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Development of composition of cementing slurry for fastening of low-cemented rocks

Roman Kondrat[1], Natalia Dremliukh[1*], Liliya Khaidarova[1]

[1]*Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, 76019, Ukraine*

**Corresponding author: e-mail nataliadremluh@ukr.net, tel. +380989882487*

Abstract

Purpose. Improving the producing capacity and ensuring the stable operation of gas wells that develop unstable, low-cemented reservoirs by preventing the sand entry from the reservoir by means of creating the cement stone with the corresponding values of strength and permeability in the bottomhole formation zone.

Methods. The technological characteristics of the cementing slurry and the formed cement stone are measured using standard recording equipment. The cementing slurry consistency is measured with a pycnometer, the cement mixture spread ability – using AzNII cone, water separation is measured according to standard methods (DSTU BV.2.7 – 86-99), and the time of the cementing slurry hardening is determined on a consistometer KTS-3. The ultimate parameters of the stone strength during bending are determined on a special device for testing linear objects in tension, and compression – on a PSU-10 hydraulic press.

Findings. The cementing slurry composition for creating the cement stone with the corresponding values of compression strength and gas permeability in the bottomhole formation zone has been developed, which includes oilwell cement, expanded perlite, non-ionic surfactant, plasticizer and water. Dependences of the cement stone compression strength and the stone permeability coefficient on the proportion of expanded perlite in the cementing slurry solution have been revealed. It is recommended to use the proposed cementing slurry for creating a cement stone with specified values of compression strength and permeability in the expanded well shaft in the interval of the producing reservoir.

Originality. The optimal proportion of the expanded perlite in the solution has been found, at which the corresponding values of the compression strength (up to 4 MPa) and gas permeability (up to 3.47 μm^2) of the cement stone is provided.

Practical implications. When using the developed composition, it is possible to increase the yield of wells with unstable reservoirs and improve their working conditions by preventing the sand entry from the reservoir into the well.

Keywords: *well, reservoir, gas, sand plug, cement stone, stone strength, gas permeability, filler material*

1. Introduction

At present, a significant amount of gas and gas condensate fields in Ukraine are at the final stage of development, which is characterized by a significant decrease in reservoir pressure, low yield of producing wells and the presence of factors complicating their work. The complications typical for the final stage of field development include water flooding of wells and destruction of the bottomhole formation zone (BHFZ) in unstable (low-cemented) reservoirs.

The operation of gas and gas condensate wells with unstable reservoirs is accompanied by the removal of rock particles from the reservoir and their accumulation at the well bottom with the sand plugs formation. Most often, unstable rocks in domestic fields are represented by low-cemented sandstones.

The main reason for the sand removal from the reservoir into the well is the bottomhole zone destruction due to high stresses in the rock during reservoir fluids filtration through the rock or pressure drop across the reservoir [1].

It is confirmed in the research that the rock particles removal from the reservoir during the wells operation is accompanied by the formation along the fractures in the bottomhole formation zone of highly permeable channels with various widths and lengths, filtering gas and reservoir water [2]. The solid phase, when carried out of the producing reservoir, leads to instability and rock caving into the bottomhole zone, the formation of caverns, stuck oilwell tubing, collapse of the production string, abrasive wear of well equipment, and the formation of sand plugs in faces, which leads to additional resistance to gas movement and reducing the well yield [3].

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One method to control the sand entry from the bottomhole zone is to drill a smart well equipped with deep pressure and temperature sensors to continuously measure the dynamic performance of the well and the reservoir, to control the volume of fluid incoming to the well [4].

The main methods to prevent the bottomhole formation zone collapse include strengthening the rock and equipping the well bottom with filters, in particular gravel-pack filters. Among the filters of domestic production, FS-1, FIL-1, FIL-2, K-168-N, FSSch can be distinguished. Filters are effective when the fissure width and gravel grain diameter are selected correctly. Filter parameters are determined using the results of the rock granulometric content [5]. The method to control plugs formation at the well bottom by setting filters is not always expedient, economically viable and is characterized by insufficient reliability. This is due to the fact that the creation and correct selection of structural elements of mechanical filters depends on many factors, both technical and geological in nature. The disadvantages of filters are their colmatation, high cost and insufficient mechanical strength [6].

To increase the wells deliverability and reduce the costs of their repair, the rocks in the bottomhole formation zone are strengthened with various chemical compositions.

