MINING

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EXPERIMENTAL AND THEORETICAL STUDIES ON THE OPERATING PARAMETERS OF HYDROMECHANICAL DRILLING

Purpose. To analyse certain complex components of the rock breaking act during the well construction stipulated by the design features of the technical means of hydromechanical drilling and diversity of manifestations of hydraulic and physicochemical properties of the activated circulation medium.

Methodology. Physicochemical parameters of the process of active substance adsorption from the water solutions on the rock surfaces were studied in terms of their disperse material by identifying optimal ratio in the "solid phase particles – volume of the activated solution" group with the recording of time interval of the adsorption equilibrium establishment. Features of bottomhole processes in terms of the operating modernized facilities of hydromechanical drilling were considered involving up-to-date methods of analytical analysis and experimental-laboratory studies, i.e. by using certain techniques of mathematical and physical modelling, methods for processing and interpretation of the research results by means of SolidWorks, STATGRAPHICS, MATHCAD, and control-and-measuring equipment and materials.

Findings. The peculiarities of the combined hydromechanical drilling technique have been analysed from the viewpoint of the creation of the most efficient conditions of bottomhole rock breaking. Since a considerable degree of the development of breaking processes is the practically proved factor of hydromechanical drilling, the rationalization and intensification of those processes may be achieved by means of controlled physicochemical effect of the surface active medium. The experimental study was carried out to analyse the directedness of the development and results of surface interaction – adsorption within the boundary of phase separation as the main factor of intensification of the rock mass breaking. A comparative analysis was performed concerning the surface activity of the corresponding substances that differ in their schemes of dissociation in a water solution whose properties are to be corrected additionally to make them close to the ones peculiar for natural drill muds. Positive influence of the adsorption phenomenon on the results of contact interaction of breaking elements of hydromechanical facilities was examined; this phenomenon is shown in the decelerated wear of metal surfaces.

Originality. Useful influence of the physicochemical properties of the substances under consideration decreases beginning from the ionogenic anion-active sulfonol towards the ionogenic cation-active katapin K and to the non-ionogenic substance OP-10 (ОП-10). However, in terms of combining the compositions of the mentioned substances, it can be strengthened additionally.

Practical value. The indicated laboratory and experimental studies are the basic ones to design the mode parameters of the washing programme for a hydromechanical drilling well; they belong to the main output data used while substantiating the design and technical-technological parameters of the modernized pellet impact devices.

Keywords: *hydromechanical drilling, well, washing liquid, rock, adsorption, surface-active substance*

Introduction. A technology of well construction as the main link of geological surveying and mining industry of a secondary sector is characterized by a considerable variety of the following: operating (rock-breaking) tools and technical means; mode and technological parameters of the operation of the latter, i.e. physicochemical properties of the circulation medium; different problems solved by drilling; properties of a rock mass as the object of well location [1].

Taking into account quite a great number of wells being constructed, one should note that a considerable share of scientific and practical papers in the sphere of drilling focuses on the searching for the means and methods to rationalize and reduce its financial as well as material and resource support [2].

A well as a specific mine working is characterized by the necessity of performing a certain technical task in terms of identification and study of a deposit as well as creation of a reliable workable channel to extract the mineral or solution of other practical problems tightly connected exclusively with the well technologies [3].

In general, the process of well construction irrespective of the well purpose as well as the final construction purpose is sure to be accompanied by the directed rock mass breaking [1]. The following depends greatly on the efficiency of the mentioned process: rate of the formation of a well shaft — as a permanent mine working; compliance of the final well structure with the design characteristics and performed tasks; accident-free installations; total energy-capacity of a production cycle.

While continuing the analysis of well construction issues, it is not hard to prove the following: each stage of the process under consideration differs with its exceptional complexity. Thus, during the rock mass breaking, it is necessary to carry out a series of main and auxiliary operations. The following operations are among them: bringing of an energy channel to the point of rock breaking, use of a stable and effective breaking tool with the great resource of steady operation, creation of the most favourable breaking conditions at the expense of directed influence on a physical state of a bottomhole, and transportation of the separated rock particles through a well shaft to the surface [4].

Basing on the logically represented facts, there is no doubt that searching for and substantiation of the innovative technical and technological means and methodological techniques (especially, the ones being implemented and adjusted without considerable complication of a well construction cycle, and the prime example here is a complex hydraulic programme of well washing) with their further implementation into production will favour the increasing efficiency and optimization of drilling operations [2, 5].

Literature review. Almost all current well drilling methods are based on some or other techniques for purely mechanical separation of rock fragments from a rock mass with the help of special tools [4, 6]. However, in the majority of cases, deep depth of wells, complex mining and geological conditions, objective imperfection of the design of a rock-breaking tool and its accompanying technical means as well as natural impossibility of reaching a rational level of mode operating parameters, i.e. circulation characteristics, have its final negative effect on the technical and economic parameters of a drilling process reducing the latter to the unacceptably minimal values. These and some other important circumstances have resulted in the advent of alternative methods of rock mass breaking being, first of all, physical ones [2, 7]. Among the latter, special attention should be paid to the techniques that rely on the use of hydrodynamic energy of a fluid stream. There are following techniques applied currently to a certain extent during the well construction: hydromonitoring (for a continuous high-pressure stream of fluid moving at high speed), hydropulse (action of a discontinuous high-pressure fluid stream of extra-high pressure moving at high speed), hydro-vacuum (for hydraulic impacting being a result of closure of vacuum empties in the liquid on the bottomhole), electrohydraulic (for the hydraulic impact waves formed in terms of high-voltage discharges of electric current in fluids).

