ISSN 2959-8311 (print)
ISSN 3006-1733 (online)

ТЕХНИКА ҒЫЛЫМДАРЫ ЖӘНЕ ТЕХНОЛОГИЯ

№ 2 (06), 2024

2023 жылдан бастап шығады
Выходит с 2023 года
Founded in 2023

Жылына төрт рет шығады
Выходит четыре раза в год
Published four times a year

Қызылорда/Кызылорда/Kyzylorda
2024

Баспа атауы – «Қорқыт Ата атындағы Қызылорда университеті»
Баспа адресі – индекс 120014, Әйтеке би, 29А, Қызылорда қ., Қазақстан Республикасы

Наименование издателя – «Кызылординский университет имени Коркыт Ата»
Адрес издателя – индекс. 120014, ул Айтеке би, 29А, г.Кызылорда, Республика Казахстан

Name of the publisher – «Kyzylorda university named after Korkyt Ata»
The publisher's address is an index. 120014, Aiteke bi street, 29A, Kyzylorda, Republic of Kazakhstan

SRSTI 622.276.5 https://doi.org/10.52081/tst.2024.v02.i6.033

IMPROVING THE ROD WELL PUMP FOR PRODUCTION OF WATERED OIL FROM DEEP WELLS

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Annotation. At present, the main part of the total reserves of oil fields in Kazakhstan is conducted using rod well pump installations. In the experience of using rod well pumping units, there is a problem of failure of the rod string in the form of breakage and rupture, given that medium-high water production in well production significantly increases corrosion processes and applied loads.

Metal corrosion occurs in almost all cases where metal comes into contact with a corrosive environment, in particular with mineralized water, and the metal, depending on the degree and nature of the loading, is subject to fatigue failure, leading to deformation or destruction of structural products (rods, platforms, pipelines, etc.). When operating sucker rod pumping units, especially when the water cut of well production is more than 80%, the rod column is subject to the combined effect of corrosion processes and increased alternating loads, which leads to corrosion fatigue of the metal.

This article discusses methods for analyzing and optimizing the method of oil production using sucker rod pumping units. Methods used to prevent corrosion of metal structures under the influence of mineralized water are shown.

Keywords: rod well pump installations, oil production, pumping units, corrosion processes, rod string, metal structures.

Introduction. Under conditions of water pressure, the formation of high-water oil in wells is an inevitable process during the exploitation of oil fields. For oil fields with high viscosity, the life of a waterless well will be shorter. At the stage of water exploitation, a huge amount of water is extracted from wells and fields along with oil, which is the stage of development of high-viscosity oil fields. From the moment water appears in the wells, the main difficulties in their work begin. Wells stop flowing, water falls to the bottom, well productivity changes, paraffin and salt deposits increase, equipment corrosion and a number of other conditions complicate the operation of wells.

Oil and gas exploration and development are differentfrom similar work on the ground with high cost and complexity. The complex of technical equipment for the development of oil and gas fields consists of the followinga large number of unique and expensive hydraulic types and typesstructures, drilling and oilfield equipment, communication systems, navigation and environmental protection. High rates of oil production by waterflooding in oil fields and the geological and geophysical features of the structure of productive formations lead to intense and rapid watering of the produced wells long before the potential level of oil production is reached.

The main reasons for water flooding of production wells are:

- violation of the tightness of the production string;
- the flow of water through the leaky annular space from above or underlying aquifers;
- pulling up the cone of plantar water;
- supply of circuit or injection water;
- water flow through cracks;
- technogenic factors.

Leakage of threaded joints, corrosion, electrical burns, mechanical damage to pipelines during repair work, and other disruptions in well support above the productive perforation interval can lead to premature oil flooding due to production line leaks, exposure to groundwater-bearing formation (Figure 1).

If water enters the well, firstly, energy costs are raised to remove extraneous water from the well. Secondly, this water penetrates into the productive formation, impairs the flow of oil from the productive formation, and reduces the phase permeability of oil.

That's why limit the ingress of water into wells, it is necessary to start with providing support and high-quality isolation of productive formations during the construction of wells. When the quality of formation isolation is low, the sealing of the cement casing in the annulus is broken, water flows through the casing from above or below the aquifers between the perforations [1].

Materials and methods of research. The rod unit is designed to lift formation fluid from the well to the surface. With their help, about 60% of the country's oil is produced.

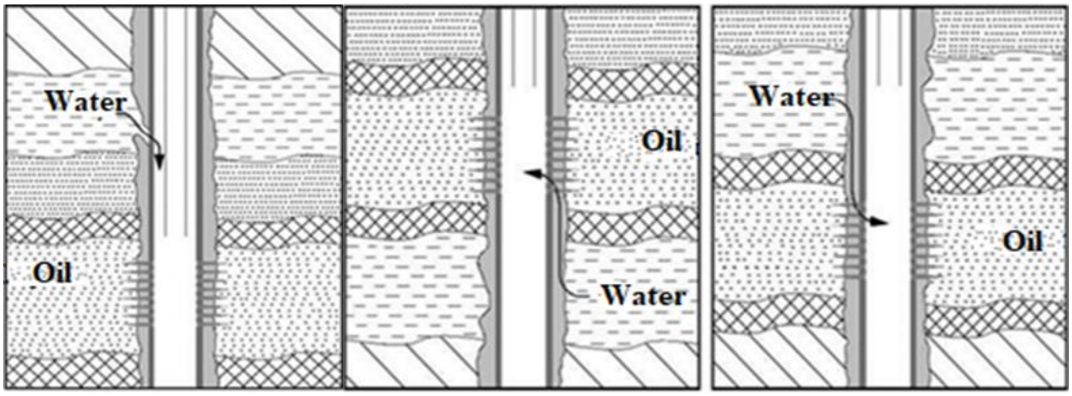

Figure 1 – Well wetting due to damage to the production coating

The design of the device consists of two parts. It consists of a rod pump with an underground pump valve and a discharge valve at the upper end of the plunger piston, a pump stem and a pipe. Also, underground elements may include gas and sand anchors, bodies.

Currently, a rod installation is usually used in wells with an average suspension depth of 1000...1500 m with a flow rate of 30-50 m^3 of liquid per day. In shallow wells, the installation provides liquid supply up to 200 m^3/day. In some cases, slurry pumping can be used at depths of up to 3000 m [2].

The development of production for the use of deep wells is developing due to the constant improvement of the strength characteristics of pump rods and pipes, increasing the accuracy and wear resistance of the surfaces of plungers and pump cylinders, updating its valves, and increasing lifting force, power, as well as improving the surface drive (oscillating machine) and kinematics. The main difficulties that arise during the work are: high gas content in the product, sand impurities in the product, presence of paraffin and corrosion. Intensive work was carried out on the production and equipping of borehole pumps with special mechanisms that ensure correct operation. One of the weakest elements of the unit's design is the rod column, which provides the return movement from the pump drive to the plunger pair. It was found that 35-40% of the causes of failure of the unit are related to the pump rod column. Analyzing the causes of defects, we found out that the main cause of failure is the breaking and destruction of columns. It can be shown the operation of a chain of sucker rods in curved wells under conditions of increased variable loads under the influence of bending moments.

Fatigue failure of rods begins with the formation of microcracks above steel. In addition, the destruction of the rod is accelerated by alternating loads, an active aggressive environment and the presence of stress concentrators. Therefore, the influence of loads on the rods in this case plays an important role.

Load types:

1. Low-cycle loading occurs at maximum stresses exceeding the yield strength of the material and resulting from plastic deformation of the volume of the material. The number of lower cycles (0.5-1 mm or more in length) according to the group crack, the amount of plastic deformation of the material and its ability to resist fracture. An example of a low-cycle failure is the failure of a wire due to bending and kinking [3].

2. High cyclicity is observed at stresses significantly lower than the permeability limit ($\sigma_{max}< 0.6_{\sigma}T$ and below). In this case, in the macrovolume, the material of the product is elastically deformed (its properties are very accurately described by Hooke's law $\sigma = E \cdot \varepsilon$, Figure 2).

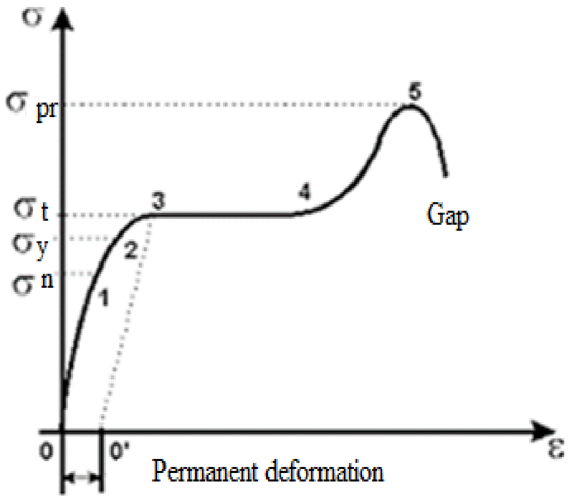

Figure 2 – Hooke Law

During elastic deformation, significant local plastic deformation occurs, called microplasticity. Repeating it several times brought of microscopic cracks. Their gradual development and melting leads to weakening of the material, and then to sudden fragility of the product in the danger zone. The duration of the high-cycle fatigue period for steel structural materials exceeds 10^5-10^6 cycles, for composite materials - more than 10^6 cycles (table 1). In addition, screw breakage involved tightening torque of the screws when lowering the rods into the well. For rods with diameters of 16, 19, 22 and 25 mm, the optimal torque is 0.3; 0.5, respectively 0.7 and 1.05 kH*m. As shown above, the main reasons for failure of rods are fatigue failure (Figure 3).

Figure 3 – Destruction of a sucker rod pump

The downstream part of the pump rod parts, made of carbon and low alloy steel, is subject to corrosion in high water oil production conditions. However, the main reason for the decrease in strength of this type of pump is corrosion-fatigue damage and abrasive fracture of ball valve joints.

Table 1 – Bar chain chart

Amount of water, %	0–11	11–31	31–51	51–71	71–91
Well volume	3	2	3	14	28
Bar machine hours, $x10^6$	5,31	2,40	0,76	0,72	0,67

Oil contains hydrogen sulfide. At the stage of oil production, hydrogen sulfide occurs mainly in the accompanying gas. These corrosive disorders - replace rod pumps 8-9 times a year, and their valves 16-17 times a year. It is possible to prevent the destruction of oil equipment in contact with H_2S, and to extend the service life of oil equipment, by performing complex works. The main thing is to make oil equipment from materials resistant to hydrogen sulfide. It is necessary to pay attention to such materials from a technological point of view, and then from an economic point of view, and in the other direction - to obtain insulating substances and anti-corrosion substances that can increase the average working time of the working equipment (Figure 4).

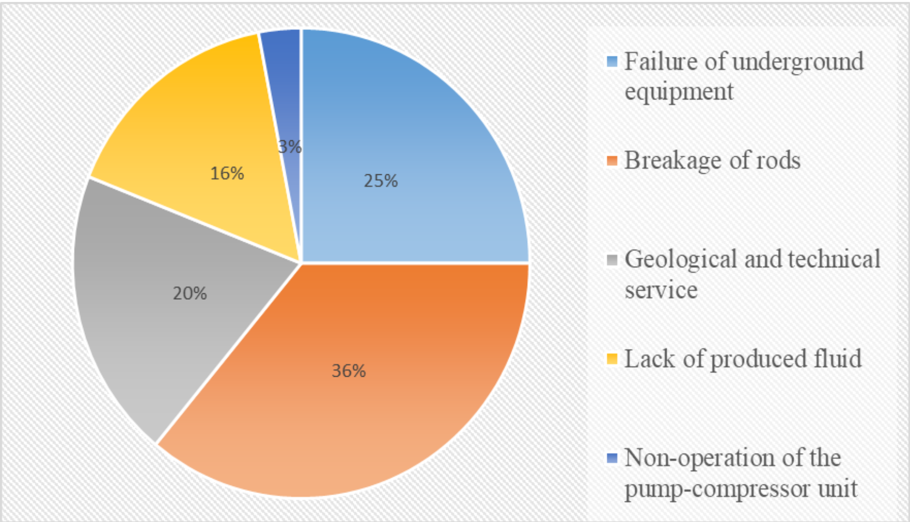

Figure 4 – Reasons for frequent malfunctions

In addition, in the event of the onset of corrosion, the normalization of sulfate, that is, the fight against bacteria and suppression of their growth, is the best thing this set of works.

Based on the experiments, in order to study in detail the difficult of electro - chemical corrosion of metals, the factors contributing to this corrosion were analyzed and similar works were analyzed using rod pump units. As a similar example, the electrochemical corrosion of offshore platforms and ships due to exposure to seawater saturated with chlorine ions has been compared to the mineralized water of a rod string operating in the wellhead region and contact with formation water [4]. Corrosion is very difficult to combat when working in the construction and marine industries. The most well-known type of corrosion is also the easiest to detect and prevent. Cases where general corrosion leads to catastrophic consequences, although rare, do occur. For this reason, general corrosion is often considered cosmetic rather than a serious problem. General corrosion spreads over the metal surface relatively evenly. When calculating pressure ratings, it is necessary to take into account the gradual decrease in the wall thickness of the component (Figure 5).

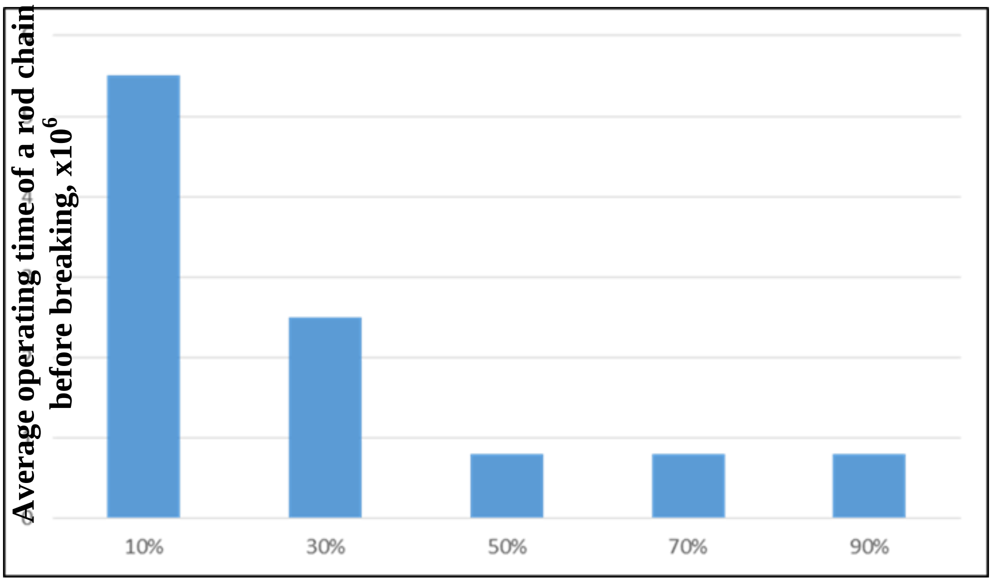

Figure 5 – Average working time in oil production

Nature of destruction, based on this feature, the following types of corrosion are distinguished:

- Solid – uniform or uneven. Affects evenly the entire surface of a metal product or structur;
- Local. Specific areas of the surface are affected;
- Pitting corrosion (spotting). Lesions - isolated, deep or through;
- Intercrystalline. Failure areas are located along grain boundaries.

