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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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ANALYSIS OF MODELING AND DECISION-MAKING PROCESSES FOR DRILLING WELLS UNDER UNCERTAINTY

Abstract. A review of the studies devoted to modeling and decision making in the process of drilling wells accumulated in recent years has been performed. The review identified the range of issues on which attention should be focused. In particular, it is noted that in order to solve optimization problems, first of all, data are required. The next step is data processing and drilling model construction. Then variant calculations are carried out and the decision-making stage is coming.

The solution of problems of optimization of the drilling process is complicated by the uncertainty of the decision-making situation, expressed by multifactority, multicriteria, inaccuracy, ambiguity. To successfully solve problems taking into account the mentioned uncertainties, it is necessary to apply appropriate methods. These methods should take into account uncertainty. Besides, they should be based on the results of geological and technological studies that became widely used in recent years. Proceeding from this, ways of perfection of methods of a choice of bits and drilling modes, as well as interpretation of the results of geological-technological researches are considered in the present article. The models based on processing and analyzing data of geological and technological researches have been constructed. Ways of decision-making taking into account uncertainty were shown. The decision is made using the provisions of the theory of fuzzy sets.

Based on the data of geological and technological studies on several wells, calculations were carried out. The appropriate program was applied for that purpose. As the result, physical and mechanical and baric characteristics of the sections were obtained. These calculations were held on the example of some deposits of Azerbaijan and Kazakhstan. The article shows the change in the indices of the physical and mechanical properties of the rocks of the Karabakhli deposit. Lithological-stratigraphic characteristics of the section are given. Graphs of the change of petrophysical (porosity, permeability), strength (hardness, abrasiveness) and elastic (Young's modulus, Poisson's ratio) characteristics of rocks with depth were constructed. As a result of the analysis, the ways of forecasting well drilling parameters and making optimal decisions on the data of geological and technological research in the drilling process are shown. This allows us to find the optimum values of the regime parameters from the condition of ensuring the maximum run speed and the minimum cost per 1 meter of penetration.

Key words: rate of penetration (ROP), run speed, cost per penetration meter, bit, mode parameters, membership function, uncertainty.

Introduction. In the world practice of drilling and scientific research, to date, quite a rich experience in studying the processes of rock destruction and associated bit work has been accumulated. A long time has been spent and large funds have been released for these studies. However, as the research results show, for today there is no scientifically grounded method of searching for the optimal combination of rock, bit type and regime parameters, which, in our opinion, is explained, in particular by the fact that during the management of technological processes, including drilling, the most important stage is the decision-making process, which includes: setting goals, shaping the decision-making task, and finally, making decisions; while decisions can be made in connection with the goals aimed at increasing the

efficiency of the drilling process by rising rate of penetration, as well as reducing the costs of drilling, eliminating the consequences of complications and accidents, etc., and under different kinds of uncertainty; great labor intensity in carrying out bench and field experiments and their high cost and, as a result, limited volumes of these studies; lack of a reliable theoretical and methodological basis for designing optimal drilling regimes and choosing the types of bits for highly dissected, heterogeneous in drillability cuts, which is typical for almost all geological sections [1, 4, 5, 10, 17].

The solving of optimization problems of a choice of bits and parameters of a drilling mode is complicated by uncertainty of a situation of decision-making, expressed by multifactority, multicriteria, inaccuracy, ambiguity. To successfully solve the problem, taking into account the mentioned uncertainties, it is necessary to apply appropriate methods that take into account this circumstance, as well as the results of geological and technological research received in recent years. Based on the noted, in this article, ways of improving the methods of selection of bits and mode parameters are considered on the basis of processing and analysis of geological and technological research data, taking into account uncertainty.

Brief review of recent research. The development of modern technical facilities and technologies for informational support of the drilling process and their widespread introduction allow improving the quality of the information received and requires its corresponding analysis. Operational information obtained during drilling is of great importance in drilling wells, especially in poorly studied regions with complex mining, geological and environmental conditions.

