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ABSTRACT

of the dissertation for the degree of Doctor of Sciences

DEVELOPMENT OF RHEOTECHNOLOGICAL METHODS FOR INCREASING THE EFFICIENCY OF OIL PRODUCTION, COLLECTION AND TRANSPORTATION PROCESSES

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

Field of science: Technical sciences

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GENERAL FEATURES OF DISSERTATION

Relevance of the theme and degree of development. Modern scientific ideas about the current state of oilfield development and the purposeful use of existing oil resources bring to the fore the problem of creating new management and regulation methods for increasing the efficiency of technological processes of oil production. The successful solution of this important issue requires a comprehensive study of the experience of developing oilfields based on monitoring, the generalization of the obtained scientific and practical results, as well as the formation of new scientific bases and different approaches for the analysis of oil production, collection and transportation processes, and the creation of appropriate innovative methods of influence, requires the adoption of operational solutions from the position of wealth-saving technologies in the production of energy and natural resources.

It is known that one of the effective methods studied for increasing the main indicators of oil production is the application of new rheotechnologies based on the regulation of technological processes by targeted use of rheological and physic-chemical properties of multi-component heterogeneous systems. For this reason that the creation of new rheotechnological methods, which enable solving the problems of increasing the efficiency of hydrocarbon production, collection and transportation processes, fully meet the requirements of saving energy and resources, and realize the adoption of important operational solutions, and their wide application in practice are distinguished by their relevance and great scientific and practical importance.

The object and subject of the research. The object of the research is the production, collection and transportation processes of oils and their various mixtures, and the subject is the development of new rheotechnological methods for increasing their efficiency.

The purpose of the research. Development of scientifically based rheotechnological methods on the basis of energy and resource conservation technologies and experimental application in mining conditions to increase the efficiency of production and transportation processes of multi-component and multiphase heterogeneous systems - high viscosity, anomalous water cut, rheologically complex oils and their various mixtures was considered as the goal of research.

Key provisions to be protected:

- conducting experimental and field researches in order to form a different scientific approach to the phenomenon of "inversion" that occurs in water-oil emulsions formed arbitrarily on the basis of abnormally water cutted, high viscosity oils, differing from existing stereotypes;
- study of the possibility of increasing the efficiency and regulation of technological processes of oil production based on the rheotechnologies of water-oil systems and "water-oil-sand" mixtures with visco-loose properties;
- researching the possibilities of early diagnosis of structural changes occurring in water-oil systems based on the fractal approach and developing the "express assessment" method for determining the limit of ultimate water cut rate;
- justification of the choice of rational operating parameters of the infield collection system on the basis of diagnostics of the rheotechnological properties of water-oil emulsions;
- development a complex method of impacting the layer with water-oil emulsions in order to increase the ultimate oil recovery coefficient of the formations;
- study of the process of covering layers characterized by absorption with a viscous-granular medium based on the rheotechnology of multicomponent viscous-dispersive systems;
- experimental study of the influence of the mixing sequence of constituent components on their rheology in "water-oil-sand" mixtures;
- development a new empirical dependence for calculating the density of "water-oil-sand" mixtures without laboratory measurements;
- development the method of thermochemical impact on the layer based on a new composition;
- development the method of strengthening the bottom zone of layers consisting of weakly cemented collectors based on a new

composition;

- development of an effective hydrotransportmethod of anomalous water cut, high viscosity oils and their emulsions, as well as storage, "trap" oils, oil slurries and bituminized oils with a pipeline in terms of saving energy and natural resources, and applying them in field conditions.

Research methods.

In the process of completing the dissertation, the issues raised for research purposes were solved theoretically and experimentally - based on the analysis of the effect of water cut and temperature factors on the rheophysical properties of water-oil emulsions and "water-oil-sand" mixtures of granular fillers, standard laboratory equipment, computer models and found using new software tools. Research works were performed both in laboratory conditions - in plane-radial type reservoirs equipped with modern control-measurement systems, as well as in mining conditions - in an active oil collection system, the scientific results obtained were based on fractal and other informative theories, as well as mathematical-statistical methods were applied.

The main objectives of the research are:

- Based on the rheotechnology of water-oil systems:

- a differently interpretation of the "inversion" event, which is considered typical for emulsions, from the existing scientific stereotypes;

- a complex effecting method with a water-oil emulsion on formation;

- efficient hydrotransport method of high viscous, water cutted oils and their emulsions, as well as storage and "trap" oils, oil bitumens and slurries based on the "hydraulic bearing" effect;

- Based on the rheotechnology of dispersed systems with viscous-granular properties:

- justification of the possibility of closing layers characterized by absorption with a viscous-dispersive medium;

- study of the influence of the sequence of mixing constituent elements in multicomponent suspensions on their rheophysical properties;

- Method of "express diagnosis" of the ultimate limit of water cut in water-oil emulsions based on fractal analysis;
- Logistic curve reflecting the dependence of the effective viscosity of water-oil emulsions on the degree of water cut from rheotechnological point of view;
- Synergistically effective new innovative methods developed at the level of Inventions of Azerbaijan Republic for the purpose of increasing oil recovery coefficientof formations and intensifying oil production, including:

- the method of thermochemical action on the layer based on a new composition to increase the productivity of the layers producing oils containing asphaltene-resin-paraffin (ARP) compounds;
- the method of strengthening the well-bottom area of the layers characterized by the manifestation of sand with a new composition.

The scientific novelties of the researchs are:

1. For the first time, the mechanism of manifestation of the "inversion" phenomenon, which is considered typical for water-oil emulsions, was interpreted differently from the existing scientific stereotypes;
2. Based on the "hydraulic bearing" effect of high viscosity oils and their emulsions, as well as storage and "trap" oils, oil bitumens and slurries, an efficient method of hydrotransportation has been developed and patented in terms of saving energy and natural resources;
3. In order to increase the ultimate oil recovery coefficient of formation, a complex method of influencing the formation with water-oil emulsion was developed;
4. On the basis of fractal theory, a new diagnostic method was proposed that allows to express the macro- and microstructural changes that occur depending on the degree of water cut and temperature factors in polydisperse systems and to determine the limit of ultimate water cut;
5. For the first time, the influence of the mixing sequence of constituent components on their rheology in "water-oil-sand" mixtures was studied;

6. A new logistic curve based on the perspective racurse of "reotechnology" for water-oil emulsionswas proposed;
7. At the level of Inventions of Azerbaijan Republic, synergistically effective new innovative methods for increasing the oil recovery coefficient of formations and intensifying oil production, including:
- the method of thermo-chemical impact on the formation based on a new composition to increase the productivity of the formations in the process of exploitation of the well product that produces high-viscosity anomalous oils, containing asphaltene-resin-paraffin compounds;
- in the process of development and operation of oil and gas fields composed of weakly cemented reservoirs, the method of strengthening the bottom zone of the formation on the basis of a new composition in order to prevent the process of migration of sand along the fluid to the bottom of the well as a result of the collapse of the formation skeleton in the area around the well as a result of depression, as well as the water cut of the produced oil processed.

Theoretical and practical significance of the work. The results of conducted research in the new hydrotransport method developed on the basis of rheotechnology, for the efficiently transportation of high viscous, abnormally water cutted, rheologically complex oils and their mixtures, as well as "trap", storage oils and oil slurries through technological pipelines were reflected.

Tree new innovative methods for the purpose of increasing oil recovery coefficient and intensification of oil production, including:
- a new method of thermochemical effect on the layer;
- the method of strengthening the well bottom zone was developed and the possibility of their practical application was shown.

Mathematical formulaes proposed for determining the technological losses of oil formed from local accidental leaks in pipelines were used in the process of compiling the "Guidance Document for determining the technological losses of oil in oil production facilities of "Azneft" PU during 2021-2025 years".

Based on multifractal analysis, the new diagnostical and control method, which allows pre-assessment of the macro- and microstructural changes caused by the effect of the water cut factor in water-oil emulsions, is useful for the express determination of ultinate water cut limit.

Based on the rheotechnology of water-oil systems, the new method of combined action with oil-water emulsion, proposed in the dissertation and stimulating the increase of oil productivity coefficient of the formation, was submitted to the "OFS Awards-2012" International Science and Innovation Competition and won the "Best engineering solution" nomination was awarded by Laureat diploma.

The proposed new empirical dependences are useful for engineering calculations in order to determine the density of heterogeneous systems with anomalous properties transported by pipeline, which is considered as the main quality indicator without laboratory measurements, depending on the temperature and water cut factors.

The scientific-practical results obtained in the dissertation, as well as the proposed new methods and technologies, can be widely used in the process of designing technological processes in oil production, in the teaching process of subjects held in relevant specialties at the undergraduate and graduate levels of higher technical schools.

The main provisions of the dissertation work were reported and discussed at the :

-International scientific-practical conference on "Modern problems of Kazakhstan's oil and gas complexes" (Aktau, Kazakhstan, 2011), IV International technical symposium on "Transportation by pipelines-2011" (Moscow, Russia, 2011), International scientific-practical conference dedicated to the 20th anniversary of the independence of the Republic of Kazakhstan "Oil-gas complexes in the conditions of industrial-innovation development of Kazakhstan" (Atyrau, Kazakhstan, 2011), International scientific-practical conference dedicated to the 10th anniversary of the establishment of the Academy of Sciences of Kazakhstan (Atyrau, Kazakhstan, 2012), X International scientific and practical conference "Khazar-neftgazyatag-2012" (Baku, 2012), "OFS AWARDS-2012" International Science and Innovation Competition (Moscow, Russia, 2012), International scientific-practical conference "Oil&Gas" organized by Kazakhstan-British Technical University problems of innovative development of the industry", 5th International scientific and practical conference (Almaty, Kazakhstan, 2013), "Kazakhstan's oil and gas complex at the International scientific-practical conference on innovative development of oil and gas industry" (Aktau, Kazakhstan, 2013),VII scientific-practical conference on "Innovative technologies in the oil and gas industry" held within the framework of the International SPE (Society Petroleum Engineering) organization at Tyumen Oil and Gas University (Tyumen, Russia, 2013), International scientific conference "Non-Newtonian systems in oil and gas fields" dedicated to the 85th anniversary of academician A.Kh. Mirzadjanzade, Scientific-practical conference (Atyrau, Kazakhstan, 2013), Technical Council of "Muradkhanli" oilfield, which is part of the structural department of "Azneft" PU (Baku, 2013), XI International scientific-practical conference "Khazarneft-gazyataq-2014" (Baku, 2014), scientific and technical seminar of the Institute of Geology and Geophysics of ANAS, (Baku, 2015), Republic seminar in the field of Earth Sciences of ANAS (Baku, 2015), International scientific and technical conference "Modern development methods of deposits with unconventional reservoirs" (Atyrau, Kazakhstan, 2019),V International conference on (Theor-2022)"Thermal methods of increasing the oil productivity of reservoirs"(Baku, 2022) and XIV International scientific conference “Rassokhin”s readings”(Uxta, Russia, 2023).

Approbation and using of results. The scientific results obtained by conducting laboratory researches were applied in order to increase the efficiency of oil collection system of "Jafarli" area of the "Muradkhanly’ oilfield and passed the experimental acceptance test. As a result of the application of high viscosity oils and their emulsions, as well as "trap", storage oils and oil slurries, efficient hydrotransportation method in terms of saving energy and resources in mining conditions, most of the existing complications in the oil collection system have been noticeably eliminated, the efficiency of the collection process is 17,4 % increased, pressure losses reduced by

22%,the actual economic effect obtained from the application was 260.000 AZN.