The main types of corrosion are divided into two types:

Gas corrosion occurs in aggressive gas and steam environments in the absence of condensed moisture on the surface of a metal product or metal structure. It can cause complete destruction of iron and alloys based on it. A protective film is formed on the surface of aluminum and aluminum alloys in gas environments, protecting them from corrosion. Examples of gases that cause chemical corrosion processes: oxygen, sulfur dioxide, hydrogen sulfide. Liquid corrosion occurs when a metal surface comes into contact with liquid non-electrolytes - oil and petroleum products [5,6]. In the presence of even a small amount of water, this chemical process easily turns into an electrochemical one (Figure 6). Protective packaging (coating) types.

To protect structural supports operating in a wet humid place from corrosion, it should be possible to apply protective paints and varnishes to the wet surface. Polypropylene, industrial oil, modified polyethylene and bitumen-based elements were used to protect this area from corrosion. Lacquer paint is used on the basis of styrene and oil-polymer rectification residue. Enamels of different colors were made in the form of given varnish. To improve the cathodic polarization of steel, it was also possible to increase the area of the cathodic current distribution, using zinc-rich paints as a primer in wet water and underwater. To protect steel from corrosion and other harmful substances, metal zinc and aluminum coatings applied to steel in various ways have been developed [7].

You can protect metal products by taking timely measures to protect the metal surface from unwanted contacts with the environment. This greatly contributes to extending the service life of structures.

At the moment, a large number of different methods have been developed to protect metals from oxidation. Industrial, building metal structures, vehicles are protected using industrial methods. This is costly and quite difficult. In everyday life, methods are used that are simpler in technology and more affordable.

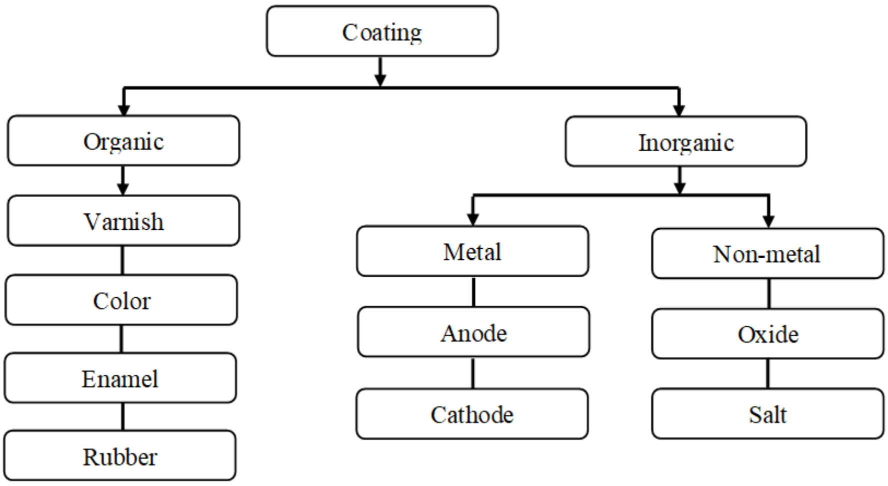

Figure 6 – Types of protective coatings

Corrosion resistance largely depends on the nature of the metal, the ambient temperature, and its type. Well equipment according to the degree of wear and tear:

1. The average working time of cores and columns does not exceed 20 percent of the total volume of the well circuit. This category includes corroded wells with less useful life of equipment subject to depreciation. The time of failure in these wells is less than 1 mm per year.
2. During the average annual replacement of the core and columns, no more than 20-50% of the entire length of the well-column, the failure time is about 1.0-1.25 mm/year.
3. It is provided by wells with permanent damage, the average annual replaceability of core and column is more than 50%. The time of destruction processes in these wells is 2-3 mm per year.

If we take experiments to determine the rate of corrosion, during the inspection of the condition of the pipes, the drilling rig was raised to replace the bit, and it was shown what the level of the drilling fluid in the well had dropped by 70-100 m. Determining the failure time of the steel in the drilling fluid was by maximum immersion in the solution and isolating the upper part of the atmospheric oxygen. Because the samples immersed in the drilling fluid were removed periodically about every 15 minutes and hung above the vessel to saturate the casing of the drilling fluid with oxygen. Experience has shown that the failure time of steel samples constantly immersed in drilling fluid is 0.014 g/m^2*h, and the failure time of steel samples periodically removed from the solution is 0.040 g/m^2*h. So, during periodic oxygen enrichment of steel surface wetted with drilling fluid, the time of failure increased by 3 times [8]. Conducted inspections showed that the drilling fluid level decreased in the annular space between the technical and protective casing, and the electrochemical operation of the damage on the surfaceof the pipes was caused by oxygen. The corrosion rate formula [9]:

$$K = \frac{1.12 * (P_1 - P_2)}{S * t}$$

where P_1 is the mass of the plate before testing, g; P_2 is the mass of the plate after testing, g; S – plate area, cm^2; t - experiment time, hour. It consists in determining the mass loss of the metal samples under study per unit time.

External factors of electrochemical breakdown include speed of movement of aggressive medium, temperature, polarization with external wire, pressure and others. Pitting consists of the formation of small lesions or spots on the surface of the material. Corrosion can be detected by careful visual inspection, but it can spread deeper before a hole appears in the pipe wall. Pits are more common in environments with high chlorides at high temperatures.

When the protective oxide layer (or passive oxide layer) on the surface is broken, the metal tends to lose electrons [9]. This leads to the following: the iron in the metal goes into a solution with a more anodic low point, and also oxidizes with the formation of iron oxide or rust. The concentration of ferric chloride solution at one point may increase as the excavation deepens. These changes lead to rapid deepening of the point, perforation of the tube walls and the formation of leakage.

In a liquid or gas system, there are spaces between supports or clamps and pipes, between adjacent pipes, and under layers of dirt and sediment that can accumulate on surfaces. Cracks in pipeline structures are almost impossible to avoid, and narrow cracks pose the greatest risk of corrosion.

Like pitting, crevice corrosion occurs when the passivated oxide layer that protects the metal is damaged. As a result of this violation, small point lesions appear. Actual corrosion grows and deepens until it spreads throughout the crack.

In some places, holes may appear in the walls of the tubes. Crevice corrosion occurs at significantly lower temperatures than pitting corrosion [10, 11].

The danger of stress corrosion cracking is that it can cause component failure at stress levels below the yield strength of the alloy. Austenitic stainless steels are prone to stress corrosion cracking in the presence of chloride ions. The ions interact with the material at the top of the crack, where the tensile stresses are highest, creating favorable conditions for crack growth. This phenomenon can be difficult to detect and the final extinction can occur suddenly.

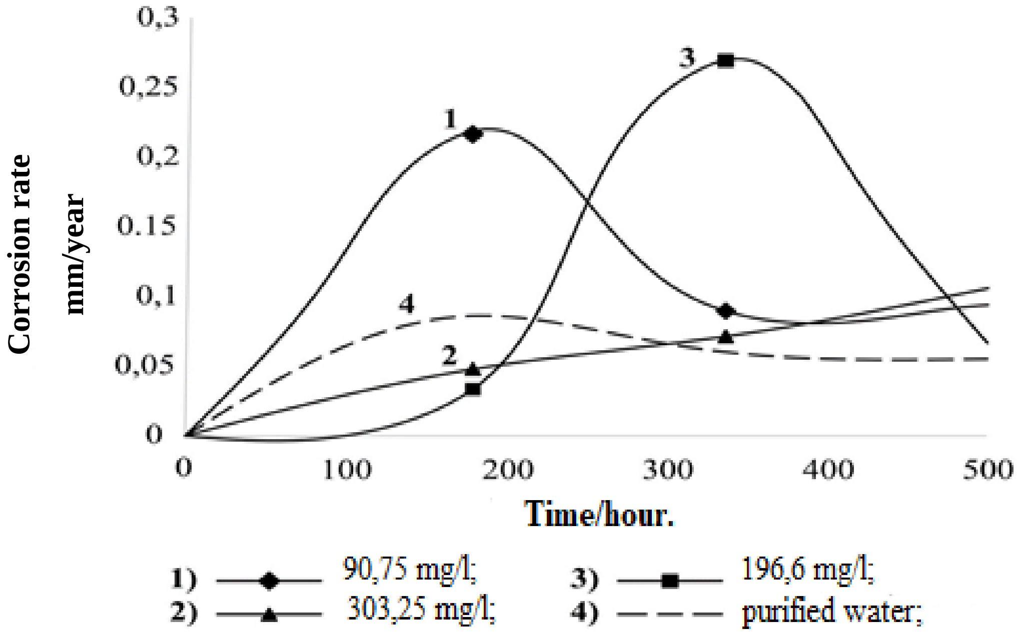

Figure 7 – Corrosion rate

The main purpose of metal coating is to protect the surface of the material from corrosion and increase the durability of the final product. There are various methods for obtaining metal coating; In this article, we have discussed important approaches. Selecting the appropriate coating process depends on the type of material, required characteristics, economics, analysis and many other factors [12]. Therefore, this process may be difficult for you. When a galvanic couple is formed, the low-potential zinc coating acts across the anode and protects the base metal from damage such as corrosion.

The following types of sucker rod pumps can be improved:

1. Constructive. They consist of protecting the metal surface with the help of non-thin-layer coatings - panels, rubber gaskets, barriers. These methods have few advantages: they are difficult and sometimes impossible to implement, materials for structural protection are expensive and take up a lot of space after installation. They are used infrequently and only in places where they are hidden from view.

2. Passive. A thin-layer coating is applied to the metal product, which performs purely barrier characteristics, that is, the protection process consists of preventing contact of the metal with the external environment. For a passive method of protection, non-metallic coatings are used - primers, varnishes, paints, enamels. After drying, they form a durable and hard film that has good adhesion to the base.

The advantages of the passive method: low price and convenient application of coatings, a wide range of compositions of different colors and characteristics, creation of a reliable barrier between the metal and the environment. Disadvantages: low resistance to mechanical damage, the need to periodically update the barrier layer.

3. Active. The most common way to create active protection for a steel surface is galvanizing (hot, thermal diffusion, galvanic, cold). The first three technologies are feasible only in production conditions. Hot-dip galvanizing is most often used. Rolled steel sheets are galvanized on continuous lines. The advantages of this process: the ability to obtain a zinc layer of sufficient thickness, high automation and productivity of the process [13].

Conclusion. In the processstudying the work of electrochemical breakdown of metals in detail and analyzing the factors contributing to these breakdowns, we conducted an analysis of works similar to the use of column pump installations. During the calculation improvements in offshore production, several models for improving oil well equipment have been identified. Among them we can mention special austenitic stainless steels and chromium-nickel steels. During storage of equipment, an analysis of electrochemical protection and specially designed packaging was carried out.

It has been determined that work to improve sucker rod pumps will be masking with hot spraying, as well as by using metal and non-metallic casings. The use of a metallic coating increases the surface hardness of the pump rod and improves its adaptation to the environment, while the non-metallic coating increases corrosion resistance at a low specific gravity. In general, when developing any oil equipment, firstly, advisableits efficiency from both sides, and secondly, to extend the service life of working equipment, it is should to take materials and anti-corrosion equipment not individually, but in an integrated manner.

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ЖОҒАРЫ СУЛЫ МҰНАЙ ҰҢҒЫМАСЫНДАҒЫ ШТАНГАЛЫҚ ҰҢҒЫМАЛЫ СОРАП ҚОНДЫРҒЫСЫН ЖЕТІЛДІРУ

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Аңдатпа. Қазіргі уақытта Қазақстандағы мұнай кен орындарының жалпы қорының негізгі бөлігі игерудің соңғы сатысындағы штангалы ұңғымалы сорап қондырғыларын (ШҰСҚ) пайдалану арқылы жүргізіледі. Штангалы ұңғымалы сорап қондырғыларын пайдалану тәжірибесінде, ұңғымаларды өндірудегі орташа-жоғары сулы мұнай өндіру, коррозия процестері мен әсер ететін жүктемелерді айтарлықтай арттыратынын ескерсек, сыну және үзілу түріндегі штанга тізбегінің істен шығуы мәселесі бүгінгі күні де өзекті екенін көрсетті.

Металдың тоттануы іс жүзінде металл тоттану ортасымен, атап айтқанда минералданған сумен жанасатын барлық жағдайларда болады, бұл ретте металл жүктеу дәрежесі мен сипатына қарай конструкциялық бұйымдардың (штангалар, платформалар, құбырлар және т.б.) деформациясына немесе бұзылуына әкеліп, тозып қирауға ұшыратады.

Штангалы ұңғымалы сорап қондырғыларын пайдалану кезінде, әсіресе ұңғыма өнімінің суы 80%-дан жоғары болғанда, штанга тізбегі коррозиялық процестердің біріккен әсеріне ұшырайды және металдың коррозиялық шаршауына әкеліп, ауыспалы жүктемелерді арттырады. Бұл мақалада сорап қондырғыларын пайдалана отырып, мұнай өндіру әдісіне талдау жасалған және оңтайландыру әдістері қарастырылған. Металл конструкцияларының минералданған судың әсерінен коррозияға ұшырауын болдырмау үшін қолданылатын әдістер көрсетілген.

Тірек сөздер: ұңғыма, мұнай кен орны, сорап қондырғылары, коррозия процестері, штанга тізбегі, металл конструкциялары.

СОВЕРШЕНСТВОВАНИЕ ШТАНГОВОГО СКВАЖИННОГО НАСОСА ДЛЯ ДОБЫЧИ ОБВОДНЕННОЙ НЕФТИ ИЗ ГЛУБОКИХ СКВАЖИН

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Аннотация. На данный момент основная часть общих запасов скважинных нефтяных месторождений Казахстана отрабатывается с использованием штанговый скважинный насосный оборудований. В опыте использовании насосных агрегатов показано, что проблема выхода из строя штанговой цепи в виде обрыва и разрыва актуальна и в настоящее время, учитывая, что добыча средне-высоководной нефти при эксплуатации скважин существенно увеличивает коррозионные процессы и приложенные нагрузки.

Коррозия металла происходит практически во всех случаях, где металл контактирует с коррозионной средой, в частности с минерализованной водой, при этом металл в зависимости от степени и характера нагружения подвергается усталостному разрушению, приводящему к деформации либо разрушению конструкционных изделий (штанги, платформы, трубопроводы и т.д.). При эксплуатации штанговых глубинных насосных установок, особенно когда обводненность продукции скважин больше 80%, колонна штанг подвергается совокупному действию коррозионных процессов и повышенных знакопеременных нагрузок, что приводит к коррозионной усталости металла. В данной статье рассмотрены методы анализа и оптимизации способа добычи нефти с использованием ШСНУ. Показаны методы, применяемые для предотвращения коррозии металлических конструкций под воздействием минерализованной воды.

