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THE DEVELOPMENT AND APPLICATION OF NEW TECHNIQUES TO CONTROL AND FIX THE FAILURES GENERATED IN OIL AND GAS WELLS WITH WATERCUT

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

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THESIS ABSTRACT

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The dissertation work was performed at "Oilgasscientificresearchproject" Institute of State Oil Company of Azerbaijan Republic.

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GENERAL DESCRIPTION OF WORK

Urgency of the research topic and the degree of development:

Robust pace of oil production are favored, first of all, by the discovery of new oil and gas fields and their rapid commissioning, by upgrading the oil and gas production techniques and technologies, the introduction of new progressive work methods, and the stabilization of oil production in mature fields. The role of SOCAR in the overall technical and economic balance of fields under long-term depletion is profound. Absheron Peninsula and a number of offshore fields (Pirallahi, Darwin Bank, Jilov Island, Palchik Pilpilasi, Oil Rocks, etc.) can be included among these fields.

In the circumstances where the decrease in the volume of oil produced in fields that have been under depletion for a long time, the concern of controlling and increasing oil production remain as an urgent issue.

Both offshore and onshore oil fields have, nevertheless, been operated up to depletion for a long time, they contain millions of tons of recoverable oil reserves. Ramping up the efficiency of development of these deposits is of great national economic importance for the country. In the course of development of mature oil fields, the drop in reservoir pressure, the decrease in the gas factor of the product, the water ingress in oil formations lead to the emergence of other physico-chemical processes, which in turn lead to the change of the rheological properties of oil, the inflow of sand and water into the well, and the formation of various other complications. In the phase of depletion, the presence or increase of water, sand and various mechanical mixtures in the production of the well seriously worsens their operational performance.

Timely execution of government tasks on oil production consists of efficient use of wells in operation, as well as rapid and maximum flow of products from hydrocarbon layers. In addition to the development of new oil fields, one of the important problems in the stabilization of oil production is the protection of operational well stock. The development and operation of new oil fields requires a large amount of investment. The return of the invested funds is mainly possible as a result of maintaining the existing well stock by achieving normal and optimal operation of the wells.

In formations where there is poor cementation, fixing the zone around the bottom of the well is considered one of the most advanced methods to prevent water, sand and various mechanical mixtures from entering the well. In order to improve the quality of these works, all crutial measures must taken in a comprehensive manner since the ingress of rocks collapsed into production wells disrupts their normal operation. This leads to the formation of sand plugs in wells, early wear-out and decommissioning of downhole equipment. Water-cut of the product increases its cost, as a result of corrosion, downhole equipment, transport lines, gathering systems fail, and the ecological balance of the environment is disturbed.

Inspite of the fact that, a number of techniques and technologies have been developed against sand and water, it is vital to work out new approaches and methods taking into account the current conditions.

The dissertation work covers the study of these current issues and the development of new ones.

Purpose and objectives of the research:

Engineering of new technical solutions to prevent sand and water ingress into the well from the formation and lift the sand from the well to the surface to increase the productivity of wells with watercut.

Target and subject matter of the research:

1. Investigation of the effect of sand and water on the operation of centrifugal electric submersible and rod pumps;

2. Development of a technology to fix wellbottom zone;

3. Development of a new composition for water shut-off;

4. Engineering of a new combined pump design to provide sand protection of the Electric Submersible Pump;

5. Development of a rod pump for depletion of sand producing deep wells.

Research methods: The stated issues have been solved by carrying out laboratory experiments and theoretical, mathematicalstatistical methods, and confirmed as a result of field tests and applications.

Scientific novelty of the research:

1. Development of a technology to fix wellbottom zone;
2. Development of a new composition for water shut-off;
3. Engineering of a new combined pump design to provide sand protection of the Electric Submersible Pump;
4. Development of a rod pump for depletion of sand producing deep wells.

The principal provisions submitted for defense:

1. Development of a technology to fix wellbottom zone;
2. Development of a new composition for water shut-off;
3. Engineering of a new combined pump design to provide sand protection of the Electric Submersible Pump;
4. Development of a rod pump for depletion of sand producing deep wells.

Practical significance of the research outcomes:

The outcomes received on the account of the dissertation have been applied in the oil industry.

Field tests of the technology of fixing the wellbottom zone under the influence of physical fields were conducted in wells 1300, 1073, 1344 and 2396 of the "Oil Rocks" field. After the application of the developed technology in these wells, 326 tons of oil were produced in addition to the wells, and the operation time between turnarounds (TAT) increased by 2.0-2.5 times.

Field tests of the technology of cement-polymer-water backfilling of the wellbottom zone were carried out in wells No. 2306 and 2182 of the "Oil Rocks" field. After the application of the developed technology, 236 tons of oil were produced from the wells, and 440 m3 of formation water was less produced. The operation between overhauls (TAT) has increased by 2.2-2.7 times.

Thus, after the application of developed technologies, in addition to the wells, 562 tons of oil were produced, 440 m3 of less formation water was produced. TAT has increased by 2.0-2.5 times.

The results obtained in the dissertation have been applied in the oil industry.

