REPUBLIC OF AZERBAIJAN

On the right of manuscript

ELECTROKINETIC REGULATION OF RHEOPHYSICAL PROCESSES IN HYDRAULIC SYSTEMS IN OIL EXTRACTION

Speciality: 2525.01 – Development and exploitation of oil and gas fields

Field of science: Technical sciences

Applicant: **Aida Ramiz Aslanova**

ABSTRACT

Of the dissertation for the degree of Doctor of Philosophy

Baku – 2025

The dissertation work was performed at the Baku Higher Oil School of SOCAR, Petroleum Engineering Department.

Scientific supervisors: Doctor of Thecnical Sciences, Professor
Fuad Hasan Veliyev

Official opponents: Correspondent-member of NASA,
Doctor of Technical Science, Professor,
Calalov Garib Isag
Doctor of Technical Science, Associate professor,
Khalilov Mubariz Sevdimali
Candidate of Technical Sciences,
Associate Professor,
Baghirov Oktay Takhmasib

Dissertation council ED 2.03 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Azerbaijan State Oil and Industry University

Chairman of the Dissertation council : Doctor of technical sciences, associate professor
Arif Alakbar Suleymanov

Scientific secretary of the Dissertation council: Doctor of Philosophy in technology, associate professor
Yelena Yevgenyevna Shmoncheva

Chairman of the scientific seminar: Doctor of technical sciences, professor
Arif Mikayil Mammad-zada

Signatures confirmed by: Candidate of Technical sciences,
Scientific Secretary of ASOIU, associate professor
Nurmina Tarlan Aliyeva

GENERAL DESCRIPTION OF WORK

The topicality and development degree of the subject. Over the past twenty years, the development and operation of unconventional oil and gas resources of small and ultra-small conductivity has been one of the main requirements of the oil industry and global energy supply worldwide, as well as in Azerbaijan.

Currently, 10% of the world's proven reserves account for low and ultra-low permeability hydrocarbon deposits. Low and ultra-low permeability oil and gas fields form the main hydrocarbon resources of such countries of the world as the USA, Canada, China, Argentina, Russia, Mexico, Arabia. In Russia, such economically important productive formations as Bazhenov, Abalak, Domanik, Achimov, Tyumen, Longmaksi, Dadong, Kuche, Shaya, Yanchang, Heshui, Junggar, Denglouku, Sishuqou in China, Spraberry Bakken, Mallercus, Haynesville, Niobrara, Barnett, Utika, Monterey, Fayatteville, Unayzah, Barik and Amin in Arabia, as well as low and ultra-low permeability oil and gas fields rich in[1].

A certain part of Azerbaijan's hydrocarbon resources are low and ultra-low permeability hydrocarbon deposits.

Low and ultra-low permeability collectors are mainly composed of clayey, dense sandy and carbonated layer rocks and are characterized by poor porosity, permeability and productivity. Such collectors are divided into a class of collectors as low permeability ($50*10^{-3}$ – $10*10^{-3}$ μm^2), very low permeability ($10*10^{-3}$ – $1*10^{-3}$ μm^2), ultra-low permeability ($1*10^{-3}$ – $0.1*10^{-3}$ μm^2) and non-permeable (<0.1*10-3 μm^2)[2].

On average, the recovery factor of these rocks is 20%, and

---

[1] Yang, G. A comparative study of geological conditions of tight oils in China and USA / G. Yang, L. Qun, Z. Zeyuan [et al.] // Petroleum Geology & Experiment, - 2022. V. 44. № 2, p. 199-209

[2] Dongqi, W. Fine classification of ultra-low permeability reservoirs around the Placanticline of Daqing oilfield / W. Dongqi, Y. Daiyin, Z. Yazhou // Journal of Petroleum Science and Engineering, - 2019. V. 174. № 4, p. 1042-1052

most of the reserves remain underground as residual reserves[3].

One of the main difficulties arising in the development of this type collectors is the manifestation of anomalies in the rheophysical properties of fluid flow in low-permeability rocks and microcracks. In rocks of low and ultra-low permeability, the linear dependence of the filtration process is violated during the movement of viscous formation fluids in the contact zone of the liquid and rock, which, accordingly, leads to a violation of Darcy's law. At the same time, it was found that as the openness of microcracks decreases, starting from a certain critical threshold, non-Newtonian properties are observed with the manifestation of the initial pressure gradient in a viscous liquid (water, oil)[4]. Since these rocks are very sensitive to pressure changes, the manifestation and increase in the initial pressure gradient leads to a sharp decrease in the permeability of the deposit. This results in a significant weakening and even stopping of the flow.

Although there are various approaches to explaining the anomalous hydrodynamic properties manifested during the movement of viscous liquids in low-permeability porous media and microcracks, so far there is no consensus on the mechanism of these phenomena.

The fact that most of Azerbaijan's conventional oil and gas fields are in the final stages of development and, as a result, the rapid involvement of low and ultra-low-permeability oil collectors in operation determines the relevance of the issue.

In none of the existing scientific works in this area, the effect of the electrokinetic potential of the system on the rheophysical properties of liquids, as well as on the flow parameters in porous media and microcracks of low and ultra-low conductivity was taken into account.

The current situation requires the development of new

---

[3] Zhou, X. Research on the recovery efficiency of crude oil in tight reservoirs with different pore sizes / X. Zhou, G. Zhang, J. Wei // Energy, - 2024. V. 306. № 2, p. 1-13

[4] Mammadova, M.A., Gurbanov, R. S. Hydromechanical substantiation of the microcrack-f luid effect // - Mechanics, 2022. V. 22. № 6, p. 483-488

approaches to the study of the processes of filtration of liquids and the patterns of their movement in low-permeability collectors and microcracks.

Based on the presented experimental studies, anomalous properties of Newtonian and non-Newtonian liquids (water, oil and emulsions) manifested during their movement in the microcrack model (transition of Newtonian liquid to non-Newtonian liquid and exacerbation of non-Newtonian properties) were studied by stationary and non-stationary methods and methods of significant weakening of anomalous properties by reducing the electrokinetic potential of the system.

The object and subject of the research. The main object of the research work is, on the basis of the microcrack model the development of a new methodology for studying and eliminating anomalous properties manifested in the rheophysical properties of viscous liquids, taking into account the influence of electrokinetic factors.

The purpose and objective of the research. The main purpose of the work, based on model studies, is a comprehensive study of the rheophysical properties of the movement of formation fluids in microcracks, taking into account the role of the electrokinetic factor, and the determination of the possibility of improving the filtration properties of microcracks by regulating the electrostatic potential of the hydraulic system by chemical and physical effects.