Ключевые слова: скважины, нефтяное месторождение, насосные установки, коррозионные процессы, стержневая цепь, металлоконструкции.

МРНТИ 532.613.5 https://doi.org/10.52081/tst.2024.v02.i6.034

ОСНОВНЫЕ КОНЦЕПЦИИ МОДЕЛИРОВАНИЯ МЕЖФАЗНОЙ КОНВЕКЦИИ

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Аннотация. В статье изложены ключевые современные концепции моделирования межфазной конвекции, вызванной явлениями Марангони или Бенарда. Данная проблема чрезвычайно важна с точки зрения поиска энергосберегающих способов интенсификации процессов тепломассообмена в промышленных устройствах. В статье кратко описан механизм спонтанной межфазной конвекции, а также предложен инновационный подход к разработке математической модели этого явления. В результате получено соотношение для расчета числа Нуссельта с учетом межфазной конвекции, а также коэффициента ускорения массопереноса, обусловленного этим явлением. В работе рассматривается актуальная проблема поиска энергосберегающих методов интенсификации процессов тепло- и массопереноса, имеющая большое значение для различных отраслей промышленности. Предложен инновационный подход к моделированию межфазной конвекции, основанный на использовании характерных размеров циркуляционных ячеек. Полученные соотношения для расчета числа Нуссельта и коэффициента ускорения массопереноса могут быть использованы для оптимизации конструкции и режимов работы промышленных устройств, где происходит межфазная конвекция. В работе используются методы гидродинамики, теории массопереноса и математического моделирования. В результате исследования получены новые соотношения для расчета числа Нуссельта и коэффициента ускорения массопереноса, которые учитывают влияние межфазной конвекции.

Ключевые слова: эффект Марангони, конвекция Бенарда, межфазные явления, тепломассоперенос, спонтанная конвекция, сверхкритичность, коэффициент ускорения переноса, конвективные ячейки.

Введение. Явление межфазной конвекции давно привлекает внимание исследователей, т.к. открывает пути существенной интенсификации процессов тепло- и массопереноса без больших дополнительных энергетических затрат. Такая интенсификация возможна при возникновении спонтанной межфазной конвекции. Спонтанная межфазная конвекция может возникать и развиваться вблизи свободной поверхности раздела жидкой и газовой, либо двух несмешивающихся жидких фаз, вследствие поверхностной межфазной нестабильности. Причиной межфазной нестабильности может, в свою очередь, стать зависимость коэффициента поверхностного натяжения от температуры и концентрации, что приводит к градиентам поверхностного натяжения на свободной поверхности раздела сплошных фаз.

Градиенты поверхностного напряжения создают касательные напряжения на межфазной поверхности. Касательные напряжения стимулируют развитие межфазной неустойчивости, приводящей к возмущению свободной поверхности, в результате чего в близких к этой поверхности областях в глубине слоев сплошной среды возникают конвективные гидродинамические структуры.

Появление и дальнейшее развитие подобных структур ведет к интенсивному обновлению межфазной поверхности и, как следствие, к возрастанию интенсивности межфазного переноса при сохраняющихся значениях средней движущей силы процесса тепло- и массообмена и средней величины удельной межфазной поверхности. Это явление получило название спонтанной межфазной конвекции.

Оно сопровождается появлением эрупций, конвективных ячеек, поверхностных волн, т.е. явной нестабильностью поверхности раздела фаз. Интенсивное перемешивание в приповерхностных слоях сплошных фаз и является основным физическим фактором интенсификации процессов переноса тепла и массы.

Принципиальной особенностью массопередачи в условиях спонтанной межфазной конвекции является зависимость коэффициента массопереноса от движущей силы. Эту зависимость можно учесть, используя критерии межфазной нестабильности в полуэмпирических моделях массо- и теплопереноса в условиях спонтанной межфазной конвекции [1-3].

Взаимное влияние диффузионных потоков тепла и массы с учетом вынужденной конвекции описывается в полном виде на основе принципов неравновесной термодинамики. Однако, полное описание приводит к появлению множества контрольных параметров, теоретическое определение которых сталкивается с принципиальными физико-теоретическими и математическими трудностями.

Поэтому с инженерной точки зрения оптимальным можно считать подход, основанный на создании упрощенных математических моделей с последующим их анализом, компьютерным экспериментом и разработкой критериальных зависимостей, подлежащих последующей экспериментальной коррекции.

Спонтанную межфазную конвекция возникает в виде совокупности конвективных ячеек вблизи поверхности раздела фаз (рисунок 1).

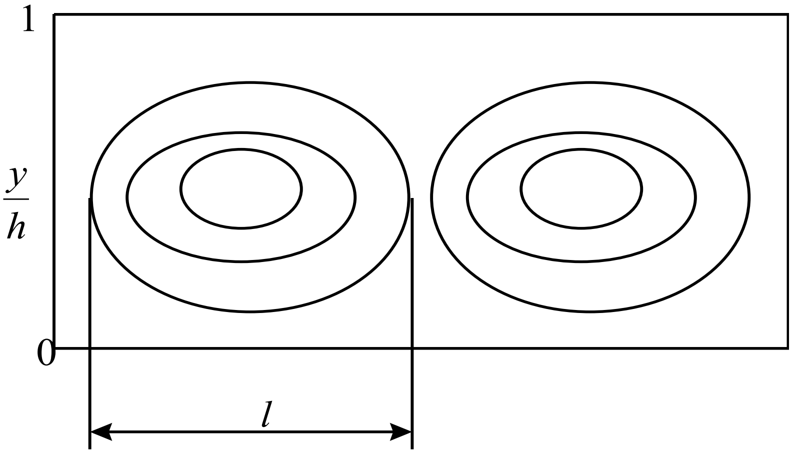

Рисунок 1 - Схема циркуляционных ячеек при спонтанной межфазной конвекции

Используя уравнений баланса касательных напряжений на межфазной поверхности и переносимого через нее вещества, получаем качественную формулу, связывающую диффузионный поток J_0 через единицу поверхности конвективной ячейки и характерную скорость циркуляции жидкости в ячейке v_S [4-6].

Основным вкладом и новизной представленной здесь статьи являются как инновационный подход к моделированию спонтанной межфазной конвекции, вызванной эффектом Марангони, так и новые управляющие соотношения для расчета соответствующих чисел Шервуда и Нуссельта.

Описание модели. Наиболее физически адекватным параметром, величина которого чувствительна к развивающейся спонтанной межфазной конвекции, является число Шервуда [4]. Этот критерий подобия описывает соотношение интенсивностей переноса тепла и массы, обусловленных конвекций и диффузионным переносом [5, 6].

Для характерного времени циркуляции жидкости в ячейке с характерным размером l получаем оценку

$$\tau_S \sim \frac{l}{v_S}. \tag{1}$$

Можно показать, что это время имеет тот же порядок величины, что и характерное время гидродинамического отклика [7,8]:

$$\tau_\nu \sim \frac{l^2}{\nu} .$$

Наша гипотеза заключается в том, что перепад концентрации на глубине диффузионного пограничного слоя в концентрационной ячейке $\Delta_\delta c$ в первом приближении пропорционален движущей силе процесса массопереноса по глубине фазы Δc.

$$\Delta_\delta c = b\Delta c , \quad (2)$$

где

$$\Delta c = c_{10} - \frac{c_{20}}{m} . \quad (3)$$

где, b - эмпирический параметр [9]; c_{10}, c_{20} - концентрации переносимого вещества в глубинах фаз; m - константа межфазового равновесия.

Соотношение (2), содержащее параметр b<<1, описывает механизмом возникновения циркуляционных ячеек при межфазной неустойчивости, а также неидеальность процесса обновления поверхности.

Физический смысл этого явления в том, что обогащенная жидкость, подводимая к центральной области ячейки из глубины фазы, смешивается с обедненной жидкостью, уходящей с периферии и затем частично возвращающейся к поверхности за счет циркуляции.

На основе этих предположений и методов работы [10,11] получаем следующую формулу для потока вещества в циркуляционной ячейке J_0:

$$J_0 = \frac{b^2}{\mu_1 + \mu_2} \left| \frac{\partial \sigma}{\partial c} \right| Sc^{-1/2} \left(\Delta c \right)^2 . \quad (4)$$

Поэтому коэффициент массопереноса для одной ячейки $K_M^0 = \frac{J_0}{\Delta c}$ получается пропорциональным движущей силе:

$$K_M^0 = K_{conv}^0 \Delta c, \quad (5)$$

где для коэффициента массопереноса в условиях спонтанной межфазной конвекции можно получить:

$$K_{conv}^0 = \frac{b^2 \left| \partial \sigma / \partial c \right| Sc^{-1/2}}{\mu_1 + \mu_2} . \quad (6)$$

Формула (6) может использоваться для расчета массопереноса через поверхность контакта фаз, когда интенсивность межфазной конвекции такова, что поверхность занята циркуляционными ячейками.

Это предполагает интенсивную спонтанную межфазную конвекцию, когда движущая сила процесса массопереноса существенно превосходит критическую движущую силу. Процесс начинается спонтанно при градиентах, соответствующих потере устойчивости слоя и началу образования конвективных структур [12]:

$$\Delta c >> \Delta c_{cr} \ . \tag{7}$$

Однако, в реальности только некоторая доля ε поверхности занята ячейками. Эта доля зависит от степени отклонения движущей силы от критического значения, при котором возникает спонтанная межфазная конвекция.

Введем меру надкритичности по формуле:

$$\Delta c - \Delta c_{cr} << \Delta c_{cr} . \tag{8}$$

С учетом этого при небольшой надкритичности получаем следующие формулы для полного потока вещества через единицу межфазной поверхности J и для соответствующего коэффициента масопереноса:

$$J = K_D \Delta c + K_{conv} \Delta c (\Delta c - \Delta c_{cr}), \tag{9}$$

$$K_M = K_D + K_{conv} \left(\Delta c - \Delta c_{cr} \right), \tag{10}$$

$$K^0_{conv} = \frac{B \left| \partial\sigma / \partial c \right| Sc^{-1/2}}{\mu_1 + \mu_2} . \tag{11}$$

где, $B = b^2 f$ - эмпирический параметр, отражающий влияние внешних гидродинамических условий.

При условии $\Delta c < \Delta c_{cr}$ получаем:

$$J = K_D \Delta c . \tag{12}$$

Результаты и обсуждение. Используем оценку степени надкритичности в виде пропорциональном разнице между текущим и критическим числами Марангони.

Тогда, в критериальном виде с помощью чисел Шервуда и Марангони [13], получим:

$$Sh = \begin{cases} Sh_0 + BSc^{-1/2} \left(Ma - Ma_{cr} \right), \text{ если } Ma \geq Ma_{cr} , \\ Sh_0 , \text{ если } Ma < Ma_{cr} \end{cases} \tag{13}$$

Отсюда можно рассчитать коэффициент ускорения массопереноса при условии $Ma \geq Ma_{cr}$ [14]:

$$\Omega = \frac{Sh}{Sh_0} , \tag{14}$$

$$\Omega = 1 + BSh^{-1/2} \left(Ma - Ma_{cr} \right). \tag{15}$$

Полученные формулы хорошо согласуются с известными эмпирическими зависимостями [1].

Аналогичным образом описывается теплоперенос при возникновении спонтанной термокапиллярной ячеечной конвекции:

$$J_T = K_T \Delta T + K^T{}_{conv} \Delta T \left(\Delta T - \Delta T_{cr} \right), \tag{16}$$

$$K_M^T = K_T + K^T{}_{conv} \left(\Delta T - \Delta T_{cr} \right), \tag{17}$$

$$K_{conv}^T = \frac{B_T \left| \partial \sigma / \partial T \right| \Pr^{-1/2}}{\mu_1 + \mu_2}. \tag{18}$$

Переходя к числу Нуссельта и температурному числу Марангони [15], получим

$$Nu = \begin{cases} Nu_0 + B_T \Pr^{-1/2} \left(Ma_T - Ma_{Tcr} \right), \text{ если } Ma_T \geq Ma_{Tcr}, \\ Nu_0, \text{ если } Ma_T < Ma_{Tcr} \end{cases} \tag{19}$$

Для коэффициента ускорения теплопереноса получаем:

$$\Omega_T = \frac{Nu}{Nu_0}; \tag{20}$$

$$\Omega_T = 1 + B_T \Pr^{-1/2} \left(Ma_T - Ma_{Tcr} \right). \tag{21}$$

Величины входящих в полученные формулы параметров должны определяться эмпирически для каждой конкретной системы с известной формой поверхности и гидродинамическими условиями.

Выводы. В работе проведен анализ основных физических факторов, способствующих развитию межфазной нестабильности и появлению приповерхностных конвективных структур, обусловленных градиентами температуры и концентрации реагентов в приповерхностных областях сплошных фаз. Предложены упрощенные математические модели для создания инженерных расчетных методик.

Показано, что, учитывая характерные размеры циркуляционных ячеек и выражая через эти параметры коэффициент ускорения массопереноса, можно прийти к компактным критериальным уравнениям для расчета чисел Шервуда и Нуссельта, описывающих интенсивность тепломассопереноса, с учетом влияния спонтанной межфазной конвекции.

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ФАЗААРАЛЫҚ КОНВЕКЦИЯЛЫҚ МОДЕЛЬДЕУДІҢ НЕГІЗГІ ТҰЖЫРЫМДАМАЛАРЫ

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М.Әуезов атындағы Оңтүстік Қазақстан зерттеу университеті, Шымкент қ., Қазақстан

Аннотация. Мақалада Марангони немесе Бенард құбылыстарынан туындаған фазааралық конвекцияны модельдеудің негізгі заманауи тұжырымдамалары көрсетілген. Бұл мәселе өнеркәсіптік құрылғылардағы жылу алмасу процестерін күшейтудің энергия үнемдеу әдістерін іздеу тұрғысынан өте маңызды. Мақалада стихиялық фазааралық конвекция механизмі қысқаша сипатталған, сонымен қатар осы құбылыстың математикалық моделін жасауға инновациялық тәсіл ұсынылған. Нәтижесінде фазааралық конвекцияны, сондай-ақ осы құбылысқа байланысты масса тасымалының үдеу коэффициентін ескере отырып, Нуссельт санын есептеу үшін арақатынас алынды. Жұмыста әр түрлі салалар үшін үлкен маңызы бар жылу және масса тасымалдау процестерін қарқындатудың энергия үнемдеу әдістерін іздеудің өзекті мәселесі қарастырылады. Айналым жасушаларының тән өлшемдерін пайдалануға негізделген фазааралық конвекцияны модельдеуге инновациялық тәсіл ұсынылды. Нуссельт саны мен масса тасымалының үдеу коэффициентін есептеу үшін алынған қатынастарды фазааралық конвекция жүретін өнеркәсіптік құрылғылардың дизайны мен жұмыс режимдерін оңтайландыру үшін пайдалануға болады. Жұмыста гидродинамика, масса беру теориясы және математикалық модельдеу әдістері қолданылады. Зерттеу нәтижесінде фазааралық конвекцияның әсерін ескеретін Нуссельт саны мен масса тасымалының үдеу коэффициентін есептеу үшін жаңа қатынастар алынды.

