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ANDRII IHNATOV[1], JAMIL SAMI HADDAD[2*],
YEVHENII KOROVIAKA[1], OLEKSANDR AZIUKOVSKYI[1],
VALERII RASTSVIETAIEV[1], OLENA DMYTRUK[1]

STUDY OF RATIONAL REGIME AND TECHNOLOGICAL PARAMETERS OF THE HYDROMECHANICAL DRILLING METHOD

Findings. The function of breaking deformations within the rock mass in the bottomhole of a hydromechanical drilling well is dependent on various technological means and methods. A sequential analysis has been conducted to identify the most influential factors in this process. Positive features of hydromechanical drilling have been outlined from the viewpoint of effective intensification of basic technical and economic parameters of the process of well construction with different purposes. Complete operational similarity and technological interconnection of a mechanism of the formation of different parts of a hydromechanical drilling well have been shown in terms of their stipulation by the properties of rock formations and mode support of a well construction process. Top-priority of a hydromechanical drilling type has been proved to generate as many parameters of dynamic effect on rock mass, which results in the increasing scope of bottomhole breaking processes. Attention has been paid to the study of the problem of tool support for drilling operations from the viewpoint of tracing the nature of bottomhole processes running in terms of different technical and technological factors. The possibility and necessity of using surface-active substances (SAS) as the main activators of positive deformation interactions in the "metal pellets – rock" pair have been proved and substantiated; use will be based on the developed methodological approaches of rational selection of a component-concentration composition of a breaking medium.

Originality. The efficiency of a hydromechanical drilling type is stipulated by the degree of dynamic effect on the rock bottomhole; depending on its geological-mineralogical and physicomechanical features, it can be intensified by increasing frequency of impacting, interpretation of the effecting mechanism, variation of the cleaning agent type as well as directed activation of the manifestation of surface and interphase interactions.

Practical implications. The represented results of analytical and laboratory-experimental studies are the basis for the development of methodological foundations to elaborate the mode parameters of

1 DNIPRO UNIVERSITY OF TECHNOLOGY, UKRAINE
2 AL-BALQA APPLIED UNIVERSITY, JORDAN
* Corresponding author: drjamil@bau.edu.jo

the technology of hydromechanical drilling for the construction of wells. They belong to the basic initial data applied while developing the design and working characteristics of the corresponding modernised operating members.

Keywords: hydromechanical drilling; mechanical velocity; well; bottomhole; disperse medium; rock; adsorption; surface-active substance; rock-breaking pellet; deformation; interphase tension; cleaning agent

1. Introduction

Statement of the problem. Currently, there are numerous methods and techniques used for mineral deposit prospecting and development. However, the most advanced and widely-used techniques involve non-competitive drilling technologies, which are implemented through mine workings of the same name. Moreover, features of geological conditions of the deposits and schemes of their development require the construction of a significant number of wells [1].

Though, in terms of scalability, the wells are somehow inferior to permanent mine workings [2-3] as for certain visible signs of geometrical dimensions and technical-technological support, such characteristic formulation is not completely objective. Wells are considered the most effective way to access deep layers of rocks, revealing a wide range of petrographic, physicomechanical, chemical, and thermobaric properties. These layers form the well walls and bottomhole [4-5]. The enumerated features stipulate the sequence of construction and content of each technological component of a drilling cycle; such a key process as rock breaking is not the exception. The latter is the operation, which means the physical formation of a well shaft within the rock mass. The complexity of the process under consideration cannot be overstated; its results are the integral characteristic of such essential factors as a range of rock properties, breaking method as well as parameters of the corresponding equipment and tools, mode and technological support, and excellent implementation of the basic parameters [6].

While considering the information materials of research and production organisations, one can trace the successive development of the solution of theoretical and practical issues dealing with the search for efficient methods of rock breaking [7]. However, despite quite a wide range of the proposed and somehow substantiated, either under laboratory or production conditions, methods of influencing a rock mass for its further breaking, the majority of currently applied technologies of well shaft sinking are based on the purely mechanical effect of the rock [1]. The aforementioned means the separation of rock fragments from the mass with the help of solid elements of the breaking tool equipment; the elements are fixed securely relative to their case. In some situations, the breaking effect is intensified additionally by the hydro aeromechanics effect of the drilling agent flows circulating within a well. In terms of such a statement of a problem, it is clear that the lifespan of a rock-breaking tool on the well bottom hole depends on the working life of the equipment; and that is the reason why a production cycle of well construction includes considerable volumes of nonproductive time and energy losses due to operations for replacing a worn breaking tool [2,8]. Those and some other interconnected circumstances are the starting point in searching for innovative high-productive methods of rock mass breaking.