The dissertationwas performed at the Geology and Geophysics, Oil and Gas Institutes of ANAS, as well as the "Oil &Gas Scietific Research and Project" Institute of SOCAR.

Publications of author. 51 scientific works, including 1 monography, 1 Patents and 2 Invention documents of the Republic of Azerbaijan, 1 Guidance Document, 44 articles published in the country and abroad (6 articles -in Web of Science and Scopus journals, included in international summarizing and indexing databases) and 2 theses were published.

The structure and scope of the dissertation work. The dissertation content an introduction, six chapters, conclusion, references used in 320 titles, 80 figures, as well as 17 tables and 7 appendics. Total scope of the dissertation - 354738 (including title page - 477, table of contents - 7666, introduction - 24875, first chapter - 99420, second chapter - 33657, third chapter - 58629, fourth chapter - 24874, fifth chapter - 66910, sixth chapter -35311, conclusion-2919) constitutes a sign.

Gratitude. The author, during formation of scientific directions inperforming process of dissertation work, always referred to the methodological principles of the scientific school and was always guided by valuable scientific results in his scientific activity, which were created by the world-famous scientist and Academician of ANAS **A.Kh.Mirzadjanzade** and his students.

For the valuable advice and recommendations he gave in the formulation of the scientific problems in the dissertation, the formation of the obtained scientific results, their discussion, the constant attention he showed, and the submission of the work to the defense at a level that meets modern requirements, the applicant considers it an important duty to express his deep gratitude :

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Also, the claimant expresses his sincere gratitude to the management of the Institutes of Geology and Geophysics, Oil and Gas of ANAS, also "Oil &Gas Scientific Research and Project" Institute of SOCAR, where the dissertation work was performed, for the goodworking conditions, technical assistance and moral support they created.

GENERAL CHARACTERISTICS OF THE DISSERTATION

The introductionis based the relevance of the work, the purpose and the key issues that have been addressed, its scientific novelty, practical significance and the defended provisions are justified, and the content of the dissertation is briefly presented. The current state of scientific research on the issues raised in the dissertation is deeply analyzed.

The first chapter of dissertation is devoted to the analysis of the physico-chemical, rheological properties of heterogeneous water-oil systems and the study of their rheotechnological properties.

In the first subchapter the importance of creating new rheotechnologies in oil and gas production and their application in technological processes has been brought to attention. Since the end of the XX century, one of the perspective directions of oil and gas science - a set of methods for increasing the efficiency of the technological processes of oil extraction based on the purposeful use of the rheological properties of non-Newtonian heterogeneous systems based on synergistical or physical effects and their regulation - is developing rapidly.

The first researches in this scientific field were carried out from the end of the last century under the leadership of the outstanding scientist, Academician A.Kh. Mirzadjanzade. As a result of numerous studies, the issues of the possibility of developing new rheotechnological methods based on the rheotechnology of heterogeneous systems and its manifestation in physical or synergistic effects arising arbitrarily in the technological processes of oil production have been investigated. The possibility of determining and regulating their rheological properties in various conditions (for example, in reservoir, well, oilfield pipelines etc.) was studied by using the physical effects created in water-oil emulsions, as well as in "water-oil-sand" mixtures.

In the second subchapterthe causes and sources of water-oil emulsions were investigated. The laboratory analysis on base reservoir fluids shows that oil products are prone to the formation of water-oil emulsions (stable or unstable) when they arbitrarily mix with the water phase, which always "accompanies" it in technological processes. Due to their high viscosity and thixotropic properties, Non-Newtonian liquids, it resembles elastic gels and is non-moving. According to many researchers, the presence of "untouchable" zones in the layer can be explained by the manifestation of these anomalous emulsion-gels. The mentioned physico-chemical factors multiply the probability of formation of emulsions and indicate the possibility of this phenomenon.

The third subchapter an analysis of existing scientific stereotypes about phase transformations in water-oil emulsions wereprovides.One of the traditional ideas widely spread in science is that phase transformation - i.e. "inversion" phenomenon - occurs as a result of water cut of mineral emulsions. At this time, the scientific interpretation of the change in viscosity of emulsions is accepted as the main indicator. The phenomenon of “phase transformation”, which is considered typical for water-oil emulsions, is one of the main factors that determine their effective viscosity. In recent times, such a scientific stereotype has been formed that the inversion of the dispersed phase in the water-oil mixture due to the increase in the percentage of water in emulsions is inevitable. Determining the "phase transformation" point plays an important role for predicting the properties of the well product, as well as for the analysis of transportation and technological processes.

In the fourth subchapter the study of structural changes, physico-chemical and rheological properties of water-oil emulsions in the example of oils from the "Muradkhanly" oilfield were considered. Crude oils produced from the wells of noted oilfield were used as an oil sample. Flow curves of high viscosity water-oil mixtures with different degrees of initial water cut were established based on the rheological parameters determined in the "Rheotest-2.1" type rotational viscometer. Researches were conducted at different temperatures and degrees of water cut, the effect of the percentage of water cut of the mixture on the rheology of oil emulsions was widely studied.

In the fifth subchapter, the issue of forming a different scientific approach to the structural-rheological characteristics of water-oil systems based on laboratory research were reflected. Researches were performed under standard conditions - temperature $t=20^0C$. Oil samples with different degrees of water cut were used as the dispersion medium, and 3 different types (distilled, technical and layer) of water were used as the dispersed phase. For the sake of accuracy, the density of the test oil was determined by 2 different methods - areometric and pycnometric, and in both cases the indicator was found to be ρ=926 kg/m^3.

By mechanically dispersing the pre-calculated volume of the water phase to oil samples with an initial degree of water cut, i.e. by mixing in a homogenizer for 10-15 minutes in order to obtain a homogeneous liquid, the degree of water cut W= 35, 40, 45, 50, 55, 60, 65, 70, 75, 80% artificially prepared water-oil emulsions in laboratory conditions were tested in the range of 12 possible speeds of viscometer. Relative viscosity (ratio of emulsion viscosity to oil viscosity) and relative density (ratio of emulsion density to oil density) were taken as the main parameters. After the tests were completed, an interesting fact such as the existence of a "free" water phase inside the Couette cylinders was repeatedly observed. During standard measurements, the "inversion point" is approximately the separation of the volume of "free" water in the dispersed phase of the emulsion as a result of the coalescence process, and in particular, the maximum - peak value of the viscosity corresponding to the limit of W = 60-85% of the degree of water cut of the emulsion. When water is added to the mixture in excess of the specified percentage, the viscosity of the water-oil emulsion begins to decrease, and at this time a "freed" phase of water is formed. According to the author, starting from the moment when the water cut percentage reaches the critical limit in the considered emulsions, during the measurements of the viscosity of the mixture located in the annular space between the rotating part of the viscometer - the spindle and the cylindrical container, the structural homogeneity of the flow is broken and the water phase in the emulsion is stratified as a result of the coalescence process. It consists of enlarged drops of water along the direction of rotation of the axis macroscopic "chains" are formed. This fact was also observed in the gaps between the "cylinder-spindle" and "cone-plate" pairs, which once again proves that the physical paradox that has arisen is not accidental. The large water globules formed as a result of the coalescence process unite in the form of "chains" and macroscopic "ribbons" and migrate towards the center of the cylinder, thereby reducing the resistance to rotation. Based on this, the sliding movement in the "spindle-cylinder" pair begins as a result of the sliding of small water droplets and large globules of beforehand "saturated" emulsion with a higher viscosity layer.

One more important fact - the "wall sliding" effect associated with the formation of a layer around the wall consisting of a dispersed phase (water) (this is often called the "hydraulic bearing" effect in literature) should be especially taken into account. ring - a "hydraulic bearing" is formed, on which the water-oil emulsion smoothly "rotates" on this "bearing" - within the annular ring.

In the sixth subchapter the evaluation of the structural changes occurring in water-oil emulsions and the development of the method of express diagnosis of ultimate water cut limit were performed by applying the fractal theory. Due to the speedly development of modern science, the existing scientific methods for the comprehensive assessment of the current state of natural processes and phenomena in nature no longer meet the requirements, in recent times, due to the application of new mathematical analysis methods and computer technologies, there is an increasing demand for control-diagnostic methods that allow a different approach to their structural changes.

"Fractal analysis" method should be shown as one of the mathematical tools that allows to analyze the modern state of natural objects based on their geological-geographical and rheological characteristics. Since the results of many studies suggest the possibility of the formation of water-oil emulsions in the formation, it is said that they also have a fractal structure, and it is considered appropriate to study the diagnosis of the structural state of water-oil systems within the framework of the fractal theory based on non-traditional Euclidean geometry. According to the researchers, the determination of the fractal characteristics of the technological indicators of the operating mode of the wells creates opportunities for early diagnosis of changes that may occur in the "reservoir-well-pipeline" unit hydrodynamic system and timely adjustment of the operating mode of the wells to optimize the field development process. By analyzing the external and internal factors affecting the system, as well as the dynamics of changes of arbitrarily selected segments of the geometric curve with different fractal numbers, it is possible to make preliminary judgments about its subsequent behavior - "pre-angle". The most interesting thing is that the fractal analysis makes it possible to diagnose the unstable state of dissipative structures in advance. The fractal indicator of the considered system can play the role of a "decline indicator" or an emergency signal - "SOS" for physical events occurring in the processes.

In order to apply the structural changes of water-oil systems depending on the degree of water cut based on fractal analysis, water-oil emulsions with different degrees of water cut were obtained by adding different amounts of water to the anhydrous oil sample taken from well prepared. Taking into account that the object of visual analysis, which allows analyzing the mutual state of the components, is photomicrographs, the "optical scanning" method known as "microphotograph analysis" was used in the experiments to determine the structural changes and fractal index occurring in water-oil emulsions. "Nu-2E" type universal electron microscope was used to study structural changes occurring in water-oil emulsions. Emulsions with different water cut degrees and temperatures were sampled in the form of drops and spread on glass slides in the form of thin layers. In an electronical microscope, these samples were studied by the diffraction method and electronic photographs of the microlines were taken from the eyepiece. During the experiments, the condition of the stability of the focal distance was achieved by attaching the electronic camera to a tripod at a fixed focal distance. In order to compare the obtained microslides in the future, the degree of magnification (zoom) of microphotographs was adopted for each slide - Z=60 times. The classical "Square method" was used to determine the average diameter of globules, which was taken as an indicator of dispersion, for the analysis of structural changes by applying fractal geometry. According to this method, the curves constructed for geometric fractals are covered with square (chekers). On the slide taken from the microscope, the length of the blade of uniform square δ (taking into account the magnification of the microscope and many influencing factors, δ= 6.11 μm was taken in the calculations) and a uniform mesh network consisting of N number of square was placed. Since oil globules are reflected in black and water globules in white shades in the repeatedly enlarged photomicrographs of water-oil emulsions at the same temperature ($t=20^0C$), but with different degrees of water cut, the total number of checkers in the studied area (i.e. enclosed in a single circle) and the number of checkers covering the water globules the number of checkers is set. Then, based on the total number of checkers and the number of checkers covering the water globules, the fractal number D was calculated:

$$D = -\frac{\ell n N(d)}{\ell n d} \qquad (1)$$

where: D- fractal number; N- number of checkers, pieces;

d- number of checkers covering the water globules, pieces.