Research methods.

Conducting experimental research on the determination of rheophysical parameters in laboratory conditions based on the microcrack model

Provisions for defence.

The provisions issued to the defense are as follows:

1. By reducing the electrostatic potential of liquids in microcracks by antistatic additives and physical effects, reducing the critical value of slit openness (h_{kr}) and initial yield shear stress (τ_0) at which viscous liquids begin to manifest as viscous-plastic liquids, and, accordingly, revealing the effect of significantly

attenuating the non-Newtonian character of the flow, thus, confirmation of the decisive influence of the electrokinetic potential of the system, as a factor, on the manifestation of non-Newtonian properties in viscous liquids filtered in microcracks, accompanied by a violation of Darcy's law.

2. Determination of the optimal concentration of antistatic additives, ensuring the maximum reduction of electrostatic potential in hydraulic systems

3. The effect of intensification of the rheophysical transmission process by reducing the electrokinetic potential of the hydraulic system, and, accordingly, a significant reduction in the pressure relaxation time in the system, detected on the basis of pressure recovery curves in microcracks.

4. Confirmation of the dependence of the efficiency of the process of displacement of oil by water in microcracks on the electrokinetic factor and the possibility of increasing the displacement coefficient by reducing the electric potential of water.

Scientific novelty of the research.

1. The influence of electrokinetic potential in microcracks on the rheophysical properties of the flow of formation fluids (water, oil, emulsions) has been comprehensively studied and the decisive influence of the electrokinetic potential of the system as a factor in the manifestation of non-Newtonian properties in viscous liquids filtered in microcracks, accompanied by a violation of Darcy's law, has been confirmed. On the basis of the extracted $Q=Q(\Delta P)$ flow curves for different openness (h) of microcracks, rheological parameters of flow were determined according to the Bingam model and it was determined that the reduction of the electrokinetic potential of the flow is accompanied by a significant improvement in the filtering properties of microcracks, which is manifested by a significant decrease in the critical value of the slit openness (h_{kr}) and the initial yield shear stress (τ_0), in which viscous liquids begin to manifest as viscous-plastic liquids.

2. In the experiments carried out to determine the optimal concentration of antistatic reagent, it was found that the dependence of the electrostatic potential of the studied liquids on

the concentration of antistatic additive is nonlinear, and it was determined that ultra-small doses of antistatic additives can significantly reduce the electrostatic potential of the hydraulic system.

3. The effect of intensification of the rheophysical transmission process by reducing the electrokinetic potential in the hydraulic system, and, accordingly, a significant reduction in the pressure relaxation time in the system was detected on the basis of pressure recovery curves in microcracks.

4. It has been experimentally confirmed that the efficiency in the process of displacement of oil by water in microcracks depends on the electrokinetic factor and the possibility of increasing the displacement coefficient in significant proportions by reducing the electric potential of water.

Theoretical and practical significance of the research.

Taking into account the electrokinetic effects, the study of the rheophysical properties of the movement of formation fluids in microcracks and the improvement of the filtration properties of microcrack through electrokinetic regulation of the electrostatic potential of the hydraulic system can be used to significantly increase the economic efficiency of developing low-conductivity and microcrack oil fields.

Electrokinetic regulation of the rheophysical properties of the formation fluids can be applied in significantly improving the intensity of the displacement process in micro-layered formations and, as a result, increasing the oil recovery coefficient.

The scientific article "Electrokinetic regulation of the process of oil displacement by water in microcracks", written on the basis of the results of scientific research, was included in the list of the most important results of 2023 and 2024 by the Department of Earth Sciences of the Azerbaijan National Academy of Sciences.

Personal contribution by the author. The practical results reflected in the dissertation were fulfilled by the author. The setting of the issue, the conduct of laboratory work, the analysis, systematization and generalization of the results were carried out with the participation of the author.

Approbation and application of the work.

The results of the dissertation work were reported and discussed at the following conferences:

- XXI International Scientific Symposium" Science and culture in the Modern world", Stockholm, Isverchra, December 26, 2021

- XXXII International Scientific Symposium "the victory of the Turks: from Canakkale to Karabakh" (the XXXII International Scientific Symposium " Turk's Victory: from CHANAKKALE to KARABAKH"), Kars-Eskisehir, Turkey, November 26, 2022

- NASCO, XXV Republican Scientific Conference of doctoral students and young researchers, Baku, Azerbaijan, November, 2022

- Scientific research collection of theses and articles (Scientific Researchers Collection of Thesis and Articles), 2022

- NASCO, XXVI Republican Scientific Conference of doctoral students and young researchers, Baku, Azerbaijan, November, 2023

- International Conference on chemical thermodynamics, (International Conference on Chemical Thermodynamics), Osaka, Japan, August 1-4, 2023

- International Conference on engineering, Science and Technology (International Conference of Engineering, Science and Technology), Las Vegas, USA, October 16-17, 2023

- International Scientific Conference "Caspian Measurements" (International Scientific Conference-Caspian Dimensions), Atyrau, Kazakhstan, October 24, 2023

-International Asian Congress on contemporary Sciences-IX (International Asian Congress on Contemporary Sciences – IX), Baku, Azerbaijan, November 1-3, 2023

- International Scientific-Practical Conference" Information Systems and technologies in Geology and oil and gas production

"(Международной научно-практической конференции" Информационные Системы и Технологии В Геологии И Нефтегазодобыче"), Tumen, Russia, November 16-17, 2023

- International Innovative Studies and Contemporary Scientific Research Congress Tokyo Summit VIII (International Congress of innovative research and contemporary scientific research, Tokyo summit VIII), Tokyo, Japan.

The organization where the dissertation work performed. Petroleum Engineering Department, Baku Higher Oil School of SOCAR.

The total volume of the dissertation with a sign, indicating the volume of the structural units of the dissertation separately.

The dissertation consists of introduction, 4 chapters, conclusions, a list of cited literature, 69 pictures and 6 tables. With introduction 12796, first chapter 77272, second chapter 5344, third chapter 51084, fourth chapter 26906 and results 3347, the dissertation consists of a total of 176749 characters.

MAIN CONTENT OF THE DISSERTATION

The dissertation work is devoted to the complex study of the rheophysical properties of the flow of formation fluids in microcracks, on the basis of model studies, taking into account the influence of the electrokinetic factor. The exceptional role of the flow potential in the regulation of the rheophysical properties of various fluid flows in microcracks, as well as in the management of displacement processes, is assigned. It has been established that the detected "electro-rheostress" effect has a significant role in reducing critical opennes and restoring and intensifying fluid flow, in which the rheophysical properties of liquids begin to sharpen in low-permeability porous media and microcracks.