In domestic and foreign practice, mixtures of cement with various filler materials, polymer compositions, foamed and synthetic resins, as well as their mixtures with sand, are used for strengthening the low-cemented rocks.

In practice, hardening resins are used, such as epoxy, furan, phenol-formaldehyde. Many years' experience of strengthening the bottomhole zone rocks with synthetic resins shows that the effectiveness of their application decreases with an increase in the size of caverns in the bottomhole zone. The resin hardened in the cavern reduces the conductivity of the bottomhole formation zone. Due to the gravity forces, the resin is placed in the lower part of the cavern and only repeated filling with resin in large volumes strengthens the bottomhole zone. Due to the high cost of synthetic resins, bottomhole zone strengthening with resin is more expensive than gravel-pack placement [7].

Currently, water-based resins are used, first tested in Egypt in 2009. The cost of strengthening the bottomhole zone with a water-based resin is half that of using a hydrocarbon-based resin [8].

For strengthening the low-cemented rocks, silicate-based compositions are used, which, unlike resins, have a high strength of rock fixing. The operational properties of silicate-based compositions are retained for a long period (more than one year), while the serviceable life of most resins does not exceed 3-6 months. Silicate-based solutions have high binding properties, stickability and increased adhesion to quartz sand [9].

To ensure long-term and efficient operation of wells with unstable, low-cemented reservoirs, the staff of the Institute of Oil and Gas Problems, Russian Academy of Sciences has developed the IPNG-PLAST 2 polymer composition, which forms an intrastratal polymer-sand filter that strengthens the bottomhole zone and prevents sand entry into the well [10].

The authors of the work [11] have developed a method for strengthening low-cemented sandstones in gas wells, which consists in using a 10% aqueous solution of calcium chloride $CaCI_2$ and a 7.5% aqueous solution of sodium hydrogen carbonate. When using the developed composition, a minimal decrease in permeability occurs – by 1.04 times compared to the initial value.

The mixtures of portland cement are of greatest interest, being the cheapest and most readily available binding agent. It is non-toxic, easy-to-use material, which forms a sufficiently strong stone, retaining its properties over time. However, in the reservoirs containing clayey silt, the cement slurry introduced into the bottomhole zone does not provide positive results when strengthening the rocks, since a mixture of cement slurry with clay does not form a durable cement stone [12].

To reduce the amount of cement in the grout mixture, the authors of the work [13] propose to use crushed granulated blast-furnace slag. Research confirms that cement stone, which contains 10% granulated blast-furnace slag as a substitute for cement, does not lose strength.

Recently, much attention has been paid to the study and use of lightweight cementing slurries. Additives such as zeolite, tripoli, rubber and plastic foam lids, ground reed, leather dust, mineral organic powder, lignin sludge, vermiculite and its varieties have found wide application in the production of grouting material [14].

In the work [15], authors propose to use a lightweight cementing slurry filler – hollow glass microspheres ranging in size from -50-100 to 400-500 μm, which are produced in many countries of the world. The low bulk consistency of the microspheres lightens the mixture, and the regular and rounded shape of particles improves the solution spreadability [15]. To increase the compression strength of cement stone, the authors in the work [16] propose to use carbon nanofibers.

In the work [17], the results are presented of experimental studies of oilwell cement with an admixture of nanoparticles under the commercial name EX-RIPI in a proportion of 9% of the cement mass. The cement stone advantage is that the compression strength is doubled. The disadvantage of the developed composition is the complex preparation technology and low solubility in water.

An acid-based cementing slurry is used to strengthen the rocks in the bottomhole formation zone of the Socar field [18]. The strengthening creates a stable and permeable barrier that prevents sand entry into the well.

A.A. Gadzhiev and E.K. Tolepberg have developed a cementing compound for rocks strengthening, tested at oil wells of the Neft Dashlary Field. After the operations for strengthening, the sand entry has stopped, the deliverability of wells has increased [19]. Analysis of the scientific-and-technological and patent literature indicates that the cementing compounds and compositions used for strengthening the rocks in the bottomhole formation zone should satisfy two main performance criteria – the preservation of the gas reservoir permeability and the formation of a strong stone (grouted sandstone), capable to withstand heavy loads when producing fluid.