Based on the obtained results, mathematical curves were constructed by bringing the dependence *lgN(d) = f (lg(1/d))* to a straight line in the double logarithmical system. At this time, the tangent of the angle of intersection of the straight line with the abscissa axis - characterizes the fractal indicator D of the considered system. The water globules on the slide placed in a single circle were grouped according to their diameter, and the number of checkers covering each water globule was calculated. Using the possibility of applying the microscopic analysis method and the method of assessing the accuracy of the measurement, the four average diameters of the globules of the emulsions were determined according to the type A of Charle’s distribution, and the accuracy of determining the parameters was determined by applying the Student's criterion - the accuracy of which was 2,9%. It was estimated based on the analysis of at least 4-6 images with a probability of $\alpha \approx 0.995$. Also, the agreement of the data with the selected model formula was checked with the χ Pearson’s criterion.

The analysis of the obtained results shows that as the percentage amount of the dispersed phase - water in emulsions increases, the dispersion medium undergoes drastic structural changes, that is, the diameter of the globules decreases and becomes approximately equal, in other words, the degree of dispersion increases and finally stabilizes.Anomalous properties starting from the threshold W =40% of water cut its emergence is reflected in the leaping nature of the shear stress - non-monotonic change (Figure 1).

At values after the limit *W*=70% of water cut, the dispersion degree indicator is observed to gradually settle, and at the limit W=78% of water cut, this indicator stabilizes, which once again proves that the water-oil system is "saturated" with the dispersed phase - water.

Since the volume of water added after this moment is no longer mixed in the emulsion, it is separated as "free" water as a result of the coalescence process.

In the second stage of the researches, studies were performed on the effect of the temperature factor on structural changes in water-oil emulsions.

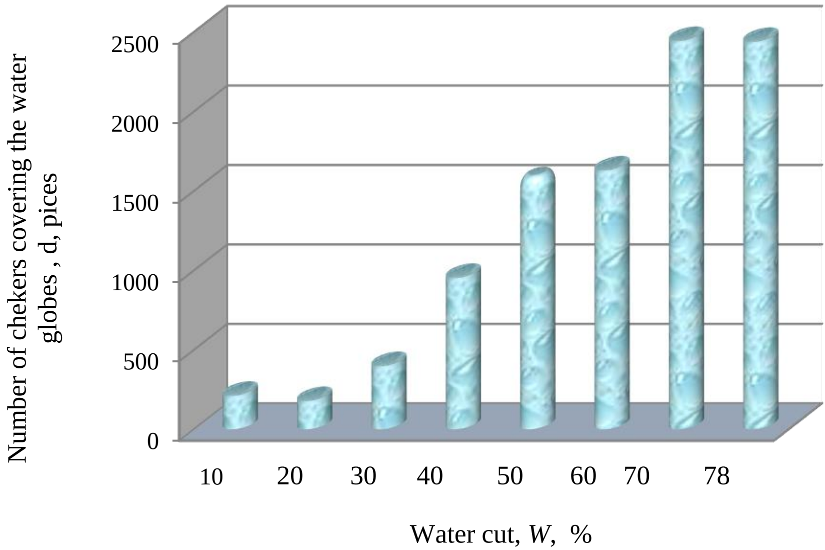


Figure 1 Dependence on number of checkers covering water globule atdegree of water cut of water-oil emulsions

The experiments were carried out at different temperatures t = 5, 20, 40, 60^{0}C, but at the same - W= 50% degree of water cut, microscopic lines of the structural indicators of water-oil emulsions were drawn and analyzed. The fractal approach can be successfully applied as a method of detecting and diagnosing structural changes occurring in polydisperse systems, which include water-oil emulsions.

In the second chapter the possibilities of increasing the efficiency of the technological processes of oil production based on the rheotechnology of dispersed systems with visco-granular properties are explainedwere studied.

In the first subchapter the effect of granular fillers on the rheological properties of water-oil emulsions. The physico-chemically changes occurring in water-oil emulsions were studied using an electronical microscope.

The oil sample mixed with water with the initial water cut

W=52%, taken from the collection tank No.2 located in the "Jafarli" area of the "Muradkhanly" oilfield, as well as different ones with diameterd= 0.1 mm fraction (C=1.0; 3.0; 6.0 %)

Photo slides were taken before and after the viscometric tests of "water-oil-sand" mixtures obtained by adding granular filler-quartz sand in 3%; 6% by weight percentages. After each test, water globules coalesce and aggregate, and as the weight percentage of sand increases, the intensity of the concentration process increases. Also, the effect of the added sand on the rheological properties of water-oil systems with different compositions was studied. In the example of mixed oils, without sand and with d=0,1mm fraction in different concentrations (C = 0.5; 1.0; 1.5; 2.0; 2.5; 3.0; 3.5; 4.0; 5.0; 6.0; 7.0%) rheological indicators of "water-oil-sand" mixtures obtained by adding sand at W= 52, 60, 70, 80% water cut rates were determined. At all studied flow rates, viscosity increases with an increase in the weight percentage of sand in the mixtures up to 3%, and in cases of further increase, on the contrary, a decrease is observed. The effect of sand on the rheological properties of water-oil systems at other degrees of dilution was also studied and the non-monotonic dependence of the effective viscosity of the system on the amount of the granular element was determined.

In the second subchapter, the factors affecting the efficiency of the process of sealing the layer with a visco-granular medium (VGM), characterized by the phenomenon of absorption, were analyzed. In order to check the possibility of using a VGM as a substance to block the absorbent channels in the event of absorption in the layer, to evaluate the efficiency of repair and isolation works and to study the condition of stability during the sealing of the absorbent layer with VGM with rheopectic properties, the issue of the symmetry of its undecided, radial movement with respect to the axis under plane-flat deformation conditions was investigated. In order to simplify the mathematical calculations, the viscosity coefficient of the viscous-granular medium was assumed to be k = 0.I addition, during the studies, the wellbore zone was imagined as a thick-walled cylinder consisting of the following two-phase medium (skeleton of the porous medium - rock and VGM applied as a sealer).

For the purpose of describing the stress-strain state of the movement of the system, it was considered as a kvazi-homogeneous medium. In the process of solving the problem, it was considered important to meet the following initial boundary conditions:

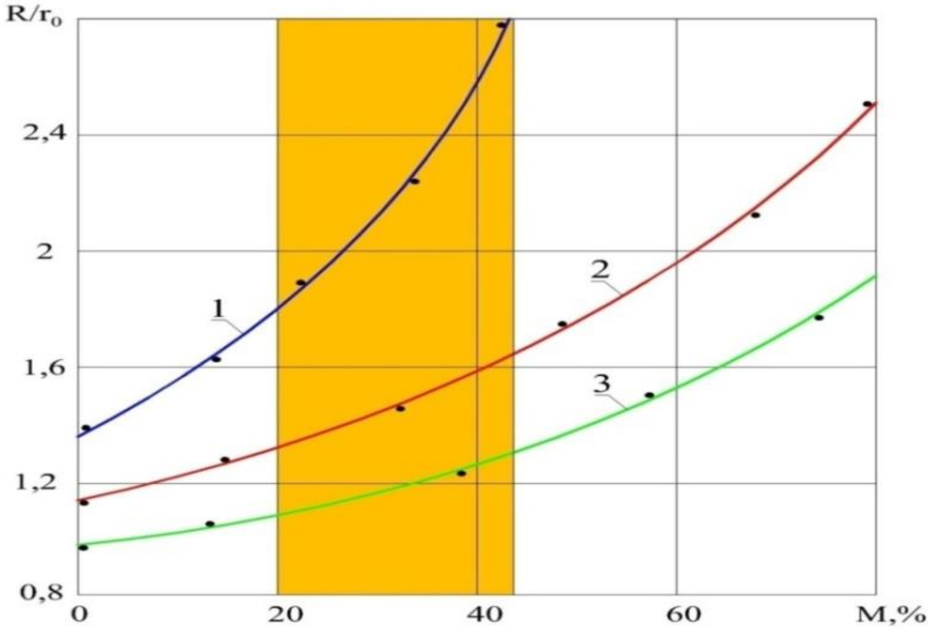
a) the stress-deformation state of the visco-granular medium depends only on the radius-vector r;

b) during the experiments, it is assumed that the enclosing medium undergoes only plane-flat type deformation, that is, $\varepsilon_{zz} = 0$.

In calculations, constant, radial (hydrostatic) pressure P_{hidr} the existence of a circular space with a radius of ro, where the force is applied, and the conditions of the prior knowledge of the velocity v for the radial movement of the particles of the VGM under the condition of equality $r=ro$ were accepted. It was determined that the determination of the radius of the penetration contour R is possible using the ratio R/r_0 in the indicated intervals for the fulfillment of the stability condition.These calculations are based on a layer characterized by absorption k=30 mD; 60 mD; 90 mD were conducted at different values of conductivity coefficients and curves were constructed based on the obtained results (Figure 2).

In cases where the percentage indicator of the filling element-sand in the composition of VGM is within the limits of the rational interval of 20-42%, it more accurately characterizes the efficiency of this process in terms of energy and time saving. Also, it was determined that the radius of the isolation screen increases sharply with the decrease in permeability of the layer.

In the third subchapter, the issue of developing a new empirical dependence for calculating the density of "water-oil-sand" mixtures without laboratory measurements was considered. Usually, the density index of technological fluids in mining conditions is measured experimentally (with a pycnometer and hydrometer) and mathematically (with known formulas).



1-k_1=30 mD; 2- k_2=60 mD; 3- k_3=90 mD

Figure 2 Selection of a rational application interval of the filler element

In some cases, when the mass fraction x of the solid particles that make up the dispersed phase - granular fillers - is known, the density of these mixtures can be determined based on the additivity condition given

$$\frac{1}{\rho_{mix}} = \frac{x}{\rho_{solid}} + \frac{(1-x)}{\rho_{liquid}} \quad (2)$$

where: ρ_{mix}, $\rho_{solid.}$,ρ_{liquid} - are the densities of the mixture, solid particle (for example, sand) and dispersion medium liquid (for example, in the considered case - water-oil emulsion), respectively, in kg/m^3 (or g/cm^3) .

In order to determine the density by the rule of additivity, it is necessary to carry out numerous analyzes to determine the composition of the granular element in terms of quantity and quality, which is accompanied by a number of expenses and time losses. For this very reason, the issue of easier and more accurate determination of the density parameter of rheologically complex mixtures containing "water-oil-sand" transported in mining conditions - a new empirical method for solving the case of determining the density of "water-oil-sand" mixtures by an indirect method (without measurements) the case of processing dependency is investigated. *"MatLab R-2010a"* for the purpose of pre-predicting the density change mechanism depending on the temperature and dilution factors of the resulting mixtures, as well as the concentration (mass share or percentage) of the granular element (sand, clay, mineral salts, corrosion products, etc.) mixed with it using the standard program, by adding a different amount of granular filler element - quartz sand sifted in the d=0.1 mm fraction to the water-oil mixture samples with the initial water cut rate W=52%, taken from the oil collection point and for 10-15 minutes. As a result of the pycnometric (or ariometric) experimental and mathematical researches,new empirical dependences for determining the density index in the 3-dimensional spatial system were proposed.