In the introduction, the relevance of the dissertation is substantiated, information is given on the purpose of the work, research methods and methods of solving the problems posed, scientific innovations, theoretical and practical significance of the work, approbation, structure and scope of the work.

The first chapter reflects the scientific and practical issues of rheophysical regulation of thermohydrodynamic processes in oil recovery systems. The local and international scientific works carried out on the topic to date have been studied and a compact description of the results has been given.

At the same time, a review of the rheological characteristics of fluid flow in low-conductivity collectors and microcracks and electrokinetic processes in hydraulic systems was given, an overview of the work done in the direction of studying rheophysical phenomena in oil and gas production systems and applying physical fields was presented.

Research on increasing the effectiveness of technological processes in oil production using rheophysical regulation methods, as a new scientific direction, has gained momentum since the 70s of the last century.

It should be noted with a sense of satisfaction that it was in Azerbaijan that the leading scientific center was formed, which determined the main problems of this direction and successfully

operated in the direction of solving its principles. At the Azerbaijan Institute of Oil and Chemistry, under the leadership of Academician Azad Mirzajanzade, large-scale studies were carried out on the study of rheophysical phenomena in oil and gas production systems and increasing the efficiency of technological processes based on the effects obtained due to the application of physical fields. The world-famous scientific center created by Azad Mirzajanzade has been operating with extraordinary efficiency for many years, many scientific discoveries on rheophysics have been made here, scientific and practical foundations of the application of chemical methods and physical fields in the regulation of technological processes of oil and gas production have been developed.

As a physical field in studies to influence hydraulic systems, mainly electric and magnetic fields of various nature, configurations, voltages were used.

Extensive research work was carried out to study the influence of electromagnetic fields on the rheophysical properties of non-magnetoactive hydraulic systems, related to the technological processes of oil and gas production (Valiyev F.H.). It has been established that the effect of electromagnetic fields of certain voltages leads to a significant improvement in the hydrodynamic properties of asphalt-resinous oils, water-oil emulsions. The obtained effect was applied to increase the throughput of real pipelines in the transport of non-Newtonian systems. The effect of a significant strengthening of the separation properties of gas condensate flows when affected by changing magnetic fields was revealed and applied on an industrial scale.

On the basis of F.H.Valiyev's idea of the decisive role of electrokinetic potential in the occurrence of many thermohydrodynamic effects, large-scale research work was carried out, it was found that by reducing the electric potential in the hydraulic system by physical field (electromagnetic field) or chemical additives (antistatic additives), using electromagnetic effects and antistatic additives, it is possible to regulate the

thermohydrodynamic properties of liquids[5]. Among the research works carried out in this direction, it is necessary to highlight the results obtained by O.T.Bagirov[6].

The application of electromagnetic fields in intensification of oil and gas extraction processes was carried out by the employees of the Department "Development and Exploitation of Oil Fields" of the Institute of Oil and Chemistry (Azerbaijan State Oil and Industry University) under the leadership of Academician A.X.Mirzajanzade. (A.M. Mammad-zada, A.M. Bayramov ,T.S. Salavatov, E.M. Abbasov, R.X.Malikov, L.R.Eydelman, and others).

It should be noted the special leading role of A.M.Mammad-zade in the implementation of this large-scale research work. As a result of multidisciplinary research, starting from experiments on porous models in laboratory conditions and up to industrial-scale application work carried out in a large number of fields, important results were obtained from a scientific and practical point of view, it was established that it is possible to seriously increase the oil recovery factor of the layer by influencing with a magnetic field of a certain intensity[7].

In the last thirty years, as a result of extensive research on the filtration of liquids in Porous Media, it was established that the flow of viscous liquids in microchannels can be accompanied by violation of Darcy's law and the acquisition of non-Newtonian properties of Newtonian fluid (V.A. Baykov, Li Syuanjan, Ko lonskikh, Makatrov, Politov, Davletova, Xiaolong Yinin, Yu-Shu Vun, Faruk Jivan, Yang Qinglan, Vei Xiong, Prada Alvaron and others).

In experiments on microcracks, it was found that as the

---

[5] Велиев Ф.Г., Научные и практические основы применения физических полей в регулировании технологическими процессами нефтедобычи. Диссертация на соискание ученой степени доктора технических наук. Баку, 1983

[6] Багиров О.Т. Исследование электризации газожидкостных потоков и методов их регулирования с целью повышения производительности газлифтных скважин. Автореферат дис.канд.техн.наук. Баку, 1985

[7] A.M. Məmmədzadə, Neftqazçıxarmada fiziki sahələrin və qeyri-tarazlı effektlərin tətbiqinin nanotexnoloji əsasları. Monoqrafiya, 207 s., Bakı, 2021.

openness of the slits decreases, starting from a certain critical size, nonlinear properties are manifested in the flow process, Darcy's law is violated, and Newtonian fluids are transformed into non-Newtonian fluids[8].

Although there were attempts to explain the manifestation of viscous liquid as a non-Newtonian liquid in filtration in microchannels by various approaches, the role of the electrokinetic factor was not taken into account, so it was not possible to develop a scientific and practical concept for regulating the process.

The second chapter provides detailed information on the complex laboratory facility where research work is carried out. At the same time, compact information on the methods of analysis of the results of research work was also reflected.

For the experimental study of the motion of Newtonian and non-Newtonian liquids in microchannels, a microcrack model consisting of two steel smooth plates was used. An ultra-small-sized slit with a length of 30 cm and a width of 40 mm is placed on the inner surface of the steel plates. Lead paper was used to adjust the size of the slit. In addition, the experimental device consists of a high-pressure gas cylinder, a regulating conductor, a container for storing liquid, a microcrack model with an ultra-small slit, a pressure gauge for measuring the difference in pressures at the inlet and outlet of the microcrack model, a thermostat and thermometers to ensure stable temperature conditions, and a potentiometer for measuring the potential difference between the inlet and outlet of the model (Figure 1).