Despite the large number of research conducted to improve the formulation of cementing slurries, the problem of the bottomhole formation zone destruction and the removal of the solid phase is still relevant. This is conditioned by the fact that most of the proposed compositions for strengthening unstable rocks do not provide a sufficiently high efficiency of rock consolidation while maintaining the filtration characteristics of the reservoir, reduce well productivity due to deterioration of reservoir permeability, which is the basis for additional studies.

The objective of the research is to create and study the properties of a lightweight cementing slurry for strengthening low-cemented rocks.

Recently, much attention has been paid to the study and use of lightweight cementing slurries. Information about the influence of lightweight additives on the strength properties of cement stone and the gas permeability coefficient is insufficiently covered in the literature.

Based on the results of the analysis of recent research on the studied issue, it is planned to conduct the research on the development of the cementing slurry composition to create a highly permeable and durable cement stone in the bottomhole zone of the well with unstable, low-cemented rocks.

2. Methods

In laboratory conditions, the cementing slurry composition has been developed to create a highly permeable and strong cement stone in the bottomhole zone of a well with unstable reservoirs [20]. The TS-100 grout mixture, filler (expanded perlite of 0.16-1.25 mm fraction), non-ionic surfactants, plasticizer and water are used as the initial reagents for creating the cementing slurry. For research, a composite grout mixture TS-100 is used as the main binding material, which in its component composition almost completely corresponds to the innovative material of the Schlumberger Company. The presence in the TS-100 composition of most of the silica component (in comparison with PTsT I-100) and a lower content of calcium oxide increases the corrosion and temperature resistance of the mixture. To form the cement stone of porous structure, an expanded perlite of 0.16-1.25 mm fraction is used as a filler, which is obtained by heat treatment of aluminosilicate perlitic rock of volcanic origin. Perlite consists of SiO_2 (65-75%) and Al_2O_3 (10-16%), K_2O, Na_2O, Fe_2O_3, MgO, CaO are also present, the water content is 2-5%. The peculiarity of pearlites is the expanding ability under heat treatment with a multiple increase in volume by 5-20 times as compared to the initial volume. This is conditioned by the content of water in the material, which evaporates at high temperatures. Expanded perlite, produced in Ukraine according to the two-stage technology of the SE Ukrainian Research and Design-and-Engineering Institute of Building Materials and Products (NDIBMV) from the secondary-hydrated perlite of the Fogos deposit, is by 2.5-3 times stronger than perlite, which is produced by one-stage technology from the primary-hydrated perlite from the Greece, Turkey, Georgia, and Armenia deposits. Due to this peculiarity, the perlite abrasion is reduced when preparing the dry mix. Expanded perlite, in comparison with prototypes, increases the cementing slurry stability, enhances pumping properties, reduces the slurry consistency and increases the strength of the hardened cement stone. The non-ionic surfactants (neonol AF-09-10, stinol, savenol SWP) are used in the research. The best results have been obtained in experiments with the use of neonol AF-09-10, which ensures the homogeneity and stability of the solution after mixing. The cementing slurry acquires plasticity, which ensures its penetration into the pores of the rock and contributes to the high-quality strengthening of the well bottomhole zone. Non-ionic surfactants unlike anionic surfactants, do not enter into chemical interaction with reservoir water salts, do not lose their surface activity, affect the wettability of the producing reservoir rock surface and increase the permeability for hydrocarbons. To ensure optimal rheological characteristics of cementing slurries and the required spreadability, the polycarboxylate superplasticizing agent Termit PT is used, which satisfies the requirements of superplasticizers EN 934-2:2001, DSTU BV.2.7-171-2008, NEQ. The grout compound for strengthening the low-cemented rocks in the bottomhole zone of wells is prepared by mixing expanded perlite, dry grout mixture TS-100, the required amount of plasticizer and surfactant with a calculated volume of water. To analyse the developed grout compound effectiveness, the properties of the cementing slurry and cement stone are studied in the laboratory conditions.

Using the AzNII cone, the diameter of the cementing slurry spreadability is measured in two mutually perpendicular directions, and the result is rounded to 1 mm. The arithmetic mean of the results of two measurements, the difference between which does not exceed 10 mm, is taken for spreadability.

After reaching the required spreadability of the cementing slurry, its consistency is determined using a pycnometer [21].