Analysis of recent studies and publications. The nomenclature of construction materials with significant operational potential is one of the current trends in the development of technologies to design and manufacture technical means and tools for well construction [9] in the field of rock mass breaking.; that is especially characteristic for tool components [2-4,10]. Nevertheless, the rotary movement of a rock-breaking tool with the application of constant acting (static) load is still the overall methodological basis for drilling techniques. That can be explained by the availability of numerous scientifically and practically approbated methods of the drilling process performance and means of technical support. However, a rotary drilling method has considerable disadvantages – low coefficient of immediate implementation of downhole efficiency within a rock-breaking tool. It is of significant importance while constructing wells in hard rocks and the formation members with frequent sharp changes in rock mass characteristics, corresponding to a breaking process [11].

Considering the existing massive series of rocks with complex and differentiated characteristics of physicomechanical properties and natural limitations of the current technical-technological scheme of drilling cycle development, it is not always possible to achieve positive and relevant parameters of a rock-breaking process. In other words, in terms of certain mining and geological conditions, there arises the urgent necessity in using cardinally new methods to eliminate the disadvantages of rotary drilling, e.g. for the problems of substantial increase in mechanical velocity of well deepening [4].

Singling out of previously unsolved parts of a general problem. Development of the operable and efficient rock-breaking tool and technical means of its support should be based only on the results of a thorough analysis of the component of a rock-breaking act. However, such a task is problematic as it is influenced by numerous factors [12].

Rock mass as the object of well localisation includes thicknesses of rocks being quite different in their origin, mechanism of formation, and metamorphism, as well as the composition of substances and textural-structural rock features [13]. These are the reasons why rock mass, as a result of breaking, demonstrates quite a wide range of characteristic features, in terms of which it is a rather complicated task to establish adequate correlation with the mode and technological parameters of a drilling process. Among other things, such a situation is stipulated by quite logical facts – there is no unified opinion as to the regularities of rock breaking and the factors determining them. The problem of giving priority to those parameters of rock properties, which are connected with the results of rock mass breaking to the fullest extent, is still unsolved.

Despite the complexity of the formulated problem, its solution is quite real; though, it should involve the elimination of uniform interpretation of basic sequenced stages of a rock-breaking process and factors determining its directionality and results [14].

A peculiarity of the approaches to design technical means of particularly hydromechanical drilling is as follows: the approaches should be based on a combined mechanism of rock mass breaking with the help of methods that differ in high indices of realisation of absolute values of downhole efficiency and a corresponding most-efficient mechanism of the development of breaking processes [15].

The objective of the research is to develop and substantiate theoretical and engineering-applied components of the methodology for the specification of design and technological parameters of modernised facilities for hydromechanical drilling based on the identified regularities of the "metal pellets – rock" interaction.

Statement of the task. Based on the aforementioned, there is no need to prove the following statement: research and design work for the development or modernisation of tools and technological support of drilling operations are to be based on the comprehensive data concerning the content of separate stages of breaking-deformation processes in the rock mass and their functional dependence on the determining factors of nature. It is the approach that is practically the only possible way of creating the basis for qualitatively new interpretations of an elementary act of rock breaking according to the capacities of technical means and tools in terms of rational variations of mode parameters.

Analysis of the breaking-process factors within the well bottomhole helps understand their strict dependence on the sources of origin of corresponding deformations within the rock mass, which results in formal transformations to be seen in disturbances of the integrity of the latter.

Breaking stresses may occur as the initiation of the action of external as well as internal forces as a result of, in particular, the deepening of special indentors into the rock mass, the effect of the dynamic pressure of liquid flows, formation of certain surface temperature gradients, generation of high-frequency electric fields etc.

In our case, hydromechanical drilling that involves movable hard pellets has important features, which manifestation is connected with principally different mechanisms of the formation of central and peripheral parts of the well bottomhole as rock-breaking elements contact the rock mass according to different technological schemes. That results in cardinal diversity between the sequence and results of each component of a rock-breaking act according to the implementation scheme and arising an insistent need for strict and unambiguous classification of complex processes of the well bottomhole formation.

2. Methods

Laboratory stand-based studies of technological peculiarities of functional directionality and results of bottomhole breaking processes in terms of operation of modernised devices of combined hydromechanical drilling have been performed involving up-to-date methods of analytical analysis and experimental studies, i.e. by using certain techniques of mathematical and physical modelling, methods of theoretical processing and interpretation of the research results applying SolidWorks, Statgraphics, Mathcad as well as corresponding control and measuring devices, toolset, and materials [16-18].

A process of solving the problems of optimal planning of laboratory-analytical experiments included the following main stages: development and substantiation of the planned model parameters; preparation and analysis of the required data; calculation of a model; obtaining of the results [19].

In their technological sequence, stand-based well bottomhole rock-breaking processes were modelled on a research unit equipped with control and measuring devices (i.e. loss metre, manometer, tachometer, coordinator, bearing unit of positioning, supply mechanism).

The results of the process of mountain massif destruction by bullet impacts were controlled in the following way. The depth of the fracture hole was determined using an electronic MIOL 15-240 calliper with a depth gauge. The volume of the destruction hole was determined after it was cleaned of destruction products and filled with plasticine/paraffin. The mould of the latter was pulled out and weighed, and the volume was determined by dividing the weight of the plastic material by its specific gravity. Before placing the plastic material in the fracture hole, the bottom of the hole was lubricated with machine oil for the plastic material to be easily separated from the bottom of the hole during the removal of the cast.

