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DETERMINING TECHNOLOGICAL PROPERTIES OF DRILLING MUDS

Purpose. To rationalize well washing by considering the influence of the annular channel limitation, granulometric composition of the mud, limitation of the joint movement of mud particles, drill string rotation, shape of the movement channel, and rheological properties of a cleaning agent.

Methodology. Applied laboratory studies on the properties of drilling fluids are carried out using modern methods of analytical analysis and experimental studies, in particular, by using general principles of mathematical and physical modelling, methods of processing the results of studies in the EXCEL, MATNSAD environment, control and measuring devices of the laboratory of washing liquids of the Department of Oil-and-Gas Engineering and Drilling of Dnipro University of Technology (hydrometer, viscometer, plastometer, stalagmometer), and materials (technical water, clay bentonite powder, reagents, stabilizers and activators, surfactants as well as equipment and laboratory base of "Ukrnafta" PJSC to carry out certain stages of research.

Findings. The properties of surface-active substances and activated washing liquids are analyzed. The main technological properties of drilling fluids are studied. Comprehensive information on the physical and chemical ability of flushing drilling fluids is provided. The main technological measures ensuring the stability of drilling process using activated-surfactant drilling fluids are considered in detail. The main technological principles of determining rational formulations of a selected cleaning agent in the circulation of Newtonian liquids are formulated and substantiated. A detailed description of surfactants, their properties and methods to study the formed solutions is given.

Originality. The process of a rock-breaking tool on the well bottom will be stable in the conditions of dynamic equilibrium of the rock-breaking processes and removal of broken products into the annular space. Therefore, for a correct understanding of wellbore washing issues, basic regularities are established of the specified processes and the influence of various factors on these processes.

Practical value. It has been proven that in order to give a drilling fluid the necessary properties that, on the one hand, will ensure an increase in the efficiency of rock breaking on the well bottom, and, on the other hand, will create favourable conditions for stable removal of cuttings onto the surface and maintenance of the well walls in a stable condition, it is necessary to apply different methods, in particular chemical activation as well as magnetic, thermal and electrochemical activation, in its different varieties.

Keywords: *drilling well, washing fluid, surfactant, rock, mode parameter, drilling fluid*

Introduction. Modern tendencies in such an important and necessary field of production as mineral mining and processing are characterized by constant complication of the mineral raw material extraction. Among other things, it is true about hydrocarbon products and metal ores [1], i.e. the components characterized by considerable occurrence depths in the levels of accumulation. Such state of things can be generally described as a factor of adaptation of the available technological methods and techniques to great changes in geological, physicomechanical, chemical, and thermobaric conditions of the construction of channels for mineral extraction from the earth's interior. The latter are meant to be deep wells. Well construction processes are rather diverse; however, several fundamental ones can be singled out among them, i.e.: rock mass breaking and removal of the broken rock from a wellbore of a specific mine working. Rock cuttings are transported along the wellbore by organizing a closed scheme of circulation of special cleaning agents. Moreover, their positioning is not limited only by the requirements for the broken rock removal; they are also meant for rationalization of breaking processes on the bottomhole of the well under construction, consolidation of unstable well walls, being a source of energy for different types of bottomhole drilling machines, and control of the required mode and technological operation cycle for a rock-breaking tool. A considerable number of the partially mentioned functions of cleaning agents are based exclusively on their having a range of technologically stipulated properties, which are produced by directed physicochemical treatment of a circulation medium. Successful operations can be organized by special techniques for the implementation of one or another scheme of bottomhole circulation of cleaning agents [2].

Practice as well as thorough theoretical studies on the essence of certain drilling operations has proved convincingly that there is a special reagent class – surface active substances, or surfactants, which are the most appropriate and the ones making it possible to have complex influence on the properties of cleaning agents by chemical compounds. It is the mentioned substances that are the most effective means of control of, for instance, surface tension of cleaning agents (and the consequent considerable reduction of energy intensity of rock breaking processes while well drilling). They also maintain a proper level of the components of rational procedure of the rock-breaking tool operations (being a reliable factor for ensuring high indices of its failure-free operating period). However, in terms of current somehow unreasonably simplified models of surfactant use in the algorithms of cleaning agent treatment, a long nomenclature list of surfactants, versatile manifestation of chemical properties, and dependence on the conditions of their application do not allow talking about reaching the boundary capacities during effective regulation of technological indices of a circulation medium of the wells being constructed.

We can be sure to state the complexity of a physicochemical scheme of interaction of surfactants with a disperse medium of cleaning agents. An additional complicating circumstance is the need in following strict requirements for the circulation circuit closeness of a wellbore (i.e. the necessity to consider a factor of high-quality operations concerning the cleaning agent regeneration with its further multiple uses without any violation of the limiting environmental aspects). Altogether, the mentioned things strengthen the need for a comprehensive scientific approach to the development of optimal and relatively elementary formulations of cleaning agents and a procedure of final product obtaining.

Methods. While analyzing the course and directedness of the well circulation processes, one can see that to reach success in getting adequate indices of failure-free well sinking, it is necessary to apply certain class of cleaning agents. Their multifunctionality in terms of the effect on each single act of rock breaking, wellbore stability, reduced power consumption, acting as a communication channel with the well bottomhole and other aspects of a complex technological algorithm of a well construction cycle are ensured by varying the quality of a specific cleaning agent. The following should be emphasized here: extreme activity within the boundary of phase separation, having useful rheological and structural-mechanical properties [3].