The consistency of the slurry is calculated as the arithmetic mean of the measurement results, which differ from each other by no more than 20°kg/m³, according to the formula:

$$\rho = \frac{m_2 - m_1}{V} \cdot 10^3, \quad (1)$$

where:

m_1 – empty pycnometer weight, g;

m_2 – weight of the pycnometer with cement slurry, g;

V – pycnometer capacity, cm³;

ρ – slurry consistency, kg/m³.

The samples of the cement stone are formed using PTsK-1 and KTs-3 devices in order to determine its strength characteristics. The maximum operating pressure is 40°MPa, the temperature – 75°C. Temperature conditions, when forming the cement stone samples, are maintained by electric heaters operating in automatic mode with registration by potentiometers. The required pressure is set using a hydraulic press and heating the process fluid in an autoclave. The conditions for filling the well with cementing slurry for rock strengthening are modeled.

3. Results and discussion

The results of the experimental research on the influence of expanded perlite on the cementing slurry spreadability by the AzNII cone and on its consistency are shown in Table 1.

The research results indicate that with an increase in the proportion of expanded perlite in the cementing slurry, its consistency and spreadability decrease. If the proportion of expanded perlite in the cementing slurry is more than 3.5% mass, the spreadability of the slurry is below 180°mm, which does not satisfy the requirements of DSTU and can cause complications in the process of the grout mixture filling.

Important physical and mechanical characteristics of grouting materials are the strength properties of cement stone, which are characterized by the ultimate resistance to compression and bending (DSTU BV. 2.7-86-99).

Four samples of each composition are tested for strength (by the destructive method in bending and compression). The bending test is performed using an MR-05 tension testing machine, and a compression test – on a PSU-10 hydraulic press.

The research results of the cement stone compression and bending are shown in Figure 1.

Table 1. Results of the experimental research on the influence of expanded perlite on the cementing slurry spreadability using the AzNII cone and on its consistency

Experiment No.	Cementing slurry composition, % mass					Cementing slurry parameters		
	Oil well cement	Expanded perlite	Non-ionic surfactants	Plasticizer	Water	Water separation, ml	Consistency, kg/m^3	Spreadability, mm
1	68.30	0.5	0.20	–	31.0	2.0	1520	222
2	65.75	1.0	0.20	0.05	33.0	2.0	1450	215
3	65.15	1.5	0.25	0.075	33.025	1.5	1380	210
4	64.625	2.0	0.25	0.075	33.05	1.0	1320	200
5	64.00	2.5	0.30	0.10	33.10	0.5	1270	195
6	63.50	3.0	0.30	0.10	33.10	0.0	1210	190
7	62.85	3.5	0.35	0.10	33.20	0.0	1160	185
8	62.30	4.0	0.40	0.10	33.20	0.5	1120	175

(a)

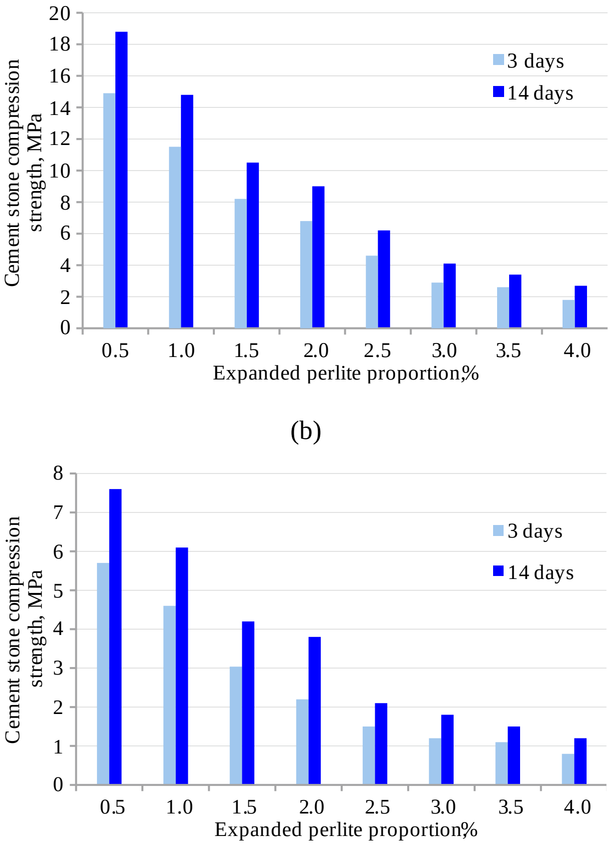

Figure 1. Comparative histogram of a change over time in the cement stone compression (a) and bending (b) strength

The results of experimental research indicate that an increase in the expanded perlite proportion in the cementing slurry of more than 3.5% mass leads to a loss of cement stone strength, which does not satisfy the requirements for strengthening the low-cemented rocks.