Approbation and application of work. The main provisions of the dissertation were reported and addressed at:

- Restoration of the structure of cement stone when fixing the bottomhole zone of wells with intense sanding. Proceedings of the International Scientific and Practical Conference "Modern methods of developing fields with hard-to-recover reserves and unconventional reservoirs", Atyrau, September 5-6, 2019. Volume I p. 339-342.
- Cutting-edge technology to prevent rock destruction in the bottomhole formation zone. Proceedings of the IV International Scientific and Practical Conference "Bulatov Readings", Krasnodar, March 31, 2020, Collection of articles, Volume 2, p. 58-60. ISSN 2587-8913.
- Regulation of production of associated water using the technology of water inflow limitation. Proceedings of the IV International Scientific and Practical Conference "Bulatov Readings", Krasnodar, March 31, 2020, Collection of articles, Volume 2, p. 64-68. ISSN 2587-8913.
- Downhole pumping unit for the operation of oil wells. Collection of abstracts of reports of the International scientific conference "Innovative technologies in oil and gas industry. Implementation experience and development prospects", Kazakhstan, Atrau, November 19, 2021, p. 33.
- Reversible deep well pump. Proceedings of the International Conference "Innovative Approaches to the Development of an Educational and Industrial Cluster in the Oil and Gas Industry". Tashkent, April 30, 2022, volume 2, p. 303-304.

The name of the institution where the dissertation work was performed:

The work was carried out at "OilGasScientificResearchProject" Institute of the State Oil Company of Azerbaijan Republic.

Publications:

The major theme of the dissertation is issued in 11 scientific works, including 6 scientific articles and 5 conference materials.

Structure and scope of work:

The dissertation is composed of an introduction, 4 chapters, 55 pictures and 16 tables, conclusions and suggestions, a list of 139 references and appendices. Dissertation work consists of 121 printed pages, excluding pictures, tables, list of used literature and appendices. The thesis consists of 191244 characters, including title page and table of contents - 4835, introduction - 24139, chapter I - 72493, chapter II - 48365, chapter III - 30031, chapter IV - 9804, conclusion and suggestions - 1577 characters.

SHORT SUMMARY OF WORK

The Introduction discusses main provisions of the dissertation are given, its purpose and main issues are briefly explained, scientific innovations and the practical importance of the work are indicated.

The dissertation work covers the development of new tools&devices to prevent sand and water ingress into the well from the formation and lift the sandy fluid to increase the productivity in sand producing wells with watercut.

The first chapter of the dissertation provides an overview of the methods of controlling sand and water production.

The first paragraph of the first chapter seeks the causes of sand ingress from the formation to the well and the analysis of the work done to control the consequences caused by it.

In the course the development of oil fields comprised of reservoir rocks that are poorly cemented, sand also enters the well along with the produced fluid. Sand production is more characteristic in most fields located in the dry areas of the Absheron Peninsula, and Oil Rocks and Pirallahi offshore oil fields.

Decomposition of the structure of the layer means that under the influence of the forces applied to the rocks that make up it, individual particles of the rock layer are detached from the general mass and their aggregate state is disturbed.

The presence of sand particles in the fluid produced during the operation of wells indicates the sand ingress, the increase in the concentration of sand particles in the fluid and intensive penetration into the bottom of the well. The variety of conditions and forms of sand formation in wells show that this mechanism is very complex. On the other hand, the multi-factorial nature of the mechanism of sand formation and rock decomposition, the fact that these factors are closely related to each other and, in most cases, their joint effect, cause great difficulties in the study of this problem.

At SOCAR, 40-45% of the operational well stock is producing sand. The life between overhauls of such wells is 30-40 days.

As a result of sand ingress, sand plugs are formed in wellbottom zone, in the casing and christmas tree. Uncontrolled production of sand from the layer is observed by the collapse of the production pipelines and the loss of the well in the productive layer. As a result of intensive production of sand, layer compaction, layer thickness and pore pressure decrease. As this happens, the vertical pressure on the rock structure increases. Pump compressor tubings and other equipment are also subject to severe erosion by sand inflowing with the fluid.

In such conditions, a number of technological measures have been developed for the normal operation of wells, and filters and gravel-packs have been applied.

In the second paragraph of the first chapter, the analysis and classification of the fight against complications in water producing wells is given. In the process of operation of wells, the inflow of bottomhole zone water, the advance flow of water through highly permeable layers, the creation of backflows, the violation of the integrity of the operation pipeline, its eccentric location, the formation of water channels in it during the setting of the cement stone, the formation of micro-cracks in the cement stone during the perforation operation, the channels on the well wall with cement are flooded due to incomplete filling, decrease of its volume during the formation of cement stone, mixing of cement and clay solution behind the casing, and sand ingress.

In order to reduce the water-cut in the well product, various methods have been proposed and some of them have been implemented. The efficiency of water shut-off first of all depends on the correct determination of the water inflow path, since technological operation and materials are selected depending on this. Shut-off with water and hydrocarbon-based cement solution occupies a key place in the technological operations. They are applied depending on the type and nature of watercut in technological processes developed on the basis of various chemical reagents (polymers, alkalis, etc.).

The use of oily alkaline waste, which is the production residue of the Baku Oil Refinery named after H. Aliyev, has given positive results. As a result of mixed relations of oily alkaline waste with many chemical agents, it was determined that coagulation products are obtained in different ways. The best is obtained when the hard-elastic mass is treated with a 10-15% calcium chloride solution on the oily alkaline waste. The product obtained from the mixture of these agents settles in the form of a solid-elastic substance in an aqueous environment, and in an oily environment it forms a soft mobile gel. This feature of the oily alkaline waste allows it to be used in the selective water shut-off.

In the third paragraph of the first chapter, the influence of sand on the operation of the centrifugal electric submersible pump (SP) and the rod pump (RP) was investigated and the classification of operations aimed at solving the problem was provided.

In the operation of wells with submersible pumps, complications arise depending on the composition of the produced product. Although various measures are taken to control sand, it is not always possible to completely eliminate the impact of sand onsubsurface and surface equipment. All working bodies in SP, plunger-cylinder pair in RP, valve nodes quickly become unusable.