A general feature of the aforementioned methods is the common use of a hydraulic channel as a source of hydraulic energy and an agent of broken rock transportation — with all its peculiar functions — like in case of classic methods for mechanical breaking. However, the represented characteristics correspond, in some points, to the essence of the drilling with bottomhole motors (turbodrill, propeller engine). Physical hydrodynamic methods are implemented by the devices of a much simpler and more reliable design — without any loss of the level of main parameters of a rock-breaking process in the corresponding similar conditions.

There is also an important thing that the methods under consideration do not require any mediation of a special bottomhole breaking tool, which in its turn requires sometimes quite frequent replacement due to wear or failure owing to the mining-geological or design reasons.

The known limitation of applying the mentioned group of physical drilling methods may be explained not by the disadvantages of the latter (though there are some, undoubtedly) but only by the gaps in their design and methodical support.

According to some requirements due to certain features of rock masses and the drilling technology itself, physical hydrodynamic techniques have got their rather successful interpretation, i.e. their organic combination with purely mechanical methods. The distinct example here is the development of a design of so-called hydromonitoring bits (equipped additionally with special washing channels with nozzles which form and direct fluid streams onto a bottomhole or corresponding breaking tool at a speed being more than 80 m/s) [8] and pellet impact drilling (rock mass is broken by impacting with hard pellets that are directed by means of high-speed fluid streams formed by the special bottomhole stream devices) [9].

Use of the mentioned methods during production proved their considerable advantages; however, in case of pellet impact drilling, due to somewhat one-sided interpretation of a breaking act and, in general, the parameters and results of the bottomhole hydrodynamic processes, the process under study has not been widely implemented so far. At the same time, the carried out analytical and laboratory studies make it possible to speak confidently about the prospects of the principles of pellet impact drilling in terms of proper technical and technological support; its design completing with purely mechanical tool is in compliance with this [10]. Pellet impact drilling differs with a high degree of the development of breaking deformation in a rock mass, whose further positive intensification can be reached by using special washing fluids capable of interacting with the bottomhole active centres. That will result in the reduced strength of the latter and increased mechanical speed of drilling.

The abovementioned became the basis [11] for further searching by the specialists of the Department of Oil-and-Gas Engineering and Drilling (OGED) of Dnipro University of Technology (DUT) for the methods to improve pellet impact hydrodynamic drilling. The result of this is the development of principally new innovative basic designs of the corresponding devices that make it possible to avoid negative effects of a standard pellet impact method of well bottom and shaft formation (in terms of their proper use).

At the same time, almost complete transformation of technical and technological schemes of pellet impact drilling is the reason why there has arisen a necessity to analyse thoroughly all the range of bottomhole along with the hydromechanical and physicochemical processes (under new circumstances) that appear while implementing schemes of the modernized pellet impact (more accurate hydromechanical) method. Moreover, in the context of the mentioned facts, special attention should be paid to the examination of the facts of physicochemical interaction of a cleaning agent (as a separate basic component of a complex hydraulic washing programme) with a well bottomhole and structural elements of the corresponding devices. These are certain reference technological parameters of a circulation medium that can be subjected to almost immediate directed operating control aimed at optimization and intensification of both breaking processes and factors of preservation of adequate operational properties of the technical means of hydromechanical drilling.

Results. Comprehensive studies on the process of well shaft formation in terms of hydromechanical drilling has proved the important role of application of breaking loads in the bottomhole process. Variations of the latter can be used widely for the directed formation and control of the components and results of the bottomhole act of rock mass deformation (breaking) [1, 12].

Since in the context of the proposed schemes of hydromechanical drilling, formation of separate parts of the well bot-

tomhole takes place at different technical and technological factors (a central part − by means of pellet impacting accelerated up to some critical speed while a peripheral part − by contact rotational or impact-rotational interaction with the help of pellets and fragments of breaking products as well as technical means accumulating them), it is necessary to follow certain operational compliance between them.

This variant of hydromechanical drilling can be characterized as a process of various-nature interaction (of different duration) at the "metal − rock" boundary; whatever it goes on in the medium of a washing fluid, the fluid components takes part in it regulating it one way or another [13].

The well construction practice demonstrates convincingly the following: rock breaking processes on the bottomhole can be intensified (as well as decelerated) by rational selection of the type and technological properties of a disperse medium of breaking − washing fluid [2, 14]. Moreover, its positive properties can be subjected to effective formation and directed control by varying the component and concentration composition of the corresponding disperse phases and regulating reagents as well as addition of surface active substances (SAS). Rationalization of a hydraulic programme of the washing liquid circulation is also of great importance here [15].