It is not a big problem to select cleaning agents for each specific case stipulated by potential manifestation of geological and technical factors. Properties of a cleaning agent are regulated basing on the selection of its fractional analysis and boundary concentration of surfactants and other compounds as well as additional reagents. Variation of the values of characteristic surfactant properties, i. e. disperse medium and disperse phase, helps provide wide range of cleaning agent types.

It is cleaning agents only that are the medium where we can implement certain constituents of a complex process for the formation of a specific mine working – bore well. Apart from the mentioned things, the following should be highlighted: washing fluids effect immediately a degree of completeness and manifestation of the peculiar technical and technological properties of the applied drilling tool and equipment in terms of reaching rational parameters of the bottomhole deepening and impossibility of complications with their further transformations into accidents. The type and property of a washing liquid being in the highest possible compliance with the concrete geological and technical conditions are selected basing on being stick to certain limiting requirements.

Washing liquids are to provide best removal of rock cuttings from the bottomhole and wellbore. If circulation within the well shaft stops, a share of rock in the washing liquid volume should be kept in a suspended state. Directed control of the washing liquid properties can help exclude almost completely possible damage of the well shaft integrity. The effect of rock-breaking tool cooling can be implemented by creating qualitative conditions of bottomhole circulation of a washing liquid. Adding some agents to the washing liquid composition can improve considerably the mode of its motion with the simultaneous reduction of hydraulic resistances and energy consumption for drillstring rotation etc.

Since the act of a rock-breaking process on the well bottomhole is the main factor for well construction in the rock thickness, it is necessary to stick with certain dynamic equilibrium between physicomechanical interaction of the cleaning agent components and the breaking sites on the well bottom, and circulation processes of removal of the rock broken by a tool.

The formulations of the weighty practical conclusions and recommendations based on the immediately obtained data should be adequate to real wellbore conditions of the laboratory and applied studies on technological properties of cleaning agents and their influence on certain borehole processes [4].

Thus, the laboratory studies on the cleaning agent features were carried out involving a series of modern methods of analytical analysis and experimental techniques, i.e. involving general principles of mathematical and physicochemical modelling, methods of research data processing in EXCEL and MATHCAD, control and measuring devices of the laboratory of washing liquids at the Department of Oil-and-Gas Engineering and Drilling of Dnipro University of Technology (areometer, viscometer, plastometer, stalagmometer) and materials (technical water; clay bentonite powder; reagents, stabilizers, and activators; surfactants) [5].

Results. Currently available and applied practical recommendations as for designing the basics of drilling for different-purpose wells are not efficient and substantiated enough. The reason here is constantly increasing depth of the constructed wells with indispensable manifestation of geological complications. In addition, certain aspects of drilling equipment undergo constant changes, i.e. continuous improvement of drilling rock-breaking tools with the resulting alternations in a technological mode of their operations on the well bottom. The fact is especially true concerning the need for developing such a progressive tool of reliable hydraulic (aerodynamic) programme of cleaning agent circulation.

In terms of the indicated conditions, selection of the cleaning agent type and its circulation mode is somehow complicated as one should follow the requirements concerning the performance of complex positional tasks with the considerable technical and technological limitations. Here, it will be relevant to consider in detail similar factors, among which those are the most significant ones: 1) ensuring qualitative bottomhole cleaning of the constructed well to get rid of breaking products with their removal onto the surface; 2) preventing the processes of deposition of the broken rock particles on the well bottom in case of sudden circulation stop; 3) time-reliable strengthening of unstable well walls and preservation of its shaft against the damages of rock occurrence balance; 4) active physicochemical influence on the rock mass to simplify its further breaking; 5) cooling of a rock-breaking tool and keeping thermohydraulic balance; 6) development of lubricant properties on the contact surfaces, etc.

A proper level of meeting the requirements concerning rationalization of the model of washing liquid circulation throughout the shaft of the constructed well can be reached by adhering the fluid formulation and certain technological parameters determined by the specific geological and technical drilling conditions [6].

Current results of the industrial drilling operations prove convincingly that only generalized characteristics of the components of the so-called hydraulic washing programme of the indicated specific mine workings, being adequate to the available wellbore conditions, are capable of ensuring their most complete performance of a geological task and implementation of their planned functions [7].

Maintaining the most appropriate indices of the cleaning agent density is the most important conditions to prevent from complications in deep, i.e. oil and gas, wells connected with the available high formation pressures and unexpected discharges of the formation fluids. Under the defined circumstances, disperse systems basing on bentonite clays, acting as cleaning agents, have proved themselves to be good. Controlled variations of the intervals of concentration of a clay disperse phase in the corresponding medium help maintain the required density of a clay cleaning agent. However, along with the growing density, there is a parallel, mostly undesirable, increase in viscosity and static shear stress. The indicated phenomena require application of reagents-regulators to process clay cleaning agents. Apart from other chemical substances, surfactants can also be such reagents; they have complex influence on the properties of clay cleaning agents, thus requiring corresponding laboratory studies on certain aspects of their properties to work within the boundary of phase separation of the interacting components.

In terms of the aforementioned, study of surfactant effects on the properties of clay cleaning agents (to identify them, a classic term "clay muds" is used) is the intermediate purpose of the research cycle [8, 9]. Dnipro municipal water was used as the disperse medium. The process of study was accompanied by determining the following clay mud properties: conventional viscosity (*T*, s), water loss (*B*, cm^3 per 30 min), and static shear stress (θ, mG/cm^2) [2]. The analyzed cleaning clay agents were processed additionally by a lignin-alkaline reagent (LAR), being necessary to reduce water loss of the circulation medium (it is of special importance to exclude active interaction of filtrate of cleaning agents with argillaceous rocks with their further swelling).