The maximum compression and bending strength of the cement stone is observed when the expanded perlite proportion is 0.5-1% mass and is 14.9 and 11.5 MPa, respectively.

According to the results of experimental research, the compression and bending strength of the cement stone increases with time up to 35%. This indicates the possibility of using the composition to create a durable cement stone. Thus, the expanded perlite proportion of 0.5-1% mass is the most effective for maintaining the strength of the bottomhole formation zone, which increases the stability of rocks in the bottomhole zone and extends the period of trouble-free well operation.

The permeability of the cement stone structure is studied in accordance with GOST 26450.2-85. Gas is passed through the cement stone sample with fixing the pressure drop before and after the sample. The absolute gas permeability coefficient for stationary gas filtration along the linear direction of the gas flow is determined by the Darcy's formula.

The results of experimental research on determining the cement stone permeability are shown in Table 2.

The results of experimental research indicate that with an increase in the expanded perlite proportion from 0.5 to 4% mass in the composition for strengthening unstable reservoir rocks, the permeability coefficient of the cement stone increases from 0.0011 to 5.5 μm^2. At the same time, it should be taken into account that an increase in the expanded perlite proportion leads to a decrease in the cement stone strength. To determine the optimal value of the expanded perlite proportion in the composition, which will provide the necessary stone strength, provided that the permeability of the rock is maintained, a graphical dependence is plotted (Fig. 2).

According to the results of experimental research shown in Figure 2, the optimal range of using the proposed composition corresponds to the expanded perlite proportion 3-3.5% mass. At such concentrations, the necessary compression strength of the stone is obtained while maintaining the filtration characteristics of the reservoir.

Table 2. Results of research on the cement stone permeability

Experiment No.	Cement stone composition, % mass					Gas permeability coefficient of the cement stone, μm^2
	Oil well cement	Expanded perlite	Non-ionic surfactants	Plasticizer	Water	
1	68.30	0.5	0.20	–	31.00	0.0011
2	65.75	1.0	0.20	0.05	33.00	0.004
3	65.15	1.5	0.25	0.075	33.025	0.01
4	64.625	2.0	0.25	0.075	33.05	0.08
5	64.00	2.5	0.30	0.10	33.10	0.15
6	63.50	3.0	0.30	0.10	33.10	2.92
7	62.85	3.5	0.35	0.10	33.20	3.22
8	62.30	4.0	0.40	0.10	33.20	5.50

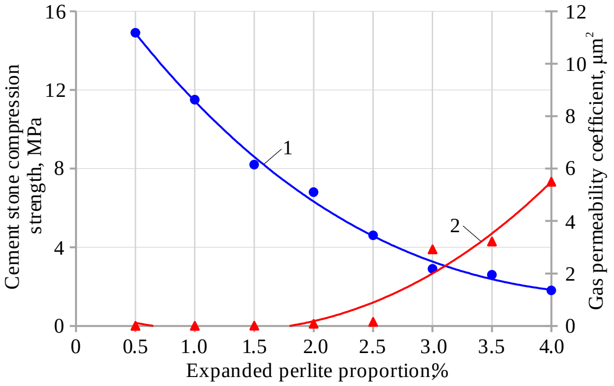

Figure 2. Dependences of the cement stone compression strength (1) and the permeability coefficient (2) on the expanded perlite proportion in the composition

The spreadability of the cementing slurry with an expanded perlite proportion of 3 and 3.5% mass is 190 and 185 mm, respectively, which is technologically convenient for the preparation and filling the slurry into the well. In this case, a high sedimentation stability of the cementing slurry is achieved, and water separation is completely absent.

Table 3 shows the generalized results of experimental research on strengthening mixtures with an expanded perlite proportion of 3-3.5% mass.

The results of experimental research indicate that the developed composition is more effective than the prototype, since with the appropriate cementing slurry parameters, the time of samples hardening and the ultimate compression strength, the value of the cement stone permeability coefficient increases by 10 times.