According to the obtained experimental data as for the nature of acts of deformation disturbances of hydromechanical breaking on the well bottomhole, one can be sure to state the following: the considered drilling method differs with its rather high degree of propagation of breaking processes connected with the developed fracture network and holes of rock fragment cutting available in the rock mass; their formation is stipulated by the intensive action of pellets activated by some means for their breaking action [16]. Those are the circumstances under which there arises a necessity to analyse the bottomhole processes of interaction between the active medium and a deformed rock mass. However, apart from the mentioned, there is certainly the medium's influence on the state of breaking elements of technical means of hydromechanical drilling − pellets and rock-breaking rings, whose operating resource can be changed respectively [17].

The following has been proved scientifically and practically: strength reduction of solid bodies can be reached by decreasing their surface energy involving the method based on adsorption interaction of the contacting phases. The indicated interaction can be of physical, chemical or complex nature; moreover, under the mentioned conditions, there are phenomena of destrengthening, developed lumpiness, reduced longevity, and decreased plasticity. The indicated effects are especially distinct on the newly formed surfaces (fractures), which have high level of uncompensated relations with the resulting great surface activity [18]. As a result of the above peculiarities, when active substance penetrates into a fracture, an absorption layer of the corresponding molecules is formed on its borders − the layer is affected by the wedging pressure acting towards further in-depth advance of the fracture, which favours the development of the latter with the corresponding rock breaking [10].

Practically, the phenomenon of influence of different media as for the reduction of solid body strength are explained by the use of so-called breaking criterion [6, 9]

$$\tau = \sqrt{\frac{2\alpha E}{\pi l(1-\mu^2)}}, \qquad (1)$$

where α is specific free surface energy; E is Young's modulus; l is fracture length; μ is Poisson's ratio.

Mathematically, there can be the following way to express the subjection of a breaking act to the absorption of the medium activity

$$A + S > K, \qquad (2)$$

where A is work of the adsorption forces of the breaking medium (washing liquid); S is work of adhesion forces in the rock matrix; K is work of the external forces deforming a solid body.

Analysis of the adsorption isotherms is the most demonstrative method of studying adsorption phenomena on the boundary of phases. The adsorption isotherms help understand the surface activity of the substance taking into account its concentration in solution C and level of reduction of surface energy σ (for water solutions of SAS, this parameter is called surface tension) [19]. Besides, the isotherms make it possible to analyse corresponding properties of a solid body relative to the value of adsorption G; to calculate the parameters of the latter, it is possible to use equations obtained from the assumptions of the available adsorption and to express chemical potential of the substance in the volume. The indicated equations help process the experimental data: having a dependence of $\sigma = f(C)$ type, one can get a function $G = f(C)$.

A set of substances were selected as the SAS under consideration. The substances differ with their chemical origin and are characterized by certain practice of their use in drilling. Parameters of SAS absorption from water solutions on the surface of fine-grained granite were analysed in terms of powders of the indicated rock with a particle size from 0.2 to 2 mm. To do that, optimal ratio between the solid phase mass and solution volume was specified as well as the time of establishment of adsorption balance. An absorption value G was determined as the difference between SAS concentrations in a solution before and after the adsorption balance establishment; it was calculated according to the formula

$$G = \frac{\Delta C \cdot V}{m}, \qquad (3)$$

where ΔC is difference of SAS concentrations in a solution before and after its adsorption; V is volume of the solution under study; m is quantity of a solid adsorbent (granite particles).

A value of the area for a molecule in the adsorption layer can be determined using the following formula

$$S' = \frac{10^2 \cdot S}{G_{gr} \cdot N_{\dot{A}}}, \qquad (4)$$

where S is specific adsorbent surface; G_{gr} is the value of the boundary adsorption value; N_A is Avogadro's number.

The values of adsorption parameters G were calculated basing on the data obtained owing to the measurement of optical density D_0 and D before and after the corresponding interaction in terms of passing monochromatic light through it [15].

The dependence of optical density D_0 on the length of wave λ of the monochromatic light is of resonance nature; it has its maximum at certain wave length λ_n and flat section at some λ_n; in this context $D = f(\lambda_n) = \text{const}$. D_0 and D were measured in terms of two values of wave lengths: λ_{max} is resonant that was adsorbed so that the inequation $0.6 \leq D(\lambda_{max}) \leq 0.7$ was met, and λ_n is the wave length, in terms of which $0 \leq D(\lambda_{max}) \leq 0.1$.

The increment of the optical densities was determined using the following formulas

$$\Delta D_0 = D_0(\lambda_{max}) - D_0(\lambda_n); \qquad (5)$$

$$\Delta D = D(\lambda_{max}) - D(\lambda_n). \qquad (6)$$

According to the adopted methodology, the adsorption value was

$$G = \frac{C_0 V}{m}\left(1 - \frac{\Delta D}{\Delta D_0}\right), \qquad (7)$$

where C_0 is initial concentration of the SAS under analysis, mole/l.