In the fourth subchapter, the influence of the mixing sequence of the constituent components in "water-oil-sand" mixtures on their rheology was studied. Based on the research, the effect of the sequence of inclusion of constituent elements in the mixture on their rheological properties and rheophysical properties was evaluated. On the basis of the existing principles of rheotechnology, that is, through the purposeful regulation of the mixing sequence of constituent elements, the possibilities of increasing the efficiency of the collection and transportation processes of multicomponent mixtures have been investigated. A high-viscosity mixed oil sample from the "Mammadli" oil collection system of "Muradkhanly" oilfield was selected as the model fluid. The initial water cut rate of the water-oil mixture was W= 18%.

As a result of research, it has a high density (ρ= 926 kg/m^3) and viscosity (μ=690 мPa·s), low paraffin (mass fraction up to 3%) and high resin (mass fractions of resin and asphaltene, respectively 11% and up to 7 %) were found to belong to oil products. Then, the emulsions prepared by adding a certain amount of water to the initially taken water-oil mixtures were rheologically studied at different temperatures (*t*=5, 20, 40^0 C) and degrees of water cut (*W*=30, 40, 50, 60, 70, 80%). Their stability was determined by the "mechanical rinsing" method, keeping the flask in a static state for t=20 min. It was considered as a "stable" emulsion in cases where the amount of "liberated" water separated from water-oil mixtures during the considered period did not exceed 1% of its volume. Water-oil emulsions diluted to *W* = 30, 40, 50, 60, 70, 80% at the initial water cut rate of *W*= 18% were studied viscometrically and corresponding flow curves were constructed based on the obtained results. In order to create 3-component heterogeneous mixtures and to study their effect on rheological properties when granular particles are mixed with water-oil emulsions, a filler element - quartz sand, with a fractional content of *d* = 0.1 mm, varying in the range of 1-7% mass fraction depending on the degree of water cut, was added and mixed in a homogenizer until a homogeneous liquid is obtained. In the tests, special attention was paid to the fact that the quartz sand was dispersed in the mixture and did not settle. In order to study the effect of the sequence of inclusion of constituent components of suspensions containing "water-oil-sand" on their rheological properties and rheophysical indicators, the interpretation of the experimental results obtained by changing the locations of these elements was investigated. Thus, depending on the order of inclusion of constituent components into the mixture, the following 3 types of suspensions were prepared:

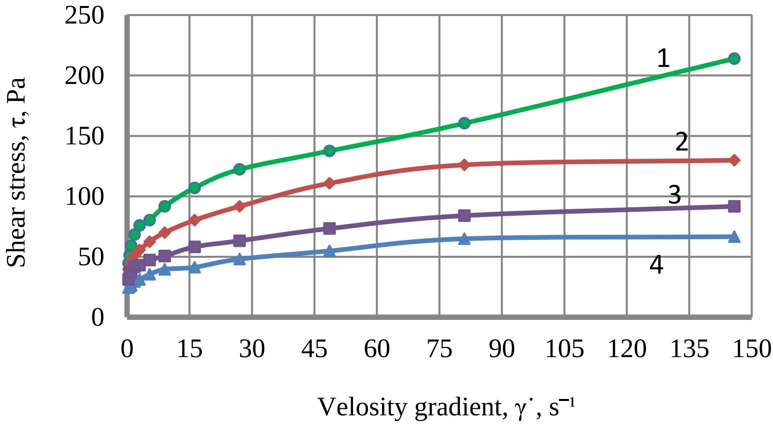
- type A – water (w) and sand (s) were first added, and oil (o) was added to the resulting mixture- *(w+s)+o;*
- type B – firstly oil (o) and sand(s) was added, and water(w) was added to the resulting mixture – *(o+s)+w;*
- type C – firstly water (w) was added to oil (o), and sand(s) was added to the resulting mixture–*(o+w)+s.*
- type 0 - sand-free water-oil emulsion – the model fluid –*w+o=em.*

Prepared mixtures were studied by viscometric method at different temperatures and degrees of dilution, based on the obtained results, dependence (flow) curves of shear stress on velocity gradient were constructed for each type of suspension and model liquid - emulsion (Figure 3).

Taking into account that the established flow curves consist of 3 parts and passing tangents to them, initial tangential voltage parameters τ_{01}, τ_{02} and τ_{03} were determined by grapho-analytical method.

Also, structural viscosities η_{st1}, η_{st2} and η_{st3}, as well as flow anomaly indices n_1, n_2 and n_3 were calculated for both "water-oil" and "water-oil-sand" mixtures on the conditionally separated areas of these curves.

Addition of the filler element-sand to water-oil emulsions results in a decrease in contact tension. Depending on the sequence of mixing of constituent elements, the largest tangential stresses are observed in type A mixture, and the smallest tangential stress is observed in type B mixtures.



1- (o+w)= em (tipe O)

2- (w+s)+o (tipe A)

3- (o+s)+w (tipe B)

4- (o+w)+s (tipe C)

Figure 3 Flow curves for different types of mixtures

Type C mixture occupies an intermediate position. The obtained results once again confirm that each type of mixture is suitable for a specific field of application.

In the end, in order to study in more detail the influence of constituent elements of different types of mixtures - the sequence of adding water, oil and sand to the mixture - on the rheology of the resulting suspensions, $\tau_0 = f(t)$, $\eta_{st} = f(t)$ *and* $n = f(t)$ curves as well as *t=const* (at temperatures of t=5, 20, 40 ^{0}C) and $\tau_0 = f(W)$, $\eta_{st} = f(W)$, $n = f(W)$ curves were plotted and studied. Referring to the graphics, the initial shear stresses and structural viscosities of the mixtures decrease with increasing temperature when the condition of constant degree of hydration is satisfied. The flow anomaly indices vary differently. Thus, with the increase in the temperature of the mixtures from 5 ^{0}C to 20^{0}C, the anomaly index n decreases in O and C mixtures, while it increases in A and B types mixtures, on the contrary. The opposite picture is observed when the temperature increases from 20^{0}C to 40^{0}C. That is, the anomaly index increases in A and B types mixtures, and decreases in O and C types mixtures. The variation of the anomaly index in these experiments is noticeable. Thus, as a result of increasing the degree of dilution from 30% to 50% (by adding water and mixing in the calculated volume), the n index increases in O, B and C types mixtures and decreases in A type mixture. During the further increase the degree of water cut from 50% to 60%, the index n increases in the mixtures of types O, A and B, and decreases in the mixture of type C.

The change in their structural-mechanical properties as a result of sequential addition of sand, which is a dispersed phase in three-component mixtures of types A, B and C, to separate components of the dispersion medium (water and oil) and directly to the water-oil mixture - emulsion, can be interpreted as follows:

- high initial tensile stress and elastic modulus, low viscosity indicators are typical for A-type suspensions created by adding sand to the water-forming component of the dispersion medium;
- formed by adding sand directly to a water-oil emulsion C-type suspensions are characterized by minimal initial tensile stress and modulus of elasticity, high viscosity indicators;
- the initial tensile stress, modulus of elasticity and viscosity indicators for B-type suspensions created by adding sand to the oil-forming component of the dispersion medium take an intermediate

position compared to A and C-type suspensions and exceed the analogous indicators for emulsions.

The mixing of the solid phase - quartz sand with water-oil emulsion resulted in the emergence of new anomalous properties in the resulting heterogeneous mixture. Based on the experimental results, the flow curves are divided into 3 conditional zones:

zone I -“viscous-plastic flow”, characterized by maximum structural viscosity η_{st1} (according to prof. A.I.Shvedov -"creeping" movement);

zone II -"Bingham" flow in an intensive dispersive structure, characterized by an average viscosity index η_{st2};

zone III -"freed" flow within a completely collapsed structure, characterized by minimal structural viscosity η_{st3} (according to prof. A.Kh. Mirzadjanzade - "restructured" movement).

It is possible to improve the rheophysical properties of multi-component heterogeneous mixtures used in the technological processes of oil extraction by changing the order of inclusion of constituent elements in "water-oil-sand" mixtures, in other words, by using the purposeful regulation principles of rheotechnology.

In the third chapter the possibility of evaluating the efficiency of the complex method of impact on the layer based on the rheotechnology of water-oil systemswas examined.

In the first subchapter, some problems of the development of water-oil zones existing within the formation, the causes of the formation of "stagnant", poorly drained, "untouchable" oil zones were studied. At the initial stage, the formation process of water-oil contact and transition zone in the formation was analyzed. In the next stage, a broad explanation of some aspects of the process of filtering formation fluids in water-oil zones is given.

It is known that the main indicators of the wells in the current and final operational stage directly depend on the selected technological mode. In the oil-rich part of the reservoir, in order to keep the pressure constant, as a result of the injection process carried out through the injection wells, a certain volume of oil is compressed towards the "water" zone of the reservoir, which is the volume of its unextractable or difficult to produce, less active - "passive" oils.

resulting in formation of "stagnant", poorly drained and "untouchable" oil zones, as well as oil "lenses" and "impermeable screens" within the formation. A sharp increase in the intensity of wetting results in an anomalous increase in oil viscosity. The existence of "stagnant", poorly drained and "untouchable" oil zones in the reservoir makes it possible to consider the formation of water-oil emulsions in reservoir conditions as an additional reason. It is for this reason that it is important to create and apply new innovative methods based on rheotechnology for the extraction of additional oil volume accumulated in water-oil zones.

In the second subchapter, the possibilities of increasing the efficiency of the process of developing deposits with difficult-to-extract oil reserves by applying rheotechnological methods have been studied. Firstly, the modeling of the technological processes of oil and gas extraction and the justification of the choice of the reservoir model were carried out.

The theory of similarity was used in the work to justify the choice of the layer model under the conditions that allow the experimental results of the research conducted in laboratory conditions to be compared to the real object - the technological processes of oil extraction. As the main model, two-dimensional plane-reservoir model (reservoir element allowing to study the characteristics of the oil yield mechanism during the injection of water into the formation based on the 5-point layout of the wells (4 extraction wells in the flanks and 1 percussive well in the center)) was applied. The dimensions of this model are determined based on the system of dimensionless parameters on which the oil productivity coefficient η depends. By applying the π-theorem known in science, the determination of the oil production coefficient η results in the acquisition of 20 independent dimensionless quantities - similarity criteria:

$$\eta = (\pi_1, \pi_{2,} \pi_3, \pi_4, \dots \dots .., \pi_{20}) \qquad (3)$$

Each π similarity criterion in the equation is a dimensionless quantity that reflects the modeling conditions of the layer. Taking into account the mentioned, a 5-point oil layer model of

60x60x20 sm size made of transparent organic glass was prepared and it was justified to accept it as a physical model for conducting laboratory research.

In order to increase the final oil productivity coefficient, based on the results of the laboratory researches, a complex method of impacting the formation with water-oil emulsion was developed. Due to the improvement of the oil productivity coefficient in the accumulated physical reservoir model, as well as time saving and the model having poor collector capabilities, the maximum percolation resistance of the artificially created water-oil mixture outside the formation, the water and oil phases, 50% oil and 50% water, were optimally selected through iteration.