Table 3. Generalized results of experimental research on strengthening mixtures

No. composition	Cementing slurry component composition, % mass	Cementing slurry parameters		Conditions for conducting research on cement stone		Time of samples hardening, hour	Ultimate compression strength, MPa	Permeability coefficient, μm^2
		Consistency, kg/m^3	Spreadability, mm	Pressure, MPa	Temperature, °C			
5	oilwell cement – 63.5 perlite – 3 surfactant – 0.3 plasticizer – 0.1 water – remaining proportion	1210	190	0.1013	20	72	2.8	2.92
		1210	190	0.1013	50	48	3.2	3.18
		1210	190	0.1013	75	24	3.4	3.47
		1210	190	5	50	48	3.6	2.35
		1210	190	10	50	48	3.7	2.07
		1210	190	20	50	48	3.9	1.64
		1210	190	40	75	24	4	1.25
6	oilwell cement – 62.85 perlite – 3.5 surfactant – 0.35 plasticizer – 0.1 water – remaining proportion	1160	185	0.1013	20	72	2.7	3.22
		1160	185	0.1013	50	48	3.02	3.65
		1160	185	0.1013	70	24	3.2	3.89
		1160	185	10	50	48	3.4	2.24
		1160	185	20	50	48	3.7	1.81
	prototype			Normal conditions			4.1	0.03 (when hardening in water) 0.265 (when hardening in oil)

Permeability in the range of 1.25-3.47 μm^2 and compression strength of 4 MPa of the obtained cement stone make it possible to increase the yield of the well without sand entry after strengthening the bottomhole zone with an increased drawdown pressure on the reservoir, as well as to increase the overhaul period of the well operation.

Experimental research has confirmed the optimal mass concentrations of the composition for strengthening unstable reservoir rocks: oilwell cement – 62.85-63.5%; expanded perlite – 3-3.5%; non-ionic surfactant – 0.3-0.35%; plasticizer – 0.1%; water – remaining proportion. A further increase in the components proportion does not significantly affect the change in the permeability coefficient, and their concentration below the specified limit is insufficient to obtain the effect of strengthening the bottomhole formation zone.

Thus, using the results of experimental research, a cementing slurry composition has been developed based on a grout mixture with the addition of expanded perlite, a non-ionic surfactant, a plasticizer and water, which bond the rock particles together. The formed cement stone is characterized by high mechanical compression strength (up to 4 MPa) and gas permeability (up to 3.47 μm^2). The advantage of the developed composition in comparison with the known compositions is the absence of the necessity to use additional equipment for implementing the technological process of filling the strengthening agents into the reservoir, high reliability and low cost of the used reagents.

4. Conclusions

Using laboratory research, the cementing slurry composition has been developed for strengthening the low-cemented rocks, which includes: oilwell cement, expanded perlite, non-ionic surfactant, plasticizer and water. The optimal proportion of the expanded perlite in the solution has been found, at which the corresponding values of the compression strength (up to 4 MPa) and gas permeability (up to 3.47 μm^2) of the cement stone are provided.

To prevent the sand entry from the reservoir into the well with an open hole, it is recommended to expand the well shaft in the interval of the producing reservoir according to known technology during the well construction for filling the formed hollow space with cementing slurry. When hardening, the cementing slurry forms a cement stone with high values of compression strength and gas permeability, followed by drilling of a cement stone (“sleeve”) in the well shaft in the interval of the producing reservoir.

In wells exploited for a long time and equipped with a filter or a perforated production string in the producing reservoir interval, the cementing slurry is injected through the filter holes into the casing string annulus to fill artificial caverns formed during long-term well operation as a result of the reservoir sand brought by the gas flow.

To intensify the operation of wells with unstable reservoirs, it is recommended to use the developed cementing slurry composition in wells operating Nizhny Dashav deposits in the gas fields of the GPU Lvivhazvydobuvannia (Zaluzhanske, Svydnytske, Sadkovetske, Pynianske and others), as well as in the fields of the eastern region of Ukraine (Bilske, Ostroverkhivske, Skorobahatkivske, Zakhidno-Solokhivske and others). High values of the permeability and cement stone strength make it possible to increase the yield of the well without sand entry after strengthening the bottomhole zone with an increased drawdown pressure on the reservoir, as well as to increase the overhaul period of the well operation.