After simple transformations, we have the final calculation formula

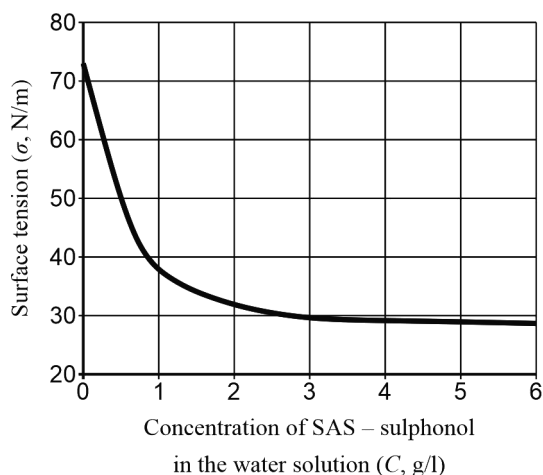$$G = \frac{10^{-5}}{m}\left(1 - \frac{\Delta D}{\Delta D_0}\right). \qquad (8)$$

The disperse medium of a drilling washing fluid represented usually by technical water often contains foreign ions that have active chemical influence on the adsorption results. Thus, background electrolyte $CaCl_2$ was introduced into the composition of solutions to specify its ranges.

The results of the studies carried out in terms of ionogenic anion-active SAS sulphonol — mixture of salts of alkyl benzene sulphonic acids with alkyl residues containing 12−18 carbon atoms with the structural formula (n − the number of carbon atoms)

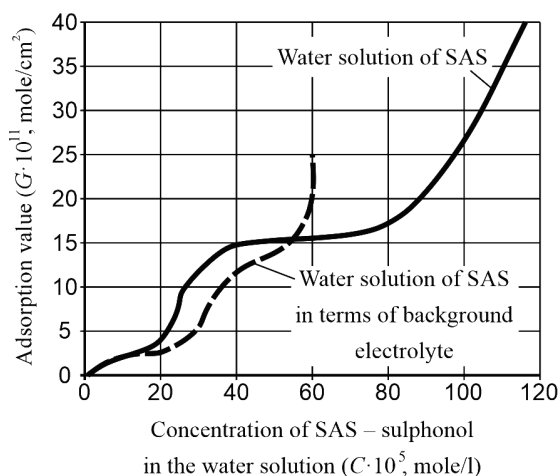$$C_nH_{2n+1} \text{—} \bigcirc \text{— } SO_3Na$$
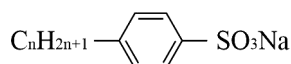
are represented in Fig. 1.

The ranges of changes in surface tension of sulphonol water solution are traced in the graph (Fig. 1, *a*). It should be noted that the represented data show clearly quite considerable activity of the mentioned SAS in the context of relatively low concentrations − up to 3 g/l. It is also important that exceedence of the indicated threshold will not result in further reduction of σ, i.e. this C value is the boundary one for the SAS under consideration. As for the adsorption properties of sulphonol on the rock surface (Fig. 1, *b*), they can have rather complicated signs stipulated both by variability of C and certain physicochemical properties of the disperse medium − determined by the available active components in the composition of a disperse phase as well. The isotherm of sulphonol adsorption is characterized by several distinct sections: the initial section is almost a direct proportionality (with $k < 1$ proportionality coefficient) that corresponds to the electrostatic sorption of certain ions by the rock surface; then there is transformation of the isotherm form into a parabolic curve with the following durational flattening − dense covering of the rock surface with the SAS ions (the plateau zone in the graph) and the next exponential increase (according to the power function of high order) of G. In this context, it has been defined that further increase in the total value C on factor G has practically no effect. As for the influence of $CaCl_2$ electrolyte on the development of adsorption processes, it is seen in the preservation of their general directedness but at much lower absolute values of G factor.

Practical tasks for the further studies (graphic data in Fig. 2) involved the examination of adsorption properties of ionogenic cation-active SAS katapin K widely used in drilling − technical mixture of alkyl benzyl pyridinium or polybenzyl pyridinium of chlorides with the structural formula

$$R \text{—} \bigcirc \text{— } CH_2 \text{— } N \bigcirc$$
$$|$$
$$Cl$$

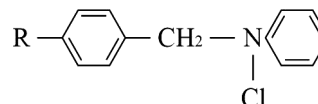where the value of radical R in a general case is from C_6 to C_8.
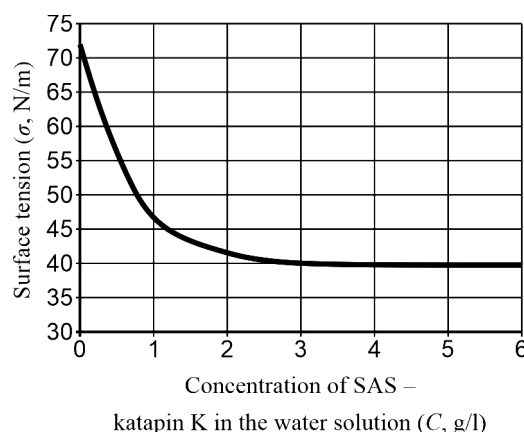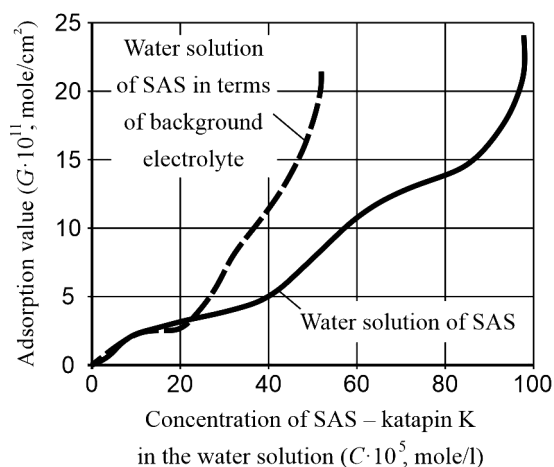