The surface tension of the destruction medium was determined by the stalagmometric method (using a professional device – stalagmometer ST-2 electronic digital), which is based on the dependence of the number of drops formed from the volume of the stalagmometer on the surface tension of the liquid σ.

3. Results and discussion

The specificity of rational organisation of drilling operations is in the design and performance of such structurally ordered technological operations that help construct wells in the shortest time possible with minimum costs. However, adequate implementation of those plans requires meeting a whole set of prerequisites with the key one – a rock-breaking velocity on the well bottomhole should reach its highest possible values [1,20].

Mechanical drilling velocity (m/hour) is a quantitative parameter of technological quality of the operation of well bottomhole advancing within rock formations.

$$u = \frac{h}{t_б} \tag{1}$$

where h is the length of the obtained well interval, axially, per net drilling time m; $t_б$ is the time of effective work of a bottomhole rock-breaking tool, hour.

The parameter u represents the efficiency of that drilling type, breaking tool, mode parameters, applied technical support etc. At the same time, u cannot be a test of identity of total well construction time, as normally, the latter also includes the time for trips and other auxiliary operations performed per run. In terms of standard conditions, the run duration determines the life of a bottomhole tool, in which breaking properties deteriorate with time due to wear, resulting in its replacement. Thus, in general, the well construction time is characterised by the total of discrete values of drilling velocity per run (m/hour)

$$u_p = \frac{h_p}{t_б + t_{cn} + t_{\partial o}} \tag{2}$$

where h_p is the length of the obtained well interval, axially, per run, m; t_{cn} is time spent for trips with a drill string, hour; $t_{\partial o}$ is time spent for auxiliary operations per run (e.g. preparation for drill string running).

In this context, it is possible to see the considerable advantage of hydromechanical drilling, i.e. maintaining mechanical drilling velocity at a certain level with no need for frequent replacement of a bottomhole tool, which is connected with the possibility to remove worn elements of drilling facilities and supply the operating ones – rock-breaking pellets. That makes it possible to simultaneously influence all the components of integral time for well construction.

Complex use of aero hydraulic power is a specific feature of all modernised pellet-impact devices, i.e.: a flow of circulating drilling fluid has the functions of well bottomhole cleaning and support of its walls, tool cooling, transportation of cuttings to the surface; besides that power has a leading role of movement activator for rock-breaking pellets and bottomhole motors, which eliminates the necessity for surface equipment to transmit rotation for a drill string. The importance of transformation for the latter fact is clearly understood from the analysis of the equation of power spent for drill string rotation (W)

$$N_{об} = K_{оа} \cdot K_c \cdot K_м (0{,}016 \cdot K_{зт} \cdot K_к \cdot (1+60 \cdot i) \cdot (0{,}9+20 \cdot \delta) \cdot D_c \times \\ \times \frac{q}{(1000 \cdot EI)^{0{,}16}} \cdot n^{1{,}85} \cdot L^{0{,}75} \cdot (1+0{,}44 \cdot \cos\beta) + 0{,}02 \cdot \delta \cdot n \cdot C_{ос}) \quad (3)$$

where $K_{оа}$ is the coefficient that considers the properties of a circulating cleaning agent; K_c is the coefficient that considers the state of a well shaft; $K_м$ is the coefficient that considers the properties of the materials the drill tubes are made from; $K_{зт}$ is the coefficient that considers design features of connecting elements of the drill tubes; $K_к$ is the coefficient that considers deformation of the drill tubes and coaxially of the connections; i is the intensity of the well shaft deviation, degree/m; δ is a lateral gap between the drill tubes and borehole walls, m; D_c is well diameter, m; q is mass of one metre of the drill tubes, N; EI is stiffness of the drill tubes Nm^2; n is the frequency of the drill string rotation, s^{-1}; L is the length of a drill string or well depth, m; β is the inclination angle of the well to the horizon, degree; $C_{ос}$ is the axial load on a rock-breaking tool, N.

Apart from the considered factor $N_{об}$, a list of main power consumption for well construction includes the operation of drill pumps (compressors) and the functioning of the system to operate a drill string and casing string.

Due to the complexity and energy consumption of certain borehole aerohydrodynamic processes, values of the power reserves developed by a drill pump (compressor) should meet the features of the realisation of all nomenclature of correlated technological cycles and tasks. Correspondingly, power consumption for a drill pump will be as follow (W)

$$N_н = K_{зп} \cdot Q_н \cdot \frac{p_н}{\eta} \quad (4)$$

where $K_{зп}$ is the coefficient of power reserve; $Q_н$ is pumping rate, l/s; $p_н$ is pumping pressure, Pa; η is the coefficient of efficiency of a pump that considers mechanical and hydraulic losses; in its turn, power for a compressor drive will be as follows (W)

$$N_к = K_{дк} \cdot K_{зп} \cdot Q_к \cdot p_к \cdot a \quad (5)$$

where $K_{дк}$ is the constant coefficient of the compressor action; $Q_к$ is pumping rate, l/s; $p_к$ is excessive pressure of the compressed air Pa; a is coefficient of excessive pressure.