Тірек сөздер: Марангони эффектісі, Бенард конвекциясы, фазааралық құбылыстар, жылу және масса алмасу, стихиялық конвекция, суперкритикалық, тасымалдау үдеуінің коэффициенті, конвективтік ұяшықтар.

BASIC CONCEPTS FOR MODELING INTERFACIAL CONVECTION

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Annotation. The article outlines the key modern concepts of modeling interphase convection caused by Marangoni or Benard phenomena. This problem is extremely important from the point of view of finding energy-saving ways to intensify heat and mass transfer processes in industrial devices. The article briefly describes the mechanism of spontaneous interphase convection, and also offers an innovative approach to the development of a mathematical model of this phenomenon. As a result, a ratio was obtained for calculating the Nusselt number, taking into account interphase convection, as well as the acceleration coefficient of mass transfer due to this phenomenon. The paper considers the actual problem of searching for energy-saving methods of intensification of heat and mass transfer processes, which is of great importance for various industries. An innovative approach to modeling interphase convection based on the use of characteristic sizes of circulation cells is proposed. The obtained ratios for calculating the Nusselt number and the acceleration coefficient of mass transfer can be used to optimize the design and operating modes of industrial devices where interphase convection occurs. The work uses methods of hydrodynamics, mass transfer theory and mathematical modeling. As a result of the study, new relations were obtained for calculating the Nusselt number and the acceleration coefficient of mass transfer, which take into account the influence of interphase convection.

Keywords: Marangoni effect, Benard convection, interfacial phenomena, heat and mass transfer, spontaneous convection, super-criticality, transfer acceleration coefficient, convective cells.

SRSTI 622.276 https://doi.org/10.52081/tst.2024.v02.i6.035

DETERMINATION OF THE DEGREE OF INFLUENCE OF HYDRODYNAMIC PRESSURE DROP AND CAPILLARY PRESSURE ON THE DEPTH OF THE ZONE OF PENETRATION OF FILTRATE OF WASHING FLUID INTO THE FORMATION

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Annotation. When mud filtrate is introduced into the formation, its rate of advancement is determined by hydrodynamic and capillary forces. Hydrodynamic forces act at a distance between points of different pressures. Unlike hydrodynamic forces, capillary pressure acts locally, at the interface. In some cases, when hydrodynamic filtration in the formation is not carried out, the entry of washing fluid is due to capillary penetration. The ratio of forces depends on changes in pressure, water supply, interfacial tension, radius of porous channels and a number of other factors. The calculation method proposed in the article allows to determine the values of the radius of the pore channels and the distance from the well at which the equality of hydrodynamic and capillary forces will be observed. A plot of the dependence of the hydrodynamic force difference and capillary pressure equation on the radius of the porosity channels determined by the distance of the radius from the well is described.

Keywords: capillary forces, hydrodynamic forces, pore radius, mud filtrate invasion zone, capillary and hydrodynamic pressure balance.

It is especially important to have actual values of interfacial tension when studying physical and chemical processes, which take place at initial formation opening in the process of formation of drilling mud filtrate penetration zone. In low-permeable gas-saturated reservoirs, the rate of capillary permeation in some cases is commensurate with the rate of penetration of drilling mud filtrate into the formation during hydrodynamic filtration [1].

It is known that the rate of advancement of impregnation front depends on capillary pressure, the value of which in turn is determined by interfacial tension [2].

Most often the penetration of drilling mud filtrate into the formation is investigated under the influence of wellbore repression. In this case, it is difficult to assess the degree of influence of physical and chemical processes in the formation of the mud permeation zone. Some researchers have studied the penetration of mud filtrate into the formation during underbalanced or underbalanced drilling [3], recording a decrease in contamination of the productive formation by mud filtrate and noting the role of the water phase, penetrating under capillary forces into the bottomhole zone of the formation. With the help of geophysical measurements of resistivity in bottomhole formation zone at certain intervals can be measured the intensity of capillary permeation at borehole equilibrium and underbalanced in real conditions. In [4] method of capillary permeation intensity determination is given. The accuracy of the measurements obtained is comparable with the logging data. Low-permeable formations are much more sensitive to the effects of physico-chemical influences that cause formation damage, and as a result, the depth of the damaged zone due to capillary impregnation can be significant and often exceeds the depth of perforation holes [5].

Thus, it is necessary to evaluate and, if necessary, regulate the capillary impregnation of the productive reservoir by the drilling fluid filtrate in order to control the process of formation of the perforated zone. For this purpose, certain surfactants are used that can be used to regulate the capillary activity of drilling fluid filtrates. The capillary pressure, which determines the rate of capillary permeation, depends on the radius of the pore channels, the wetting angle and the interfacial tension.

The scientific and technical literature identifies the main factors whose influence on the interfacial tension between hydrocarbons and formation water in productive formations can be summarised as follows:

1. Temperature: an increase in temperature leads to a decrease in interfacial tension.
2. Pressure: Increasing pressure also reduces interfacial tension.
3. Gas dissolved in oil and water: the more gas dissolved in oil at pressure above boiling point, the less interfacial tension; the more dissolved gas at pressure below boiling point, the more interfacial tension.
4. Viscosity: a reduction in the differences in viscosity between oil and water leads to a reduction in interfacial tension.
5. Density: a reduction in the differences in density between oil and water usually results in a reduction in interfacial tension; a reduction in density usually also means a reduction in viscosity; thus the relationship between density and interfacial tension may be similar to that between the latter and viscosity.
6. Surfactants: The magnitude of the interfacial tension depends on the activity of the surfactant under real thermodynamic conditions.

Thus, in order to control the rate of capillary permeation it is necessary to select surfactants for real reservoir conditions, taking into account the influence of thermal and pressure conditions on the value of interfacial tension.

Drilling fluid filtration leads to the formation of a penetration zone, which is often divided into two zones: the replacement zone (transition zone), where two-phase filtration of formation fluid and drilling fluid filtrate takes place, and the flushed zone, where the displacement process has already been completed. The flushed zone is understood as a part of the formation characterised by unchanging water-oil-gas saturation of rocks during filtration of mud into the formation (from this point of view, the flushed zone can be observed only in reservoirs with high filtration-capacitance properties). The penetration zone is considered to be the part of the reservoir where changes in fluid saturation occurred due to the penetration of solution filtrate under the action of hydrodynamic and capillary forces [1].

Capillary forces have a special influence on the formation of the penetration zone [2-4]. In spite of the numerous studies, to date, no final conclusions have been formed about the relationship between capillary and hydrodynamic forces at different stages of penetration zone formation.

A characteristic feature of displacement of formation fluids by filtrate is that, strictly speaking, displacement occurs under different regimes in an area whose dimensions are commensurate with the size of the well radius. Capillary forces influence the character of phase distribution in the pore space, and the ratio of capillary and external hydrodynamic forces determines the conditions of displacement of formation fluids and, accordingly, the values of their residual saturation [5]. It is considered that the formation of the penetration zone occurs under capillary-pressure and so-called "automodelling" modes of displacement and the nature of phase distribution is determined by the action of both capillary and hydrodynamic forces. Hydrodynamic forces characterise the pressure distribution in the system "well - clay crust - colmatisation zone - penetration zone - reservoir". They initially control the displacement in the penetration zone. In the process of growth and compaction of the clay crust, formation of the colmatisation zone and increasing the size of the penetration zone, the hydrodynamic pressure gradient decreases. This leads to an increase in the influence of capillary forces on phase distribution during filtration [1].

Gravitational forces can also have a certain effect on the process, creating an additional pressure drop due to the difference in phase densities in the elementary microvolume of downhole zones. At small hydrodynamic pressure gradients the phase distribution in the process of displacement is completely controlled by capillary forces and the displacement modes are purely capillary. The wetting phase is introduced into the pores under the action of capillary pressure. Thus, the capillary displacement mode is manifested, as a rule, only at the end of formation of the penetration zone and is characteristic mainly for the period of its dissolution [6].

Methodology and example of calculation

When drilling fluid filtrate is introduced into the formation, the rate of its advancement is determined by hydrodynamic and capillary forces, as well as by other physical and chemical processes. The ratio of forces depends on pressure drop, wettability, interfacial tension, radius of pore channels and a number of other factors.

The peculiarity of determining the degree of influence of hydrodynamic and capillary forces is that the pressure drop acts at a much greater distance compared to the capillary pressure, which acts at the interface. The following is a calculation methodology, which results in determining the values of the pore channel radius and distance from the well, at which the equality of hydrodynamic and capillary forces will be observed. That is, at the values of distances from the well and pore diameters less than the calculated ones, hydrodynamic forces will prevail in the pores, and at larger distances and for smaller pores - capillary forces.

Capillary pressure is calculated by the formula [7-10]:

$$P_{\text{к}} = \frac{2\cdot\gamma}{r}\cos\theta, \quad (1)$$

where, γ – is interfacial tension, N/m;
r – radius of pore channels, m;
θ – marginal wetting angle, deg.

The equation for calculating the edge wetting angle in the presence of data on spontaneous capillary impregnation has the following form [8]:

$$\cos\theta = \frac{x^2\cdot\eta\cdot 2}{r\cdot\gamma\cdot t}. \quad (2)$$

In the absence of laboratory measurements, the pore radius is calculated using the empirical formula [9]:

$$r = 1{,}571\cdot 10^{-6}\cdot\left(\frac{1-\varphi}{2\varphi}\right)\sqrt{\frac{150k}{\varphi}}, \quad (3)$$

where, φ – porosity, darcy; k – permeability, mkm^2.

The initial data for the calculation are given in Table 1. The calculation was carried out for sandstone samples of the Tula horizon obtained during drilling of boreholes in the Enapaevskoye and Zhukovskoye licence areas.

Table 1 - Initial data

№	Parameter	Unit of measurement	Significance
1	Interfacial tension γ at the boundary «washing liquid filtrate – gas»	N/m	0,073
2	Reduced well radius, r_w	m	0,3
3	Power circuit radius, r_c	m	20
4	Pressure drop, $P_k – P_w$	MPa	2,48
5	Porosity, φ	%	20
6	Permeability, k	mD	210
7	Time t, during which the capillary impregnation front travels a distance of 0.03m	seconds	95
8	Dynamic viscosity of the fluid б, η	mPa·s	0,03
9	Sample length, x	м	0,03

At given values of porosity and permeability, the following values of the cosine of the wetting edge angle and average pore radius are obtained:

$$cos\theta = 0{,}208;\ r = 1{,}25,\text{мм}\cdot 10^3.$$

Under these conditions, the capillary pressure P_k*=0.561MPa.*

To calculate the pressure drop, we will use the equation of pressure distribution in the reservoir [3]:

$$P = P_c + \frac{P_{\text{кп}} - P_c}{ln\frac{r_k}{r_c}} \cdot ln\frac{R}{r_c}, \quad (4)$$

where: P_w – pressure in the well;

P_{sc} – pressure in the supply circuit;

r_{rw} – reduced radius of the well;

r_c – radius of the supply circuit;

R – distance from the well.

Let's express the pressure drop Δ*P*:

$$\Delta P = \frac{P_{\text{кп}} - P_c}{ln\frac{r_k}{r_c}} \cdot ln\frac{R}{r_c}.$$

Determine at what distance from the well the pressure drop ΔP equals the capillary pressure. Express the distance *R*:

$$R = r_c \cdot e^{\frac{\Delta P \cdot ln\frac{r_k}{r_c}}{P_{\text{кп}} - P_c}}. \quad (5)$$

At capillary pressure P_c*=0.563MPa*, the distance from the well *R=0.78m* with r_{rw}*=0.3m* and r_c*=20m.*

As the radius of pore channels increases, the capillary pressure decreases. Consequently, as the radius of pore channels changes, the distance from the well where the hydrodynamic differential and capillary pressures are equal will change [11-12]:

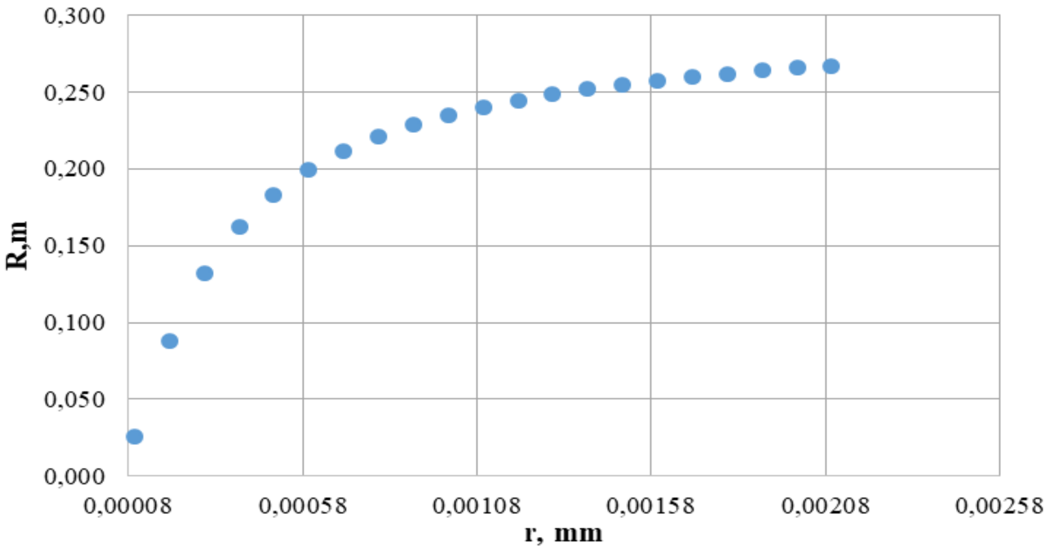

Figure 1 - Dependence of distance R on the radius of pore

Figure 1 shows the dependence of the distance R from the well on the radius of pore channels for which the equality of hydrodynamic differential and capillary pressure will be observed. Figure 1 shows that with distance from the well, the radius of capillaries, in which the above balance will be observed, increases. Consequently, as the distance from the well increases, the proportion of pores in which the movement of phases occurs under the action of capillary pressure increases. The calculations given in this article allow us to estimate the degree of influence of capillary and hydrodynamic forces on the depth of penetration of filtrate of washing fluid at the initial opening of the formation [13-15].

Conclusions:

1. The study of the kinetics of physico-chemical processes occurring during the initial opening of productive formations is an urgent task.
2. A large number of theoretical models indicate the complexity and multifactoriality of these processes.
3. A large number of experimental studies indicate the high interest of the scientific community in determining the role of physico-chemical processes in the displacement of hydrocarbons from the reservoir.
4. In most studies, capillary impregnation is considered as one of the mechanisms for increasing oil recovery, and not as a factor reducing the permeability of the bottom-hole zone during drilling.

The ranges of gas permeability and water saturation have been determined, at which spontaneous capillary impregnation can have the most significant effect on the formation of a zone of penetration of drilling mud filtrate into the formation.