Fig. 1. Isotherms of surface tension of water solution (a) and adsorption of SAS sulphonol from the water solution on the surface of fine-grained granite (b)
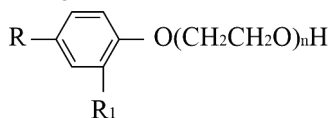

Fig. 2. Characteristic isotherms of surface tension of the water solution (a) and adsorption of SAS katapin K from it on the surface of fine-grained granite (b)

Individual (Fig. 1) and comparative (Fig. 2) analyses of the corresponding isotherms have the following conclusions. Maximum surface activity of katapin K (Fig. 2, *a*) as for the regulation of σ parameter belongs to the concentration interval $C \leq 2.5$ g/l. Along with that, it falls short to the one for sulphonol; in case of $1 \leq C \leq 2$ (g/l), surface tension σ of water solution of katapin K is on average by 28 % higher than the corresponding values for SAS − sulphonol (Figs. 1, 2, *a*). The following is also obvious: adsorption isotherms (Fig. 2, *b*) in some acceptable approximation can be approximated completely by the line of direct proportionality; factor *G* for katapin K has a narrower range, according to the concentration and absolute numerical indices, while its comparing with sulphonol (Figs. 1, 2, *b*). The availability of electrolyte $CaCl_2$ in the interphase interactions is clearly seen on the boundary *C* values at the preserved general tendencies relative to *G* factor.

Contrary to ionogenic SAS, for which interaction with water molecules (solubility) is determined by the properties of their polar groups, solubility of non-ionogenic SAS is far less and stipulated by the polyoxyethylene chains in the composition of the latter.

Auxiliary substance OP-10 − mixture of polyethylenglycol mono- and dialkylphenols with the following formula was used as the analysed non-ionogenic SAS with the practical results presented in Fig. 3

$$R - \langle\text{benzene ring}\rangle - O(CH_2CH_2O)_n H$$
$$R_1$$

where R is alkyl residue containing mostly 8−10 atoms of carbon; $R_1 = R$ or H; *n* is on average equal to 10−12.
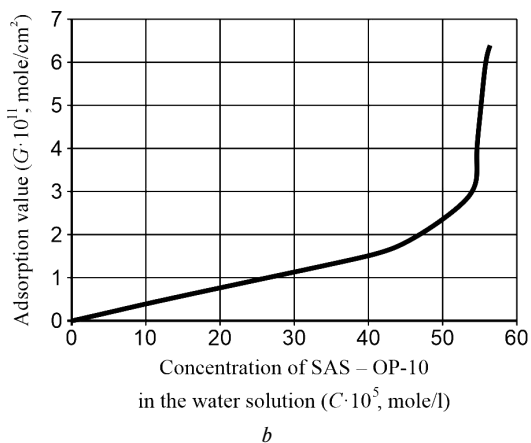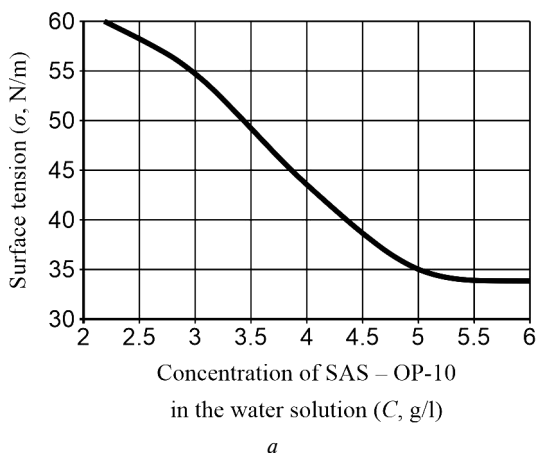

Fig. 3. Examples of isotherms of surface tension of the water solution (a) and auxiliary adsorption of SAS − OP-10 from it on the surface of fine-grained granite (b)

A range of qualitative characteristics of a surface active substance OP-10 represented by the corresponding isotherm (Fig. 3, *a*) differs on the background of previously considered SAS by a considerably greater set of parameters *C* that influence significantly the level of reduction of surface energy σ. Attention should be also focused on the geometrical view of the isotherms − within the range of operating values *C* it approaches the straight line from *tg* inclination angle to axis *C* being equal to a unit (up to $C \leq 5$ g/l).