Sulphonol, ditalan, and "progress" were studied as the ionogenic surfactants (the ones forming differently charged organic ions during the ionization process); among non-ionogenic surfactants (their molecules do not form any ions in a water solution), a special activator was used.

Adding up to 2 % of sulphonol to clay muds not processed with LAR reduces viscosity (T) from 30 to 19 s and static shear stress (SSS) from 78.5 to 27.2 mG/cm^2 per 10 min. On the contrary, if sulphonol is added to clay muds processed with LAR, we can observe insignificant increase in viscosity from 29 to 40 s and static shear stress from 7.9 to 3.5 mG/cm^2 per 30 min. Consequently, sulphonol additives to clay muds within 2 % do not deteriorate their properties. Fig. 1 represents the indicated properties of clay muds depending on the sulphonol concentration.

Adding up to 0.5 % of ditalan to clay muds not processed with LAR results in growing viscosity from 30 s to "not flowing" and increasing static shear stress from 78.5 to 121.3 mG/cm^2; water loss of muds experiences practically no changes. Naturally, those muds are not good for practical use. Adding ditalan to clay muds processed with LAR does not change their properties significantly. Water loss of the muds remains practically the same; viscosity grows from 29 to 35 s. Static shear stress also increases from 7.9 to 17.3 mG/cm^2.

Clay muds with added ditalan are widely used while constructing different groups of wells in complex geological conditions. As a rule, there are following parameters of the mud for treatment: conventional viscosity is 18–20 s; water loss is 24–28 cm^3 per 30 min. according to the VM-6 device. While adding 0.4–0.6 % of ditalan in this mud, the mud viscosity in-

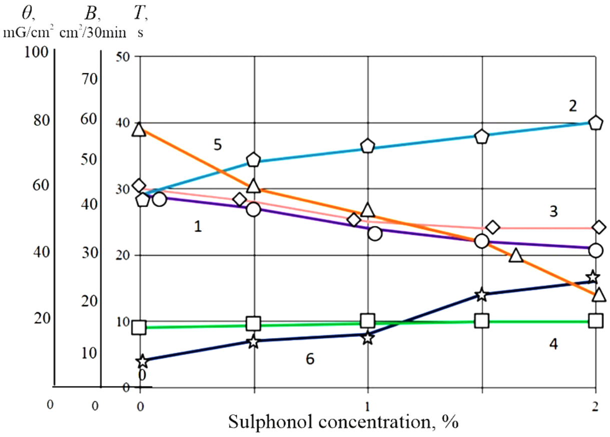

Fig. 1. Characteristic dependence of changing properties of clay muds on the sulphonol concentration:

1 – mud viscosity without LAR; 2 – mud viscosity with LAR; 3 – water loss without LAR; 4 – water loss with LAR; 5 – SSS without LAR; 6 – SSS with LAR

creases up to 24 s along with the water loss decrease down to 23–25 cm^3 per 30 min; thus, ditalan does not result in significant deterioration of the mud properties. It is the basis to conclude that the muds to be treated with ditalan should have the initial viscosity lower than 30 s; in other case, ditalan additives make the mud unusable.

Graphic dependences of the conventional viscosity, water loss, and static shear stress (in 10 min) on the ditalan concentration for clay muds either processed or not processed with LAR are shown in Fig. 2.

Adding up to 2 % of "progress" to clay muds not processed with LAR results in a decrease in conventional viscosity from 30 to 20 s and static shear stress from 11.3 to 15.7 mG/cm^2. Water loss decreases from 46 to 35 cm^3 per 30 min. Thus, "progress" additives to clay muds up to 2 % in volume do not cause deterioration of their properties. Data in Fig. 3 illustrate dependences of the properties of clay mud on the "progress" concentration.

Adding a non-ionic surfactant with the concentration of 2 %, i.e. special activator, to clay muds not processed with LAR results in their reduced viscosity from 30 to 22 s and static shear stress from 8.5 to 37.8 mG/cm^2; water loss of the muds decreases insignificantly – from 46 to 35 cm^3 per 30 min. If a special activator is added to clay muds processed with LAR, then conventional viscosity grows from 29 to 36 s; along with

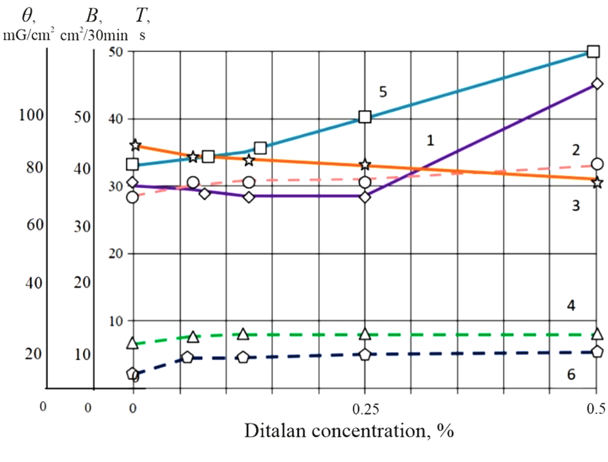

Fig. 2. Graphic dependence of the properties of clay muds on the ditalan concentration:

1 – mud viscosity without LAR; 2 – mud viscosity with LAR; 3 – water loss without LAR; 4 – water loss with LAR; 5 – SSS without LAR; 6 – SSS with LAR