There is no need to prove the following: operations of drill string pulling-out are characterised by the greatest power consumption values (W) among the transportation drilling operations:

$$N_{пк} = K_{ор} \cdot G \cdot \cos\theta (1 + f \cdot \mathrm{tg}\,\theta) \cdot V_к \quad (6)$$

where $K_{ор}$ is the coefficient that considers additional resistance of drill string movement during its pulling-out; G is the weight of a drill string, N; θ is the inclination angle of a well from the vertical (zenith angle), degree; f is coefficient of friction at the "steel-rock" boundary; $V_к$ is the velocity of the drill string pulling-out, m/s.

The represented analytical dependences (3)-(6) provide almost comprehensive information (with some exceptions that will be considered later) about the factor content of main positions of drilling-related power consumption balance; at the same time, they help follow the way of their reformatting. The latter is connected with the necessity of a certain increase in level $N_н(N_к)$ in terms of considerable reduction of $N_{пк}$, and, especially, $N_{об}$.

Distinct features of the designed hydro mechanical drilling technique are in the use of principally different methods of rock breaking, within different sites of well bottomhole [21]. However, they are not separated: directed rock breaking with impacts of circulating pellets is aimed at the well shaft creation with a specific curvilinear profile that requires compulsory correction using a special, original design of a mechanical rock-breaking tool.

Absolute mobility of rock-braking pellets allows for increasing the duration of a drilling run, which will be defined now only by stability, being subject to effective regulation of certain bottomhole structural elements of drilling devices. One more specific feature of the pellet's operation is the logical sequence of their functioning: at the initial stages, that is the main initiator of circulating breaking processes; further, that is the element of equipment of the bottomhole mechanical profile-forming tools. Design solutions and technological schemes of the facility operation allow continuous removal of the pellets, worn due to some reasons, onto the surface.

Impact drilling, being the basis of operation of the devices under analysis, with appropriate regime-parametric support, differs in a high level of the efficiency of dynamic effect on a rock mass. This method can and should be agreed upon with the physicomechanical properties of rock formations (they include hardness, strength, granularity, and monolithicity). It is also the factor of visible decrease in rock resistance to breaking due to the formation of the developed network of fractures in it as well as the initial zones of irreversible deformation, which together improve considerably the formation conditions of all the well bottomhole sections.

Finally, the last affecting component of the energy consumption balance is as follows: power for rock breaking on the well bottomhole also experiences significant transformations towards its reduction due to reformatting of the interaction content in the "breaking element – rock mass" pair.

Thus, such a detailed analysis of power components reveals a considerable level of reduction of power consumption in terms of hydromechanical drilling. Nevertheless, the aforementioned can be achieved only based on a detailed study of all the features of bottomhole processes in terms of meeting the requirements of identifying their physical nature and getting some leverages for effecting them to increase efficiency and other technical-economic parameters [22].

A process of well borehole formation will be analysed in a logical sequence, i.e. from the identification of a mechanism of its central share breaking with the transition to the operation of curvilinear peripheral zone processing [23].

Since well formation in rock mass involving movable pellets is chaotic and nonuniform, which prevents a clear specification of a conditional current site of the well bottomhole, relative to which we can characterise breaking processes, it is considered to be an alternative to studying geometrical properties of certain breaking holes in terms of a complex of factors determining the hydromechanical drilling efficiency. According to a technological scheme of the well construction method under consideration, the only regulator of rock-breaking intensity during the operation of the pellet is their level of absolute velocity (formed by variation of cleaning agent consumption), with which they impact a bottomhole. However, there is a possibility of additional intensification of the magnitude of rock-breaking processes by using the effect of cleaning agents, which has considerable activation potential (demonstrated from the data in Tables 1-2).

TABLE 1

Characteristic parameters of a rock-breaking process by means of pellet impacts

Petrographic feature	Estimated velocity of the breaking load application v, m/s	Preliminary state of rock	Results of a breaking process			
			Features of a breaking medium			
			Technical water		Technical water processed with the sulphonol reagent (concentration per litre is C = 3 g/l)	
			Depth of a breaking hole h_p, mm	Approximate volume of a breaking hole $V_p \cdot 10^3$, mm^3	Depth of a breaking hole h_p, mm	Approximate volume of a breaking hole $V_p \cdot 10^3$, mm^3
coarse-grained granite	20	monolithic	5.5	0.734	6.2	0.829
	30		6.2	0.986	7.0	1.13
	40		6.5	1.512	7.8	1.814
fine-grained granite	20		4.8	0.646	5.3	0.724
	30		5.3	0.859	5.9	0.986
	40		6.1	1.406	6.9	1.598

The data obtained from Table 1 clearly shows a stable correlation between the properties of a cleaning agent and the results of the breaking process. This correlation is unquestionable. Selection of sulphonol (concentration content is C = 3.0 g/l) as a component of a cleaning agent (technical water) was stipulated by its well-known universality for the application conditions.