[8] Mamedova, M. A., Gurbanov, R. S. Investigation of the Rheology of Fluids in Fracture and Pore Channels and Determination of Their Opening // Journal of Engineering Physics and Thermophysics, 2015. V. 88. № 4, p. 815-824

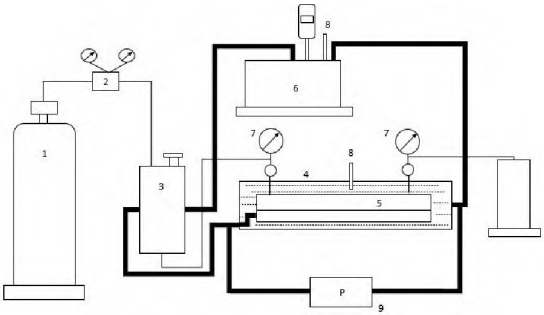

Figure 1. Scheme of the experimental device:

1-high pressure gas cylinder, 2-regulating conductor, 3-container, 4-thermo-bath, 5-microcrack model, 6-thermostat, 7-pressure gauge, 8 - thermometer, 9-potentiometer

In order to study the anomalous rheophysical properties manifested and exacerbated during the movement of Newtonian and non-Newtonian fluids in the microcrack model, extensive laboratory studies were carried out and the results were studied on the basis of flow curves $Q=Q(\Delta P)$ and velocity gradient yield shear stress dependence curves $\gamma = \gamma(\tau)$. The flow rate of the fluid flowing in laminar mode between two parallel plates was determined by the formula $Q = bh^3 \Delta P/12\mu l$. Where b, L and h are, respectively, the width, length and thickness of the slit of the microcrack model. The parameters γ and τ were calculated on the basis of the formulas $\gamma=6Q/bh^2$ and $\tau=\Delta Ph/2L$, respectively. The flow of Newtonian fluids (water and oil) was analyzed according to the Bingham model, and the viscosity of the fluid flow and the initial yield shear stress were determined.

For each of the liquids under consideration, the critical openness value of the microcrack slit h_{kr} is defined. It has been confirmed that at the values of openness $h \leq h_{kr}$, the linear filtration process is disturbed, the Newtonian liquid (water) shifts to a non-Newtonian liquid, and the non-linear properties of a non-Newtonian liquid (emulsion) are exacerbated. At values above the critical opennes of a microcrack model, however, the liquid retains its initial rheophysical properties.

It has been established that at values below h_{kr}, as the value of the slit opennes of the microcrack model decreases, the flow viscosity of the water increases sharply nonlinearly and reaches its maximum limit at the value of h=10μm. At values above the h_{kr} of the slit, the change in flow viscosity is practically not noticeable.

It has been established that the sharp changes in the rheological properties of liquids in microcracks can be explained by the well-known electro-viscosity effect.

In the third chapter, an experimental study of the regulation of the rheophysical properties of fluid flows in microcracks by physico-chemical effects was carried out.

It is known that real oil and gas condensate systems are heterogeneous, multicomponent, and also consist of water, asphaltenes, resins, paraffin and other components. According to the well – known Coen rule of electrostatics, "when two substances with different dielectric conductivity are in contact, an electrical charge occurs in them-a substance with a higher dielectric conductivity is positively charged, and the other is negatively charged"[9]. According to this rule, an Electric Double Layer (EDL) is formed at the boundary of the components in contact, and thus a real heterogeneous hydrocarbon system is manifested in the form of a complex composition of an infinite number of local ion-electrostatic microfields distributed in the volume of the dispersion medium. In this composition, the EDL is formed on oil-water, oil-gas, condensate –water, water-gas, paraffin-water and other boundary surfaces.

Due to the fact that in pipes and large-sized porous media, the thickness of the EDL is very small compared to the flow dimensions, its special effect on the flow parameters is not manifested. However, in microchannels and small-sized porous media, the electrokinetic factor has a significant impact on the flow characteristics, as the thickness of the EDL is comparable to the flow dimensions.

Extensive research has been carried out to determine the role of the electrokinetic potential of the system in the regulation of

[9] Loeb, L. B. (1958). Static Electrification. Springer Berlin Heidelberg, p. 52

anomalous rheophysical properties manifested during the movement of hydraulic systems in microcracks, under the influence of electrokinetic effects.

Initial experiments were carried out at four different openings – 25μm, 10μm, 15μm, 20μm, 25μm, including the critical value (25μm) of the slit of the microcrack model with water. The output pressure of the model was adjusted to atmospheric pressure, and the input pressure was changed through the conductor in the range of $0.5x10^5$ Pa – $5x10^5$ Pa. Once the fluid flow has settled only, the dependence $Q=Q(\Delta P)$ has been plotted.

At values of slit openness $h \geq h_{kr}$, water flow maintains Newtonian fluid properties. However, starting from h_{kr}, as h decreases, the linear filtration process is disrupted, and non-Newtonian properties are manifested in the hydraulic system. The obtained $Q=Q(\Delta P)$ curves showed that the flow clearly corresponds to the Bingham model. The viscosity was calculated on the basis of the known formula $\mu = bh^3\Delta P/12QL$ at 4 different values of h.

Antistatic additives were used to regulate the electrokinetic potential of water and water-oil emulsions. ND-12 reagent was used as an antistatic agent to regulate the electrokinetic potential of water, and a 5% solution of chromium salt of Natural Petroleum acid was used as an antistatic reagent to regulate the static potential of water-oil emulsions.

First of all, the tendency of the electrode potential of water to change under the influence of the additive was studied in order to determine the optimal concentration of antistatic additives. It has been established that this dependence is not monotonous and manifests itself in very small amounts of the minimum potential reagent. Initially, with an increase in concentration, the potential decreases, but after reaching a minimum, the opposite process is observed – as the concentration increases, the potential also increases.

The amount of optimal concentration at which the minimum potential is achieved is set at approximately 0.006% (60 ppm). At this value of the antistatic additive, a multiple (up to 10 times) decrease in potential is observed. From 60 ppm, up to about 400 ppm, an increase in the static potential of water is observed with an

increase in the concentration of the antistatic additive. At higher values of the additive than 400 ppm, however, the static potential remains practically unchanged[10] (Figure 2).

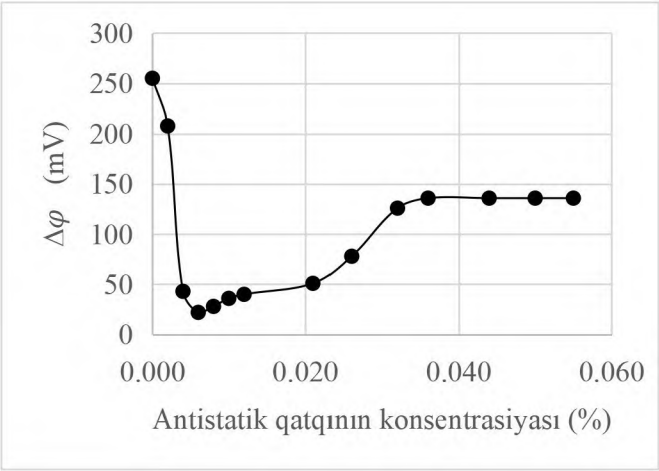

Figure 2. Changes in the static potential of water under the influence of an antistatic reagent.