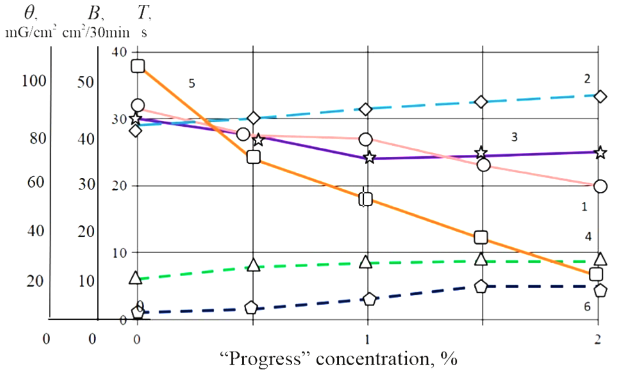

Fig. 3. Dependence of the “progress” concentration influence on the clay mud properties:

1 – mud viscosity without LAR; 2 – mud viscosity with LAR; 3 – water loss without LAR; 4 – water loss with LAR; 5 – SSS without LAR; 6 – SSS with LAR

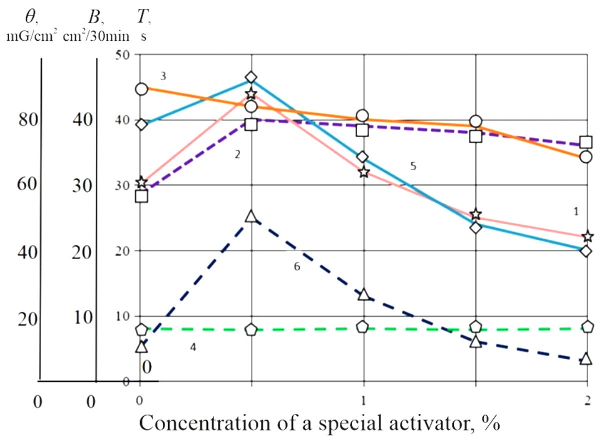

Fig. 4. Experimentally obtained graphic dependence of clay mud properties on the concentration of a special activator:

1 – mud viscosity without LAR; 2 – mud viscosity with LAR; 3 – water loss without LAR; 4 – water loss with LAR; 5 – SSS without LAR; 6 – SSS with LAR

that, water loss of the muds remains practically constant. Fig. 4 shows dependence of the properties of clay muds on the concentration of a special activator.

Table 1

Results of the studies on surface tension value σ of water solutions of some surfactants

No.	Surfactant	Surface tension value σ of water solutions (mJ/m^2) at concentration, %				
		0.125	0.25	0.5	1.0	2.0
1	“Progress”	42.8	36.2	31.7	30.4	30.4
2	Sulphonol	34.2	30.8	30.4	29.6	29.6
3	Ditalan	42.3	38.2	36.6	35.0	35.0
4	Special activator	40.3	37.6	36.3	36.3	36.3
5	OP-7	44.8	40.4	38.2	36.8	36.8
6	OP-10	44.2	40.6	37.8	34.5	34.5
7	Katapin	45.0	38.9	37.8	37.8	37.8
8	Prevacel	36.8	32.4	31.6	31.6	31.6

Theoretical and applied studies have allowed demonstrating complex positive influence of density, viscosity, and water loss of a drilling mud on the operating parameters of, for instance, roller bits, which can be explained also on the basis of the effect of different additives and on the surface tension value σ of a specific washing liquid (Table 1) [10, 11].

Analysis of the represented data shows that clay mud viscosity is the most considerable factor determining bottomhole conditions of breaking processes; viscosity and water loss are less significant.

Table 2 represents data concerning the effect of different surfactant groups on the clay mud properties. Substances with practically no influence on the mud properties belong to anion-active and non-ionogenic types. Coagulation of clay muds can be caused by cation-active and non-ionogenic surfactants; moreover, one and the same substance at different concentrations is of quite different influence, increasing, decreasing or almost not affecting the indices of structural and mechanical properties [2].

Water solutions of surfactants (in terms of OP-7 and OP-10) have considerable effect on a rock-breaking process [12, 13]. Special studies were carried out to prove that; the results are represented in Table 3. Calcite and limestone were used as the samples under study.

Analysis of the results, given in Table 3, shows that both water and surfactants reduce micro-hardness of rocks. How-

Table 2

Data concerning the effect of surfactants on the properties of muds of hydromicaceous and montmorillonite clays

Class of the analyzed surfactant	Surfactant	Parameters of the analyzed drilling mud		
		Viscosity, s	Water loss cm^3 per 30 min	SSS, mG/cm^2
Anion-active	Cleaned Petrov’s contact	Up to 0.2 % increases, lower 0.2 % – decreases	Practically does not change	Increases
	Sulphonol	Decreases	Does not change	Decreases
	Sulfosodium salts	Decreases	Does not change	Decreases
	DS RAS (soluble acidose)	Practically does not change		
	Sopal			
	Proxanol			
	Proxamin			
	Wetting agent NB	Increases	Decreases	Increases
Cation-active	Katapin A	Additives of 0.2–0.3 % results in active mud coagulation		
Non-ionogenic	UFE-8, KAUFE-14	Practically does not change		
	OP-7, OP-10	Additives of 0.5–1.0 % results in active clay mud coagulation		

Table 3

Results of studying the active medium effect on the rock micro-hardness

Rock	Analyzed parameter	Values of micro-hardness in kg/mm^2 and efficiency		
		Dry surface	Surface wetted with an active medium	
			distilled water	0.15 % of sulfonol
Calcite	Micro-hardness, $P_м$	62	38	59
	Efficiency, %	–	39	5
Limestone	Micro-hardness, $P_м$	169	138	102
	Efficiency, %	–	18	39

ever, the reduction is rather ambiguous. Influence of water solutions of surfactants is higher only in case of limestone breaking as opposed to their use while calcite breaking.

