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Development of the Composition of the Process Fluid to Eliminate Bit Seizure

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During well construction, one of the most complicated types of accidents is the bit seizure as a result of which oil and gas companies incur significant losses due to the abandonment of a portion of the drill string in the well, cutting of an additional wellbore, and sometimes loss of the well. In the case of the elimination of seizure due to packing a positive result can be achieved by pumping portions of the process fluid into the seizure area. Destruction of the packer during the physicochemical effect of the process fluid, in general, allows for complete or partial softening of the packer, changing the pressure in the seizure area and significantly reducing the force required to release the stuck tool. The article presents the results of laboratory studies on the effect of various compositions of process fluids on the packer to eliminate the bit seizure. The effectiveness of the packer destruction was estimated by reducing the tangential stresses after the physicochemical effect of various compositions of process fluids for the same period. A 10% aqueous solution of hydroxyethylidene diphosphonic acid with an addition of 0.5% surfactant alpha olefin sodium sulfonate is recommended as a process fluid to eliminate packer seizures.

***Key words*:** well; wall packer; bit seizure; process fluid

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Introduction. During well construction, the seizure of a drilling tool most often occurs due to a violation of the drilling technology, not properly considering the features of the geological structure of the field, the low degree of knowledge of the lithological composition and properties of rocks. The analysis carried out by foreign researchers shows that 45 % of the total expenditure balance of emergency time is accounted for by eliminating the seizure of a drilling tool, and the oil and gas industry spends significant funds to eliminate this complication.

By the nature of the holding force and the circumstances preceding the accident, the bit seizures are divided into several types [1, 6, 7, 12, 13]: due to pressure drop or differential; in the channel development; due to settling of the solid phase; due to jamming in the constricted part of the shaft; foreign objects and pieces of fallen hard rock; due to debris, landslides and creep of plastic rocks; as a result of packing.

The seizure due to packing is mainly caused by a decrease in the stability of clay rocks, which is associated with a violation of the natural conditions of occurrence and the action of various factors (geological, technical, technological) during the construction of the well [14]. The reasons for the decrease in the stability of the borehole wall are the stress state of rocks in the near-wellbore zone and the physicochemical properties of drilling fluids used in drilling and with the deepening of the well the probability of seizure increases [5]. Therefore, the main factor causing the packing seizures is the physical-chemical interaction of the drilling fluid with the clay during the drilling of thick clay deposits, rocks containing mainly clay minerals, as well as collapsed overlaying rocks.

Currently, the concept of structural bonds in clay minerals is based on the fact that their formation occurs under the influence of chemical, physical, physicochemical, and osmotic processes that contribute to the formation of complex interactions of various nature and energy on places of contact of clay particles (molecular, capillary, magnetic, dipole, ion-electrostatic and chemical interaction) [8, 11]. Clay minerals are prone to surface hydration and dispersion in water-based solutions, osmotic wetting and drying, a significant decrease of strength during wetting, and susceptibility to the erosive effect of the solution flow [3]. When clay minerals contact the drilling fluid, ion exchange takes place between them, leading to a change in the structure of clay minerals, i.e., to in-

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crease the volume of clay minerals with preservation of their connectedness, traditionally called the clay swelling. This process is determined by the type of clay minerals; for example, montmorillonite clays are the most swelling and preserving adhesion, while kaolinic clay is less adhesive [15].

The wall packer on the rock-breaking tool forms like an avalanche, the clay particles stick together with each other through adsorption layers due to Vander-Waals forces, as a result of which a rather dense packer is formed that prevents further drilling. There is no doubt that clay minerals are the main factors determining such properties of rocks as moisture capacity, the activity of ion exchange, swelling, plasticity, strength, dispersion, and soaking. Consequently, the success of trouble-free drilling of a well to the design depth depends largely on the degree of knowledge of the geological section and the mineralogical composition of the clay part of the rocks.

The existing methods for the seizure elimination are based on the use of physicochemical, hydraulic, mechanical effects on the adhesive zone or their combinations [2, 4, 10].

• Physico-chemical methods are based on the injection into the seizure area portions of process fluids, which weaken or eliminate the holding force by chemical dissolution, liquefaction or other effects, or their combinations.