The life betwenn overhauls and failure of SP are affected by the geological characteristics of the location of the wells, the amount of mechanical impurities and corrosive properties in the well product, high gassiness at the pump inlet, high watercut of the formation environment, high activity of the produced fluid against corrosion and other various complicating factors. Accumulation of sand in the travelling bodies of the pump leads to deterioration of its working characteristics, reduction of efficiency, useful work coefficient, heating of the electric motor and deterioration of pump pressure values. The mechanical mixtures in the product produced during the operation of RP intensify the wear of the working surfaces of the plunger-cylinder pair. Due to the high hardness of oil sands, they subject the working surfaces of the plunger and cylinder to intense corrosion. Adequate conditions accelerate the increase of leakage, pump and well shutdown for maintenance. Small-sized sand particles are one of the main reasons for the failure of integrity in the valves and the increase of the gap in the plunger-cylinder pair. Large-grained sand particles fall between the plunger and the cylinder pair and become riveted there and destroy the pump. As it can be seen, the main parts of SP and RP fail due to the effect of sand and mechanical mixtures.

Taking into account all this, technological and technical measures were developed in the dissertation work in the direction of controlling the sand from the reservoir to the wellbottom and eliminating complications caused by the sand in the rod pump.

The second chapter sets forth the development of technologies for fixing the wellbore area in order to regulate the sand&water ingress from the formation.

The first paragraph of the second chapter, provides the development of the technology of fixing the wellbottom zone to control the sand ingress from the formation.

Experimental studies of the effect of magnetite additives on the physical and mechanical parameters of the cement system were conducted in the process of fixing wellbottom zone. Rocks taken from different fields in Azerbaijan were used as magnetite particles. At this time, it is intended to create plugging material whose resistance is restored around the wellbottom zone with the application of physical fields. In order to improve the physical and mechanical properties of the plugging mass, a plugging solution made of a mixture of cement and magnetic material, which adheres to the aqueous environment, was proposed. Magnetites are minerals in crystal lattices where the magnetic moments of the atoms are opposite to each other, but their total magnetic moment is not equal to zero. They have high values of magnetic susceptibility and residual magnetization. These include magnetite, Zn, Ni, Co, Mg ferrites and other metals. Magnetite consists of 31 % FeO, 69 % Fe_2O_3, and often $MgO, Cr_2O_3, Al_2O_3, MnO, ZnO$, etc. is available.

Different fields in Azerbaijan such as magnetite particles

ground magnetite rocks were used. Crushed magnetite had the following properties:

density, kg/m3 5000-5200

granulometric content, mm 0.3-0.6

compressive strength, MPa 150.2

5.5-6.0 hardness according to the Mohs scale

These magnetic rocks have special anomalous physical properties. The most important of these, which forms the scientific basis of the technology to be developed, is the presence of residual magnetism (ferromagnetism) in these rocks and their magnetization in a highly magnetic environment. These properties make it possible to use magnetic ores to control sand production. In order to improve the physico-mechanical properties of the plug system (resistance, spread, setting time, etc.) in laboratory conditions for the purpose of quality hardening, experimental studies were carried out when the water-cement ratio was changed in the range of 0.5-0.6.

Damping solutions with added magnetite were studied to investigate the effect of particles on the resistance properties of cement stone. Studies have determined the resistance and permeability properties of cement stone depend on the amount of magnetite particles (C %). Based on the obtained experimental data, the dependence of the resistance and permeability curves of cement stone on the amount of magnetite particles was established.

When the amount of magnetite particles in the plugging system is at the level of 5%, an increase in the resistance of the cement stone (up to 30-40%) is observed. When the amount of magnetite particles reaches 7%, the resistance of cement stone becomes relatively stable. The permeability increases to 0.06 μm2 - 0.35 μm2. The permeability and resistance of the resulting backfilling material is satisfactory when the amount of magnetite is 5-7 %. Its distribution is one of the main indicators for pumping the plugging solution into the well. Studies have shown that when the amount of magnetite in the system is 5-7%, its spread is between 20-19×10-2m. When the amount of magnetite particles in the plugging solution is 5%, a significant decrease in spread (10-15%) is observed. With further increase in the amount of magnetite, the diffusivity of the plugging solution changes slightly and is equal to the minimum indicator of diffusivity.

The cycle of the liquid state of the backfill solution is conventionally limited by the initial ignition time, which is characterized by a sharp decrease in the movement of the system. The final set time is determined when the movement is completely restricted and the liquid mass becomes a stable body, but still does not have significant solidity. Thus, adhesion is considered as the initial stage of setting, and at this stage the plastic plugging paste becomes a solid body. Depending on the depth of the wells and the formation temperature, the setting time should be adjusted when planning the technological process.

The study of setting time was carried out by adding up to 10% magnetite particles to the backfill solution. Since the temperature significantly affects the setting time in layer conditions, the experiments were carried out at 20 °C and 75 °C. When adding 6% particles at 20 °C, the onset of setting is 2 hours 18 minutes, and the end is 2 hours 38 minutes. At 75 °C, when adding 6% particles, the start of setting is 1 hour 40 minutes, and the end is 1 hour 15 minutes. As can be seen, as the amount of magnetite particles increases in the backfill solution, the setting time accelerates. As the temperature increases, the average sticking time of the backfill solution accelerates, as it decreases, on the contrary, it slows down.

Then the backfill system was passed through the magnetic field and its physical and mechanical parameters were studied experimentally.

Complex studies conducted in the laboratory revealed that various changes in the properties of the plugging solution occurred as a result of the effect of the magnetic field. Based on the values obtained from the studies, the dependence curves of the resistance of cement stone on the voltage of the magnetic field were developed (Fig. 1).