Based on the main principles of rheotechnology, the possibility of visually creating water-oil emulsions in formation conditions was studied, and the possibilities of application of these systems as a fuel for the process of residual oil compression were investigated based on innovative technology. In order to visually monitor the residual oil compression process of the water-oil system in the formation along the contour, an experimental layer model with 5-point formation elements was made of transparent organic glass, with 1 ventil imitating a percussive well in the middle, and 4 ventiles replacing production wells around it (Fiqure 4).

Before each laboratory experiment, the volume of the porous medium of the model was determined based on the volume of the granular element - quartz sand, which replaced the mountain rocks that were filled into the formation model and molded inside it, and this indicator was determined to be $V_m = 935.6$ sm^3.

A transparent layer's model was previously filled with quartz sand that was vibro-sieved in the fraction d = 0.2 – 0.4 mm, washed and dried in an oven. In order to exclude the sliding of the injected liquid between the porous medium and the walls of the model, arbitrary lines of epoxy resin were drawn on the inner surface of its walls, and an artificial roughness was created.

Then, the reservoir model was connected to a vacuum pump, the air inside was blown out, and the process of saturating it with the water phase was carried out.

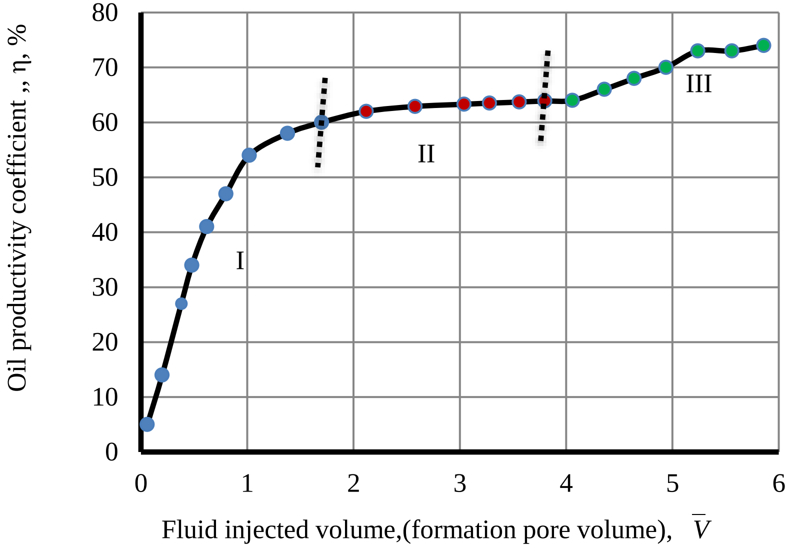
Figure 4 Experimental simulation of layer

During the laboratory tests, ordinary technical water was used as a saturating liquid, and as a pressing fluid, both ordinary technical water and a stable water-oil emulsion prepared artificially by mixing in homogenizer based on the produced "oil product" sample were used. The process of water injection into the formation was carried out at a temperature of $t=20^0C$ and a pressure difference of $\Delta P= 0.02$ MPa, through "pumping well" located in the center of the formation model.

The production process was carried out through "production wells" located along the diagonals of the square model. Taking into account that the calculated pore volume of the model is approximately $V\approx1000$ sm^3,the process of water saturation of the formation was carried out until it reached 3 times of the pore volume of the formation, that is, $V = 3000$ sm^3. The determined water permeability was $k_{water}=12.99$ mkm^2, and the porosity of the layer was $m=33\%$. Then the process of saturating the reservoir model with oil was started. The heavy oil product produced from well No.37 of the "Muradkhanly" oilfield, with the initial degree of water cut $W_1 = 22\%$ and density $\rho_1= 914$ kg/m^3, was taken as the saturating liquid. As a result of the relevant calculations, it was determined that the kinematic viscosity of oil is $\nu_{20}{}^{0}$ = 153.1 sSt,which indicates that it has non-Newtonian properties. Oil saturation of the reservoir model is similar to the one mentioned above, but in terms of saving time, with a pressure difference of ΔP = 0.04 MPa, it was carried out until 3 parts of the reservoir pore volume, i.e. V_{oil} =3000 sm^3, and this process is "clean product" from the production wells of the reservoir model was continued until the moment when the oil seepage occurred. As a result of calculations, it was determined that the volume of oil adsorbed in reservoir rocks is V=750 sm^3, which indicates that the reservoir model is saturated with 80% of oil and 20% of water.

Then, the process of compressing oil adsorbed by quartz sand in the formation model with technical water was started. In order to speed up the compaction process in terms of time, the process of penetration of the compressive liquid into the layer was carried out at a pressure difference of ΔP=0,08 MPa. By injecting water up to 1.5-2.0 of the formation pore volume, i.e. V_{water}=1500-2000 sm^3 and temperature t=20 ^{0}C, through the well, the volume of oil "prodused" from the production wells was determined using measuring vessels. After the process of water displacement of oil in the formation model, the oil permeability indicator remained small, which is due to the presence of some ("stagnant", poorly drained and "untouchable") oil zones that are not in contact with the compressive element. In experiments, the fact that water does not penetrate the mentioned zones and "bypass" them when it displaces oil from the reservoir in the transparent formation model is visually clear. At this time, the end of the "waterless" period and the beginning of the "wet" period (period) are determined visually in the measuring vessels - that is, starting from the moment when the water phase appears in the produced oil.

The compression coefficients of oil in the "waterless" and "wet" stages of operation are defined as the ratio of the volume of oil compressed to the volume of pores in the corresponding periods, to the volume of oil before the compression process, which is 35.3% and 62.6%, respectively. the water content of the oil was determined using the Dina-Stark device and it was determined that W_2=28%. Therefore, in the processes of mixing and dispersion occurring in the layer, the oil "absorbed" the water as a result of dispersion and was diluted by another 6% (Figure 5).



I - initial compression of oil with water
II - compression of oil with water-oil mixture
III – re-displacement of residual oil with water.

Figure 5 Dependence at ultimate oil recovery coefficient on the fluid injected volume

Due to the additional water cut of the oil, its density also increased and the next indicator determined by the pycnometer was ρ_2= 919 kg/m^3. In order to speed up the compression process, the water-oil emulsion to be injected as formation liquor was prepared by mechanical mixing based on the oil sample of the "Muradkhany" oilfield, with an optimal composition consisting of 50% water and 50% oil selected through iteration. kg/m3 and the water level W_{em}=50% was determined. The introduction of the prepared water-oil emulsion into the reservoir model was carried out through the injection well at a pressure difference of ΔP = 0.1 MPa.

Through repeated compression of residual oil in the formation with water, the process of filtering fluids - the incoming water-oil emulsion, until the complete compression of residual oil and the stabilization of the pressure difference in the reservoir model - was continued.

Re-compression of residual oil (in other words - creation of a "water shaft") once again showed that the permeability indicator of the reservoir model for oil approached its initial value and was K_{n2ef} =2,49 mkm^2. This fact once again confirms that the layer is fully covered by the compressive element. The amount of water in the repressed oil product was similarly determined and this indicator increased by another 5%, W_3 = 33%. The water-oil emulsion squeezed from the formation had a high viscosity (μ =53.57 Pa·s) and density (ρ_{em2}= 953 kg/m^3), and the degree of water cut reached W_{em2}= 57%, which caused high seepage resistances in two-phase flow fields. shows its possibility, and this fact is reflected in the perceptible vibrations and pulsations of the indicators of the manometers installed in the layer model. Therefore, in the fluidized bed model, in the process of compressing oil, there are not only areas where water does not penetrate - "stagnant", poorly drained and "untouchable" oil zones, but also water-oil emulsion, which is likely to be newly formed, and these fluids (oil, water, emulsion) viscosities, as well as percolation resistances, are different and differ from each other.

When the reservoir model is complexed with water-oil emulsion based on "own" oil product, the oil productivity coefficient increases by 11%, which once again confirms the efficiency of the applied technology.

At the next stage, in order to study the rheological properties of water-oil systems, it was determined as a result of the study of the rotoviscosimetric indicators of model systems - water-oil emulsions at a temperature of t=20^{0}C, prepared by adding a certain volume of water to the reservoir product - oil and mechanical mixing, that the degree of dilution of the considered emulsions as it rises, their viscosity also increases sharply (about 50-70 times). According to academician Rebinder, based on the fact that the reason for the anomalous increase in viscosity of water-oil emulsions is the deformation of dispersed particles in the process of increasing shear stress, 2 additional dependence curves were constructed – dependence curves on the velocity gradient of shear stress, as well as the dependence curves on the velocity gradient of effective viscosity.

The analysis of the rotoviscosimetric results confirms again the significant effect of increasing the percentage of water in the test emulsions on their rheological properties.

It was determined that the water phase, like the gas phase, can be dissolved or emulsified in oil. However, unlike gas, after the water component exceeds a certain existing "threshold" limit, it leads to a decrease in its mobility due to a sharp increase in the viscosity of oil in formation conditions, which manifests itself in a sharp increase in the degree of its hydration during the initial compression of oil with water.

The water-oil emulsion created on the basis of the oil product produced from the formation reaches the saturation limit by "absorbing" a part of the free water in the formation model as a result of dispersion, increasing its viscosity many times compared to oil, compressing the residual oil in the formation like a "liquid porshen", thereby increasing the production of additional oil, the formation it leads to expansion of the scope (compression "front") and a "water-oil shaft" is formed in the formation.

Considering that the outer phase of these emulsions is hydrocarbon-based, they easily solubilize (collect) the residual oil, create an oil-rich zone at the compression "front" and push it towards the production wells. In addition, these emulsions partially absorb the high permeability layers in the formation. isolates, directs the pumped water flow towards the low-permeability layers and brings them into operation. Also, some components of the emulsion-containing mixture are adsorbed on the formation rocks and hydrophobize them, reducing the phase permeability of water in the liquefied zone of the collector, redistributing the flow of injected water and reducing the flow of water to production wells, providing a selective isolation process in the formation.

In the dissertation, a new diagnostic method was proposed based on the mapping of hydrodynamic indicators of collector stimulation using the "Complex variable function" theory. This method, according to the current volumes of fluid "produced" from the porous medium before and after stimulating the layer model, as well as as a result of the comparative analysis of the distribution of the equipotential lines and their gradient vectors obtained through mathematical calculation, allows visualization of the zones of filtration state change (stagnant and poorly drained) and allows to characterize the reaction of the simulated environment to various influences, to choose the necessary mechanism of impact on the layers according to its individual characteristics and current situation.

In the fourth chapter based on the diagnosis of the rheotechnological properties of high-viscosity oils, the issues of justifying the choice of rational operating parameters for improving the working regime of intra-mining collection and transport systems were studied.

In the first subchapter the possibility of regulating the properties of water-oil emulsions based on rheotechnology on the example of Azerbaijan oils and the study of the anomalous rheological properties of emulsions formed in connection with the process of liquefaction of high viscosity oils were set. For this purpose, the initial water cut rate was taken from wells No. 17 and 37 of the "Muradkhanly" oilfield, and the initial water cut rates were W_1 =38% and W_2 =58%, respectively. On the basis of oil samples with W_{water3}=16%, as well as from the "Kalmas" area of the after named A.Amirov oilfield, with different initial dilution rates, by adding a certain amount of water to them, i.e. by artificially increasing their dilution rate and by mechanical mixing Laboratory studies were conducted with prepared water-oil emulsions at different temperatures (t=20, 40, 60^{0}C) and their rheological properties were studied. $\tau = \mu\ (\dot{\gamma})$ flow curves were established for all tested water-oil systems depending on the degree of hydration and the dynamics of changes in their external viscosity were studied.