The substance OP-10 shows its principally original properties relative to *G* factor: when *C* values are within the range of 50 mole/g, the adsorption properties of the SAS under consideration are characterized by a rather low level; however, while going beyond the indicated threshold, rapid *G* increase is observed even relative to the insignificant ranges of growth of *C* parameter.

Comparison of physicochemical studies on SAS makes it possible to classify the substance OP-10 according to the effect of σ value and reaching of boundary values of *G* as the intermediate (towards the reduction of controlling regulation) between sulphonol (ionogenic anion-active SAS) and katapin K (ionogenic cation-active SAS)

The latter factor gave rise to the corresponding studies aimed at analysing possibilities and effects of using complex SAS (in this case, mixture of active substances with different types of hydrophilic groups). To make the experiment conditions as close to the real wellbore ones as possible, the mixtures under analysis (Fig. 4) were the systems containing sulphonol
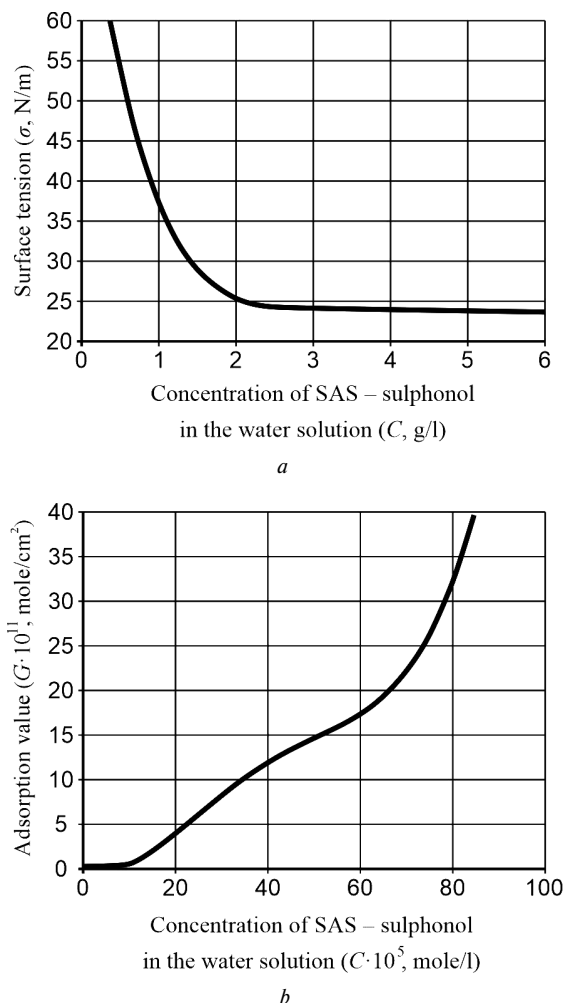

Fig. 4. Experimental isotherms of surface tension of the water solution (a) and adsorption of a complex SAS (sulphonol, OP-10, electrolyte CaCl₂) from it on the surface of fine-grained granite (b)

(variational parameter C), OP-10 ($C = 3 \cdot 10^{-6}$ mole/l), and electrolyte $CaCl_2$ ($C = 1 \cdot 10^{-3}$ mole/l).

Examination of the data concerning physicochemical activity of a complex SAS on the basis of construction and analysis of a corresponding isotherm (Fig. 4, a) that is approximated by the equation

$$\sigma = -0.0521C^5 + 1.1235C^4 - 9.4623C^3 +$$
$$+ 38.81C^2 - 77.502C + 84.455, \qquad (9)$$

allows stating the following. Addition of the substance OP-10 into the composition of a main sulphonol solution results in the considerable increase in the surface activity of the medium (on average, up to 20 % compared to the individual values). In other words, great reduction of σ takes place in terms of sulphonol concentration C being not more than 2 g/l. Factor G also varies in terms of using complex SAS. As for the specified conditions, it is characterized by the narrowed acting concentration range with the preservation of the values G themselves. The fact is proved by the adsorption isotherms (Fig. 4, b) with the approximation equation

$$G = 5 \cdot 10^{-6}C^4 - 7 \cdot 10^{-4}C^3 + 0.0348C^2 -$$
$$- 0.2569C + 0.1805. \qquad (10)$$

Generally, since factor G for the substance OP-10 is comparatively small ($G = 1 \cdot 10^{-12}$ mole/cm^2), the value of the latter for the rock surface is determined by G increasing of the sulphonol itself.

There is also the experimentally proved possibility to speak about the available much more complicated scheme of interaction of active components in terms of the applied complex SAS that is shown also in positive intensification and transformation of the adsorption phenomena peculiar for one SAS when another one is absent. Practical significance of the represented material for rock mass breaking while well constructing is in the substantiation of the existing deviation (sometimes quite significant) of theoretical surface SAS properties from the really recorded ones, which is the result of certain component variability of a chemical composition of active substances and complexity of their unambiguous keeping. Since the SAS under analysis (sulphonol) is peculiar with its interaction with cations Ca^{2+} and Mg^{2+} — indispensable components of a disperse medium of drilling washing liquids, which results in the formation of corresponding insoluble compounds, electrolyte $CaCl_2$ acts as a preventer for the mentioned negative effect. The obtained experimental data also demonstrates the intensification of $CaCl_2$ possibilities at the expense of parallel use of non-ionogenic SAS (in this case, in terms of OP-10).