In order to more deeply study the effect of the change in the flow potential of the fluid system on the rheophysical properties of the flow, experiments were carried out with water with additives at two different concentrations of the reagent – 60ppm, where the potential is minimum, and 450ppm, where the potential does not depend on the concentration of the reagent.

It has been established that at different values of h, a significant improvement in flow parameters is observed under the influence of an antistatic additive. It was found that the effect is higher at small openness of the slit, and decreases as it approaches h_{kr}.

For comparison, for water without additives at an opennness

[10] Veliyev F.H., Aslanova A.R., Electrokinetic regulation of non-Newtonian character of water flow in microcrack model//-Almatı: Нефтехимия, - 2023, V. 5. № 137, - p. 136-143.

of the slit of the model of 10 μm, water with additives of 60 ppm and 450 ppm, at a temperature of 30°C, the characteristic $\gamma=\gamma(\tau)$ curves are shown (Figure 3).

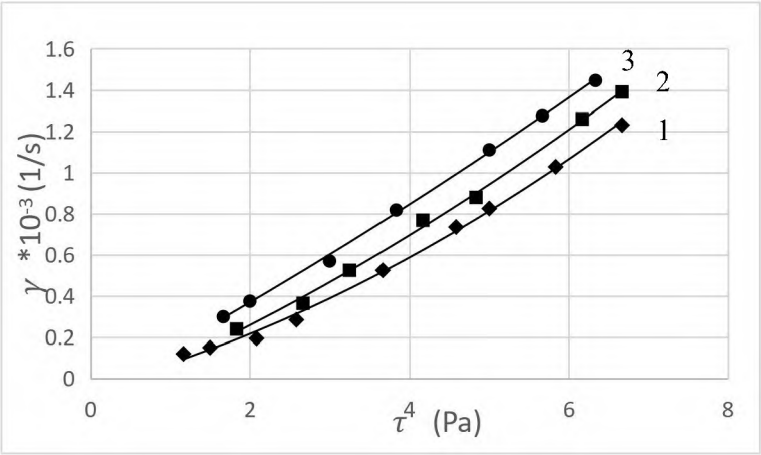

Figure 3. Curves $\gamma=\gamma(\tau)$ at 10 μm openness of the slit of the model for water:

1 - water without additives, 2 - water with 0.045% additives, 3 - water with 0.006% additives.

As can be seen, with a decrease in electropotential, the non-Newtonian property of water in microcrack flow is seriously weakened, and this effect is more pronounced at the optimal value of the additive, and, accordingly, at the minimum value of the potential[11].

As a result of reducing the electrokinetic potential of the hydraulic system under the influence of the optimal concentration of the additive, a significant decrease in the initial yield shear stress τ_0 is also observed. While the formation of τ_0 in the water without an additive is observed at values of h<25μm of openness, with a decrease in potential, the critical openness h_{kr} decreases to 20μm.

[11] Veliyev F.H., Aslanova A.R., Non-Newtonian characteristics of water flow in microchannels//-Indian: Indian Journal of Science and Technology, - 2023, V. 16. № 47, - p. 4605-4611.

Figure 4 gives the dependence of τ_0 on h for water in the absence and presence of additives. Apparently, as h shrinks, τ_0 increases, and at the minimum value of h (10μm) in the range under consideration, τ_0 becomes the maximum.

It also appears that shrinking the potential leads to a serious decrease in τ_0. Consequently, at the optimum concentration of the antistatic reagent at the openness of the slit h=20μm, the non-Newtonian character almost disappears, and the Newtonian fluid properties of the water flow are restored.

As can be seen from the comparison, at a higher concentration (450 ppm), the effect is more weakly manifested.

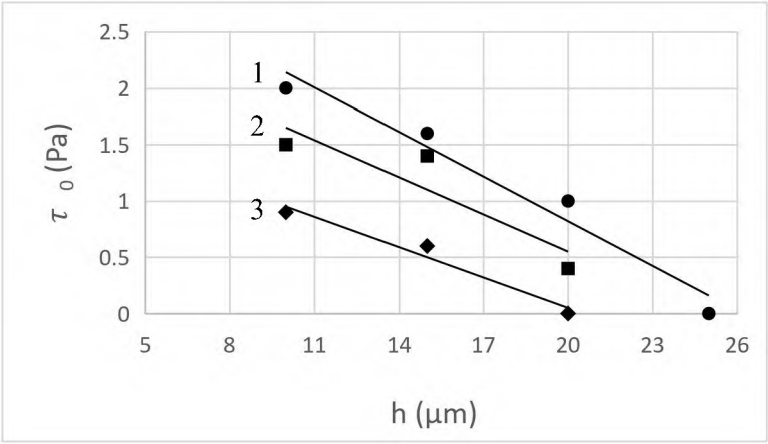

Figure 4. Change of τ_0 depending on the openness of the slit during the flow of water from the microcrack model:

1-water without additives, 2 - water with 0.045% additives, 3 - water with 0.006% additives.

Comparison of flow curves in microcracks for water in the absence and presence of additives shows that the decrease in potential leads to a significant decrease in the initial yield shear stress in the system, although it practically does not affect the viscosity of the system. This discovered phenomenon was called the electro-rheostress effect.

In parallel, the flow potential of the system – the difference in potentials at the input and output of the model-was also measured. It has been established that under the influence of antistatic additive, the difference in potentials of the system is significantly reduced. Thus, in the case of optimal concentration of water at the openness of the slit h=10μm, the difference in potentials decreased from 3300 mV to 2700 mV. Under the influence of the 450 ppm additive, the difference in potentials decreased less to 2950 mV[12].

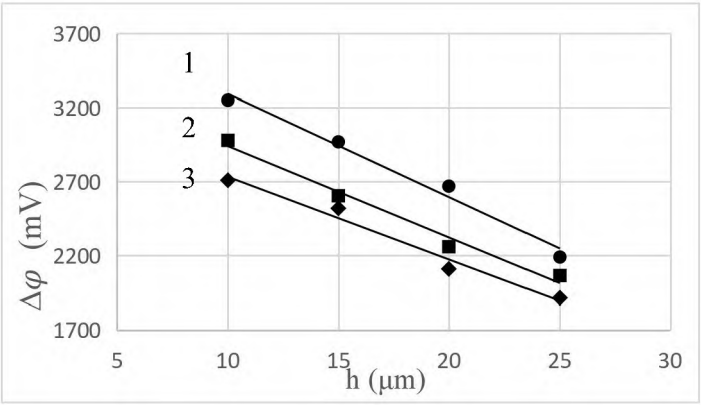

Figure 5. The difference in potentials at the inlet and outlet of the model depending on the openness of the slit during the flow of water from the microcrack model:

1 - water without additives, 2 - water with 0.045% additives, 3 - water with 0.006% additives.