In order to once again clearly demonstrate the possibilities of regulating technological processes with the application of rheotechnological methods, by adding the volume of oil to water-oil emulsions that are maximally water cutted and "saturated" with excess water through the well-known "hysteresis" ("straight-reverse movement") method studies were also carried out to study the possibilities of returning their hydration rates to their previous values - i.e. adjusting them and the dynamics of changes in existing rheological parameters (Figure 6).

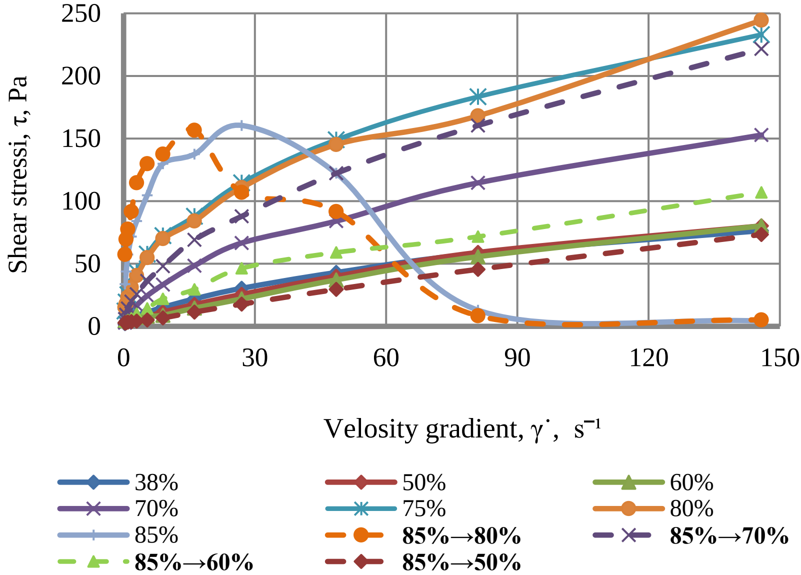


Figure 6 Flow curves obtained by the "hysteresis" method in water-oil systems

Rheological flow on the basis of viscometric indicators obtained by adding a certain amount of oil to the water-oil emulsion first, gradually increasing the degree of water cut, and then by adding a certain amount of oil to these emulsions, and returning their dilution percentages to the previous indicators. curves were constructed and compared to each other.

The results of laboratory studies give reason to say that the traditional ideas about the absoluteness of "phase transformation" based on axiomatic, stereotypical scientific considerations are outdated in time. The "inversion" point determined by the interpretation of the external viscosity of the water-oil emulsion is not always explained by the change of the emulsion type.

Probably, it characterizes the maximum saturation limit of water globules dispersed in oil - i.e. dispersity. The mechanism of the decrease of the external viscosity in the subsequent degrees of water cut is not due to the inversion phenomenon, but to the "hydraulic bearing" which is possible as a result of the stratification of the "free" water phase after reaching the "saturation limit", separation from the emulsion in the form of drops and their coalescence, which is possible as a result of the intermediate water layers ("floes") It is more correct to explain it with the manifestation of the "bearing" effect. Thanks to this effect, the phenomenon of "slipping" of the spindle occurs in the zone around the wall of the inner cylinder of the rheotest, which, as a result, revives the imagination of a sharp decrease in external viscosity.

In the second subchapterthe need to diagnose the rheological properties of heterogeneous systems taking into account the temperature and water cut factors,transported by pipelines. Dependences of the rheological properties of well product samples taken from the "Mammadli" oil collection point on their temperature and degree of water cut factors were studied in a wide range of rotation speeds of the viscometer spindle. It was determined that depending on both factors, the viscosity of oils changes dramatically. So, if the viscosity of the water-oil mixture decreases as a result of the increase in temperature, its increase is observed with the increase in the percentage of water cutwas brought to attention.

While the viscosity of the heterogeneous mixture decreases by 3-5 times due to the influence of the temperature factor, due to the increase in the degree of hydration, it can even increase 100 times. In addition to the temperature factor, it is very important to take into account the influence of the dilution factor in the processes of collecting and transporting oils with complex rheological properties and their emulsions. The fact that diluted oils and their mixtures have anomalously high viscosity also greatly complicates the process of transporting emulsions with the existing system. From this point of view, the diagnosis of rheological properties (especially viscosity) of water-oil systems with anomalous properties depending on temperature and dilution factors during pipeline transportation is currently of great practical importance. The conducted analyzes show that in order to increase the efficiency of the technological processes of oil extraction, depending on the factors of temperature and dilution percentage, the occurrence of heterogeneous systems should be constantly monitored, and operative preventive and diagnostic measures should be prepared.

In the third subchapter, it is rational based on the analysis of technological indicators of underground pipelines transporting water-oil mixturethe choice of operating parameters was justified. Researches show that due to the increase in the percentage of dispersed phase - water in the heterogeneous mixtures created in the systems of in-mine collection and transportation of the well product, the viscosity of those emulsions increases significantly, the energy costs of the transportation process in pipelines increase, and in some cases their transportation becomes impossible at all (Figure 7).

During the calculations, the inner diameters of the technological pipes through which the water-oil mixture is transported correspond to the real values that are more typical in mining practice - D=0.06 m; 0.1 m and 0.15 m, and temperatures t= 20; 40; 60^0 C was adopted.

In the next stage, the selection of rational operating parameters was made to increase the efficiency of the collection and transportation processes of high viscosity, rheologically complex oils and their mixtures.

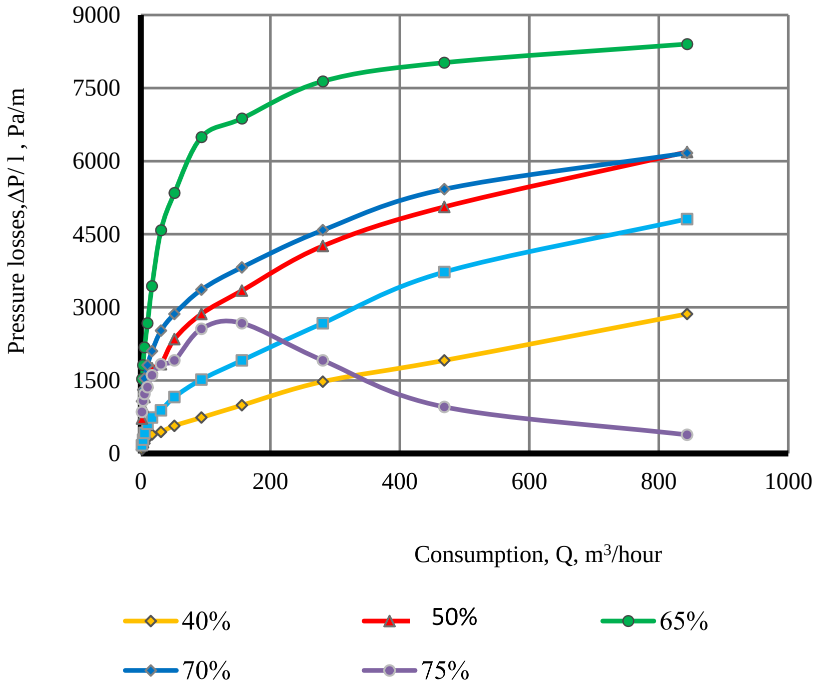


Figure 7 $\Delta P/l=f(Q)$ curves for mixed oil sample (at $t=20^0$ C and D=0.15 m)

At the initial stage of the research, taking into account the degree of water cut of water-oil systems and the structural stability of the flow, pressure losses in the "collection-transport" system were determined (Figure 8).

It is necessary to apply the generalized Reynolds number *Re**, which was previously applied for oils with complex properties, which allows to more accurately explain the structural changes occurring in water-oil emulsions, not with the usual Reynolds (Re) number.

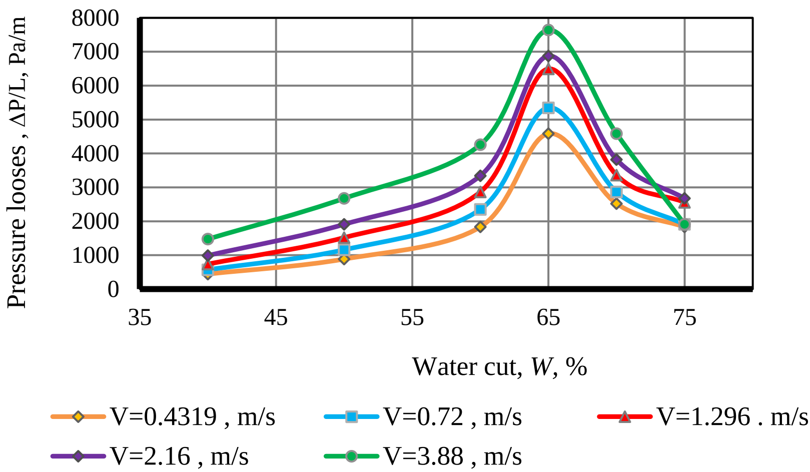


Figure 8 ***ΔP/l = f(W)* curves (at t=20^0 C and D=0.15 m)**

As a result of the analysis of the dependencies of *λ=f(Re*),* it was revealed that the structural stability of the flow in the laminar regime of the water-oil mixture flow, i.e. before reaching the threshold *Re= 2320* value of the turbulent zone, was violated (Figure 9).

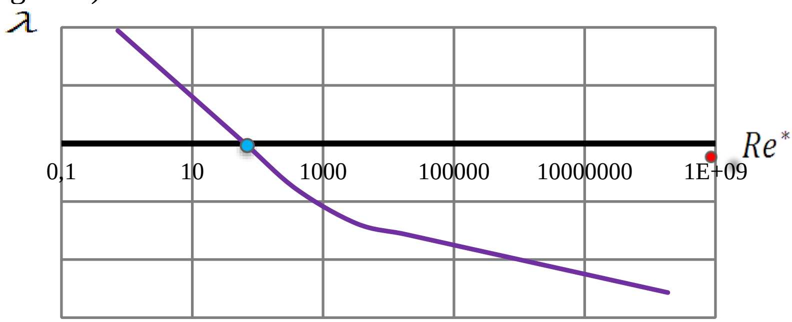


Figure 9 Dependence at generalized Reynolds number on structural stability

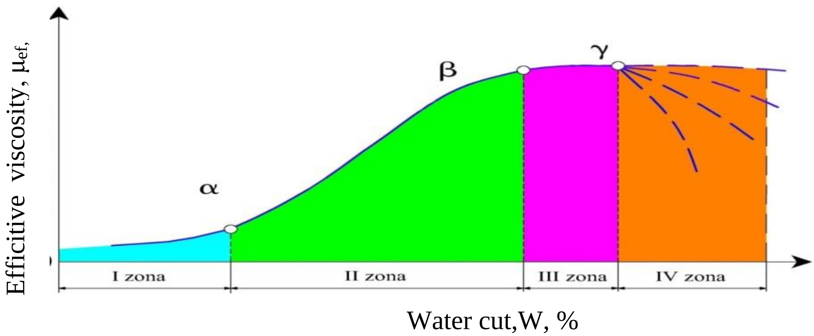
In the fifth chapter on the basis of the creation of new rheotechnological methods, the issues of increasing the efficiency of the intra-mine collection and transportation processes of rheologically complex water-oil systems were considered.