In addition to the aforesaid, the studies were also carried out to examine context interaction of the participants of a rock-breaking cycle on the well bottomhole and the effect of active component of the washing liquids on it [10, 20].

A process of bottomhole circulation in terms of hydromechanical drilling has its own specific features that should be taken into consideration obligatorily while developing a hydraulic programme of well cleaning [10]. The main condition of reaching rational parameters of well deepening (in the context of the hydromechanical method under analysis) is to provide appropriate criteria of contact interaction between the rock-breaking pellets (including their fragments), their special retaining rings (or matrices) of hydromechanical devices, and the rock mass itself. The performed studies have demonstrated persuasively that the required contact interaction is determined mostly by the right nature of the corresponding surfaces (in most cases, that is true about metal elements) that should be preserved or developed during the operation of hydromechanical devices.

The experimental values of Fig. 5 demonstrate clearly the considerable changes in the operation of a rock-break-
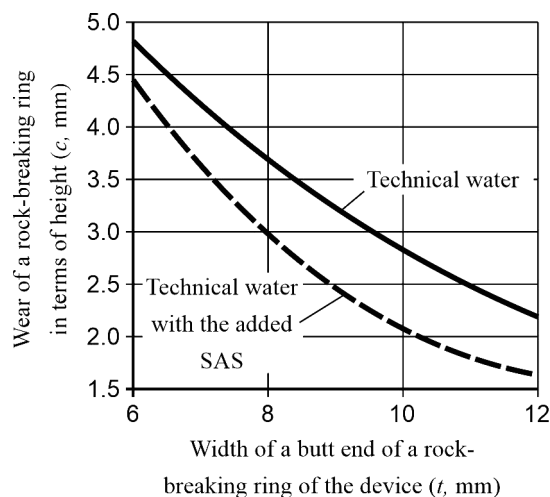

Fig. 5. Mechanical criteria of the operation of a rock-breaking ring with the variable width of butt section (t) in terms of different conditions of implementation of a hydraulic washing programme

ing ring of a hydromechanical device under the additional introduction of SAS into a washing liquid — ionogenic anion-active sulphonol with $C = 2$ g/l for all the studies on contact interaction of the participants of bottomhole rock breaking. These changes are seen in the reduced (on average, down to 22 %) intenseness of wear c of the contacting metal surfaces. It can be explained by the phenomenon of SAS adsorption on the metal surfaces as well, favouring their protection.

The next stage of the identified area of experimental study involved analysis of the features of contact interaction — for the operating conditions of the accumulating rock-breaking matrix on the well bottomhole (Fig. 6) according to the previously represented identical physicochemical characteristics of a circulation medium.

Basing on the experimental material of Fig. 6, it is possible to state objectively the following: intensity of abrasive action of the rock-breaking tools on the matrix of a hydromechanical device is prone to the influence of inter-phase phenomena of the adsorption processes that decelerates notably (on average, up to 20 % and sometimes even more) the wear processes of the contacting surfaces under consideration.
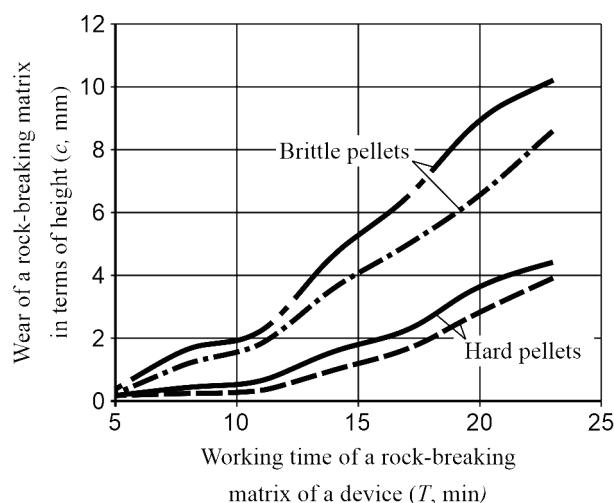

Fig. 6. Comparative analysis of the intensity of abrasive action (c) of the rock-breaking tools on the hydromechanical device matrix in terms of different conditions for the washing programme implementation

Thus, the represented data are the convincing evidence of the complexity of the SAS adsorption phenomenon (in terms of sulphonol) within the boundary of phase distribution and their multifunctional action of the process and results of hydromechanical drilling in general and contact interaction of the rock-breaking act members in particular.

Conclusions.