The similarity in character of the dependencies $\tau_0 = \tau_0(h)$ and $\Delta\varphi = \Delta\varphi(h)$, given in Figures 4 and 5, once again confirms the electrokinetic origin of the effect under consideration.

The above-mentioned experiments were carried out with 30% and 70% water-oil emulsions, and similar results were obtained.

---

[12] Велиев Ф.Г., Мамедова М.А. Асланова А. Р., Реофизические особенности течения воды в микротрещинах//- Минск: Инженерно-физический журнал, - 2024, V. 3. № 97, - p. 679-683.

The dependence of the known inversion phenomenon on the electrokinetic factor, accompanied by an extreme change in the viscosity of the system, depending on the relative amount of water in water-oil emulsions, was separately studied. Figure 6 gives the curves of dependence of the viscosity (μ) and potential (Δφ) of the emulsion on the relative amount of water. Apparently, there is an obvious correlation between the change curves of these two parameters, which confirms that the inversion phenomenon in emulsions is electrokinetic in nature.

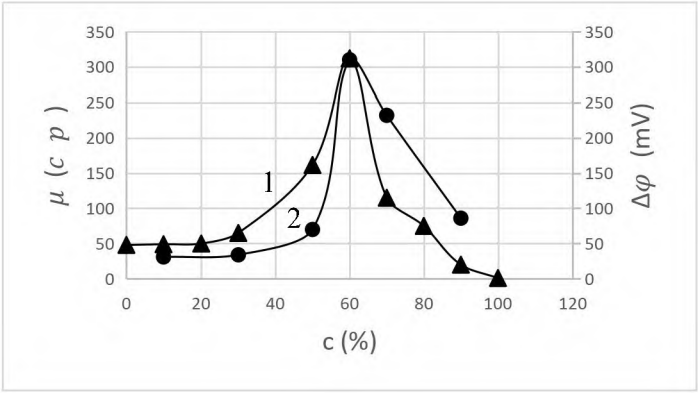

Figure 6. Dependence of the 1-viscosity μ and 2-static potentials of water-oil emulsions $\Delta\varphi$ on the amount of water in the composition

Extensive research work was carried out in order to study the effect of reducing the electrokinetic potential of hydraulic systems in microcracks by physical methods on the rheophysical properties of liquids. The effect of electromagnetic fields was used as a physical method. The experiments were carried out with water and water-oil emulsions.

The fluid flows under consideration were passed through a special magnetic device and introduced into the microcrack model. The magnetic device is basically composed of 4 fixed magnets, with a diameter of 4.2 cm and a distance of 3.3 cm, coaxially placed inside a steel pipe with a length of 20 cm and an inner diameter of 5

cm. The maximum magnetic induction in the slit between the magnets and the inner surface of the tube is equal to 0.15 T.

The obtained results show that as a result of reducing the electrostatic potential of the system, both through additives and under the influence of a magnetic field, qualitatively identical rheological changes are observed in the microcrack flows – a decrease in τ_0 and, accordingly, a weakening of the non-Newtonian properties of the flows, a decrease in the critical openness of the slit, increased microchannel transport capacity.

The results once again confirm that the electrokinetic potential of the system has a dominant role in the regulation of the rheophysical properties of hydraulic systems.

The fourth chapter reflects the results of experimental work to study the effect of reducing the electrokinetic potential of hydraulic systems on the intensity of transmission processes in the microcrack model. In the first part of the chapter, the effect of reducing the electrokinetic potential in water-microcrack and oil-microcrack systems on the pressure recovery process was evaluated, and in the second part, the effect of reducing the electrokinetic potential of the compressing fluid on the intensity of the oil displacement process in the microcrack model was investigated.

First, in experiments with water, pressure recovery curves (PRC) were extracted in various openness of the silt of the microcrack model. It has been established that during the flow of water from the microcrack model, starting from the h_{kr}, as the openness of the slit decreases, the pressure increases during recovery. While the pressure at 25μm openness of the slit was 50 s during recovery, at 10μm openness it rose to 250 s.

At the same time, at the values of openness $h \geq h_{kr}$, a complete restoration of pressure at the entry and exit points of the microcrack model is recorded, but starting from h_{kr}, as h decreases, the difference in the settled pressures at the entry and exit points is manifested and reaches a maximum limit at the smallest value of openness (h=10μm).

These results are fully consistent with the final conceptual conclusions established on the role of the electrokinetic factor in this process, transforming water into a non-Newtonian liquid in

microcrack of a certain size on the basis of Q=Q(ΔP) curves.

An important result of the experiments is that reducing the potential of the system by an antistatic additive to water significantly increases the intensity of the pressure recovery process in the microcrack model. Thus, the recovery time of the pressure at h=10μm for water without additives was 250s, while with the effect of the optimal concentration of the additive, it is 150s, and with the effect of 0.045% of the additive, it is 170s. In the considered range, similar intensification in the pressure recovery process was recorded at other values of h (Figure 7).

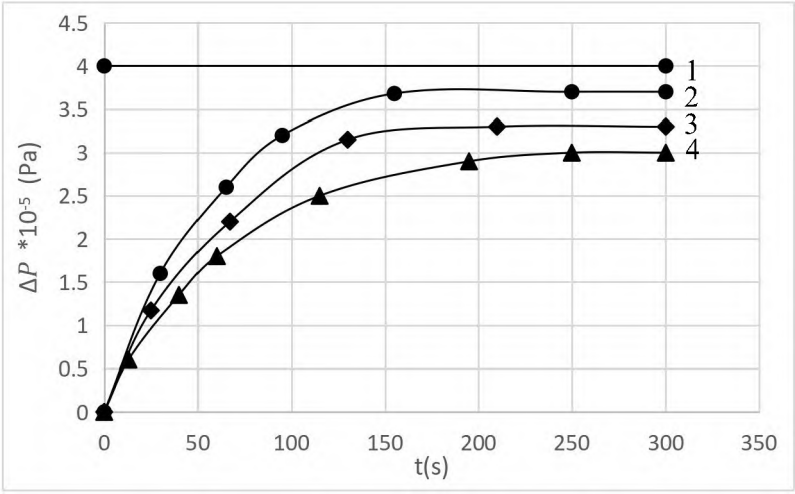

Figure 7. Pressure recovery curves during the flow of water at the openness of 10 μm of the slit of the microcrak model:

1-inlet pressure of the model, 2-0.006% additive water, 3-0.045% additive water, 4-water without additives

Under the influence of the antistatic additive, a decrease in the difference in settled pressures manifested at the entry and exit points of the model was also recorded at values below h_{kr}. At the smallest value of openness (h=10μm) in the range under consideration, the difference in settled pressures during pressure recovery for water without additives was 1 atm, with the effect of the

optimum amount of additive this value was 0.3 atm, and with the effect of 0.045% additive-0.7 atm (Figure 7).