In the first subchapter, the prospects of applying the effective hydroconveyance method in Azerbaijan for the transportation of anomalous water cutted water-oil systemswere thoroughly investigated.Studies show that the probability of phase transformation in emulsions, depending on the physico-chemical properties of oil and water, and primarily the density of the water phase, and the presence of various emulsifiers in the emulsions, is higher at values corresponding to the interval W= 0.5-0.9 it is really. Also, the increase in the percentage of water cut in transported water-oil mixture reduces the efficiency of the hydrotransport method after a certain critical threshold. On the other hand, this method can be considered unsatisfactory, as the transportation of water, which plays the role of "ballast", along with oil in the pipeline, significantly increases the transportation costs. In this regard, determining the optimal amount of carrier - water in the transported mixture is of great economic and technological importance.

Based on the research conducted with water-oil dispersed mixtures, he proposed a new logistic curve based on the rheotechnological perspective, reflecting the dependence of their effective viscosity on the degree of water cut (Figure 10).

The geometric shape of the constructed curve confirms once again the "*S*"-shaped characteristic of the process, which is typical for non-Newtonian fluids. Starting from the α point of the curve, the increase in the degree of water cut of the water-oil mixture leads to an increase in the effective viscosity of the considered system. At point β, this growth rate gradually decreases, and at point γ, the determination of the effective viscosity indicator is observed.

However, starting from the γ point of the curve, the rate of reduction of the effective viscosity can’t fail to attract attention, so it is more appropriate to look for the explanation of this paradox in the manifestation of the systems and its manifestation in the physical "hydraulic bearing" effect.



zone I – initial (or able additional water cut) zone;
zone II – rheotechnology (or able regulate) zone;
zone III - zone already cutted with water(or "free" water phase);
zone IV – zone with "hydraulic bearing" effect.

Figure 10 Dependence at effective viscosity on degree of water cut

The development of new rheotechnological methods based on the rheotechnology of heterogeneous effects(for example, "umbrella", "dynamical closure", "hydraulical bearing" etc.) appearing in the technological processes of oil production is reflected in the second subchapter. Studies show that the processes occurring in such systems exist at the boundary of phase separation of "liquid-liquid" (two-phase) or "liquid-solid-liquid" (as well as "liquid-gas-liquid") type (multiphase) environments. a number of capillary and surface - molecular manifestations are often characterized by the appearance of various paradoxical effects. As the main research object was the analysis of the causes of complications arising during filtration of water-oil emulsions in a porous medium and transportation through pipelines, the theoretical and experimental aspects of some physical effects arbitrarily manifested in technological processes were considered and the perspective of their application in ways of increasing the efficiency of technological processes of oil production was considered.

In the third subchapterthe results of the application of the new innovative method proposed for increasing the efficiency of the oil collection and transportation systems of "Muradkhanly" oilfield based on the rheotechnology of water-oil systemswere interpreted.As a research object, water-oil mixture samples were taken from several wells located in the "Jafarli" area of the field (for example, No. 34, 36, 37, 39, etc.) and their physico-chemical, as well as rheological properties were studied. Viscometric tests of different high viscosity oils were performed and flow curves were constructed. During the studies, the influence of the degree of water cut on the rheology of oil emulsions at different temperatures and degrees of water cut was also studied.

Based on the research, the "threshold limit" considered satisfactory for the activation of the "hydraulic bearing" effect was determined from the flow curves. While the pressure at the beginning of the collector before the test was P_1 = 2,3 MPa, as a result of the application of the new technology, the mentioned initial pressure was reduced to P_2 =1,9 MPa. At that time, due to the application of new technology, pressure loss ΔP = 0,4 MPa, collection efficiency increased by 17,4%,the pressure losses reduced by 22%. The economical benefit obtained as a result of the application was 260.000 AZN.

In the fourth subchapterthe method of express assessment of oil losses caused by local accidental leaks in technological pipelineswas analyzed. Due to the fact that the existence of leaks is hidden for a long time due to the fact that the flow of liquids under the pressure of the pump or the wellhead meets the steady and pressurized flow conditions in the underground technological lines, the occurrence of "imbalance" during oil accounting is inevitable. The following mathematical expression was proposed to calculate the mass consumption of oil leaking from the technological line:

$$G_{leak} = F_d \cdot \mu_s \sqrt{2\rho \left[(P_b - P_{at}) - (P_b - P_s) \frac{x_{leak}}{L} \right]} \qquad (4)$$

The quantity included in the expression is dimensionless and varies in the interval (0-1). At this time, 2 cases are possible:

1) The leak is at (or near) the beginning of the collection linein the field) to determine the amount of oil leakingthe mathematical expression becomes :

$$G_{leak(max)} = F_d \cdot \mu_s \sqrt{2\rho[(P_b - P_{at})]} \quad (5)$$

2) When the leakage is at the end of the line (or in the area close to it), the amount of oil leaking can be determined by the following formula:

$$G_{leak_{(min)}} = F_d \sqrt{2\rho[(P_b - P_{at}) - (P_b - P_s)]} \quad (6)$$

In order to analyze the change of oil losses to the environment depending on the leakage locations according to these dependencies, calculations were performed at different values of the initial pressure and the leakage location (area) for the technological line with a diameter of D =0.1 m. Initial pressure P_1 =0.5; 1.0; 1.5 MPa, results were made by giving arbitrary values of 1-5 and 10% of the live cross-sectional area of the pipe F_i to the cross-sectional area of the hole F_d. According to the area of the accident-damage place where the oil leak occurred-the area of the created hole, the live cross-sectional area ofthe technological pipeline: 1 2; 3; 4; 5 and 10%. (Figure 11).

It was determined that oil losses into the environment due to certain reasons in operational technologicallines depend on the technological and geometrical parameters of the line (initial and final pressure, length, diameter, etc.) factor) directly depends.

In the sixth chapter of dissertation, the issues of creating new innovative technologies for the purpose of increasing oil yield and intensifying oil extraction were reflected.

In the first subchapter, the importance of creating new innovative technologies in oil production was brought to attention.

In the second subchapter the issue of developing a method of thermochemical impact on the layer based on a new composite composition was considered.

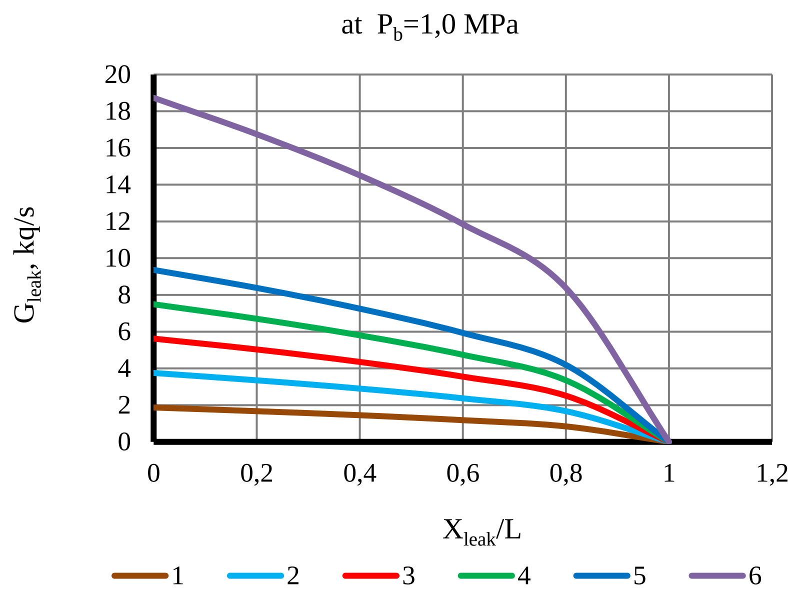


Figure 11 Diagnostic curves for determination of place of oil leaking

At present, the main volume of the reserve base of the oil industry of most countries producing hydrocarbon resources is made up of hard-to-product of heavy oils with high viscosity and anomalous properties.

Taking into account the above, the results of the research conducted on the development of a new method of thermochemical impact on the formation in order to increase the productivity of the formations in the process of exploiting the oil fields of Azerbaijan, where the product of the wells producing highviscosity anomalous oils contain APR(asphalten-paraffine-rezin) compounds, have been brought to attention. The essence of the new innovative method is that diethylamine – $C_4H_{11}N$ *(or* $(C_2H_5)_2NH$) is applied as a reagent reacting with acid in the method of thermochemical treatment of reservoir rocks, which is carried out by sequentially injecting a reagent, separating and solution of acid in water into the layer :

√ In the method of thermochemical treatment of reservoir rocks, the application of a water solution of diethylamine as a reagent that reacts with acid eliminates the complications that may arise during the operation (for example, the danger of explosion in the formation, etc.) and prevents the corrosion of the equipment inside the well;
√ Due to the use of high viscosity oil-soluble polymer-polyisobutylene with relaxation properties to delay the initiation time of the thermochemical reaction, it ensures the stability of the heating "front" of the reservoir rocks in all directions and the full coverage of the oil horizon.

For the application of the proposed method in mining conditions, depending on the volume of the well bottom area, a certain amount of diethylamine water solution is prepared in a special tank, and in another tank, water solutions of 1.5-2.0% polyisobutylene and 20% HCl are prepared. First, a diethylamine solution is injected into the well using a pump, and it is forced into the formation through a polyisobutylene (PIB) solution prepared in another tank, and then 20% HCl acid is injected there and for 24 hours (completely until the water in the formation undergoes a hydrolysis reaction and combines with the acid solution for reassurance) is kept under pressure. It is also necessary to take into account the fact that after the relaxation period of PIP, it "meets" with oil in that layer, then it dissolves completely. Separating layer - since PIB is "removed" as a barrier as a solution in oil, hydrogen chloride reacts with diethylamine without hindrance. Since aragati prevents this contact for a while, the exothermic reaction takes place far beyond the well bottom zone - in the depths of the formation. The relaxation property caused by the visco-elastic property of PIB also causes the process to start a little later.

At the next stage of the research, experiments were conducted to determine the optimal amount of components injected into the layer for the purpose of exothermic reaction, the viscosity of PIB used as , and the optimal ratio of PIB with HCl, which ensures a later start of the reaction. First, in order to visually observe the reaction of diethylamine with hydrochloric acid, a high-viscosity oil product sample from wells located in the "Jafarli" area of the "Muradkhanli" oilfield was beforehand filtered into a refractory glass flask and a diethylamine solution was added to it. Then 1.5-2.0% PIB and 20% *HCl* acid were added to that flask. The exothermic reaction occurs after the complete dissolution of the polymer alcohol in the oil, and the resulting temperature rises to T=95-120^0 C. Through iteration, the optimal amount of components necessary for the realization of the exothermic reaction was determined. At the next stage of the research, in order to study the influence of the concentration of PIB on the initiation time of the exothermic reaction, the PIB solution was taken in different concentrations in the range of C=0.25-4.0% in laboratory conditions. The optimal viscosity indicator of the polymer, which can provide the maximum delay value of the start of the exothermic reaction by means of selective selection, was also determined (Figure 12).