Silicate solutions are the ones based on silicates of alkali metals (Na, K), which, influenced, for instance, by chlorine salts of two- and three-valency metals as a result of chemical reactions, form silicic acid gel. Water alkali solutions of natrium $Na_2O\ (SiO_2)_n$ and/or potassium $K_2O\ (SiO_2)_n$ silicates are called liquid glass. Liquid glass is used in drilling muds (e.g. for rock strengthening and waterproofing); it forms insoluble compounds (so-called surface silicatization) [14, 15].

When argillaceous shales and other argillaceous varieties are drilled through [16, 17], silicate and silicate-humic solutions show good results. That is why the study focused on the effect of additives of the previously analyzed surfactants for the properties (conventional viscosity, specific weight, and surface tension) of the mentioned muds.

Silicate solution containing 20 % of soda liquid glass and 80 % of water had the following parameters: viscosity – 16 s, specific weight – 1.08 g/cm^3, and surface tension – 69.1 mJ/m^2.

Silicate-humic solution containing 4 % of liquid glass, 16 % of LAR, and 80 % of water had following parameters: viscosity – 16 s, specific weight – 1.02 g/cm^3, and surface tension – 64 mJ/m^2.

The laboratory studies defined that adding up to 0.2 % of prevacel and up to 1 % of KAUFE, ditalan, and neonol to the muds results in almost no changes in their viscosity and specific weight. In this context, one can observe considerable changes in surface tension (isotherms of surface tension – curves characterizing varying surface tension in case of increased substance concentration) of those muds.

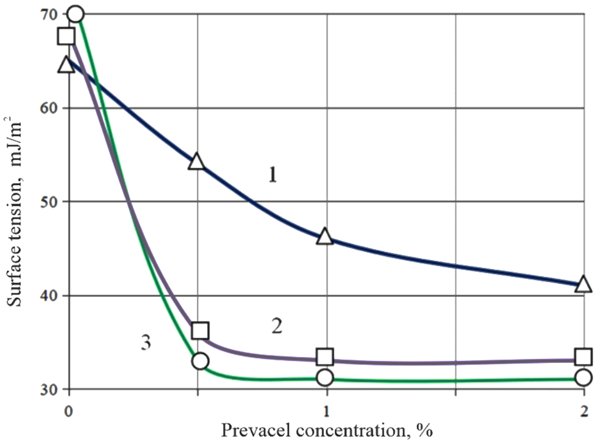

Fig. 6. Experimentally determined isotherms of surface tension of the muds with added ditalan:

1 – silicate-humic solution with prevacel; 2 – silicate solution with prevacel; 3 – water prevacel solution

The Fig. 5 data show that the KAUFE additives reduce surface tension of a silicate mud down to 37.0 mJ/m^2; in case of a silicate-humic mud, the reduction is down to 38.8 mJ/m^2.

Basing on the results represented in Fig. 6, the following conclusion can be made: up to 0.2 % of prevacel added to silicate-humic and silicate muds reduce their surface tension down to 39.4 and 32.0 mJ/m^2, respectively.

Ditalan adding (Fig. 7) results in the reduction of surface tension of silicate mud down to 51 mJ/m^2; in case of silicate-humic mud, the reduction is down to 34.4 mJ/m^2.

The results represented in Fig. 8 show that neonol adding (the concentration is not more than 1 %) to silicate and silicate-humic muds reduce their surface tension down to 30.8 and 34.4 mJ/m^2, respectively.

Thus, the additives of prevacel, KAUFE, ditalan, and neonol do not change the parameters of silicate and silicate-humic muds; however, they reduce their surface tension that results in growing velocity of well sinking.

The following should be noted: use of non-ionogenic surfactants (OP-7 and OP-10) in the amount of 0.5 % (in volume) results in certain increase in viscosity of drill muds of hydromicaceous clay and bentonite [18, 19].

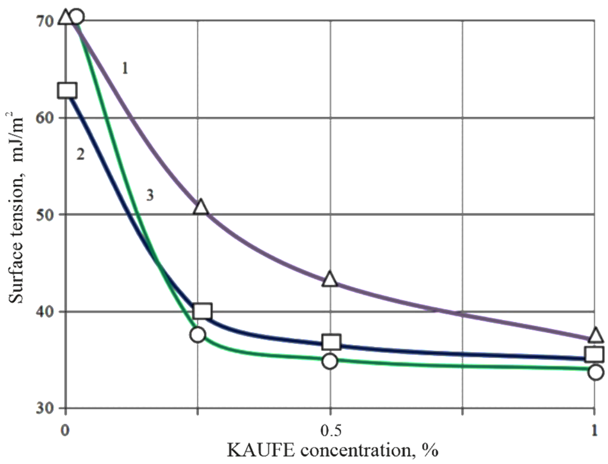

Fig. 5. Isotherms of surface tension of the muds with added KAUFE:

1 – silicate-humic solution with KAUFE; 2 – silicate solution with KAUFE; 3 – water KAUFE solution

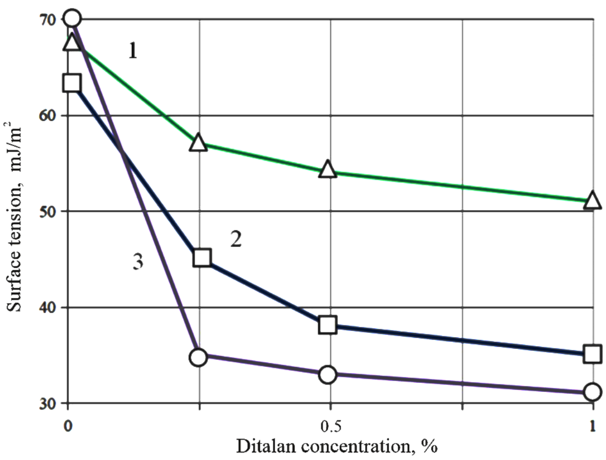

Fig. 7. Experimentally determined isotherms of surface tension of the muds with added ditalan:

1 – silicate solution with ditalan; 2 – silicate-humic solution with ditalan; 3 – water ditalan solution

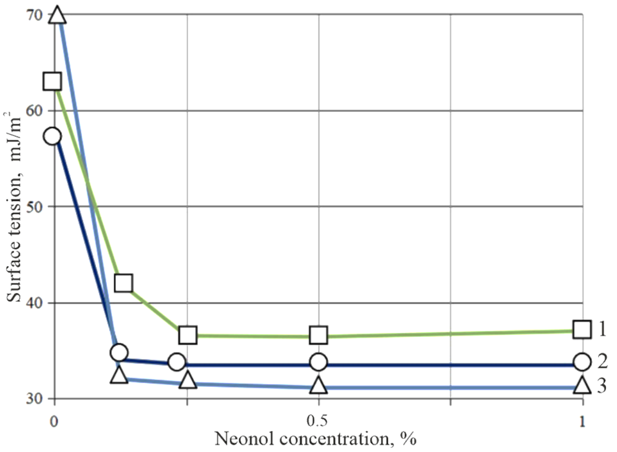

Fig. 8. Experimentally determined isotherms of surface tension of the muds with added neonol:

1 – silicate-humic solution with neonol; 2 – water neonol solution; 3 – silicate solution with neonol

In case of kaolinite clays, coagulation under the effect of OP-7 is shown more slightly than in the hydromicaceous ones. Clay mud coagulation under the effect of OP-7 can be prevented by processing with chemical reagents (sodium pyrophosphate, lignin-alkaline reagent). Action of a lignin-alkaline reagent can be explained by the fact that it increases the charge of clayey particles and causes intense mud stabilization. Since OP-7 (non-ionogenic surfactant) does not change the clayey particle charge; while absorbing on the particle surfaces, it intensifies activity of an interacting surface of argillaceous minerals. As a result of clay mud coagulation under the effect of OP-7, it is recommended to be used only in terms of treatment with active stabilizers such as lignin-alkaline reagent (if there is no mineralized formation water), sodium pyrophosphate as well as oxidized lignine and carboxymethyl cellulose.

Cation-active surfactant causes intense coagulation of clay muds irrespective of mineralogical composition of clays. In all cases of katapin adding, viscosity and water loss increases sharply. Intense coagulation caused by katapin makes us refuse to use it for clay mud treatment [20].

Anion-active surfactants have become widely used. Being added to clay mud, 0.01–0.03 % of sulfonol reduces its viscosity and static shear stress. The coefficient of friction during drillstring rotation decreases as well. This phenomenon can be used to prevent from drag and reduce possible sticking of a drilling assembly. However, sulfonol additives increase viscosity and static shear stress at high temperatures (about 120 °C). In this case, adding sulfonol with liquid glass results in mud dilution and reduced water loss. The best results were obtained while adding 0.2–0.3 % of sulfonol and 0.5–0.1 % of liquid glass into the mud. This solution forms strong protective film on the "water-air" boundary.

Adding 1.5–2.0 % of sulphate and cellulose ethanesulfonate will provide stability of fresh mineralized solutions of non-argillaceous rocks and increase their thermal resistance. The fluid processed with cellulose sulphate are resistant to mineralization. Owing to the efficient action of these reagents, it is easy to control viscosity of weighted muds; moreover, consumption of weighing agents and caustic sodium is reduced sharply.

Non-ionogenic surfactants are other reagents for thermally resistant muds; those are polyoxyethylated phenol and monooxyethylated alkylphenol. Basing on the performed studies, we can conclude that adding surfactant to washing liquids can either improve or deteriorate structural and mechanical properties. Content of the considered surfactants in some specific mud should be specified completely.

The following should be also noted: negative feature of adding surfactant to a drilling mud is its possible foaming, which can result in its reduced specific weight. In cases when there is no need to deal with, for instance, absorption of drilling mud by reducing its specific weight, i.e. when foaming prevents from the normal drilling process, it is necessary to take foam-suppression measures.

The well construction practice has several methods to deal with foaming: mechanical, hydraulic, vacuum, physicochemical etc. (generally, we can talk about application of so-called degassers – technological equipment functioning to recover specific weight of drilling muds after their desludging). Actually, the efficiency of using one or another method depends on the foaming causes.

We have analyzed the currently applied methods of foaming control; the analysis showed that different mechanical or hydraulic degassers, whose operation is based on destroying the mud structure by active mixing, flow shocks etc., are absolutely inappropriate for foam suppression of the fluids processed with SSL, CSAS, synthins (obtained from different organic compounds: phenol and its derivatives, aromatic hydrocarbons, naphthols, sulphons, lignosulphonic acids), and other reagents.

Drilling muds foamed by surfactants can be suppressed either by reagents-foam suppressors (namely, involving a physicochemical method) or by their passing through special vacuum degassers. In this context, physicochemical methods of foam suppression are the most simple and universal ones requiring no additional devices. The purpose of reagents-foam suppressors is to affect the physicochemical properties of a system to create the conditions or prevent from foam formation, or to destroy and liberate gas from the liquid film. There are following important conditions for the foam suppressor application: minimum consumption; inertia relative to general physicochemical properties of a system, duration of effective action in terms of certain geological conditions.