As can be seen from the figure, the magnetic field voltage varies in the range of 0-50000 A/m. When the content of magnetite particles is 5% and the magnetic field voltage varies in the range of 0-50000 A/m, the strength of the obtained stone increases from 50 to -70 MPa. At a magnetic field strength of 30,000 A/m, cement stone has a resistance of 69 MPa, and then stabilization occurs. Although the subsequent increase in the magnetic field stress provides high strength properties, the rate of increase appears to be slow.

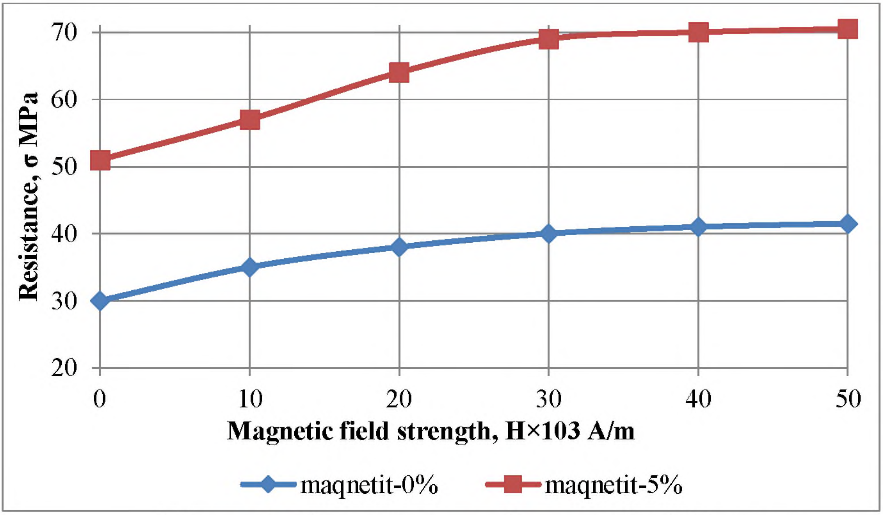

Figure 1. Cement stone of magnetic field stress effect on strength

In the following experiments, the effect of the magnetic field voltage on the propagation of the plugging system was studied.

A significant change in the diffusion of the backfill solution is observed when the magnetic field strength is 25000 A/m. At this time, the spread of backfill solution is 19×10-2 m. The subsequent increase in the magnetic field strength causes very small changes in the propagation radius.

The setting time of backfill solution with added 5% magnetite was studied experimentally. When the magnetic field voltage is 25000 A/m at t=20 °C, the start of setting is 1 hour 45 minutes and the end is 2 hours, while at t=75 °C it is 1 hour 20 minutes and 1 hour, respectively. The results obtained in the subsequent increase of the magnetic field voltage are identical. The effect of the magnetic field on the water used in the preparation of the backfill solution was also considered. As water, the formation water of the Oil Rocks field was taken. After impacting the reservoir water with a magnetic field, a backfill solution was prepared on its basis. The strength of cement stone made in magnetized water was 15% higher than the strength of cement stone made in ordinary water.

Research shows that temperature and pressure have a very significant effect on the strength of cement stone. At a temperature of 20 °C, the strength of cement stone increases depending on time. Although the mechanical compressive and flexural strength increases at temperatures above 75 °C, the growth rate and absolute strength indicators decrease. If the strength of cement stone made in magnetized water at a temperature of 20 °C is 80 MPa, then the strength of cement stone made at a temperature of 75 °C is 115 MPa.

The permeability of the cement stone is one of the main indicators in the strengthening of the wellbottom area. The permeability of cement stone depends on a number of factors, including the nature of cement and admixtures, water-cement ratio, setting conditions (temperature and pressure), and time. At a temperature of 20 °C, the permeability decreases as the curing time increases, and at a temperature of 60 °C, the permeability is small and varies within small limits. As the temperature increases to 75 °C, the rate of change of strength slows down and the permeability is 0.90-0.170 μm2.

The water-cement ratio has a significant effect on the permeability of cement stone. With its increase, the volume and quantity of capillary pores increases; in the course of hydration, they are filled with helium content of low permeability. By increasing the water-cement ratio and adding magnetite particles, the expected result of permeability at the required strength can be obtained.

The permeability of cement stone before magnetization varies from 0.09 to 0.14 μm2, depending on the water-cement ratio, and from 0.06 to 0.15 μm2 after magnetization. The effect of the amount of particles on the structural properties of the system was examined in the studies. Increasing the amount of H particles increases the viscosity of the backfill solution and leading to a gradual increase in shear stress (from 15% to 30%).

Similar studies were conducted to study the effect of magnetic field stress in the range H = 10000-50000 A/m on the structural-mechanical parameters of the backfill solution. Based on the obtained experimental data, the dependence of the shear stress of the structural viscosity of the backfill solution on the magnetic field stress was established. A significant increase in viscosity and shear stress (up to 30%) corresponds to a magnetic field strength of 50,000 A/m. The effect of the ferromagnetic particle added to the system on the hydraulic parameters of the plugging solutions was studied.

Early turbulence is observed during the movement of backfill solutions with added ferromagnetic particles. When the amount of particles is 0%, turbulence mode is observed at $Re^* > 500$. When the amount of particles in the cement solution is 1%, the early turbulence mode occurs at $Re^* > 450$. After that, increasing the amount of magnetite particles in the backfill solution by 5% leads to earlier breaking of the structural mode, and the early turbulence mode occurs at $Re^* > 250$. The presence of magnetite particles in the tamponade solution leads to early disruption of the structural mode, early turbulence. Changes in the hydraulic resistance of the backfill solution depending on the amount of particles and the magnetic field voltage were also considered. An increase in hydraulic resistance is observed when the amount of magnetite in the backfill solution and the magnetic field voltage field increase.