At the openness of the slit h=20μm, when restoring the pressure for water without additives, a pressure difference of 0.2 atm was obtained, due to the optimal amount of the additive, a complete restoration of the pressure was provided throughout the model, which is an indicator that the water has already regained its Newtonian liquid characters.

The recorded results are also consistent with the tendency of the flow potential to change under the influence of the antistatic additive. In the considered range, a decrease in the flow potential by up to 1.3 times was recorded due to the optimal concentration of the antistatic additive, which results in a decrease in pressure recovery time by up to 2 times in the corresponding openness.

In accordance with the decrease in the flow potential under the influence of two different concentrations of the additive in all the values of h, intensification in the pressure recovery process was also recorded.

In addition to chemical effects, constant and variable magnetic fields were used to reduce the flow potential, and qualitatively similar results were obtained to those mentioned above.

The above-mentioned experiments were carried out with 30% and 70% water-oil emulsions, and similar results were obtained.

Consequently, it was found that reducing the electrokinetic potential of the fluid flow has a significant effect on the intensity of non-stationary processes. Thus, by reducing the electrokinetic potential of the hydraulic system, the rheophysical transmission process in the system intensifies, and as a result, the pressure recovery time in the hydraulic system is significantly reduced.

Extensive laboratory work was carried out in order to experimentally study the effect of electrokinetic regulation of the rheophysical properties of fluid systems on the process of oil displacement by water in the microcrack model. A significant increase (up to 30%) in the displacement coefficient was recorded by reducing the electrokinetic potential of the displacing fluid under the influence of an antistatic additive and an electromagnetic field.

For comparison, Figure 8 shows graphs of the dependence of the displacement coefficients of Newtonian oil with water without additives and without magnets, water with antistatic additives and water passed through a magnetic field under the pressure difference $\Delta P=2*10^5$ Pa. In all the considered values of h, it can be clearly seen that the process of displacement is significantly intensified as a result of reducing the electrostatic potential of water due to the influence of an antistatic reagent and a magnetic field.

In parallel, with the displacement process, the difference in potentials – the flow potential-was also measured between the input and output points of the system. In Figure 8, the dependence of the flow potential h in the processes of displacement of Newtonian oil with water, water with antistatic additives and water passed through a magnetic field under the pressure drop $\Delta P=2*10^5$ Pa is also shown.

Apparently, with a decrease in potential at all values of h, the displacement property of water intensifies, which, consequently, is accompanied by a significant increase in the displacement coefficient[13].

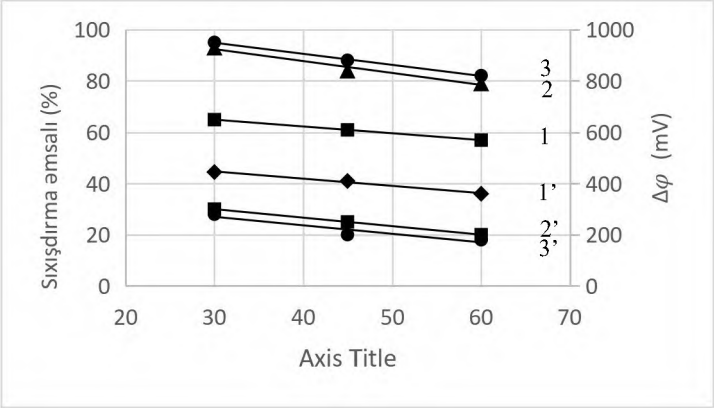

Figure 8. Dependence of the coefficient of displacement of

[13] Veliyev F.H., Aslanova A.R., Electrokinetic regulation of the process of oil displacement by water in microcracks//-Baki: Azerbaijan Oil Industry, - 2023, 12, - p. 18-21.

Newtonian oil by water in the microcrack model under the pressure difference $\Delta P = 2*10^5$ Pa:

1- displacement by water without additives, 2 – displacement by water with magnetic field, 3 – displacement by water with antistatic additives and the dependence of the flow potential on the openness of the slit in the process of displacement: 1' – displacement with water without additives, 2' – displacement with water passed through a magnetic field, 3' – displacement with water with antistatic additives.

Consequently, it has been established that the reduction of the electrokinetic potential of the fluid system significantly affects the intensity and effectiveness of the process of displacement of oil with water in the microcrack model. The results of experiments on displcement of oil with water without additives, water with additives and under the effect of magnetic field under various pressure drops show that an increase in the displacement coefficient of up to 30% is achieved.

Conclusion

1. The influence of electrokinetic factors on the rheophysical properties of the flow of formation fluids in microcracks has been studied in a complex manner on the basis of model studies. It has been established that in the process of filtration of viscous liquids in microcracks, the electrokinetic potential of the system has a special role in the manifestation of non-Newtonian properties, accompanied by a violation of Darcy's law. Thus, reducing the electrokinetic potential of the system using physical and chemical influences significantly weakens the non-Newtonian nature of the flow and, consequently, improves the filtration properties of microcracks.
2. It has been established that small doses of antistatic additives significantly reduce the electrostatic potential of the fluid system. The curves of dependence of the electrode potential ($\Delta\varphi$) of liquids (water, oil, emulsion) on the concentration of antistatic additives in the system are nonlinear, and at an ultra-small concentration of the antistatic additive, the electrostatic potential decreases to the minimum value of $\Delta\varphi$.
3. On the basis of $Q=Q(\Delta P)$ and $\gamma=\gamma(\tau)$ curves in different openness of the slit of the microcrack model, for water and water-oil emulsions, with the absence and presence of antistatic additives, the rheological parameters of the flow according to the Bingham model were evaluated. By reduces the electrokinetic potential of the fluid flow, the optimal concentration of the antistatic reagent, seriously reducing the initial pressure gradient $\Delta \boldsymbol{P_0}$ and the initial yield shear stress $\boldsymbol{\tau_0}$ of the system, and, consequently, significantly improves the filtration properties of microcracks. The resulting effect was called the electro-rheostress effect. In the smaller openness of the slit of the microcrack model, the effect is manifested more strongly.
4. It has been established that with the reduction of the electrokinetic potential of the liquid system under the influence of an antistatic reagent, the critical value of the slit openness of the microcrack model at which viscous liquids begin to manifest

as viscous-plastic liquids, decreases, this means, the transition of a Newtonian liquid to a non-Newtonian liquid is manifested in smaller slits.