1. According to the results of thorough analysis of literature sources as well as industrial and laboratory data, further ways for rationalization and optimization of the bottomhole rock-breaking processes while using well hydromechanical technologies have been outlined. Specific experimental and analytical examples were given to prove the possibility of controlled intensification of bottomhole processes of hydromechanical drilling by correlated selection of the type and technological properties of the medium for rock mass breaking processes (washing liquids) by its complementing with the surface-active substances (SAS) that affects considerably the physicochemical characteristics of the liquid, i.e. surface tension and adsorption capability. According to the aforementioned, features of the behaviour of surface interactions aimed at intensification of the development of deformation and breaking on the well bottomhole have been specified in terms of the analysis of fine-grained granite samples.

2. The detailed experimental studies on the properties of a series of SAS different in their directedness and intensity of interaction with a disperse medium (ionogenic anion- and cation-active and non-ionogenic), rational boundaries of their efficient concentrations have been determined. That is the obligatory condition of the use of these substances as the components of drilling washing liquids. The following has been proved: ionogenic cation-active SAS katapin K is characterized by the lowest effective concentration interval $C \leq 2.5$ g/l, which, however, makes it impossible to reach the maximum possible level of reduction of surface tension σ for a drilling washing liquid that is typical of sulphonol ($C \leq 3$ g/l) and OP-10 (but in case of $C \leq 5$ g/l). Quite different results were obtained while analysing the properties of activated washing liquids containing a mixture of SAS (sulphonol, OP-10, and electrolyte $CaCl_2$). For them, the surface tension grows on average up to 20 % comparing to the individual indices in terms of sulphonol concentration C being not more than 2 g/l.

3. It has been proved under laboratory conditions that there is an effect of the adsorption of active components on the processes of contact interactions between the breaking elements of hydromechanical devices. In this context, when the composition of a drilling washing liquid is complemented with the sulphonol with boundary concentration $C = 2$ g/l, the wear intensity c of the contacting metal surfaces experiences its average reduction by 22 basic percent.

4. Further experimental and analytical studies on the technical and technological features of implementing the principles of hydromechanical drilling and design characteristics of the corresponding devices should be carried out in terms of creation of possibilities for applying rational mode parameters of each of the bottomhole deepening operations with maximum consideration of the mining-geological and economic conditions of a drilling process.

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Експериментально-теоретичні дослідження робочих параметрів гідромеханічного буріння

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Мета. Аналіз окремих комплексних складових акту руйнування гірського масиву при споруджені свердловин, обумовлених конструктивними особливостями технічних засобів гідромеханічного буріння та різноманіттям прояву гідравлічних і фізико-хімічних властивостей активованого циркуляційного середовища.

Методика. Фізико-хімічні параметри процесу адсорбції активних речовин із водних розчинів на поверхні гірських порід вивчалися на їх дисперсному матеріалі, шляхом визначення оптимального співвідношення у групі «частки твердої фази − об'єм активованого розчи-

ну» з фіксуванням часового інтервалу встановлення адсорбційної рівноваги. Дослідження вибійних процесів, за умов роботи модернізованих пристроїв гідромеханічного буріння, виконане із застосуванням сучасних методів аналітичного аналізу та експериментально-лабораторних досліджень шляхом використання прийомів математичного й фізичного моделювання, методик обробки та інтерпретації результатів досліджень у середовищі SolidWorks, STATGRAPHICS, MATHCAD, контрольно-вимірювальних приладів і матеріалів.

Результати. Проаналізовано, з позицій створення якнайефективніших умов вибійного акту руйнування гірського масиву, особливості комбінованого — гідромеханічного способу буріння. Оскільки практично доведеним фактором гідромеханічного буріння є значний ступінь розвитку руйнівних процесів, саме тому їх раціоналізація та посилення можуть бути досягнуті за рахунок скерованого фізико-хімічного впливу поверхнево-активного середовища. Проведені експериментальні дослідження з вивчення спрямованості розвитку й результатів поверхневих взаємодій — адсорбції на межі розділу фаз, як головного чинника інтенсифікації руйнування гірського масиву. Виконано порівняльний аналіз поверхневої активності відповідних речовин, що відрізняються схемою дисоціації у водному розчині, властивості якого додатково корегувалися у напрямі наближення до таких, які притаманні природним буровим промивальним рідинам. Прослідковано позитивність впливу явищ адсорбції також на результати контактної взаємодії руйнівних елементів гідромеханічних пристроїв, що проявляється в уповільнені зношування металевих поверхонь.

Наукова новизна. Корисний прояв фізико-хімічних властивостей досліджених поверхнево-активних речовин знижується у напрямі від іоногенного аніоноактивного сульфонолу, далі до іоногенного катіоноактивного катапіну К, закінчуючи неіоногенною речовиною ОП-10. Проте, за умов комбінування складу означених речовин, він може бути додатково підсилений.

Практична значимість. Зазначені результати лабораторно-експериментальних досліджень є базовими для проектування режимних параметрів програми промивання свердловин гідромеханічного буріння й належать до основних вихідних даних, що застосовуються при обґрунтуванні конструктивних і техніко-технологічних характеристик модернізованих кулеструминних пристроїв.

Ключові слова: *гідромеханічне буріння, свердловина, промивальна рідина, гірська порода, адсорбція, поверхнево-активна речовина*

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