During operation, the strength of the created barrier decreases. To restore the strength of the barrier created in the area around the well bottom, a pipe with permanent magnets is lowered into the well and the backfill barrier is exposed to the magnetic field.

In the second paragraph of the second chapter, the technology of controlling the water level in operational wells with elastic backfill solution has been developed. Portland cement, polyethylene polyamine (PEPA) agent and water were used in the experiments. The effect of their amount on the properties of the backfill solution and cement stone was studied by using the solution of polyethylene polyamine agent in water in different percentages in the preparation of the backfill solution.

In order to determine the initial and final setting time of the cement solution, samples mixed with water containing 1-6% of PEPA mass at a ratio of 0.5 water-cement factor were studied. As the water-cement ratio increases, the beginning and end of the setting time of the backfilling solution lengthens, but the increase in temperature causes a sharp decrease in the beginning and end of the setting time. So, the water-cement ratio is 0.45; 0.5; At 0.55 and temperature t=25 °C, the beginning of setting time was 7 hours 10 minutes to 8 hours 30 minutes and the end was 10 hours to 11 hours 40 minutes. When the temperature of the environment is t=100 °C, the beginning of the setting time is 1 hour 40 minutes to 2 hours 5 minutes, and the end is 5 hours to 5 hours 50 minutes. One of the main indicators of cement stone is its strength and permeability against bending and compression. From this point of view, the resistance of cement stone samples containing 1-6% PEPA against compressive and bending forces was measured. The flexural and compressive strength of cement stone increases with increasing water-cement ratio and temperature. Thus, at a water-cement ratio of 0.45, 0.5 0.55 temperature t=25 °C and a pressure of 0.1 MPa, the strength of cement stone against bending and compression is 4-5.5MPa and 8-9.5 MPa, respectively and when the temperature is t=100 °C, it is 7-9.5 MPa against bending and 25-29 MPa against compression.

0.45 of water-cement ratio; 0.5; At values of 0.55, the permeability of the stone increases relatively, and decreases as the temperature increases. So, the water-cement ratio is 0.45, 0.5 0.55 temperature t=25 °C permeability is $17\text{-}21 \cdot 10^{-2}$ μm2 while at t=100°C it was 10-12.5·10^{-2} μm2. As the amount of PEPA increases, the permeability of cement-polymer stone increases, and as the temperature of the environment increases, the permeability decreases.

At 25 °C, 50 °C and 75 °C, the disintegration pressures of samples made of pure cement with a water-cement ratio of 0.5 were 11.5, 17.4 and 23.4 MPa, respectively, while that of stone made with 4% polymer addition the disintegration pressures were 11.8, 17.8 and 23.8 MPa, respectively. Thus, the strength of cement stone against compression (disintegration) increased to 2.6, 2.3 and 1.7%, respectively, at the specified temperatures. When the sample made of cement was checked for compressive (dispersion) pressure at a temperature of 50 °C, it was determined that the sample disintegrated when the height of the sample decreased by $l - l_1 = 40 - 39 = 1$ mm at a pressure of 17.4 MPa.

When adding 4% PEPA to cement, the stone obtained at a value of 17.8 MPa decreased in height $l - l_2 = 40 - 37 = 3$ mm, and the sample disintegrated. Thus, the elasticity of the stone obtained after 48 hours from the cement 4% PEPA mixture was 3 times more than the cement stone. In this work, the adhesion of the cement stone with the operational casing and the rock was considered. The results of the laboratory studies conducted in order to investigate the adhesion force of the backfill material prepared by adding different amounts of PEPA to the metal are given in figure 2. As can be seen from the figure, the adhesion force increases as the amount of PEPA increases up to 4%, and the adhesion force decreases after 4%. As the temperature of the environment increases, the adhesion force increases up to 75 °C, and at further temperature increases, the adhesion force decreases sharply. So, the amount of PEPA in excess of 4% to 6%, the adhesion force is 2.0-0.4 MPa and 3.5-1.0 MPa between 25 °C and 100 °C, respectively.

One of the main characteristics of stone made by adding 3-4% PEPA to cement is that it is more durable due to its disintegration force. This characteristic is due to the high elasticity of the received plugging stone.

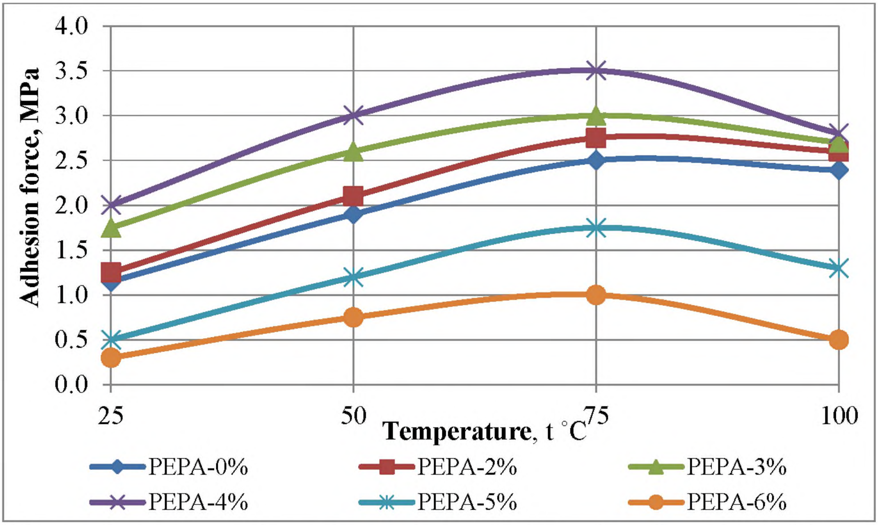

Figure 2. Temperature dependence of the adhesion strength of G-CC-1 cement and stone obtained after 48 hours with PEPA addition to steel rod

As a result of the conducted research, it was determined that the parameters of the solution and cement stone were higher when 3-4% of the required water was added to the cement with a water-cement ratio of 0.5. Therefore, in order to prevent or limit the watercut in the well product, it is necessary to take the components of the backfill solution to be injected into the layer in the following proportions (by weight): cement-100; liquid-cement ratio-0.5; PEPA-3-4%; water-47-46.