Thus, the use of a class of substances with clearly seen surface activity (SAS) [24], where sulphonol belongs, is aimed at reducing the surface tension within the boundary of phases separation and increasing penetration; the effect of the growth of marking parameters of a breaking act (h_p and V_p) can be referred undoubtedly to the result of a mechanism of capillary pressure manifestation, consisting in intense deceleration of the closing of breaking fractures. Hydromechanical drilling is characterized by a high degree phenomena and interpretations considered

It is important to take note of the rising signs of breakage as the parameter v increases. This can be attributed to the increased interaction between the "rock-breaking tool – rock mass" pair, with a constant number of circulating pellets M. The phenomenon is supported by the data presented in Fig. 1.

a b c

Fig. 1. Photos of the bottomhole state of a modelled well of hydromechanical drilling

In Fig. 1, the photos are arranged according to the increasing velocity of application of breaking load v, which values were 20 m/s (Fig. 1a), 30 m/s (Fig. 1b), and 40 m/s (Fig. 1c); light zones indicate the sites of a modelled well bottomhole, which are not disturbed by breaking deformations.

Data from Table 2 are additional pieces of evidence to prove the efficiency of SAS use in circulation processes of hydromechanical drilling.

TABLE 2

Characteristic parameters of a rock-breaking process using pellet impacts in terms of the changed state of a rock bottomhole

Petrographic feature	**Estimated velocity of breaking load application *v*, m/s**	**Preliminary state of rock**	**Results of a breaking process**			
			Features of a breaking medium			
			Technical water		**Technical water processed with the sulphonol reagent (concentration per litre is C = 3 g/l)**	
			Depth of a breaking hole h_p, mm	**Approximate volume of a breaking hole $V_p \cdot 10^3$, mm^3**	**Depth of a breaking hole h_p, mm**	**Approximate volume of a breaking hole $Vp \cdot 10^3$, mm^3**
coarse-grained granite	20	deformed with fractures	5.8	0.764	6.9	0.926
	30		6.3	1.012	7.8	1.262
	40		6.8	1.582	8.9	2.068
fine-grained granite	20		5.2	0.698	5.8	0.798
	30		5.6	0.908	6.8	1.138
	40		6.2	1.422	8.0	1.884

As shown in Table 2, it is possible to observe the features of the considerable transformation of the effects of bottomhole deformation processes, whose physical manifestation is in increasing breaking magnitude.

Based on the obtained data and peculiarities of the operational sequence of the development of a bottomhole cycle of rock mass breaking in terms of hydro mechanical drilling, it is clear that the top-priority problem is to specify the required amount of pellets to be within the active zone for creating the most favourable conditions for running of deformation processes. However, prerequisites for the solution of that problem are represented by the need to specify the functional content of components of an elementary bottomhole breaking act and its integral factors. Experimental data in Fig. 2 make it possible to obtain quite an objective understanding of the essence of factor M.

As for the data in Fig. 2, they can be interpreted as follows. The results of breaking processes (volume of a breaking hole V_p) are within the zone of action of such arguments as the intensity of load application v – velocity of pellets, and amount of the latter M. However, a parameter M has quite an ambiguous effect: in terms of interval $10 < M < 30$, a range of considerable V_p increase is singled out – by approximately 6 times relative to the minimum base value; a site $30 < M < 40$ is characterised by deceleration and stabilisation of the increase in V_p parameter for its control

