil recovery technology using pulsed action methods for the production of heavy oils in the Republic of Kazakhstan. The paper uses physical modeling of oil hydrogenation processes at the interface by means of impulse action at the frequency of water decomposition.

The main scientific results led to the following conclusions:

- Based on the results of experimental work, the conditions for changing the chemical composition of oil components at the interface have been determined, namely, with a pulse impact at a frequency of 42.8 kHz, hydrogen is separated from water;
- Experimentally substantiated the method of increasing oil recovery without a significant increase in costs at the stage of industrial production and in field conditions by reducing the viscosity of oil, which makes it possible to increase the oil recovery factor;
- The developed methodology and physical model can be used in research, design and operational oil production enterprises to increase the recovery factor of heavy oils by changing the chemical composition of fluids using pulsed action.

The technology and equipment have been proposed, allowing to produce low-frequency hydraulic impulse impact on the bottomhole formation zone. The impact on the reservoir with different frequency and thickness can significantly change the structure of the bottomhole formation zone, increase permeability, and reduce filtration resistance in the reservoir-well system. The combination of low-frequency hydraulic impulse action with electromagnetic waves of treatment of the bottomhole formation zone can be successfully applied in all fields.

Application of this technology as part of pilot tests on the territory of the Republic of Kazakhstan will have a positive effect on increasing the efficiency of the water-driven operation of the well, as well as increasing the oil recovery factor and ensuring a decrease in the viscosity of the produced oil to 10 cp., Increasing the water saturation in the waterflooding front to 55.7% as well as an increase in the oil recovery factor to 39.37%.

It is recommended to use the developed electromagnetic treatment method, that is, ultrasonic action on wells with high values of oil viscosity, as well as with a large difference in viscosities produced and injected by fluids to stimulate the bottomhole zone.