The third chapter is devoted to the development of the equipment complex for lifting the sandy liquid to the surface of the operational wells.

In the first paragraph of the third chapter, a combined new structure that provides sand control of the Centrifugal Electric Submersible Pump (CESP) is developed.

Since CESPs are pumps that transport liquid under the influence of centrifugal force as a result of high rotation speed, the effect of the composition of the transported liquid (a mechanical mixture is meant) on the travelling parts of the pump is very large. The stability and life cycle of the pumps depends on the amount of transported mechanical mixture and its granometric and lithological composition. If one takes into account that majority of oil fields in Azerbaijan is made up of poorly consolidated rocks, then we can justify the reasons for the constant development and relevance of the sand control systems of the pumps we are talking about.

The protection of CESP from sand flow is based on the principle of separation of other mechanical particles, including sand, from the composition of the formation product at the upstream of the pump, and the separated particles are bypassed around the CESP and re-mixed with the fluid transported around it in the upper part of the riser (at the outlet of the CESP).

A series pump combination was proposed to solve the problem. A sump pump (SP) or an ejector is connected in series to the CESP, in its upper part. In the lower part of the entrance of the CESP, a sandblaster is placed, which is intended to ensure the separation of sand particles (picture 3).

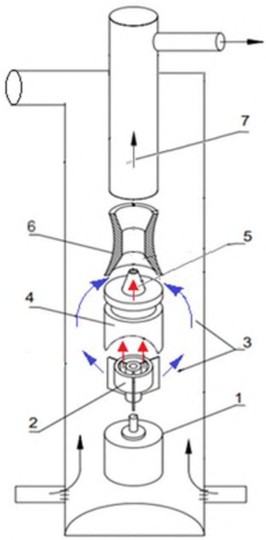

Figure 3. The principle scheme of the structure

The working principle of the developed structure is as follows. When the CESP is activated, the rotor (2) connected to the axis of the motor (1) also starts to rotate. Grains of sand (3) in the liquid filtered from the well receive centrifugal force as a result of the eddy flow and are pushed to the edges. The CESP (4) blows off the sand-cleaned liquid and transfers it under pressure (5) to the SP (sump pump)-ejector (6) and, in addition to starting the SP, provides the energy required for lifting it and the general liquid (7). The ejector (6) simultaneously blows the sand granular mixture (3) passing around the CESP and mixes it with the de-sand liquid (5) to form a total liquid (7). Finally, the sand flow generated at the bottom of the well is transported to the surface without contacting the CESP. Although the principle scheme of the structure seems convenient, it needs to be theoretically and empirically substantiated. The main purpose of the proposed well layout is to minimize the possibility of the CESP being eroded from the sand by preventing physical contact of the working parts of the CESP with the mechanical mixtures.

Since the impeller is directly connected to the CESP, the linear (v_h) or angular velocity (ω_h) generated in the vanes during rotation increases the kinetic energy of the particles ((m_h-mass). The particle moves perpendicular to the axis of rotation (R_k-is the distance from the axis of rotation of the crusher to the particle) towards the inner surface of the casing (v_h-tangentially) due to the centrifugal force. Here, the amount of movement of the particle - P_h depends on its mass and density.

As you can see, the amount of mechanical mixture produced here is of great importance. For the smooth operation of the device, this limit depends on the efficiency of the RP and CESP and the volume of the annular space between the CESP and the operating pipeline.

The developed structure consists of three different hydraulic units, and therefore all three units must work in a certain tandem. It is one of the important issues to determine the parameters that determine this balance for the smooth operation of the well. For this purpose, the requirements imposed on the SP and CESP should be defined. More precisely, sand (q_q), liquid bypassing the CESP ($q_{m.DN.y}$), sum of the mixture transported from the SN ($q_{.ŞN}$), total (q_t),), CESP the conditions between liquid production (q_{DN})) and the total flow to the bottom of the well (q_{qd}) must be maintained, that is, the collection of this combined scheme must be carried out according to the technological and operational parameters of the individual well. Studies have been conducted to model the combined well structure and create a laboratory scheme.

Studying the influence of the density of the concentrated production on the operation of the unit is also an important issue, as it transports a system that is re-mixed with liquid sand or mechanical particles above the outlet of the RP in the developed construction. For this purpose, by changing the density of the ejected liquid, the consumption of the pressure liquid and the ejected liquid was determined. Studies show that despite the 13% increase in the density of the ejected solution, there is no significant change in the optimal operating mode of the combined unit. In other words, the change in the density of the pressure solution, i.e., pure water, mixed with the mechanically compound solution, does not have a noticeable effect on the indicators. So, while the density is 1130 kg/m3 in the mentioned optimal mode (13%), in the other case, the appropriate density is set to 1050 kg/m3 (only 5%). Considering that the obtained results are equivalent to a 4% mixture of quartz sand with fresh water, it can be concluded that the efficiency of the unit depends on the percentage of sand in the stream.