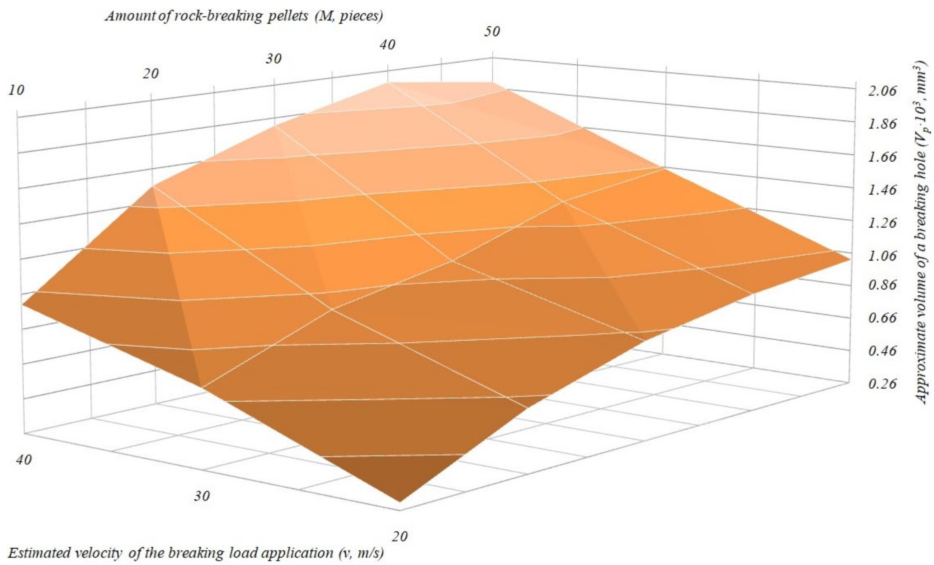

Fig. 2. Results of the studies of bottomhole processes in modelled wells of hydromechanical drilling in terms of variation of the amount of rock-breaking pellets *M*

values; further *M* increase in terms of $v \leq 30$ m/s does not result in any significant V_p changes, and if $v \geq 30$ m/s, then even its decrease is observed.

Metal pellets of $d_к$ = 5 mm diameter were used as the rock-breaking elements during the study; the bottomhole processes run within the cleaning agent – technical water activated with SAS sulphonol (concentration content is C = 3.0 g/l) [25].

Besides, analysis of the represented information has helped to understand the following objective regularity: technical water (non activated cleaning agent) does not have sufficient capacity to force deformation phenomena within the rock mass; SAS-containing cleaning agents (in our case, technical water) are active participants of a breaking process. Moreover, a mechanism of their surface capacity is seen in terms of an available developed system of deformation disturbances (fractures) and a stable completed cycle of realisation of dynamic loads on the well bottomhole.

Fig. 3 contains the data concerning comparative features of surface activity of different SAS [26] and their combinations in terms of the effect on the results of breaking processes on the well bottomhole.

The data in Fig. 3 help to understand unambiguously the effect of certain SAS types on the processes of development and results of breaking deformations. Special attention should be paid to the fact that reagent compositions are of the highest surface activity (that is proved by the mixture of sulphonol and OP-10); moreover, the cleaning agent (technical water) is activated in the following component ratio: sulphonol – C = 3.0 g/l, OP-10 – $C = 3 \cdot 10^{-6}$ mol/l, and electrolyte $CaCl_2$ – $C = 1 \cdot 10^{-3}$ mol/l. The use of $CaCl_2$ substance was explained by the necessity to neutralise the effect of foreign ions of a dispersed medium, which have an active chemical influence on the adsorption results – the main factor of the phenomenon of breaking processes intensification.

The indicated regularities were analysed in terms of the samples of coarse-grained granite not affected by deformation loads; however, the general tendencies mentioned before are still

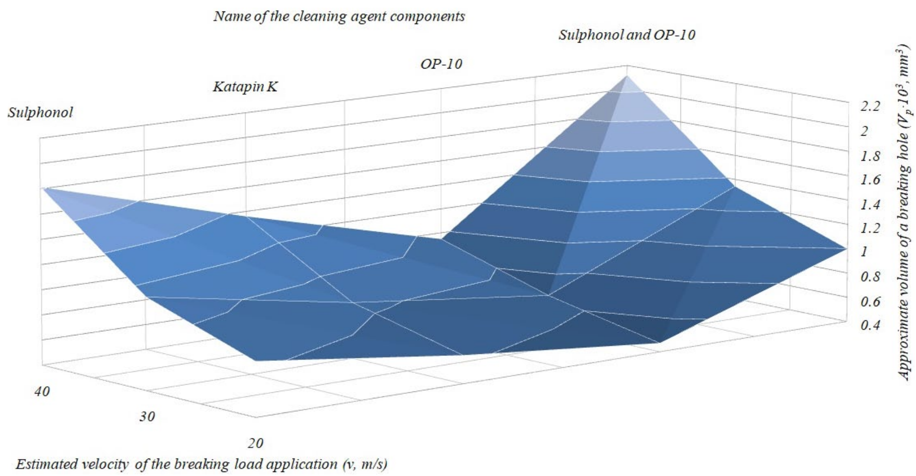

Fig. 3. Mechanics of a rock-breaking process on the bottomhole of a modelled well of hydromechanical drilling in terms of using SAS-activated cleaning agents

true for the conditions of fine-grained granite and different mechanical states of the rock mass. (monolithic or disturbed by the crack system)

As aforementioned, it is possible to formulate the following experimentally substantiated intermediate conclusion. Development of compositions of cleaning agents (in terms of technical water) should be based obligatorily on the study of regularities of bottomhole breaking processes in the conditional "metal pellets – rock" pair. In terms of the interpretation under consideration, hydromechanical drilling differs in its ability to create quite a branched complex of fractures and breaking holes within the formations. It can be confirmed indirectly by clear manifestation of the phenomenon of strength decrease due to available external surface interactions stipulated by SAS absorption. Laboratory studies of the surface activity of substances represented graphically in Fig. 4 are additional evidence of that fact.