• Hydraulic methods are based on changing primarily the hydraulic pressure in the seizure area by regulating the hydrostatic component of the pressure or the formation of hydraulic impulses and waves in the mud column (in pipes and hole clearance).

• Mechanical methods are based on the creation of quasistatic (reciprocating and beating), vibration, or shock loads on the drill string.

The absence or presence of drilling fluid circulation limits the choice of possible methods. The simplest methods are those that do not require unscrewing the free part of the drilling tool over the stuck area and lowering the special device into the well [16]. Therefore, in case of bit seizure due to packing with partial loss of circulation, one of the effective ways to eliminate it is to inject process fluid into the seizure area, while the greatest probability of its elimination is provided when the process fluid is pumped into the seizure area immediately after it was discovered.

Methodology. To select an effective composition of a process fluid on a water basis, a laboratory facility at OJSC «Gazprom VNIIGAZ» [9] has been developed to eliminate seizures; its scheme is shown in the figure.

The laboratory unit includes a tank 1, a wall packer 2, a hollow metal cylinder 3, having on one side a vertical row of through holes 4 and an upper hole 6 for pouring the investigated process fluid 5, a plate 7 attached to the rear wall of the tank 1, a metal wire 8, a dial indicator 9, thread 10, weighing cup 11, suspended tension roller 12, fixed roller 13 and rack 14.

The choice of an effective composition of water-based process fluid to eliminate seizures was carried out according to the following procedure. A clay paste (imitating wall packer 2) with a density of 1300 kg/m^3 was prepared from a bentonite clay powder. The tank 1 was filled with clay paste and placed into it a hollow cylinder 3 with a length l = 0.25 m, density ρ = 2700 kg/m^3, outer diameter d = 0.04 m, mass m = 0.262 kg to a depth l_c = 0.18 m and left alone for a given period of time. Then, the composition of the process liquid of 75 ml volume was poured into the hollow cylinder through the opening 6, and after the expiration of the prescribed period the liquid was applied to the packer, the cup was weighted with weights, the Q force needed to move the hollow cylinder was determined.

In this case, according to the presented scheme of the laboratory installation, the force can be determined by the formula

$$Q = G + S_\tau, \quad (1)$$

where G – hollow cylinder weight, H; S_τ – contact area of the hollow cylinder with the packer, m^2; τ – shear stresses on the contact surface of a hollow cylinder with the packer, Pa.

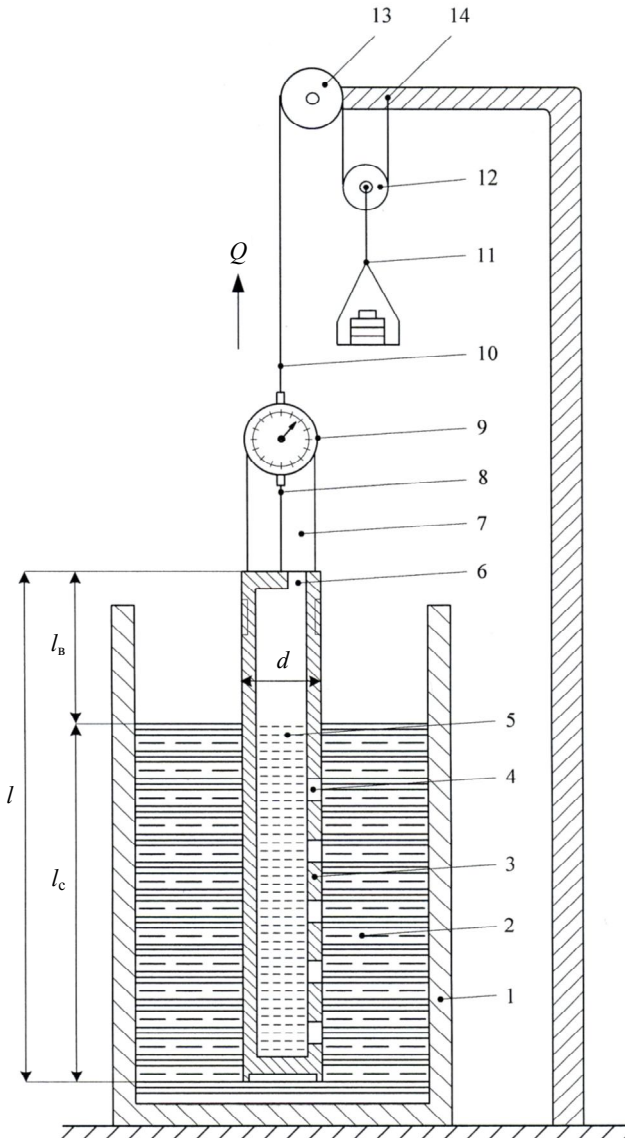
The tangential stresses from the source data from equation (1) can be represented as follows:

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$$\tau = \frac{Q - gm / l[l_в + l_c(1 - \rho_c / \rho)]}{\pi l_c d}, \qquad (2)$$

where $l = l_в + l_c$ – length of the hollow cylinder, m; $l_в$ – length of the hollow cylinder above the upper limit of the seizure area, m; l_c – the length of the hollow cylinder in the wall packer, m; g – gravitational acceleration, m/s^2; m – mass of a hollow cylinder, kg; ρ, ρ_c – density of the material of the hollow cylinder and wall packer, kg/m^2; d – diameter of the hollow cylinder, m^2.

The tangential stresses τ calculated by the formula (2) are used as an indicator of the effect of various compositions of process fluids on the packer to destroy its structure during the time $t = 6$ h. In the course of laboratory experiments, the immersion length of the hollow cylinder in the packer ($l_c = 0$, 18 m) is selected from the interval of values of half the perimeter of the outer diameter of the drill pipe used in drilling wells ($\pi d/2 = \pi(0.042\text{-}0.273)/2 = 0.065\text{-}0.428$ m), and the average time of the impact of the technological fluid on the packer (6 h) was taken on the basis of the analysis of field seizure elimination data.



Laboratory unit scheme

As compositions of process fluids for the bit seizure elimination, we investigated the following:

• 10 % aqueous solution of sodium sulfate ($Na_2S_2O_3 \cdot 5H_2O$) with 0.5 % addition of surfactant – sulfanol;

• 10 % aqueous solution of hydroxyethylidene diphosphonic acid ($C_2H_8O_7P_2$) with a 0.5 % surfactant additive – sodium alpha olefin (SAO);

• 10 % aqueous solution of potassium nitrate (KNO_3) with 0.5 % surfactant additive – neonol AF 9-12.

Discussion. In the course of the experiments, it was established that the destruction of the packer under static conditions, when exposed to a 10 % aqueous solution of $Na_2S_2O_3 \cdot 5H_2O$ with 0.5% addition of sulfanol, does not occur. Process liquid based on a 10 % aqueous solution of $C_2H_8O_7P_2$ with a 0.5 % addition of alpha-olefin sodium sulfonate more effectively destroys the packer compared to a 10 % aqueous solution of KNO_3 with a 0.5 % addition of neon AF 9-12.

For example, after the physicochemical effect of the process fluid (10 % $C_2H_8O_7P_2$ aqueous solution with 0.5 % SAO additive) on the packer, the Q force on the moving the hollow cylinder was 3.5 N. In this case, the tangential stresses at the moment of moving the hollow cylinder out of the packer are

$$\tau = \frac{3{,}5 - 9.81 \cdot 0.262 / 0.25 \cdot [0.07 + 0.18 \cdot (1 - 1300 / 2700)]}{3.14 \cdot 0.18 \cdot 0.04} = 80.54 \text{ Pa}.$$

The results of laboratory experiments on the choice of the effective composition of the process fluid to eliminate bit seizure are presented in the table.

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The values of tangential stresses τ after the physicochemical effects of various compositions of process fluids on the packer for *t* = 6 h

Process fluid composition	Moving force *Q*, N	Tangential stresses τ, Pa
10 % $Na_2S_2O_3 \cdot 5H_2O$ + 0.5 % of sulfonol	4.22	112.38
10 % KNO_3 + 0.5 % of neonol AF 9-12	3.98	101.77
10 % $C_2H_8O_7P_2$ + 0.5 % of SOA	3.50	80.54

Conclusions. Laboratory studies have shown that the process fluid developed by OJSC «Gazprom VNIIGAZ», based on a 10 % aqueous solution of hydroxyethylidene diphosphonic acid with the addition of 0.5 % alpha olefin sodium sulfonate, makes it possible to increase the efficiency of release of bit seizures due to packing by increasing dispersing properties of the composition.

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