Clarifying a mechanism of action and application of different foam suppressors is of considerable importance. For instance, it is not expedient to suppress foam by such a widely sued foam suppressor as fusel oil in the mud foamed by a soap-like surfactant of a sulphonol type as this oil has smaller surface activity; thus, it is not capable of displacing foam suppressor from the adsorption layer. In these cases, one should use other more effective foam suppressors, i.e. soap stock as well as technical fats.

According to the studies carried out, the following can be considered as one of the most effective complex foaming suppressors: quicklime, stearic acid, and diesel fuel (in small portions while mixing) are mixed in certain proportions; a thin white-coloured grayish emulsion is formed. Consumption of the indicated foam suppressor is 0.05 % of the drilling mud volume (we can use other fatty acids instead of stearic acid, e.g. lauric, linoleic, oleinic, palmitinic and others).

Surfactants also change actively a degree of rock hydrophilic properties. That is why the surfactants, which can be used to control rock caving, should have the following features: prevent water penetration into micro-cracks; form impermeable film on the rock surface or at least on the sealing areas in micro-cracks; and have adhering capability, if possible.

Basing on the aforementioned and according to the studies carried out, we believe that so-called cation-active surfactants (compounds, dissociating in a water solution with the formation of cations determining the surface activity) are the most prospective substances. Among them, surfactants that form colloidal solutions with water, being as viscous as possible, are the most effective ones; they prevent water from entering into micro-cracks.

Red-brown and banded clays (dense, salty, with lensoid layers and inclusions of dense fine-grained sand) were analyzed for stability. While drilling in these sedimentary varieties, circulation fluid is enriched with active sludge; thus, its viscosity increases greatly and wellbore walls creep resulting in serious complications and accidents.

Table 4

Generalized data on the stability of samples of argillaceous varieties in different media

No.	Medium	Stability of the samples of argillaceous varieties
1	Water	Complete disintegration in an hour
2	Water + 0.5 % of neonol	Complete disintegration in 20 min
3	Water + 10 % of liquid glass	First cracks appeared in 3 hours. The cracks grew but a sample was unbroken for 24 hours
4	Water + 10 % of liquid glass and 0.1 % of neonol	First cracks appeared in 3 hours. The cracks grew but a sample was unbroken for 24 hours
5	Water + 10 % of liquid glass and 0.25 % of neonol	First cracks appeared in 4 hours but a sample was unbroken in 2 days
6	Water + 10 % of liquid glass and 0.5 % of neonol	First cracks appeared in 4 hours but a sample was unbroken in 2 days
7	Water + 0.1 % of polyacrylimide (PAA)	No disintegration within 2 days. There were some cracks
8	Water + 0.25 % of polyacrylimide (PAA)	No disintegration within 2 days. There were some cracks
9	Water + 0.5 % of polyacrylimide (PAA)	No disintegration within 2 days. There were some cracks
10	CSAS – 5 % OP - 7 (2:1) – 0.5 %	Disintegration in 1.5 hours
11	CSAS – 7.5 % OP - 7 (2:1) – 1.0 %	Disintegration in 3 hours
12	CSAS – 10 % OP - 7 (2:1) – 1. 5 %	Disintegration in 3 hours
13	CSAS – 5 % OP - 7 (5:1) – 0.5 %	Disintegration in 2 hours
14	CSAS – 7.5 % OP - 7 (5:1) – 1.0 %	Disintegration in 7 hours
15	CSAS – 10 % OP - 7 (5:1) – 1.5 %	Disintegration in 2.5 hours
16	CSAS – 5%, sulfonol – 1 %, liquid glass – 0.5 %, trietanolamine – 0.1 %	Disintegration in 2 hours
17	CSAS – 10 %, sulfonol – 2 %, liquid glass – 0.75 %, trietanolamine – 0.2 %	Disintegration in 4 hours
18	CSAS – 15 %, sulfonol – 3 %, liquid glass – 1.0 %, trietanolamine – 0.25 %	Disintegration in 7 hours

Behaviour of clay varieties was studied by their immersion into the liquids, whose volume components are shown in Table 4.

The best results (Table 4) as for prevention of violated sample integrity were reached by using silicate solution consisting of 80–90 % of water, 10–20 % of liquid glass, and a surfactant additive. Samples of clay varieties immersed into this solution did not disintegrate within several days. Among the surfactants, katapin A, and polyacrylimide (PAA), neonol turned to be the most effective ones. Being added to silicate solutions with 5–10 % of liquid glass, they prevent clay varieties from disintegration within several days.

Geological section of most constructed wells contains both relatively unstable (argillite, aleurite, clay loam) and strong (sandstone, limestone) rocks; consequently, while designing a hydraulic washing programme, the following problems should be solved: casing of wellbore made up by the rocks prone to swelling and caving; reducing strength of rocks while their breaking.

To case wellbores, drilling muds of the following composition were studied and recommended to be used in the industrial conditions: 1) hydrolyzed polyacrylonitrile (10 %) – 0.2–0.5 %, LAR – 1.0–2.0 %, clay 3–5 %, water – other; 2) ferrochromelignosulfonate – 2.0–4.0 %, liquid glass – 2.0–3.0 %, sulphate soap – 1.5–2.0 %, water – other; 3) calcium chloride – 0.3–0.6 %, lime – 0.1–0.15 %, spent sulphite liquor (SSL) – 0.1–0.3 %, carboxymethyl cellulose (KMC) – 1–1.5 %, water – other. Use of the mentioned drilling muds will help reduce considerably different costs related, for instance, to bottomhole drilling out, wall caving, and other nonproductive operations.