After comparison of Fig. 3 and 4, there is a clear distinction of a close correlation between the gained properties of a cleaning agent and the results of bottomhole deformation processes. Additionally, a driving factor here is a transformation of σ parameter – surface tension of a breaking medium; as for immediate conditions of rock breaking, that factor is represented by interphase tension [25]. Nevertheless, due to a particular chemical structure and component-concentration composition, physicochemical properties of the dispersed medium, mineralogical characteristics of rock formations, and geological-technical conditions of their use, each SAS (or their combination) demonstrates its specific features. The latter may be referred to as the manifestation of adsorption forces [26] provoked by a considerable level of uncompensated surface energy – the newly formed surface of the rock-breaking surface [27].

The research has also identified some peculiarities of the deformation processes run during the formation of a rectangular profile of a peripheral zone of well bottomhole with the help of pellets and special design of breaking members.

A process illustrated in Fig. 5 is a quantitative physical pattern of the development and results of technological modes: axial load on a rock-breaking member of a hydromechanical device and its rotation frequency.

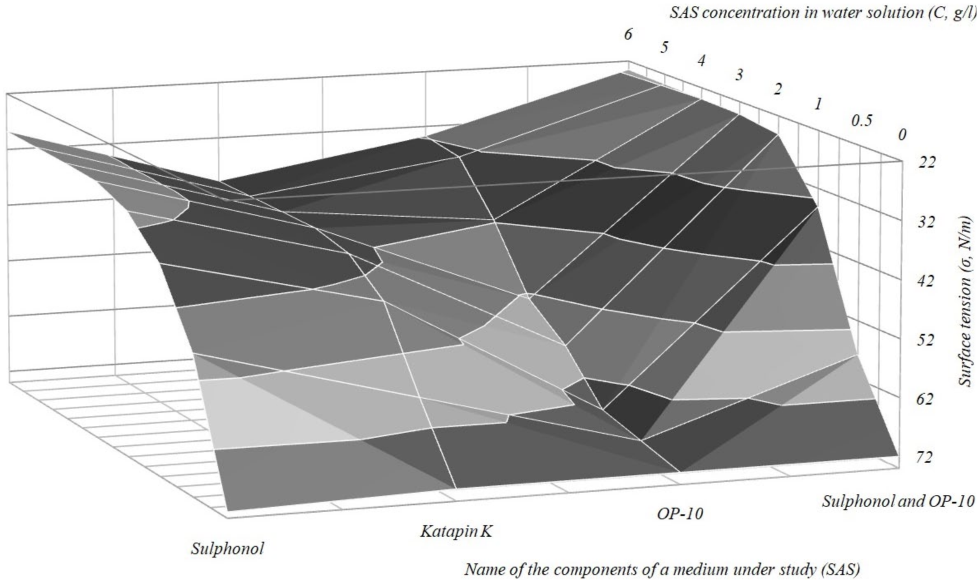

Fig. 4. Results of studies of surface interaction of the "technical water – SAS" complex

A comprehensive analysis of the Fig. 5 data shows the dependence of deformation phenomena on the action of the rotation frequency of a rock-breaking member of a hydromechanical device and the absolute values of axial load on it. A specific feature of the analysed process is that the increase in deepening velocity u is observed both in terms of growing mode parameters n and C; however, the effect of the rotation frequency is more considerable. In other words, increasing rotation frequency may be accompanied by reducing values of axial load in the same manner as the insufficiency of the latter may be compensated by increasing n. Nevertheless, those facts require a thorough study of all features of bottomhole processes of movement and immediate operation of rock-breaking pellets. Pellet diameters and their correlation with the design and geometrical parameters of mounting sockets of mechanical rock-breaking members will also play an important role here. Features of bottomhole processes of pellet movement, connected with the realisation of high indices of drilling mode parameter n and the inevitable effect of centrifugal force action, should also be considered in detail.

In terms of the examined cycle of studies, it is obligatory to analyse bottomhole features of the formation of a well peripheral zone under conditions of action of activated SAS medium, which the results are represented in Fig. 6. There are the following research conditions: concentration of corresponding SAS in the activated solution is $C = 3.0$ g/l; rotation frequency of a mechanic rock-breaking member is $n = 260$ min^{-1}

Based on the data in Fig. 6, it is possible to state the following. Like in the case of SAS used to intensify bottomhole processes of the formation of a central part of a hydromechanical-drilling well, deformation phenomena depend on active components available within the working medium; however, when a peripheral well zone is formed, that is not clear as it occurs within a much narrower range of breaking characteristics. That can be explained by the fact that there is no developed system of deformation disturbances within the outline share of the well bottom-