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ГИДРОДИНАМИКАЛЫҚ ҚЫСЫМ АЙЫРМАСЫ МЕН КАПИЛЛЯРЛЫҚ ҚЫСЫМНЫҢ ҚАБАТТА ЖУУ СҰЙЫҚТЫҒЫ ФИЛЬТРАТЫНЫҢ ЕНУ АЙМАҒЫ ТЕРЕҢДІГІНЕ ӘСЕР ЕТУ ДӘРЕЖЕСІН АНЫҚТАУ

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Аңдатпа. Қабатқа бұрғылау ерітіндісінің фильтраты енгізілгенде оның ілгерілеу жылдамдығы гидродинамикалық және капиллярлық күштермен анықталады. Гидродинамикалық күштер әртүрлі қысым нүктелері арасындағы қашықтықта әрекеттеседі. Мұндағы капиллярлық қысымның гидродинамикалық күштерден айырмашылығы, бір нүктеде, интерфейсте әрекет етеді. Кей жағдайда қабатта гидродинамикалық сүзілу орындалмаған кезде, жуу сұйықтығы капиллярлық сіңдіру түрінде енеді. Күштердің арақатынасы қысымның өзгеруіне, суланауына, фазааралық керілуіне, кеуек каналдарының радиусына және басқа да бірқатар факторларға байланысты болады.

Мақалада ұсынылған есептеу әдісі кеуекті арналардың радиусының мәндерін және гидродинамикалық және капиллярлық күштердің теңдігі байқалатын ұңғымаға дейінгі қашықтықты анықтауға мүмкіндік береді. Гидродинамикалық күштер айырмасы мен капиллярлық қысым теңдігі сақталатын ұңғымадан радиус алшақтығы бойынша анықталған кеуек арналарының радиусына тәуелділігі графигі суреттелген.

Тірек сөздер: капиллярлық күштер, гидродинамикалық күштер, кеуекті каналдардың радиусы, бұрғылау сұйықтығы фильтратының қабатқа ену аймағы, капиллярлық және гидродинамикалық қысымдардың теңгерімі.

ОПРЕДЕЛЕНИЕ СТЕПЕНИ ВЛИЯНИЯ ГИДРОДИНАМИЧЕСКОГО ПЕРЕПАДА ДАВЛЕНИЯ И КАПИЛЛЯРНОГО ДАВЛЕНИЯ НА ГЛУБИНУ ЗОНЫ ПРОНИКНОВЕНИЯ ФИЛЬТРАТА ПРОМЫВОЧНОЙ ЖИДКОСТИ В ПЛАСТ

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Аннотация. При проникновении фильтрата бурового раствора в пласт скорость его продвижения определяется гидродинамическими и капиллярными силами. Гидродинамические силы обусловлены перепадом давления между давлением на забое и в пласте. В отличие от гидродинамических сил, капиллярное давление действует локально, на границе раздела фаз. В некоторых случаях, когда гидродинамическая фильтрация в пласте не осуществляется, поступление промывочной жидкости происходит за счет капиллярного проникновения. Соотношение сил зависит от изменения давления, подачи воды, межфазного натяжения, радиуса пористых каналов и ряда других факторов.

Предложенная в статье методика расчета позволяет определить значения радиуса поровых каналов и расстояния от скважины, при которых будет соблюдаться равенство гидродинамических и капиллярных сил для заданных скважинных условий. Описан график зависимости разности гидродинамических сил и уравнения капиллярного давления от радиуса каналов пористости, определяемого расстоянием радиуса от скважины.

Ключевые слова: капиллярное давление, перепад давления, радиус поровых каналов, зона проникновения фильтрата промывочной жидкости в пласт, баланс капиллярного и гидродинамического давлений.

SRSTI52.47.19 https://doi.org/10.52081/tst.2024.v02.i6.036

METHODS OF IMPROVING THE EFFICIENCY OF ENERGY SUPPLY TO OIL AND GAS ENTERPRISES

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Annotation. Realization of high-tech designs in gas and oil industry contributes to more efficient functioning of production. Development of quality minerals is not a scientific and technical progress, but a stable level indicator based on the general economic aspect.Therefore, the introduction of high quality updated technologies and additions to production functioning systems always leads to a greater need for their use.

To maximize energy efficiency in gas and oil production, it is recommended to use high-quality autonomous power sources. The sets of optimization possibilities on algorithms of systems of distribution of power loads of electric transformer substations taking into account large productivity of producing wells at oil fields are developed. Recommendations on quality utilization, developed on the basis of long algorithms, allow to increase step-by-step nominal level of power loads at pumping units operation. It is proved that to maximize energy efficiency enterprises need to use their own high-quality autonomous power sources.

The article considers the efficiency and cost-effective possibilities of production energy-consuming and quality functioning equipment in the oil&gas industry. In addition, taking into account the benefits on the basis of the study was carried out a large-scale analysis of data on the characteristics of relative efficiency and reliability to the technical condition of gas turbine and gas piston power plants.

Keywords: energy costs, gas turbine power plant, small power plant, alternative electricity, small unit capacity.

Introduction. The efficiency of oil&gas production is determined by the degree of productivity and costs for the production of products. They are based on several factors: research costs, material costs, structural formation, repair work, labor resources, environmental and energy costs, which are more priority. Also, these factors vary in relation to the following characteristics: the area of location of the oil field, methods and stages of development, the technical condition of production equipment, etc. some factors related to the properties of the deposit are objective and unchangeable by natural and climatic conditions. Other factors depend on the technologies used and are aimed at using the most advanced production approaches.

Materials and methods. The country has a number of advantages in the production characteristics of oil&gas fields in terms of operational and production equipment and their reliability indicators, as well as in terms of energy resources. Therefore, it is more important for oil enterprises to effectively implement the stage of application of the developed methods. One of the most pressing problems of the economy is the low level of quality of energy consumption. The country has 2-3 times more energy consumption per unit of production compared to the industrialized countries of the West [9]. In the new economic conditions of the transition to market-oriented relations, the level of decline, the lack of the ability to use a centralized stock system to replenish working Resources and the need to replace productive power sources, the formation of a traditional centralized energy supply of variable production sources pose these problems. Traditional centralized energy systems are not based on efficiency in fuel economy and in the general case. It can be said that this situation is due to the following reasons: the impact of the energy supply centralization system on industrial economy and in the process of using the level of efficiency of energy sources in comparison with heating boilers is reduced by the lowest indicator [1]. Heat losses during further transportation of hot water under the second fuel effect component of combined heat and power generation were lower than the calculated indicator. These costs reach 20-25%. The energy security of the oil&gas industry is of great importance. The possibilities of new technologies in the industry are huge.

Another aspect in this issue is the reliability of energy supply to consumer sources [2]. The decrease in the reliability of energy supply of production facilities of fields can be attributed to the divergence of power supply foci and a number of significant losses that lead to emergency failures. For example, the main oil&gas production zones located in the south of the Republic are covered with electricity by the power transmission line (transmission line) with an average distance of more than 300-500km, where a disconnection occurs annually due to an average of 4-6 emergency failures [3]. Recently, the construction of decentralized mixed sources of the country's power system has been frequently observed. The advantages of installing such electrical installations are many. The main ones are construction works carried out in a short period of time, increasing the reliability of power supply to consumers, reducing the inertia of energy heat regulation and costs in power grids. However, there are disadvantages associated with the complex system of installing the units, as well as the need to address environmental concerns and the problems of sending excess electricity to the general grid [5]. Regarding the listed reasons, oil&gas-producing enterprises intend to generate electricity on their own territory. In addition to a significant reduction in costs due to the production of electricity at oil&gas fields and the utilization of associated gas coming out with underground products, the assembly of gas turbine sources of electric and thermal energy will reduce the construction of overhead power lines, electrical substations, high-pressure gas pipelines and the construction of compressor stations[8]. Today, the drives of generators for decentralized small CHP are gas piston (Figure 1) and turbine engines [6].

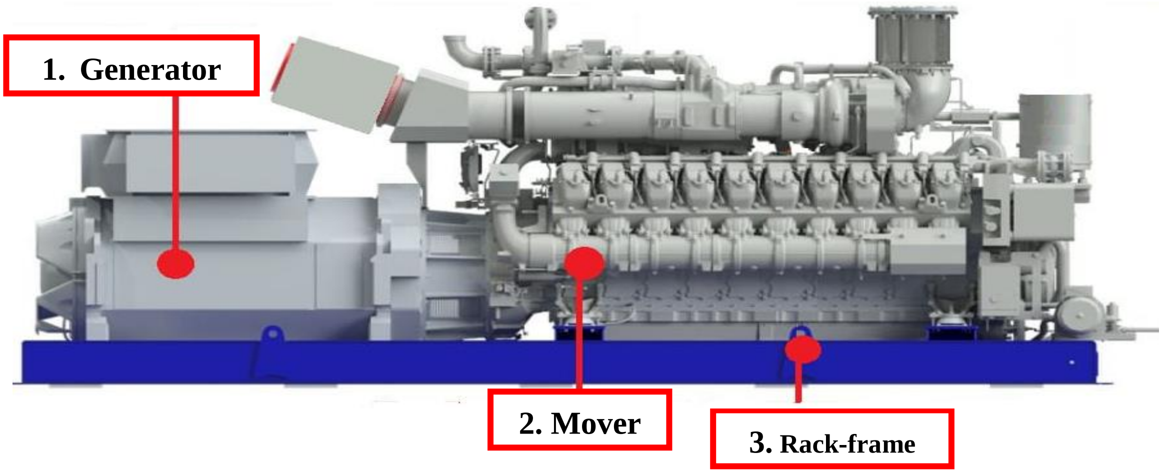

Figure 1 – Gazporshen power station

In terms of global production, the products of Aviadvigatel JSC (Perm) and Rybinsk Motors JSC (Yaroslavl), which produce gas turbine small power plants with capacity from 2.5 to 110 MW, are in demand in the Russian Federation. The approximate cost (excluding VAT) of a gas turbine power plant (GTP) of the minimum configuration (for power generation only) is US$1,200,000. The cost of electricity produced in the data of the manufacturing enterprise is 1.20...1.25 tenge/kWh, and the cost of heat generated is 40...50 tenge/Gcal [4]. In recent years, autonomous power plants with a gas piston drive have been making serious competition with the GTPP. The advantages here include high efficiency in accordance with a large working resource and low parametric requirements in the characteristics of the gas used in the fuel boiler. The small unit power (up to 1-2MW) of the gazporshen ES is the main disadvantage. At the moment, sectional (several dozen) implementations with general computer control are used. At the same time, Mini-Es have high dynamic indicators, effective in terms of several times the accelerated output power [7].

Results and discussion. Table 1 presents several types of ES according to the criteria of «additional gross profit» and «payback period».

Table 1 – Comparative characteristics of some industrial small ES

№	Electric station	Manufacturing firm	Type	S	Resources, H.	1-comp. repair	N, Power W	W, product million.t	T, years
1	GTU-6P	Perm	GT	0,30	120000	40000	6500	165,1	9,1
2	URAL-6000	Perm	GT	0,28	140000	35000	2750	71,1	6,4
3	TCG 2020 V16K	Saint-Petersburg	GP	0,22	50000	25000	250	3,9	4,2
4	Waukesha LX7500	Stamford	GP	0,20	180000	33000	1250	71,3	4,3
5	290GSP	Detroit	GP	0,19	45000	25000	250	4,6	2,9

According to the first criterion, a powerful power plant is the most suitable, but with a payback period equal to 6-10 years (Line # 1 of Table 1). The next optimal criterion is a low – power gas-piston power plant-0.1-1.1 MW (line No. 5 of Table 1). A relatively reliable 2MW gas piston imported power plant with two criteria (resources 250,000..350,000 hours) is an acceptable Es of medium power (line # 4 of Table 1). According to this indicator, the small ES market is currently developing on a large scale, and providing enterprises with reliable energy is considered the tasks of reconstruction. The state of their regional location depends on the choice of optimal types of powerful power plants [10]. Their regional location depends on the selection of optimal types of power plants.

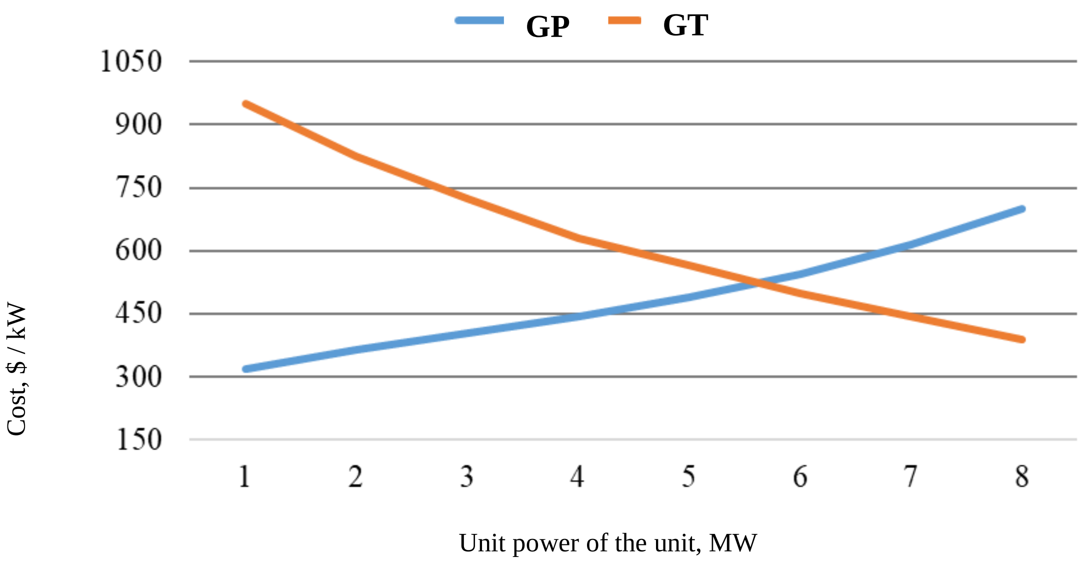

Figure 2 – specific cost of Piston and turbine units: GPH – gas piston unit; GTZ-gas turbine unit

It should be noted here that the cost of equipment and the cost of the station are not the same, especially when supplying high-pressure gas (necessary for gas turbines). Since fuel consumption and ancillary costs are relevant to the operation of power plants, they are directly related to the operating profit and payback period of the plant [11]. The specific fuel consumption per kWh produced at a gas station and under any load mode of the ES will be minimal (Figure 3, 4). Piston power plants have an efficiency of 35-45%, while gas turbine plants have an efficiency of 25-34%. The operating costs of a piston power plant are relatively low compared to a gas turbine power plant [14]. There are no significant changes in the operating costs of GPPs, which means that there are few requirements for financial and labor resources during major repairs. Table 2 shows in comparison other important issues of operation of gas piston and gas turbine engines. In the comparative recommendations of turbine and piston engines based on the use of industrial enterprises with a separate production area, a qualified specialist for the operation of the station, the possibility of high-pressure gas supply, it is advantageous to install gas turbine stations with high electrical loads(more than 8-10 MW).