The studies showed that the problems of rock strength reduction while well constructing should be solved from the viewpoint of electric surface phenomenon. Moreover, analysis of rock breaking processes should be based on the effect of double electric layer (DEL) of charges on the inter-phase boundary "rock – washing fluid". Basic parameters are as follows: electrokinetic potential of DEL, rock hardness, and mechanical velocity of drilling. Increase in the mechanical velocity of drilling is taken as the criterion to evaluate the influence of washing liquid efficiency with the additives for hardness reduction on a rock breaking process.

The laboratory-stand studies identified that in terms of specific adsorption, mechanical velocity of drilling and rock hardness are inversely proportional to the absolute value – ζ-potential. This index characterizes the charge of a diffusive layer, and it is a measure of intensity of electrokinetic phenomena in the inter-phase area. A value of ζ-potential can be determined both with and without consideration of surface conductivity. During the adsorption stipulated by the forces of electrostatic interaction, mechanical velocity of drilling is directly and rock hardness is inversely proportional to the absolute value of ζ-potential determined without considering surface conductivity. Maximum growth of a mechanical drilling velocity is observed at the isoelectric point (IEP) in terms of specific adsorption and at a point of adsorption equilibrium while adsorbing stipulated by the forces of electrostatic interaction. The indicated value acts as the characteristic for some substance value pH, at which maximum ion share of this substance gains zero electric charge in the solution; in addition, this substance is the least movable in the electric charge. Among other things, the described phenomenon can be used successfully for drilling mud cleaning by electrophoresis. It should be also noted that rock hardness in water solutions of electrolytes of non-ionogenic surfactants and polymers depends on the value of loading applied to a drilling tool. The following is the specific feature here: in terms of IEP, if loads are lower than the boundaries of rock elasticity, a hardness value is higher than the one in case of loadings being more than its value.

The laboratory and production studies have defined surely that the use of washing liquids with the added hydrolyzed polyacrylonitrile, sulphate soap, and LAR allows increasing mechanical velocity of drilling by 1.15–1.45 times, respectively.

Conclusions. The paper represents briefly the main purpose of drilling fluids and considers principles of the development of perfect mud hydraulic programme. Effective performance of completely identified functions in different geological and technical conditions of well drilling requires that washing fluids have certain values of the properties determined by their volume component and concentrations. Some properties of a cleaning agent can influence considerably the intensity of well cleaning. The capacity of cleaning agents to prevent aggregation of particles is rather important for well cleaning. Such a property is characteristic for the agents containing surfactants and gas-liquid mixtures. Having high penetrating capability, surfactants improve cleaning and simplify rock breaking.

It is considered that the wellbore is in proper condition if it has no tightening, drag, and sticking of a drilling tool.

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Визначення технологічних показників властивостей бурових розчинів

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Мета. Раціоналізація режиму промивання свердловини на основі обліку впливу обмеженості кільцевого каналу, гранулометричного складу шламу, обмеженості спільного руху частинок шламу, обертання бурильної колони, форми каналу руху й реологічних властивостей промивальної рідини.

Методика. Проведені лабораторні дослідження характеристичних властивостей очисних агентів виконані із застосуванням низки сучасних методів аналітичного аналізу та прийомів експериментального вивчення, зокрема шляхом використання загальних принципів математичного й фізико-хімічного моделювання, методик обробки результатів досліджень у середовищі EXCEL, MATHCAD, контрольно-вимірювальних приладів лабораторії промивальних рідин кафедри нафтогазової інженерії та буріння Національного технічного університету «Дніпровська політехніка» (ареометр, віскозиметр, пластометр, сталагмометр), матеріалів (технічна вода, глинистий бентонітовий порошок, реагенти стабілізатори та активатори, ПАР). Для здійснення окремих етапів досліджень також використовувалося відповідне обладнання й лабораторна база ПАТ «Укрнафта».

Результати. Наведена оцінка властивостей поверхнево-активних речовин і активованих промивальних рідин. Вивчені основні технологічні властивості бурових промивальних рідин. Наведені вичерпні відомості щодо фізико-хімічної здатності промивальних бурових рідин. Докладно розглянуті основні технологічні заходи, що забезпечують стабільність процесу буріння із застосуванням активованих ПАР бурових промивальних рідин. Сформульовані та обґрунтовані основні технологічні принципи визначення раціональної рецептури очисних агентів при циркуляції ньютонівських рідин. Дана детальна характеристика ПАР, їх властивостей і методів дослідження утворюваних розчинів.

Наукова новизна. Стійким процес роботи породоруйнівного інструменту на вибої свердловини буде в умовах динамічної рівноваги процесів руйнування гірської породи й видалення продуктів руйнування до кільцевого простору. Тому для правильного розуміння питань промивання вибою свердловини встановлені основні закономірності зазначених процесів і вплив на них різних факторів.

Практична значимість. Доведено, що для надання промивальній буровій рідині необхідних властивостей, які, з одного боку, забезпечать підвищення ефективності руйнування гірських порід на вибої свердловини, а з іншого, створять сприятливі умови для стабільного винесення шламу на поверхню й підтримання стінок свердловини у стійкому стані, її необхідно піддавати обробці різними методами, зокрема хімічній активації, а також магнітній, термічній та електрохімічній, в їх різних варіаціях.

Ключові слова: *свердловина, промивальна рідина, поверхнево-активна речовина, гірська порода, параметр режиму, буровий розчин*

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