With a centrifugal pump, the unit - the well is started and stabilization of production is ensured. After that, the sandblaster-mixer is started and the process of separation of sand particles by the rotation of the mixer at the pump inlet and acceleration towards the well wall is observed in the glass tube, and the densities of the liquid flowing through the samples taken from different points are measured and compared. Using capacity V2, the amount of sand in the mixture is gradually added and the amount of mechanical mixture is increased to 5%. Thus, as a result of the rotation of the sandblaster, the sand is separated, transferred from around the centrifugal pump to the pump, raised to the "surface", and in the end, the smooth operation of the structure was observed. As mentioned, the experimental tests of the developed well construction were carried out in laboratory conditions. The factors affecting the synchronous operation mode and ejection coefficient of the three different hydraulic units that make up the well scheme as a single system were investigated through the experiments carried out while maintaining the principle dimensions, and the optimal and crisis parameters of the construction were determined.

In the second paragraph of the third chapter, a reversible depth pump was developed for the operation of deep wells with sand problem.

The need to transfer the offshore wells of our country to the mechanical operation method and the layers lying deeper make the development of new generation pumps urgent. For this purpose, a reversible (two-way) pump unit (RPU) was developed.

The working principle of RPUs is based on the reversible movement of double plungers due to hydraulic power (Fig. 4). The RPU consists of a reversible pump (RP), a hydraulic power distribution system and an electric motor.

The hydraulic power distribution system is an internal (closed, not connected to the external environment) system consisting of an axial-piston pump (2), 2 hydraulic power distribution boxes (3, 4), a reverse mechanism (5) and a push mechanism (6). Its function is to transfer the rotary motion of the electric motor to the RP by converting it into a rectilinear-reversible motion.

Axial-piston pump has a simple working principle. Rotational motion is transmitted to its shaft by an electric motor. The shaft rotates the rotor, driving the pistons on the inclined disk. The pistons move between the bottom dead center and the top dead center, performing the blowing and pumping operation. The working principle of the RPU power distribution system is as follows. Under the pressure of the axial-piston pump (2), the hydraulic fluid passes through the first-stage hydraulic distribution (3) and the second-stage

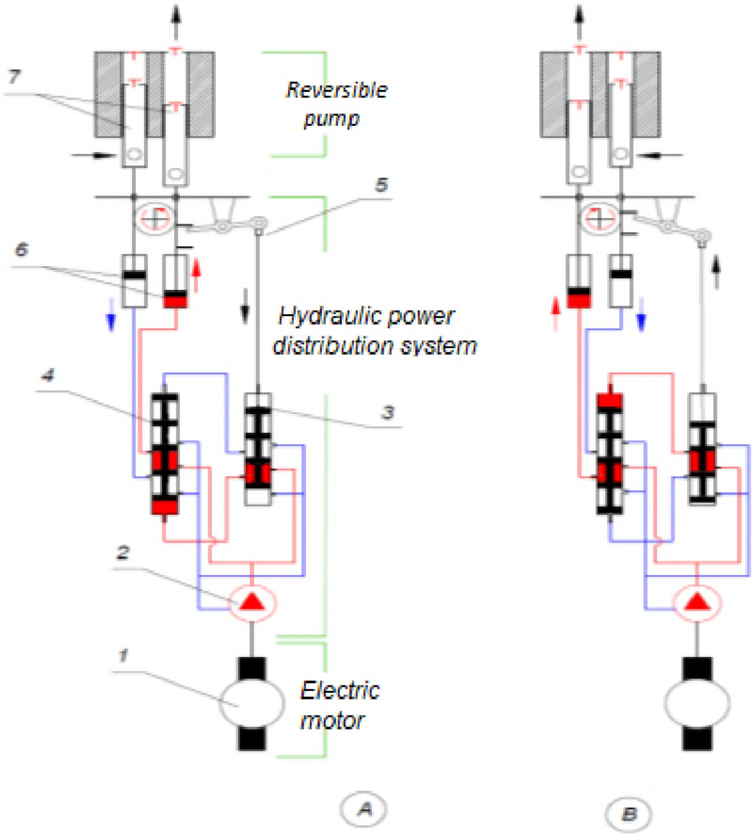

Figure 4. Reversible depth (plunger) pump device scheme

hydraulic distribution boxes (4) (red line in the figure) under the influence of the force of pushing the piston (6) of the corresponding cylinder of the RP above the bottom dead center moves to dead center (Fig. 5, A). At this time, the corresponding plunger (7) of the RP repeats the same movement together with the piston. This action continues until the reverse (5) is engaged. As soon as reverse is engaged, the axis of the first stage hydraulic distribution box (3) shifts and transfers part of the pressure fluid to the other side of the second stage hydraulic distribution box (4), and the axis of the second stage hydraulic distribution box is also displaced. The pressure fluid is directed to the other cylinder (6) of the RP and the opposite process takes place (Fig. 5, B). Thus, the independent reversive movement of the plungers (7) continues until the power is cut off. Distinctive features of the developed device are the short travel path of the plungers and the fact that the number of plungers and the actuation mechanism are not the same.

In order to study the mechanism of the device, a laboratory model was developed and experiments were conducted on the model. The following results were obtained from the experiment conducted on the test model:

• Plungers will ensure continuity of liquid transport by reversibly moving;

• The logical value of the dynamogram curve of a plunger consists of "1" and "0" - a rectangle.

• At the moment of transfer of movement from one plunger to the other, the flow movement is instantaneously reset, but the total curves can be considered as "1" set if small gaps (hereafter error) are not taken into account. The duration of the error is taken to be a very small quantity compared to the time spent on the useful travel path of the plungers. Therefore, the continuous movement of the liquid can be taken as a steady state.