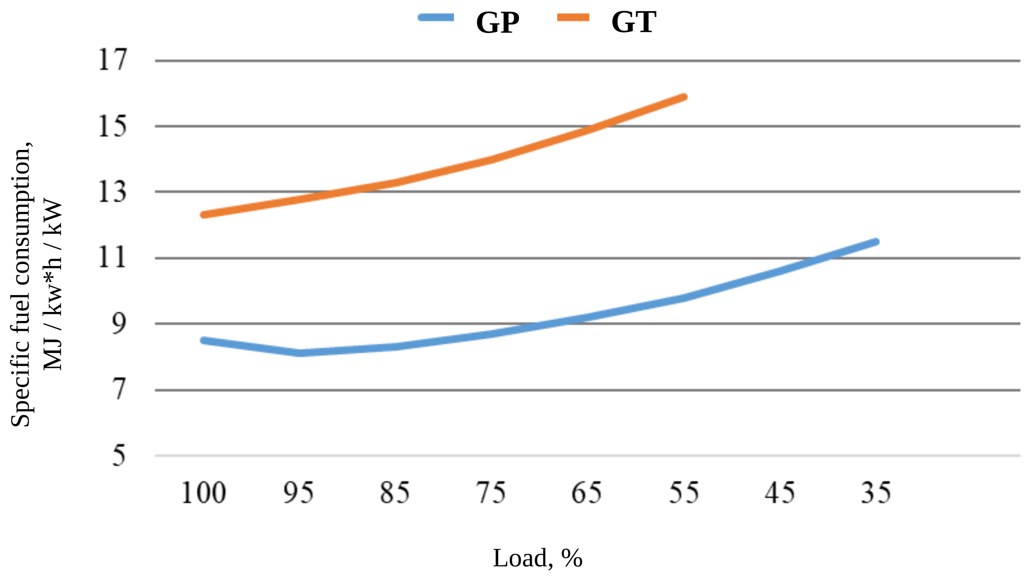

Figure 3 – Fuel consumption in Piston and turbine installations own loss

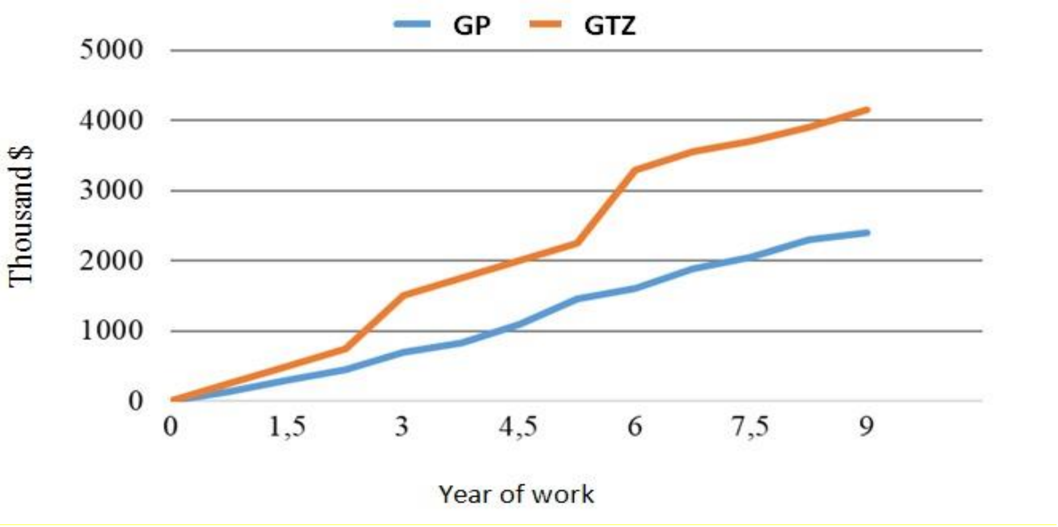

Figure 4 – Operating costs of an ES with a capacity of 5 MW

Small gas piston engines are used in production at the widest range of enterprises, in particular: service and prospective economic complexes as the main units of power and heat supply. There are no significant changes in the operating costs of GPES, which means that there are few requirements for financial and labor resources during major repairs.

Table 2 – Indications for the use of gas piston and gas turbine engines

Indications	Gas piston drive (GPH)	Gas turbine drive (GTZ)
Working hours	Unlimited, provided that the rules of Use and service are followed	
Serviceability	- ability to carry out repairs in the work area and perform in less time	- repair work is carried out in special places; - transportation, centralization, etc.requires time and financial costs
Conservation indicator	- does not lose properties if maintained; - ability to be transported by any type of transport	- does not lose properties if maintained; - transportation by rail is not required
Efficiency indicator	- there is no difference in efficiency from full (100%)load(50%) to partial load	- efficiency decreases sharply at partial loads
Specific fuel consumption at full (100%) and partial (50%) load	- 9.3-11.6 MJ/kWh.; -0.264-0.329 M3/kWh.	-13.2-17.7 MJ/kWh; -0.375-0.503 M3 / kWh
Recovery time when the voltage drop and load are reduced by half (50%)	- 22%; -8 c	- 40%; -38 c
Variable load effect	-less than half (50%)load, more work is not required; -with a small unit power of the unit, the overall efficiency of the ES and the reliability of the energy supply are high	- work at partial loads (less than 50%) has no effect on the normal state of the turbine; - when the unit power of the unit is high, the termination will result in a loss of 30-50% of the power of the unit
Placement in the building The minimum working pressure of the inlet gas is 12 bar., requires a high pressure gas or compression compressor as well as a turbine start-up assembly	- requires a large area space, as it has a large weight according to the unit of power; - gas compression does not require a compressor, the working pressure of the inlet gas is 0.1-0.35 bar.	- with an ES capacity of 5 MW, the benefit of a small area does not matter; - the minimum operating pressure of the inlet gas is 12 bar, high pressure gas or compression compressor and turbine starting equipment are required
Service life	- every 1000 hours. after the working period, it is necessary to stop and change the oil; - every 72,000 hours. later, repair work will be carried out in the installed area	- every 2000 hours. it is necessary to stop later (according to Solar data); - every 60,000 hours. after major repairs, special repairs are made at the site

Table 2 shows in comparison other important issues of operation of gas piston and gas turbine engines. In the comparative recommendations of turbine and piston engines based on the use of industrial enterprises with a separate production area, a qualified specialist for the operation of the station, the possibility of high-pressure gas supply, it is advantageous to install gas turbine stations with high electrical loads (more than 8-10 MW).

The base of small gas piston engines is used at enterprises of the widest range of production, in particular: in the service sector, etc. in promising economic complexes as the main source of electricity and heat. Today, the leading supplier of piston small power units is the company «World machinery», which is the official dealer of the Caterpillar Corporation (Caterpillar, USA). The high reliability of Caterpillar equipment is known all over the world and is based on extensive experience in the production of these units and a single manufacturer of almost all assemblies (engine, generator, control systems, etc.). This ensures a unique sequence of operation of energy systems and guarantees the reliability of the nodes of the supplied equipment [12].

The firm «World machinery» produces piston engine generators in the gas system at power intervals from 10 kW to 6.1 MW and carries out installation, commissioning and periodic maintenance of power plants in a guaranteed agreement [13]. The same is true in terms of reducing the energy costs required for oil&gas production. Consumers are also obliged to assign optimal energy supply opportunities for the oil&gas field. Also, issues of electricity should be resolved taking into account the nature of the regional location of the consumer and power sources. Optimization capabilities are carried out in a separate order for each field. The initial data for calculating losses are formed into a system of scale maps of the entire energy-consuming facility (wells, pumping stations for water supply, etc.), the dimensions of the power assigned to them, and the specified fields. To obtain data on the location of energy-intensive objects, it is recommended to use a software package that allows designing spatial surfaces and levels of their location (isoclines). As part of the solutions to the tasks set, the horizontal coordinates are the coordinates of energy consumption (production and injection wells) for local areas, and the vertical ones – electricity consumption.

In the practice of performing the calculation, for the initial data, data on the coordinates of the cluster of wells in the area of the local Kumkol oil&gas field and the current loads of the transformer in the cluster obtained on the basis of the manufacturing enterprise in this region were used [14]. In the practice of placing small power plants, the total costs for power grids are reduced by 1.9 times compared to current power plants. Therefore, on the basis of such experimental indicators, the use of several small power plants is a rational solution.

Conclusion. Based on the analysis of the current state of increasing the reliability and effective resources of energy equipment used in the oil&gas industry, the following conclusions can be determined: 1.from the criteria for assessing the working conditions before the failure of electrical equipment, the ability of some Station Units to operate in a mode of increasing their own energy costs was determined. Differences in the volume of energy costs during oil production by individual field zones were limited to the possibility of 3-5 times; 2. a methodology for using optimized load distribution algorithms for transformer substations in the oil&gas field is proposed, taking into account changes in actual productivity in the well cluster. The proposed algorithms are provided in accordance with the strength and expended power of the equipment of pumping units of the transformer substation with the possibility of increasing the degree of their load to the nominal level; 3. in the oil&gas industry, it is recommended to use independent sources of electricity on the basis of compliance with energy safety. The priority is the use of a powerful gas piston autonomous power unit system on the principle of «strength – cost of energy reliability»; 4. the Article considered concepts for improving the energy efficiency of the oil&gas industry. In order to maintain energy safety during Operation, enterprises are provided with the use of individual independent electric power sources. However, at present, the technical and economic characteristics of the choice of a small ES type based on the principle of «cost of electricity – capital costs – payback period – durability» have been analyzed and shown.

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МҰНАЙ-ГАЗ САЛАСЫ КӘСІПОРЫНДАРЫН ЭНЕРГИЯМЕН ЖАБДЫҚТАУ ТИІМДІЛІГІН ЖЕТІЛДІРУ ӘДІСТЕРІ

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Аңдатпа. Мұнай және газ өнеркәсіптеріндегі техникалық құрылымдарды іске асыру деңгейі өндірістің тиімді жұмыс жасауына ықпал етеді. Пайдалы қазбаларды игеру ғылыми-техникалық мәселе емес, жалпы экономикалық тұрғыға негізделген тұрақты көрсеткіш. Сол себепті өндірістік жүйелерде жаңартылған технологиялар мен толықтырулар енгізу оларды пайдалану кезінде әрдайым қажеттіліктерге алып келеді.

Мұнай және газ өндірісін жүзеге асыруда энергетикалық тиімділікті жетілдіруде электр энергиясының дербес көздерін қолданысқа енгізу ұсынылады. Мұнай кеніштеріндегі өндіру ұңғымалары өнімділігінің шарттарын бағамдап, кәсіпшілікке негізделген электр трансформаторлық қосалқы станциялардың энергиялық жүктемелерін таратуды алгоритмдері бойынша оңтайландыру мүмкіндіктері әзірленді. Алгоритмдерге негізделіп әзірленген ұсынымдар трансформаторлық қосалқы станцияның сорапты қондырғылар жұмысындағы энергиялық жүктемелердің номиналды деңгейін арттыруға мүмкіндік береді. Өндірістің энергетикалық қауіпсіздігін арттыру үшін кәсіпорындар дербес энергия көздерін пайдаланудың қажеттілігі көрсетілген.

Мақалада мұнай-газ өндіріс орнының энергия тұтыну жабдықтарының тиімділігі және экономикалық мүмкіндіктері қарастырылған. Сонымен қатар, зерттеу негізінде газ турбиналы және газ поршенді электр станцияларының салыстырмалы сенімділік сипаттамалары және техникалық күйі бойынша мәліметтерге талдау жүргізілді.
Тірек сөздер: энергетикалық шығындар, газтурбиналық электр станция, шағын электрстанция, баламалы электр энергиясы, шағын бірлік қуаты.

МЕТОДЫ СОВЕРШЕНСТВОВАНИЯ ЭФФЕКТИВНОСТИ ЭНЕРГОСНАБЖЕНИЯ ПРЕДПРИЯТИЙ НЕФТЕГАЗОВОЙ ОТРАСЛИ

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Аннотация. Реализация высоко технологичных конструкций в газовой и нефтяной промышленности способствует более эффективному функционированию производства. Разработка качественных полезных ископаемых – это не научно-технический прогресс, а стабильный показатель уровня, основанный на общем экономическом аспекте. Поэтому внедрение высоко качественных обновленных технологийи дополнений в производственных функционированию системах всегда приводит к большей необходимости их использования. Для максимального повышения энергетической эффективности при осуществлении добычи газа и нефти рекомендуется использовать качественные автономные источники электроэнергии.

Разработаны множества возможности оптимизации по алгоритмам систем распределения энергетических нагрузок электро трансформаторных подстанций с учетом больших производительности добывающих скважин на нефтяных месторождениях. Рекомендации по качественному использванию, разработанные на основедлинных алгоритмов, позволяют повысить пошаговый номинальный уровень энергетических нагрузок при работе насосных установок. Доказано, что для максимального повышения энергетической эффективности предприятиям необходимо использовать собственные качественные автономные источники электроэнергии.

В статье рассмотрены эффективность и экономически выгодные возможности производственного энерго – потребляющего и качественно функционирующего оборудования в нефте газовой отрасли. Кроме того, учитывая выгоду на основе исследования был проведен масштабный анализ данных по характеристикам относительной эффективности и надежности к техническому состоянию газотурбинных и газопоршневых электростанций.
Ключевые слова: энергетические затраты, газотурбинная электростанция, малая электростанция, альтернативная электроэнергия, малая единичная мощность.

SRSTI 226.245 https://doi.org/10.52081/tst.2024.v02.i6.037

FORMATION OF THE BOTTOM BOTH ZONE OF THE WELL

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Annotation. One of the important factors in oil fields is the technology of formation of the bottomhole zone. This process can improve well operation efficiency and improve well completion. High permeability of bottomhole zones of productive formations, low well productivity. In practice, the decrease in formation permeability at the bottom of the well is largely due to the effects that cause the interaction of filter fluids that occur during major repairs.

The purpose of the study is to identify the features of the interaction of process fluids and rocks based on the integrated use of modern laboratory studies of field data, and also to study the features of the formation of bottomhole zones of productive formations during the operation of production wells in fields.

An analysis of scientific publications based on the study of articles showed that one of the main problems of existing methods for assessing the condition of well bottoms is their diversity in the physical sense and the impossibility of identifying the predominant factors that form them.

Keywords: bottomhole zone of a well, bottomhole formation zone, hydrodynamic studies, drilling fluids, filtration channels.

The wellbore in the productive part of the section and the reservoir areas bordering the wellbore constitute the bottomhole zone (BHZ). The concept of the bottom-hole section of a wellbore includes a set of data on the elements of wellbore support against the pay zone.

A reservoir is considered stable or strong if it retains its structure at working underbalances during well development and operation, is not destroyed by rock pressure and is not eroded by filtration flows.

An unstable reservoir is a weakly cemented reservoir whose solid phase is carried by formation fluids from the reservoir into the well.

Based on the granulometric analysis of the reservoir rocks, the homogeneity coefficient of the fractional composition (Figure 1) and the average size of fractions are determined.