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Розроблення складу тампонажного розчину для кріплення слабкозцементованих порід

Р. Кондрат, Н. Дремлюх, Л. Хайдарова

Мета. Підвищення видобувних можливостей і забезпечення стабільної роботи газових свердловин, що експлуатують нестійкі, слабкозцементовані пласти-колектори, шляхом запобігання надходження піску із пласта створенням у привибійній зоні пласта цементного каменю з відповідними значеннями міцності та проникності.

Методика. Вимірювання технологічних характеристик тампонажного розчину та сформованого цементного каменю проводили із застосуванням стандартного реєструючого обладнання. Густину тампонажної суміші вимірювали пікнометром, розтічність тампонажного розчину – конусом АзНДІ, водовідділення тампонажного розчину вимірювали за стандартною методикою згідно з ДСТУ БВ.2.7 – 86-99, час тужавіння тампонажного розчину визначали на консистометрі КЦ-3. Граничні параметри міцності каменю під час вигинання визначали на спеціальному приладі для випробовування лінійних об’єктів на розтягування, а під час стискування – на гідравлічному пресі ПСУ-10.

Результати. Розроблено склад тампонажного розчину для створення у привибійній зоні пласта цементного каменю із відповідними значеннями міцності на стискування та проникності по газу, що включає: тампонажний цемент, спучений перліт, неіоногенну поверхнево-активну речовину, пластифікатор і воду. Виявлені залежності міцності цементного каменю на стискування і коефіцієнта проникності каменю від вмісту спученого перліту у складі тампонажного розчину. Рекомендовано створювати у розширеному стовбурі свердловини в інтервалі продуктивного пласта цементний камінь із заданими значеннями міцності на стискування і проникності із запропонованого тампонажного розчину.

Наукова новизна. Встановлено оптимальне значення вмісту спученого перліту у розчині, за якого забезпечуються відповідні значення міцності на стискування (до 4 МПа) і проникності по газу (до 3.47 мкм^2) цементного каменю.

Практична значимість. Використання розробленого складу дозволяє підвищити дебіт газових свердловин з нестійкими колекторами і покращити умови їх роботи за рахунок запобігання надходженню піску із пласта у свердловину.

Ключові слова: *свердловина, пласт, газ, піщаний корок, цементний камінь, міцність каменю, газопроникність, наповнювач*

Разработка состава тампонажных растворов для крепления слабосцементированных пород

Р. Кондрат, Н. Дремлюх, Л. Хайдарова

Цель. Повышение добывающих возможностей и обеспечения стабильной работы газовых скважин, эксплуатирующих неустойчивые, слабосцементированные пласты-коллекторы, путем предотвращения поступления песка из пласта созданием в призабойной зоне пласта цементного камня с соответствующими значениями прочности и проницаемости.

Методика. Измерения технологических характеристик тампонажного раствора и сформированного цементного камня проводили с применением стандартного регистрирующего оборудования. Плотность тампонажной смеси измеряли пикнометром, растекаемость тампонажного раствора – конусом АзНДИ, водоотделение тампонажного раствора измеряли по стандартной методике согласно ГОСТ БВ.2.7 – 86-99, время схватывания тампонажного раствора определяли на консистометре КЦ-3. Предельные параметры прочности камня во время изгиба определяли на специальном приборе для испытания линейных объектов на растяжение, а во время сжатия – на гидравлическом прессе ПСУ-10.

Результаты. Разработан состав тампонажного раствора для создания в призабойной зоне пласта цементного камня с соответствующими значениями прочности на сжатие и проницаемости по газу, включающий: тампонажный цемент, вспученный перлит, неионогенное поверхностно-активное вещество, пластификатор и воду. Обнаружены зависимости прочности цементного камня на сжатие и коэффициента проницаемости камня от содержания вспученного перлита в составе тампонажного раствора. Рекомендуется создавать в расширенном стволе скважины в интервале продуктивного пласта цементный камень с заданными значениями прочности на сжатие и проницаемости из предложенного тампонажного раствора.

Научная новизна. Установлено оптимальное значение содержания вспученного перлита в растворе, при котором обеспечиваются соответствующие значения прочности на сжатие (до 4 МПа) и проницаемости по газу (до 3.47 мкм ^{2}) цементного камня.

Практическая значимость. Использование разработанного состава позволяет повысить дебит скважин с неустойчивыми колторами и улучшить условия их работы за счет предотвращения поступления песка из пласта в скважину.

Ключевые слова: *скважина, пласт, газ, песчаная пробка, цементный камень, прочность камня, газопроницаемость, наполнитель*