• It is possible to study the operation of the pumps by adjusting the load (current intensity) of the electric motor and the pressure of the pump (RP). With this, the malfunctions in the suction and injection valves of the Reversible pump, the power distribution system failure, the loss of electricity, etc. it is possible to detect such negative cases. Mathematical researches show that the flow of liquid percolated through the formation is interrupted during operation. Since the movement of the liquid entering the pump forms a "cycle", the dynamic level changes in the space behind the pipe. As a result, small-amplitude high-frequency oscillations occur in the well. Due to the effect of high-frequency oscillations of small amplitude, rocks are scattered in the area around the well bottom. Thus, conditions are created to bring sand particles with the flow to the well. Due to the cyclic interruption of the flow, extreme loads on the equipment - static, inertia, vibration, etc. the price and the risk of its failure increases.

In used pumps of this type, the movement of the liquid is almost continuous and is considered a fixed movement. Therefore, the possibility of sand coming from the formation and other complications is reduced. According to calculations, it is possible to launch this pumping unit to a depth of 3500-4000 m.

In the fourth chapter, field tests of the developed technologies are given.

In the first paragraph of the fourth chapter, the results of field tests of the technology of fixing the well bottom zone with the influence of physical fields are shown.

Wells No. 1300, 1073, 1344 and 2396 were selected from the operating stock of the "Oil Rocks" field for testing the developed process. The operational indicators of each well were investigated.

After the introduction of the developed technology, 326 tons of oil were produced in addition to the wells, and TAM increased by 2.0-2.5 times.

In the second paragraph of the fourth chapter, the results of field tests of the technology of fixing the well bottom zone with cement-PEPA-water backfill mass are shown.

Wells 2306 and 2182 were selected from the operating stock of the "Oil Rocks" field for testing the developed process.

After the application of the developed technology, 236 tons of oil were produced from the wells, and 440 m3 of formation water was less produced. TAM has increased by 2.2-2.7 times.

Thus, after the application of advanced technologies, 562 tons of oil were produced from the wells, and 440 m3 of formation water was less produced. TAM has increased by 2.0-2.7 times.

OUTCOME AND PROPOSALS

1. The technology of fixing wellbottom zone, which allows to create a permeable barrier in wellbottom zone under the influence of physical fields, has been developed.

2. On the basis of experimental studies, it was determined that the presence of magnetite particles in the backfill solution and its passage through a magnetic field causes a 15-20% increase in setting the cement stone. Maximum strength is achieved at a concentration of 5-7% of magnetite particles.

3. Water flow shut-off technology was developed using polyethylene polyamine in backfill solution. The obtained cement stone has elastic properties and has a long life.

4. During experimental studies, it was determined that the optimal composition is obtained when 3-4% of polyethylene polyamine is added to the backfill solution. Addition of the component in the specified amount increases the strength of the cement stone, improves its adhesion properties and strengthens its resistance to depressions. So, the amount of polyethylene polyaminšt from 4% to 6%, the adhesion force is 2-0.4 MPa and 3.5-1.0 MPa, respectively, between 25 °C and 100 °C.

5. A new combined pump structure has been developed that provides sand protection for the Electric Submersible Pump. In this design, the mechanical mixtures are separated from the product at the intake of the centrifugal electric submersible pump, and the pump is blown into the compressor tube.

6. A reversible pump device was developed for the operation of deep wells with sand. Reversinle pump unit is planned provided that its outer diameter does not exceed 90 mm. Reports indicate that this pump unit can be run down to the depths of up to 3500-4000m and in directional wells.

7. After the application of developed technologies, 562 tons of oil were produced from the wells, 440 m3 of formation water was less produced. The period between overhauls has increased by 2.0-2.7 times.

Main content of dissertation reflected in the following works:

1. Ahmed, F.F., Bayramov, E.E. Restoration of the structure of cement stone in the process of fixing downhole zone in sand producing well. Materials of the International scientific and practical conference "Modern methods of field development with hard-to-recover reserves and unconventional reservoirs", Atrau, September 5-6, 2019. Volume I, p. 339-342.

2. Ahmad, F.F., Hamidov, N.N., Bayramov, E.E. Evaluation of elastic-solid properties of cement stone in the processes of separation of formation waters. Scientific Works of "Geotechnological Problems of Oil, Gas and Chemistry" Scientific Research Institute, Baku, 2019, volume XIX, p. 93-100.

3. Ahmed, F.F., Gamidov, N.N. Bayramov, E.E. Innovative technology for preventing rock destruction in the downhole zone of the layer. Materials of the IV International scientific-practical conference "Bulatovskie chtenia", Krasnodar, March 31, 2020, Collection of articles, Volume 2, p. 58-60.

4. Bairamov, E.E. Regulating the extraction of associated water using technological limitations of water inflows. Materials of the IV International scientific-practical conference "Bulatovskie chtenia", Krasnodar, March 31, 2020, Collection of articles, Volume 2, p. 64-68.

5. Bairamov, E.E. The technology of fixing the downhole zone of sand producing wells. Neftepromyslovoe delo, Moscow, 2021, No. 8(632), p. 27-29.

6. Bayramov, E.E. Deep-pump installation for the development of oil wells. Collection of theses reports of the International Scientific Conference «Innovative technologies in the oil and gas industry. Experience of implementation and development prospects», Kazakhstan, Atrau, November 19, 2021, p. 33.

7. Bayramov, E.E. Reversible pump unit for operation of deep wells with sand ingress. Azerbaijan Oil Industry, 2021, No. 10, p. 21-23.

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11. Bayramov, E.E. Reversible deep well pump. Materials of the International conference "Innovative approaches to the development of an educational-production cluster in the oil and gas industry". Tashkent, April 30, 2022, volume 2, p. 303-304.

<u>The personal contribution of the author:</u>

[4, 5, 6, 7, 8, 10, 11] works were independently performed;

[1, 2, 3, 9] participated in setting the problem, conducting laboratory research and analyzing the results.

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