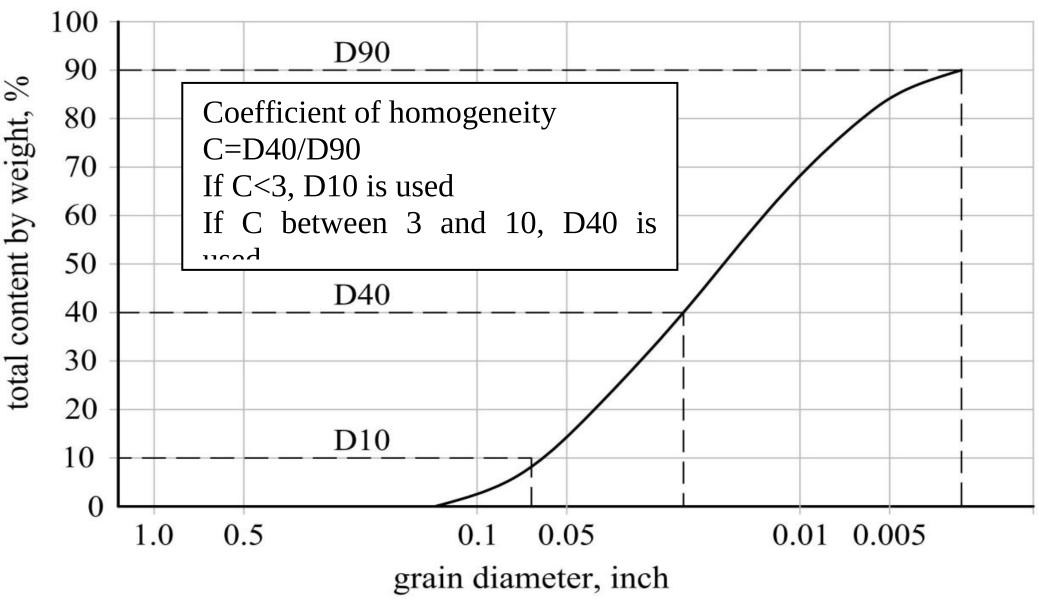

Figure 1 – Example of granulometric analysis of a rock

Rocks are distinguished:

- fine-grained with the size of sand particles within – 0,10-0,25 mm;
- medium-grained – 0.25-0.50 mm;
- large-grained – 0,5-1 mm.

At the initial stages of formation of the zone of penetration into the bottomhole formation (drilling, cementing and cementing, secondary penetration, formation treatment and flow inducing), the volume of displaced fluids in the bottomhole formation (mobile phase), which moves to one or the opposite side depending on the direction of differential pressure is determined:

- the reservoir properties and structure of the pay zone;
- the magnitude and nature of repression or depression;
- composition and properties of formation and injected fluids;
- viscosity ratio of formation fluids and injected filtrate;
- the magnitude, direction and duration of the resulting forces of physical and chemical processes occurring in the penetration zone.

When drilling fluid filtrate enters the bottom-hole (at drilling penetration) and is subsequently displaced back by formation fluid (at induced inflow), there is a redistribution of water-oil-gas saturation and the ratio of mobile and immobile (at pressure gradients realised in formation conditions) phases.

The volume of non-displaceable fluids (residual phase) in the BHZ includes:

- firmly bound layers and films;
- trapped fluids in dead-end channels and pores;
- fluids, which are held by surface and physical-chemical forces at acting pressure drops.

These phases include "loosely bound" water in diffusion (hydrate) layers and sorption layers of hydrocarbons and slow-moving inorganic formations and asphalt-resin deposits. According to I.G. Markhasin, the thickness of "non-displaced" films in the reservoir at a gradient of 0.5 MPa/m can reach 1 μm, and at lower gradients up to 2-3 mkm.

The complexity of the problem of well bottomhole zone formation and treatment is caused by:

- a complex of negative natural factors and mining and geological conditions;
- diversity and mutual overlapping of processes in the bottomhole formation zone;
- instability of bottomhole formation zone condition at all stages of well construction and operation.

The necessary hydrodynamic connection between the formation and the wellbore is created by secondary penetration (perforation) and development (treatment of the formation and inducing flow). The efficiency of perforation depends on the technique and technology of the operation, which depends on the following factors:

- conditions of work (composition of perforation fluid, pressure in the bottomhole formation zone during perforation, etc.);
- length-diameter ratios of perforation channels (deep-penetrating with relatively small holes or large holes but at a shallower depth);
- distances between perforations or perforation density;
- phasing angle.

The density of perforation should ensure maximum possible hydrodynamic improvement of the well with simultaneous preservation of casing integrity and tightness of cement stone outside the perforation (Table 1).

The effectiveness of inducing influx is facilitated by:

- preliminary acid, acoustic or vibration treatment to de-harden the structures in the penetration zones;
- cleaning of bottomhole formation zone by methods based on physicochemical, thermal and capillary processes.

The greatest effect of penetration zone deformation is given by the combination of processes when influencing the bottomhole formation zone (e.g., combining physicochemical and oscillatory processes). Excitation effect during flow induction depending on the characteristic of bottomhole blockage.

Table 1 – Rock characteristics of formations to be perforated

Category of breeds	Permeability, mcm^2	Density of perforation	
		depression	repression
Слабоуплотненные песчано-алевролитовые породы **с** глинистым цементом	>0,1 <0,1	6 10-12	12 12-18
Уплотненные песчано-алевролитовые породы с кварцевым и карбонатно-глинистым цементом	>0,01	18-20	12-20
Карбонатные, аргиллиты и другие породы, в которых отсутствует трещиноватость	<0,001 >0,01	18-20 10-12	20-24 18-20
Сильно уплотненные песчаники, алевролиты, известняки, доломиты, мергели и другие породы с развитой трещиноватостью	<0,01	12	18-24

The formation of the bottomhole zone of wells is accompanied by many processes that are diverse in nature. The influence of these processes is reflected in the state of the wellbore zone (Table-2).

All listed in table 1 impacts to one degree or another affect the productive reservoir. The ability to control impacts on the reservoir depends on the natural state of the reservoir (real mining and geological conditions) and on the technological methods used (completion technology, type and composition of well fluids, duration of operations, etc.).

Under the influence of the above processes, the following occurs:

1. Outside the penetration zone in the near-wellbore space due to changes in thermobaric conditions:

- change in the viscosity of formation fluids according to downhole conditions;
- release of gas from oil or condensation of new formations.

2. In the zone of penetration of drilling fluid filtrates:

- saturation of the reservoir with drilling fluid filtrates;
- swelling of hydrating minerals;
- change in the wettability of the surface of the filter channels;
- chemical interaction of introduced phases with formation fluids and rock.
- adsorption of substances from formation and introduced fluids;
- condensation of neoplasms.

3. In the zone of solid phase movement:

- partial or complete clogging of the rock;
- suffusion or blockage of the near-wall sections of the rock with the mobile solid phase of the reservoir;
- adhesion of the solid phase of solutions on the surface of the filter channels.

4. In the volume of absorbed portions of drilling fluid:

- structure formation and coagulation;
- formation of an internal filter cake on the permeable walls of channels and cracks.

Table 2 – Systematization of impacts during well completion that affect the near-wellbore zone of the reservoir

Process (driving force)	Type of impact in the bottomhole formation zone	Result of exposure
Physical (mechanical stress)	High effective stresses in the rock	Skeletal deformity
		Skeletal disintegration
		Formation of rock fracture products
Thermobaric (temperature and pressure gradient)	Phase formation at change of thermobaric state	Gassing when gas saturation pressure is reached
		Condensation of heavy hydrocarbons
Chemical (chemical potential)	Chemical interaction of downhole fluids	Dissolution of rock on the borehole walls
		Precipitate formation from exchange reactions
		Destruction of polymers and organic reagents
Hydraulic (static, dynamic and pulsating modes)	Filtration of the liquid phase into the collector	Redistribution of phase saturation in the bottomhole formation zone
	Filtration of the solid phase into the collector	Surface and internal ringing of the collector
	Mixing of gaseous and liquid phases in dynamic and cyclic mode	Emulsion formation
		Formation of gas dispersions
Electro-chemical (EMF value)	Action of electric potential	Change in diffusion-adsorption activity
Physicochemical (activity at the phase contact)	Rock dispersion	Increase in the volume of dispersed phase in the pore space
	Chemical and thermodynamic interaction of formation and injected phases	Changes in the composition and volume of bound water on the surface of pores and cracks
	Swelling of reservoir minerals	Reduction of pore space volume
	Absorption and adhesion of reagents and surfactants	Formation of films on the surface of pores and cracks
	Capillary processes at contact of well solutions with reservoirs	Capillary penetration of wetting phase in bottomhole formation zones
	Diffusion flows between the wellbore and the formation	Equalisation of water phase salinity in the well and reservoir
	Osmotic flows between the trunk and the reservoir	Equalisation of mineralisation in the well and reservoir in the presence of a semi-permeable baffle

5. In the zone where high effective stresses occur:
- formation and deformation of cracks;
- destruction of the rock skeleton.

The complexity of controlling processes in the near-wellbore formation zone is determined by:

- features of mining and geological conditions (abnormal pressures, composition of formation fluids and gases, high viscosity of hydrocarbons, low permeability and other difficulties);

- diversity, differences in kinetics and overlapping processes in the near-wellbore zone of the formation;

- the dependence of each of the processes on many factors simultaneously (reservoir properties of rocks, thermobaric conditions, intensity of physical and chemical phenomena, composition and properties of saturating phases, etc.);

- limited range of possibilities for controlling processes in the well and, especially, in the near-well space, including the near-wellbore zone, of the reservoir.

When developing technology for forming the bottom-hole zone of a well (the bottom-hole zone of wells), predicting significant factors influencing the productive reservoir is one of the important tasks, because makes it possible to optimize the completion stage to obtain high well performance.

In the process of designing well completion technologies, the following are developed:

- methods and modes of drilling penetration, securing and development of productive reservoir;

- types and compositions of well fluids (during drilling, cementing, perforation and induction) and their parameters;

- hydraulic opening program and permissible range of equivalent circulation density values;

- systems for circulation and purification of solution from sludge of formation fluids and gas;

- measures to prevent and eliminate possible complications.

The most important factor influencing the bottomhole zone of the formation is the duration during which the processes are realized, because a number of processes in the formation are of a fading nature (filtration, colmatation, capillary impregnation), and other processes are realized as the intra-formation situation changes (deformation, pressure changes in porous-fractured reservoirs, suffusion).

When forming the bottomhole zone of wells, numerous operations are carried out related to changes in pressure in the wellbore (working out the wellbore, changing flushing modes, lowering and raising tools, etc.). This creates a variety of filtration conditions (hydrostatic, hydrodynamic, hydraulic pulse), which ultimately affects the state of the zone of penetration of solid, liquid and gaseous phases into the bottomhole zone of the formation.

The processes of filtration into the formation are characterized by gradual attenuation due to the formation of a filtration cake and a colmatation zone, which depend, in addition to the filtration mode and the structure of the permeable space of the rock, on the dispersity and surface activity of the solid phase of well solutions.

The depth of penetration of some organic reagents into the pore space of the reservoir is proportional to the depth of penetration of the filtrate. The volume of displaced fluids in the near-wellbore zone of the formation (mobile phase), which moves in one direction or the other, depending on the direction of action of the pressure drop, can be increased by reducing the volume of non-displaced or inactive fluids (residual phase).

The residual phase depends on: the strength of hydration and sorption films; specific surface area; size and configuration of channels and pores, their number and size distribution; on the surface properties and lithological composition of rocks. In low-permeability reservoirs, the volume of the residual phase is much larger due to the more significant participation of physico-chemical processes in the formation of the penetration zone into the near-wellbore zone of the formation.

To achieve the required level of well completion quality, which represents a set of properties (functionality, manufacturability, environmental and technical reliability, durability, resource intensity, cost-effectiveness), it is guided by a certain level of requirements and restrictions on the technical condition of the well and its bottom-hole zone.

The complexity of controlling processes in the near-wellbore zone of a formation is determined by their diversity, overlap, differences in kinetics and limited capabilities for controlling processes.

As a result of penetration by drilling, negative consequences for productive deposits may include:

- redistribution of phases saturating the bottomhole zone, formation of emulsions;
- change in the size and volume of filter channels within the penetration zone (redistribution of pore sizes);
- changes in the pore structure and fracture structure of the reservoir due to destruction and deformation of the reservoir;
- reduced mobility of formation fluids both in the penetration zone and beyond the penetration zone due to changes in thermobaric conditions;
- filling of perforation channels and cracks with low-moving volumes of flushing solution.

During the process of opening, fastening, cementing and perforation, it is necessary to monitor and, if necessary, adjust:

- the process of formation of the bottomhole formation zone: composition and properties of drilling and grouting fluids; quality of adhesion of cement stone to rock and column; ionic composition of filtrates; surface tension at the interface; condition of the column and cement stone after perforation; perforation pressure; composition and properties of perforation fluids, etc.);
- direct interaction with the bottomhole formation zone: duration of operations; hydrostatic and hydrodynamic repression on the formation; height of rise of cement mortar behind the column; influx of formation fluids into the well; solution filtration; perforation density; location and configuration of perforations, etc.

Based on the results of hydrodynamic studies (productivity ratio, productivity, radius of the penetration zone; permeability in the penetration zone; skin effect in the penetration zone, etc.), the effectiveness of the well completion technology used is assessed.

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ҰҢҒЫМАНЫҢ ТҮП МАҢЫ АЙМАҒЫН ҚАЛЫПТАСТЫРУ

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Аннотация. Мұнай кен орындарында ұңғыманың түп маңы аймағын қалыптастыру технологиясы маңызды факторлардың бірі болып табылады. Бұл процесс ұңғыманы пайдаланудың жоғарғы тиімділігін қалыптастырып, ұңғыманы аяқтау кезеңін оңтайландыруға мүмкіндік тудырады. Ұңғыманың өнімді қабаттарының түп маңы аймақтарының жоғары өткізгіштігі ұңғыма өнімділігін төмендетеді. Тәжірибе жүзінде ұңғыманың түп маңы аймағында коллектор өткізгіштігінің төмендеуі көп жағдайда ұңғымаларды жөндеу кезінде пайдаланылатын сұйықтықтар сүзгісінің өзара іс-қимылын сүйемелдейтін әсерлермен негізделген.

Зерттеу мақсаты кәсіпшілік деректерді қазіргі заманғы зертханалық зерттеулерді кешенді пайдалану негізінде технологиялық сұйықтықтар мен тау жыныстарының өзара іс-қимылының ерекшеліктерін анықтау. Мақала кен орындардағы өндіру ұңғымаларын пайдалану процесінде өнімді қабаттардың түп маңы аймақтарының қалыптасу ерекшеліктерін зерделеуге арналған.

Мақала зерттеуі негізіндегі ғылыми жарияланымдарды талдау ұңғыманың түп маңы аймақтарыныңң жай-күйін бағалау үшін қолданыстағы әдістердің негізгі мәселелерінің бірі оның физикалық мағынада әртүрлілігі және оны қалыптастыратын басым факторлардың бөлінуі мүмкін болмайтындығын көрсетті.