5. Qualitatively identical results were obtained in experiments with water-oil emulsions. In addition, it was established that the inversion process, characterized by an increase in the viscosity of the emulsion depending on the relative amount of water in it and a decrease after reaching a maximum, is essentially electrokinetic in nature, and this thesis is confirmed by the existence of an obvious correlation between the changes in curves of the viscosity of the emulsion and electric potential.
6. Reducing the electrokinetic potential of the fluid flow with the addition of antistatic additives has a significant effect on the intensity of non-stationary processes. In the absence and presence of antistatic additives, from the comparative analysis of pressure recovery curves in microcracks of different sizes it is clear that with a decrease in the electrical potential, the rheophysical transmission process in the system intensifies and, as a result, the pressure relaxation time in the hydraulic system is significantly reduced.
7. It has been established that the presence of a small amount of antistatic additive in the water in the process of oil displacement from microcracks, and, accordingly, the reduction of electrokinetic potential in the system significantly increased the displacement ability of water. The obtained results give reason to believe that water containing ultra-small doses of antistatic reagent in accordance with the optimal concentration can be used as a highly effective compacting agent in the process of compressing oil from microcracks or microcrack-porous collectors.
8. Before entering the microcrack model of the studied liquids, experiments were carried out on the basis of reducing the electrostatic potential by the action of constant and variable magnetic fields, and qualitatively identical results were obtained with the above-mentioned ones.

LIST OF PUBLISHED WORKS ON THE SUBJECT OF THE DISSERTATION:

1. Aslanova, A.R., Challenges in heavy oil operations due to non-Newtonian behavoir // Stockholm: The XXI International Scientific Symposium "Science and Culture in the Modern World", - Baku: - 2021, - p. 285-286.
2. Aslanova, A.R., The role of electrokinetic effects in microcrack flow // The XXXII International scientific symposium “Turk's victory: from Chanakkale to Karabakh”, - Kars-Eskişehir: -2022, - p. 352-354.
3. Aslanova, A.R., Mikroçatlarda axının elektrokinetik tənzimlənməsi// Doktorantların və Gənc Tədqiqatçıların XXV Respublika Elmi Konfransı, - Bakı: - 2022, - p. 117-120.
4. Aslanova, A.R., Rheophysical problems of non-Newtonian fluids in oil production processes // Bilimsel araşdırmalar, Tezis və məqalələr toplusu, - Ankara: - 2022, - p. 272-273.
5. Aslanova, A.R., Electrokinetic regulation of fluid flow in microcracks // Doktorantların və gənc tədqiqatçıların XXVI respublika elmi konfransı - Bakı: - 2023, - p. 103-107.
6. Veliyev, F.H., Aslanova, A.R., Electrokinetic effects in microcrack flow // International Asian Congress on Contemporary Sciences – IX, Proceeding Book - Bakı: - 2023, - p. 150-154.
7. Veliyev, F.H., Aslanova, A.R., About the non-Newtonian behaviour of fluid flow in micro-slit model // International Scientific Conference, Caspian dimension - Atırau: - 2023, - p. 26-31.
8. Veliyev, F.H., Aslanova, A.R., A rheophysical study of the non-Newtonian behavior of fluid flow in thin channels // International Conference on Engineering, Science and Technology (IConEST), Abstract Book - Las Vegas: - 2023, - p. 144.
9. Veliyev, F.H., Aslanova, A.R., Electrokinetic regulation of flow in microcrack reservoirs // 26th IUPAC International

Conference on Chemical Thermodynamics, Abstract Book - Osaka: - 2023, - p. 103.
10. Veliyev, F.H., Aslanova, A.R., Electrokinetic regulation of non-Newtonian character of water flow in microcrack model // Almatı: Нефтехимия, - 2023, V. 5. № 137, - p. 136-143.
11. Aslanova, A.R., Jalilov, J.Y., The study of rheophysical analysis of water flow in microcracks // Almatı: Нефтехимия, - 2023, V. 6. № 138, - p. 227-233.
12. Veliyev, F.H., Aslanova, A.R., Electrokinetic regulation of the process of oil displacement by water in microcracks // Azerbaijan Oil Industry, - Baku: - 2023, 12, - p. 18-21.
13. Veliyev, F.H., Aslanova, A.R., Non-Newtonian characteristics of water flow in microchannels // Indian Journal of Science and Technology, - Indian: - 2023, V. 16. № 47, - p. 4605-4611.
14. Veliyev, F.H., Aslanova, A.R., The investigation of rheophysical properties of fluid flow in microchannels // International innovative studies & contemporary scientific research congress Tokyo Summit – VIII, Proceeding Book - Tokyo: - 2024, - p. 184.
15. Велиев, Ф.Г., Мамедова, М.А. Асланова, А. Р., Реофизические особенности течения воды в микротрещинах//- Минск: Инженерно-физический журнал, - 2024, V. 3. № 97, - p. 679-683.
16. Veliyev, F.H., Aslanova, A.R., A rheophysical study of the non-Newtonian behavoir of water flow in thin channels // Eureka: Physics and Engineering, - Estonia: - 2024, N1, - p. 11-17.
17. Veliyev, F.H., Aslanova, A.R., Rheophysical characteristics of hydrocarbon flow in microcracks // International Journal on Engineering, Science and Technology, - Las-Vegas: - 2024, V. 2. № 6, - p. 163-170.
18. Veliyev, F.H., Mamedova, M.A., Aslanova, A.R., Rheological features of water flow in microcracks // Journal of Engineering Physics and Thermophysics, - USA: - 2024, V. 3. № 97, - p. 663-667.

Personal contribution of the claimant in the works performed.

[1, 2, 3,4, 5] works were performed independently, in [6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18] works, she took an active part in setting the issue, the implementation of theoretical and experimental research, analysis of the results and compilation.

The defence of dissertation will be held on 03 june at 11:00 at the meeting of Dissertation Council ED 2.03 operating under Azerbaijan State Oil and Industry University.

Address: AZ1010, Baku city, D. Aliyeva st., 227.

The disserartion is available in the library of Azerbaijan State University of Oil and Industry.

Electronic versions of the dissertation and abstract have been posted on the official website of Azerbaijan State Oil and Industry University.

The abstract has been submitted to the necessary addresses on 30.04.2025

Signed for print: 28.04.2025
Paper format: A5
Volume: 38658
Number of hard copies: 20