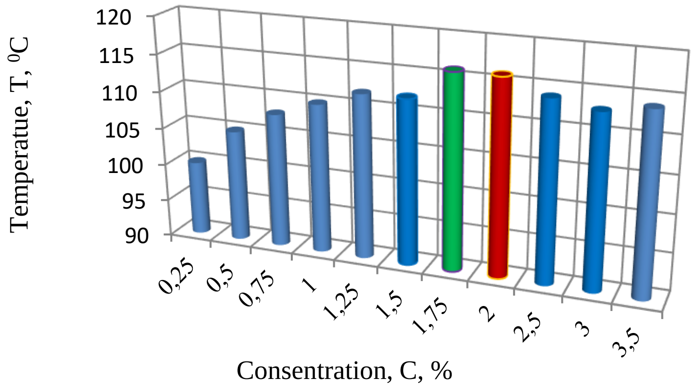


Figure 12 Determination of the optimal density of PİB

When the concentration of PIB rich is 1.75-2.0%, the temperature rises more and the start time of the necessary exothermic reaction is maximally delayed.The subsequent increase in the concentration of PIB does not significantly affect the temperature increase caused by this reaction and is economically ineffective.At the last stage of the research, studies were carried out in order to determine the required amount of PIB used as alcohol in the exothermic reaction. 20% solution of PIB and diethylamine were taken in a refractory flask.

During the experiments, the amount of oil-soluble polymer was taken as 0.25-3.0% of the total volume of V_{um} calculated together with diethylamine and *HCl* acid. The analysis of the histogram proves once again that the maximum delay of the start of the reaction occurs at the concentration of polyisobutylene C=1.5-2.0% (Figure 13).

Since the subsequent increase in hardness did not change the course of the reaction, these indicators were finally taken as the basis.

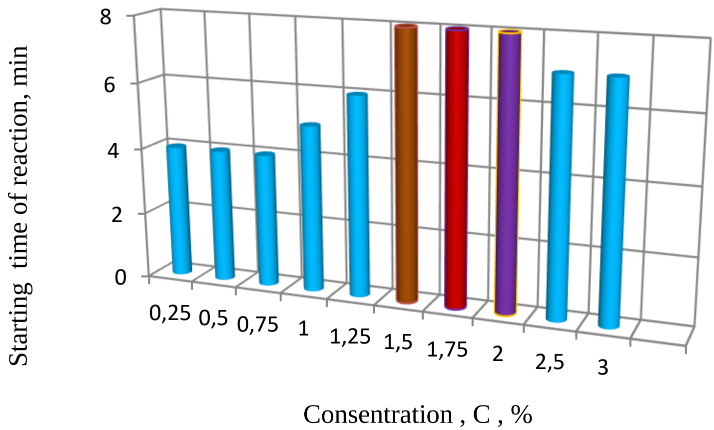


Figure 13 Dependence at initiation time exothermic reaction on viscosity of PIB

The obtained results show the prospect of applying a new method of thermochemical impact on the formation and the feasibility of implementing this innovative method in the oil fields of Azerbaijan, which produce rheologically complex oils, in order to increase the efficiency of production process of hard-to-produce high viscosity, heavy oils and bitumen.

In the fourth subchapter, the development of the method of strengthening the well-bottom area based on a new composite composition was described.

In order to prevent the collapse of the layer skeleton of the well surrounding area, a new innovative technology has been developed, which involves injecting a reinforcing, or in other words, a "barrier-creating" composite system into the layer.The main goal of the new method is to improve the quality of the process of solidification of the zone around the well of the productive formation, to prevent the destruction of the "barrier" created against the sand transported to the bottom of the reservoir consisting of weakly cemented rocks by subsequent perforation, and during the process of solidification of the bituminous sand, which is considered "dead" soil, contaminated with oil products. it is used as a filling element, which prevents additional pollution of the environment and aims to dispose of soil contaminated with oil products, and partially solves the environmental problem. There is no need to repeat the perforation operation, because the "barrier" created against the sand is porous in its self-viscosity and is more resistant to being washed away by the formation product. In the proposed method, the use of a mixture of tar and calcium-chloride solution in water as a hardening element leads to the maximum penetration of the liquid into the depths of the layer and its complete coverage, as well as to increase the relaxation time of the hardening process of the new composition.

Bituminous sand belonging to the GaLD formation set, taken from tank No.3 of the "BinaqadiOil" Operating Company, with permeability ξ = 9.5-48.3 *mD* and oil saturation coefficient K_{oil} = 6.75-29.2%, was used as a reinforcing element. The applied sand was previously subjected to special processing - mechanically chopped and directed to the mixer, where at the same time - along with it, the content of organic compounds – 6.3%, oil - 1.8 %, naphthenic acid – 4.5% and acidity number J= 228 - 230 was added. The mixture was mechanically stirred for 10-15 minutes and the separated tar solution was filtered. At this time, the bituminized sand had hydrophilic properties, and its conductivity was k = 3400 - 4000 mD. At the next stage of the research, that is, after the tar solution is separated from the sand by filtering, a 0.5-1.0% calcium chloride ($CaCl_2$) solution in water is added to the remaining bituminous rocks in the container and mixed regularly for 3-5 minutes. At this time, the mixture of bituminous oil and alkaline solution contained in the grainstar of bituminous rocks reacts with the ions of $CaCl_2$, creating solid granular products of the reaction on its surface, so that small (mainly clay) particles aggregate, turn into larger particles- clathrates and become bituminized. It has high adhesive properties that increase the permeability of rocks. The filtration time is t=5 hours.

The volume of bituminized sand treated in the mentioned manner was emptied from the formation model equal to the volume of sand to be injected into the formation, mixed with the water solution of tar and again included in the formation model. At this time, the ratio of bituminized sand and mixture (a mixture of tar and $CaCl_2$ solution in water) included in the layer model was taken as *1:3*, respectively. Taking into account the sensitivity of the influence of alkaline wastes containing calcium-chloride to the reaction, after the sand and the mixture, add tar from the additional tank to the formation model - a separating liquid (for example, water thickened with a polymer), and then in a volume equal to the volume of the water solution of tar, 10% a solution of $CaCl_2$ in water was injected.The expediency of the application of the new composition was confirmed on the basis of research conducted on 6 different test models (1-when the new composition was not applied and 2-6 in different volumes of the constituent elements of the new composition) (Figure 14).

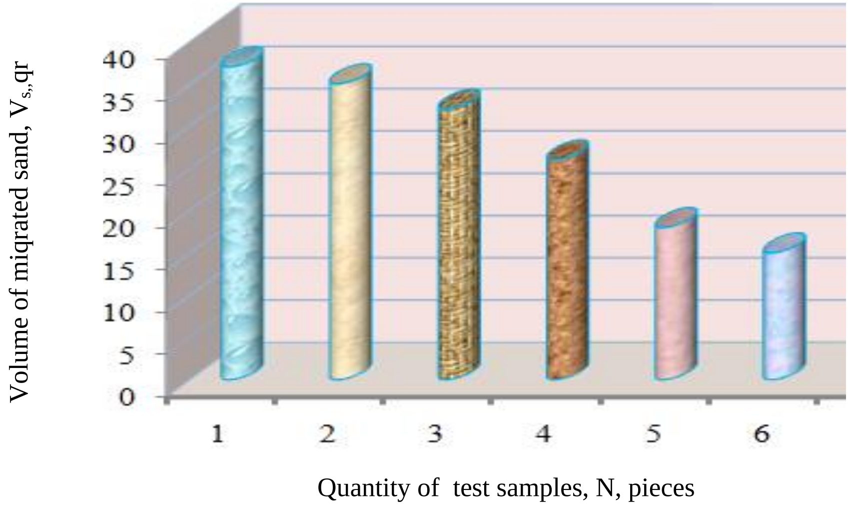


Figure 14 Dependence at volume of miqrated sand of test samples numbers

GENERAL CONCLUSIONS

1. A different explanation of the tendency of the apparent decrease of the effective viscosity with the increase in the degree of water cut in water-oil emulsions, not always as a characteristic phenomenon of "inversion", but as a manifestation of the "hydraulical bearing" effect, which in most cases is realized by the formation of a "free" water phase occurs as a result of the flocculation and coalescence of large water globules in the internal structure interpretation has been proposed.
2. It has been shown the possibility of increasing the efficiency of the process of development of deposits with difficult to product oil resources by rheotechnological methods, and a new complex method

of impacting the formation with water-oil emulsion in order to increase the ultimate oil rocovery coefficient has been developed.
3. Based on the rheotechnology of multicomponent visco-granular systems, the factors affecting the efficiency of the process of sealing the layer characterized by absorption with a viscous-dispersive medium were analyzed, the optimal radius of the layer penetration contour was determined, and the percentage of the filling element contained in the sealing medium was rationally applied in terms of energy and time saving that the interval is around 20-42% was determined.
4. A new logistic curve reflecting the dependence at effective viscosity of water-oil systems on degree of water cut from the rheotechnological aspect was proposed.
5. New empirical dependences for the purpose of calculating the density, which is considered as the main quality indicator of heterogeneous "water-oil-sand" mixtures without experimental measurements have been proposed.
6. On the basis of the fractal theory, the expediency of the explanation of the micro- and macrostructural changes occurring as a result of watercut in dispersed water-oil systems based on the "Feygenbaum” scenarios was shown, and the "express assessment" method to determine the ultimate water cut limit of emulsions was developed.
7. Based on the rheotechnology of dispersed systems with viscous-granular properties, the influence of the mixing sequence of constituent components on their rheology in "water-oil-sand" mixtures experimentally was studied.
8. Based on the "hydraulical bearing" effect of high-viscosity oils and their emulsions, as well as storage and "trap" oils, oil bitumens and slurries, an efficient method of hydrotransportation by pipeline in terms of saving energy and resources has been developed and patented.
9. The method of "express assessment" of oil losses caused by local accidental leaks from technological pipelines into the environment was proposed.

10. On the basis of a new composition, a method of thermochemical effect on oil layers with high viscosity, anomalous properties, containing asphaltene-resin-paraffin compounds was developed and an invention document was obtained and patented.
11. The method of strengthening the wellbore area of layers composed of weakly cemented collectors based on a new composition was developed and an invention document was obtained and patented.

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Personal contribution of the applicant:

[4 - 6, 14, 16, 21, 24, 27, 29, 31, 33, 39, 40, 47, 49]- were performed independently (without co-authorship);
[1, 2, 36] - Co-owner of Patents and Inventions;
[8,11,12,18,19,25,26, 28, 35, 41, 43,44] - formulation of the problem, planning of experimental and theoretical studies, determination of rheophysical properties, systematization and analysis of the obtained results;[
[9,10,13,15, 20, 32, 37, 50] - development of research methodology, proposal of algorithm of mathematical model, systematization of scientific results and execution of experimental application issues;
[17, 23, 34, 38, 42,51] - general overview of the considered issues, collection of mining data based on monitoring, calculations using mathematical and statistical methods, analysis and interpretation of scientific results, selection and justification of diagnostic methods;
[3, 7, 22, 30, 45,46,48] - the participation share of the authors is equal.

The claimant's personal contribution in the dissertation was to indicate the purpose and tasks of the research, to justify its relevance, to choose research directions and methods, to determine the structure, and to solve the considered issues. The proposed structure of the dissertation work, the results obtained in the work, the analyzes carried out, the proposed criteria, models, methods and methods, mechanisms, recommendations belong to the applicant. Also, the schemes, pictures, graphs, tables included in the dissertation work were drawn up by the applicant personally.

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