Тірек сөздер: ұңғыма түп маңы аймағы, қабат маңы аймағы, гидродинамикалық зерттеулер, бұрғылау ерітіндісі, сүзгі арналары.

ФОРМИРОВАНИЕ ПРИЗАБОЙНОЙ ЗОНЫ СКВАЖИНЫ

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Аннотация. Одним из важных факторов нефтяных месторождений является технология формирования призабойной зоны. Этот процесс позволит сформировать высокую эффективность эксплуатации скважины и оптимизировать этап заканчивания скважины. Высокая проницаемость призабойных зон продуктивных пластов снижает продуктивность скважин. На практике снижение проницаемости пласта на забое скважины во многом обусловлено эффектами, сопровождающими взаимодействие фильтрующих жидкостей, используемых при капитальном ремонте.

Цель исследования – выявление особенностей взаимодействия технологических флюидов и горных пород на основе комплексного использования современных лабораторных исследований промысловых данных, а также является изучение особенностей формирования призабойных зон продуктивных пластов в процессе эксплуатации добывающих скважин на месторождениях.

Анализ научных публикаций на основе изучения статей показал, что одной из основных проблем существующих методов оценки состояния забоев скважин является их многообразие в физическом смысле и невозможность выявления преобладающих факторов, их формирующих.

Ключевые слова: призабойная зона скважины, призабойная зона пласта, гидродинамические исследования, буровые растворы, фильтрационные каналы.

Қолжазбаларды рәсімдеу жөнінде авторларға арналған нұсқаулық

«Техника ғылымдары және технологиялар» журналында мақала жариялау үшін дайын ғылыми жұмысты автор(лар) Vestnik.korkyt.kz сайтындағы Онлайн мақала жіберу жүйесі арқылы, арнайы нұсқаулықты пайдаланып жіберуге болады. Мақала Windows 10 оперативті жүйесіндегі Word форматында Times New Roman шрифтінде жазылуы қажет (Осы талапта жазылмаған мақала автоматты түрде қабылданбайды). Жарияланым – тілдері қазақша, орысша, ағылшынша. Мақала құрылымы мен безендірілуі:

1. Мақала көлемі 6-12 бет аралығында болуы тиіс (аннотациялар мен әдебиеттер тізімін қоспағанда 6 беттен төмен болмауы тиіс).

– Мақаланы құру схемасы (беті – А4, кітаптық бағдар, туралау – ені бойынша. Сол жақ, үстіңгі және төменгі жақтарындағы ашық жиектері – 2,5 см, оң жағында – 2,0 см. Шрифт: тип Times New Roman, өлшемі – 12) (Windows 10 оперативті жүйесіндегі Word форматында);

- ХҒТАР индексі – бірінші қатар жоғарыда, сол жақта (http://grnti.ru); оң жақта – журналдың doi индексі (префикс және суффикс) – редакцияда беріледі;
- мақала атауы – ортасына қалың он екінші қаріппен;
- автор(лардың)дың аты-жөндерінің бірінші қарпі мен тегі – ортаға 11-қаріп, (авторлар саны 5 адамнан артық болмауы тиіс);
- ұйым, қала, елдің толық атауы – ортаға, курсив – 11-қаріп;
- **Аңдатпа.** Түп нұсқа тілінде (**150-200 сөз**; мақала құрылымын сақтай отырып), өлшемі (кегль) – 11-қаріп;
- **Тірек сөздер** – қазақ, орыс, ағылшын тілдерінде (3-5 сөз/сөз тіркестері), өлшемі - (кегль) 11-қаріп;
- Негізгі мәтін (аралық интервал – 1, «азат жол» - 1,25 см, 12-қаріп) құрылымы төмендегідей болады:

2. **Кіріспе:** тақырыптың таңдалуын негіздеу; таңдалған тақырыптың, мәселенің өзектілігі, объектісі, пәні, мақсаты, міндеті, әдісі, тәсілі, тұжырымы және мағынасын анықтау

3. **Зерттеу материалдары мен әдістері:** материалдар мен жұмыс барысы сипаттамасынан, сондай-ақ пайдаланылған әдістердің толық сипаттамасынан тұруы тиіс.

4. Кестелер, суреттер айтылғаннан кейін орналастырылуы керек. Әр иллюстрациямен жазу(өлшемі (кегль) – 11) болуы керек. Суреттер анық, таза, сканерленбеген болуы керек.

Мақала мәтінінде сілтемелер бар формулалар ғана нөмірленеді. Мәтінде сілтемелер тік жақшада көрсетіледі. Сілтемелер мәтінде қатаң түрде нөмірленуі керек.

5. **Нәтижелер/талқылау:** зерттеу нәтижелерін талдау және талқылау келтіріледі.

6. **Қорытынды/қорытындылар:** осы кезеңдегі жұмысты қорытындылау; автор айтқанұсынылған тұжырымның ақиқатын растау. Жұмысты қаржылық қолдау туралы ақпарат Қорытындыдан кейін түседі. Әдебиеттер тізімі (өлшемі (кегль) – 11, пайдаланылған әдебиеттер саны – 15-тен кем болмауы қажет). Әдебиеттер тізімінде кириллицада ұсынылған жұмыстар болған жағдайда әдебиеттер тізімін екі нұсқада ұсыну қажет: біріншісі – түпнұсқада, екіншісі – романизацияланған алфавитпен (транслитерация). Мақаладағы дәйексөз тізімінде тек рецензияланған әдебиет көздері, DOI индексі бар әдебиеттер болуы тиіс. Романизацияланған әдебиеттер тізімі http://www.translit.ru сайты арқылы рәсімделуі керек.

7. Авторлар туралы мәліметтер: (автордың(лардың) аты-жөні, ұйымның толық атауы, қаласы, елі, байланыс деректері: телефоны, эл.пошта, орсид номері) 3 тілде.

Келген мақала талапқа сай рәсімделген жағдайда ғана Антиплагиат бағдарламасынан өткізіледі. Тұпнұсқалығы 80% - дан жоғары көрсеткіште болған мақала Редакцияның карауына жіберіледі. Ал 80% - дан төмен болған мақала автордың толықтыруына жіберіледі. Ал, екінші рет өткізілген жағдайда тиісті көрсеткіш болмаса жарияланымға қабылданбайды. Рецензенттердің оң пікірінен соң мақала журналға қабылданып, авторға төлем жасау жөнінде хабарлама жіберіледі. Автор төлемақының түбіртегін редакцияның электронды почтасына жіберуге міндетті (Technique_Journal@korkyt.kz)

Руководство для авторов по оформлению рукописей

Готовая научная работа для публикации в журнале «Технические науки и технологии» может быть подана автором (авторами) через систему онлайн подачи статей на сайте vestnik.korkyt.kz, используя специальные инструкции. Статья должна быть написана в формате Word в Windows 10 шрифтом Times New Roman (статья, не написанная в соответствии с этим требованием, не будет принята автоматически). Язык публикаций казахский, русский, английский. **Структура и оформление статьи**:

1. Объем статьи в пределах от 6 до 12 страниц (не менее 6 страниц, за исключением аннотаций и списка литературы).

- Схема построения статьи (страница – А 4, книжная ориентация, поля с левой, верхней и нижней сторон – 2,5 м, с парвой – 2,0 мм. Шрифт: тип – Times New Roman, размер (кегль) - 12) (В формате Word в операционной системе Windows 10):
- индекс МРНТИ - первая строка сверху слева (http://grnti.ru); индекс DOI (предоставляется редакцией журнала);
- название статьи – прописными буквами по центру полужирным шрифтом, размер-12;
- инициалы и фамилию автора(ов) – по центру полужирным шрифтом, размер (кегль) – 11 (адрес эл.почты авторов, номер орсид, количество авторов не должно превышать 5 человек);
- полное наименование организации, город, страна – по центру, курсив, размер - 11.
- **Аннотация** на языке оригинала (**150-200** слов; сохраняя структуру статьи) размер-11.
- **Ключевые слова** (на казахском, русском, английском от 5 до 8 слов/словосочетаний) размер (кегль) - 11.
- Основной текст (12 шрифт, межстрочный интервал - 1, отступ «красной строки» - 1,25 см), структура:

2. **Введение**: обоснование выбора темы; актуальность темы или проблемы, определение объекта, предмета, целей, задач, методов, подходов, гипотезы и значения работы.

3. **Материалы и методы исследования**: должны состоять из описания материалов и хода работы, а также полного описания использованных методов.

4. В статье нумеруются только те формулы, на которые есть ссылки в тексте. В ссылках в тексте указывается в квадратных скобках.

5. **результаты/обсуждение**: приводится анализ и обсуждение полученных результатов исследования.

6. **заключение/выводы:** обобщение и подведение итогов работы на данном этапе; подтверждение истинности выдвигаемого утверждения, высказанного автором.

Список литературы (размер (кегль) – 11, количество используемой литературы не менее 15). При наличии в списке литературы работ, представленных на кириллице, список литературы должен быть представлен в двух вариантах: первый - в оригинале, второй - в латинизированном алфавите (транслитерация). Список ссылок в статье должен содержать только рецензируемые литературные источники, литературу с индексом DOI. Список латинизированной литературы должен быть подготовлен через сайт http://www.translit.ru.

7. Сведения об авторах: (должны содержать ФИО автора (ов), полное наименование организации, город, страна, контактные данные: телефон, эл.почта, номер орсид) на 3-х языках.

8. Статья должна обладать не менее 80% уникальности текста для публикаций. В случае если оригинальность статьи ниже 80%, работа будет возвращена автору для исправление и корректировки. После вторичной проверки статья набирает необходимого показателя в антиплагиат, направляется на рассмотрение редакционной коллегии. Статья, не отвечающая соответствующим требованиям, оригинальность который, проверена дважды, к публикации не принимается. После положительного отзыва рецензентов, статья принимается для публикации в журнал и автору направляется уведомление об оплате. Автор обязан отправить квитанцию об оплате на электронную почту редакции. (Technique_Journal@korkyt.kz).

Manual for authors of manuscripts

Ready scientific work for publication in the journal «Technical sciences and technologies» can be submitted by the author (authors) through the system of online submission of articles on the site vestnik.korkyt.kz, using special instructions. The article should be written in Word format in Windows 10 in Times New Roman font (an article not written in accordance with this requirement will not be accepted automatically). Language of publications Kazakh, Russian, English.

Structure and design of the article:

1. The size of the article ranges from 6 to 12 pages at least 6 pages, excluding annotations and bibliography).

- description of the scheme of the article (page - A 4, book orientation, indents are calculated with respect to the left top and bottom sides page margins – 2.5 m, with right - 2.0 m, Standard font: type - Times New Roman, size (font) - 12) (Word format on Windows 10 operating system):
- the ISTIR index is the first line at the top left (http://grnti.ru).
- DOI index (provided by the editorial office);
- title of article – with capital letters, alignment on the center in bold, size (font) 12.
- initials and last name of author(s) - alignment on the center in bold, size (font) – 11, (e-mail address of the authors, orsid number, the number of authors should not exceed 5 people);
- the full name of the organization, city, country, alignment on the center, italic, size (font) - 11.
- **Annotation** in the original language (150-200 words; retaining the structure of the article) size (font) - 11.
- **Keywords** (in Kazakh, Russian, English from 5 to 8 words/phrases) size (font) - 11.
- **Main text** (12 font, line spacing - 1, indentation of red line#- 1.25 cm)
- Structure:

2. **Introduction:** rationale for the selection of the topic; relevance of the topic or problem; definition of the object, subject, objectives, tasks, methods, approaches, hypotheses and meanings of the work.

3. **Research materials and methods:** should consist of a description of the materials and the progress of work, as well as a full description of the methods used.

4. In the article, only those formulas that are referenced in the text are numbered. References in the text are indicated in square brackets.

5**. Results/discussion**: an analysis and discussion of the results of the study is given.

6. **Conclusion/conclusions**: summarizing and summarizing the work at this stage; confirmation of the truth of the assertion put forward by the author.

List of references (size (point size) - 11, the number of used literature is at least 15). If there are works presented in Cyrillic in the list of references, the list of references should be presented in two versions: the first - in the original, the second - in the Latinized alphabet (transliteration). The list of references in the article should contain only peer-reviewed literary sources, literature with a DOI index. The list of romanized literature should be prepared through the site http://www.translit.ru.

7. Information about the authors: (should contain the full name of the author (s), full name of the organization, city, country, contact details: telephone, e-mail, orsid number) in 3 languages.

8. The article must have at least 80% uniqueness of the text for publication. If the originality of the article is below 80%, the work will be returned to the author for correction and correction. After a secondary check, the article gains the required indicator in anti-plagiarism, and is sent for consideration by the editorial board. An article that does not meet the relevant requirements, the originality of which is double-checked, is not accepted for publication. After a positive feedback from the reviewers, the article is accepted for publication in the journal and the author is sent a notification of payment. The author is obliged to send a payment receipt to the editorial office by e-mail (Technique_Journal@korkyt.kz)

МАЗМҰНЫ

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2023 жылдан бастап шығады Издается с 2023 года Published since 2023	Жылына төрт рет шығады Издается четыре раза в год Published four times a year

Редакция мекен-жайы: 120014, Қызылорда қаласы, Әйтеке би көшесі, 29 «А», Қорқыт Ата атындағы Қызылорда университеті	Адрес редакции: 120014, город Кызылорда, ул. Айтеке би, 29 «А», Кызылординский университет им. Коркыт Ата	Address of edition: 120014, Kyzylorda city, 29 «A» Aiteke bie str., Korkyt Ata Kyzylorda University
Телефон: (7242) 27-60-27 Факс: 26-27-14 E-mail: Technique_Journal@korkyt.kz	Телефон: (7242) 27-60-27 Факс: 26-27-14 E-mail: Technique_Journal@korkyt.kz	Tel: (7242) 27-60-27 Fax: 26-27-14 E-mail: Technique_Journal@korkyt.kz

Құрылтайшысы: «Қорқыт Ата атындағы Қызылорда университеті» КеАҚ
Учредитель: НАО «Кызылординский университет им. Коркыт Ата»
Founder: «Korkyt Ata Kyzylorda University» NJSC

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігі
берген № KZ KZ37VPY00066487 16-наурыз, 2023 ж
бұқаралық ақпарат құралын есепке алу куәлігі

Техникалық редакторы: Абуова Н.А.
Компьютерде беттеген: Кулманова С.А.

Теруге 14.06.2024 ж. жіберілді. Басуға 21.06.2024 ж. қол қойылды.
Форматы 60 × 841⁄8. Көлемі 6,2 шартты баспа табақ. Индекс 76216.
Таралымы 50 дана. Тапсырыс 0183 Бағасы келісім бойынша.

Сдано в набор 14.06.2024 г. Подписано в печать 21.06.2024 г.
Формат 60 × 841⁄8. Объем 6,25 усл. печ. л. Индекс 76216.
Тираж 50 экз. Заказ 0183. Цена договорная.

Университет баспасы
120014, Қызылорда қаласы, Әйтеке би көшесі, 29А.