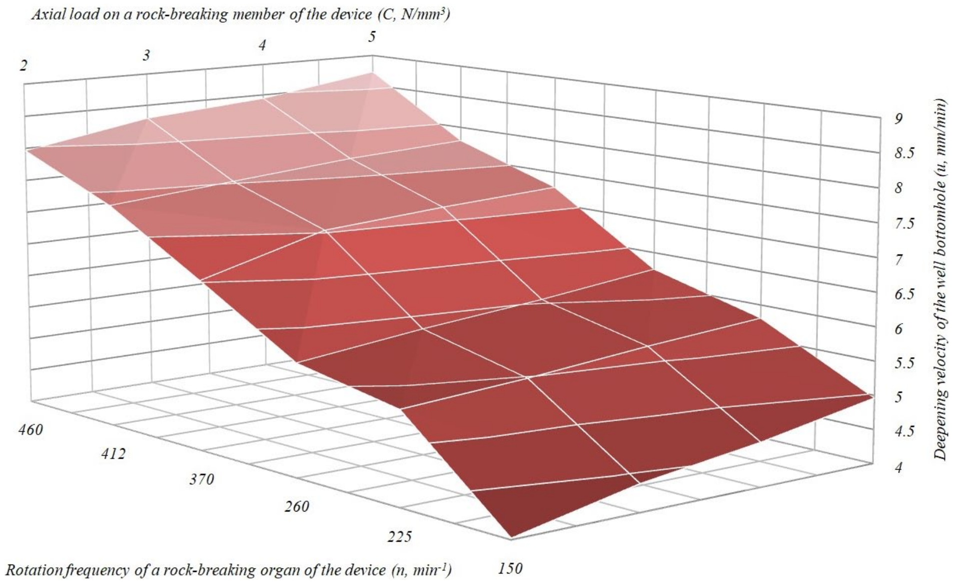

Fig. 5. Peculiarities of the deformation processes run while processing a peripheral zone of a hydromechanical-drilling well

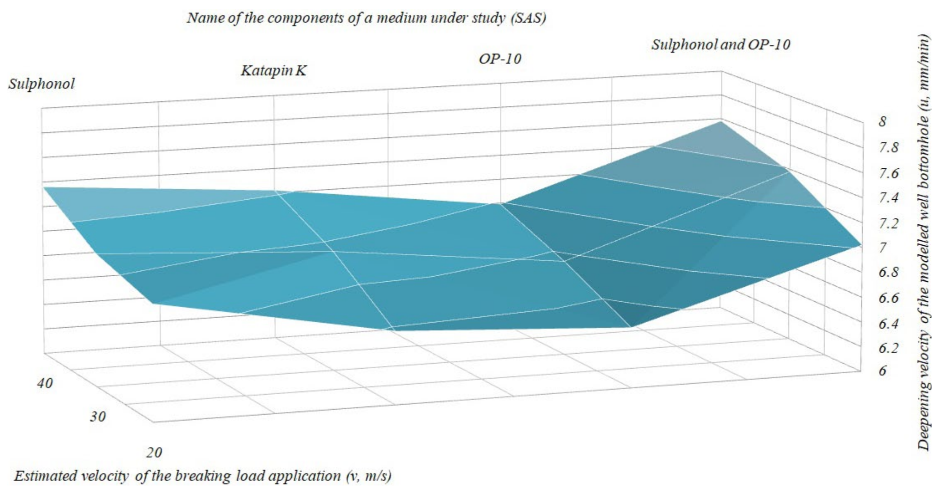

Fig. 6. Effect of active component on the nature of deformation processes run while processing peripheral zone of a hydromechanical-drilling well

hole. The indicated disadvantage is quite reparable by correcting the motion trajectory of rock-breaking pellets and applying those methods of processing of a peripheral zone, which differ in their considerable degree of responsiveness. Nevertheless, the problems that arise require further detailed study and analytical and laboratory analysis.

4. Conclusions

1. Considered, in a logical sequence, the main influential indicators of the technological process of constructing wells, based on the analysis of which the main advantages of the hydromechanical method of drilling using rock-destroying balls are shown, as well as the ways of further improvement of this progressive method are outlined.

2. Analysis of separate and common features of a mechanism of formation of different well parts (central and peripheral) has been used to study the main components of rock-breaking and their state of being affected by physico mechanical rock properties (hardness, strength, granularity, monolithicity) and mode-parametric characteristics of a well construction process.

3. Concrete and laboratory-tested examples have been represented to prove that, in terms of the interpretation under study, hydromechanical drilling is capable of considerable dynamic action on the rock mass, which can be used maximally to force the bottomhole breaking processes in case of certain technological development of a well construction cycle.

4. A necessity of clear interconnection between the minimum required and a technologically reasonable amount of working rock-breaking pellets on the well bottomhole with their absolute motion velocities has been argued.

5. Progress and results of the process of deformation interaction in the "metal pellets – rock" pair, taking place in the activated (with the help of SAS – surface active substances) medium, have been traced; a high degree of their efficiency in terms of increasing magnitude of the manifestation of effects of breaking load application has been demonstrated.

6. Certain methodological basis of rational selection of the component-concentration composition of a breaking medium has been elaborated; it has been aimed at implementation of the conditions of intensification of a complex operation of processing for different well bottomhole parts.

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