As follows from the analysis of drilling experience in different conditions, the desired result can be achieved when considering the problem in the form of a system that takes into account the interrelationship between various technical, technological and geological characteristics that affect well drilling performance. In addition, it is also necessary, in our view, to use the level of development of various mathematical methods and software in the course of the classification of objects, the construction of models, that allow to make technological decisions that are hampered in the usual conditions by the presence of uncertainty. This indicates the urgency of the problem of improving decision-making methods when drilling wells, taking into account the uncertainty of conditions. To date, various systems and tools for monitoring the drilling process have been developed, which make it possible to solve a number of geological and technological problems [2]. In all the works, the role of optimization of the drilling process is noted, which is a very important stage during drilling operations. This is caused by the reason that optimization allows to save time and money spent on drilling a well, achieve a high drilling speed and, thus, increase profits. Optimization of the drilling process is aimed at selecting the controlled variables during the drilling process, such as the regime parameters (weight on bit, bit speed, mud flow rate), mud parameters, bit type, based on the desire to achieve the maximum drilling speed. For many years, so-called basic models have been developed and used (Badalov R.A., 1958, Fedorov V.S., 1958, Cunningham, R.A. and J.G. Eenink, 1959; Garnier, A.J. and N.H. van Lingen, 1959; Graham, J.W. and N.L. Muench, 1959; Galle E.M. and Woods H.B., 1963; Bingham M.G., 1965; Bourgoyne Jr., A.T. and F.S. Young, 1974; et al.). These works were further developed in the studies [3,4,8,11,12,13,14,16], on their basis optimization methods have been proposed, for which patents [5-7] were obtained. For example, in [4], based on the statistical analysis of information on the operation of bits of cutting action with the application and development of the basic model of Bingham, a model of rate of penetration is constructed that takes into account the influence of the rock properties (hardness and abrasiveness), the depth of their bedding, regime parameters, mud density. Based on the generalization of the studies, the reliability of the bits and their service life was estimated. The parameters of the model in each case were specified by the random search method. The method [5] includes the characteristics of rocks selected from drilled wells, the establishment of the characteristics of at least one drilling rig; iterative modeling of the borehole wiring. The proposed method involves calculating the economic criterion at each stage of the modeling. Based on the results of modeling at various stages, a package of proposals is created. Thus, an iterative drilling modeling system and a corresponding computer program are created. Using the appropriate information, scenarios of various virtual combinations of equipment, drilling rig, bits, solutions, etc. are modeled. The company provides a virtual modeling service with logging (geophysical) information from exploratory wells and information about the rig, and the service, in turn, develops an economic model based on this information. The flowcharts shown in the work show the input and output (output) information. Based on the input geological and technological information, an analysis of the working time and

bit wear is made, a model of the rate of penetration and an economic model, according to the authors, are constructed. The bit is selected based on the minimum cost of drilling and the minimum drilling time. The bit selection model is built by gradual approximation (improvement) using a computer program, which, according to the author, more accurately describes the process than previously proposed methods, and thereby provides a more correct economic solution and recommendations for drilling contractors and operators. In [3], the well-known Burgoyne and Yang model [2] was chosen as the base, taking into account the influence of several parameters on the rate of penetration. The main factors, such as depth, pore pressure, equivalent circulating density, bit speed, wear of drilling bit teeth and jet impact force, are obtained from the drilling report. To study their correlation, a statistical analysis was performed using multiple regression analysis, and as a result, a model of the rate of penetration for the field was constructed. First, private dependences of the rate of penetration on each of the parameters including the factors under consideration, which were subsequently generalized to the plural, were constructed. As a result, using the results of the marked analysis, optimal values of the weight on bit are determined, which provide the best performance. The optimum weight on bit was calculated for several data points. With the help of the same approach, the model of the rate of penetration was constructed in the paper [8], the cost of one foot of penetration, the specific mechanical energy taking into account the values of the weight on bit, bit speed and rate of penetration were calculated, and expressions are obtained for determining the optimum values of the weight on bit and bit speed providing the minimum cost. In this case, the authors tried to take into account a large number of factors, which is the main advantage of the model. A model based on field observations and statistical analysis of their results, takes into account rock properties for two categories (soft and hard) at a qualitative level, whereas rocks have a wide variety of hardness and abrasivity, which are one of the main factors. In this regard, various methods for evaluating hardness and abrasiveness have been proposed: experimental; using core-slime material; using the results of geophysical studies, For example, in [9], a method is proposed for using geological and geophysical information on the geological section of wells in the assessment of rock drillability, which allows one to quantitatively take into account these important properties of rocks when constructing a model of rate of penetration. In recent years, a sufficient number of studies have been accumulated.

In [12], in order to compile the drillability model for PDC bits, the entire array of data on the performance of PDC bits in the Uzen field is divided into groups by the number of drillhole intervals for the production string, in which each bit is used up to full working, i.e. before replacement. Then the resulting variational series were processed by mathematical statistics methods to obtain the average drilling speed and time of the interval, taking into account the previous bit wear, dispersion, standard deviation and coefficient of variation. As a result, the technique of the approximate evaluation of the process of gage wear of PDC bit after the penetration of each interval under the production casing, taking into account its previous use, has been established. A mathematical model of drillability, taking into account the initial rate of penetration of the new, unused bit, the rate of decrease in the rate of penetration in time, has been established. The same model of drillability is also made for roller bits used earlier in the Uzen field. A comparative evaluation of both tools showed that the PDC bit exceeds the rolling cutter bit by 7 times in durability, and by 1.6-1.8 times in productivity. In general, the works performed can be divided into four groups: works devoted to assessing the properties of rocks and associated intervals with complications, matching the design features of the bit [9, 15], constructing models for rate of penetration and making decisions. In recent years, methods that take into account the uncertainty of the decision-making conditions when drilling wells, in particular, multicriteria, as well as the classification of geological objects, have been applied in solving these problems. In this connection, the theory of fuzzy sets has been used, which allows to make compromise decisions in conflict situations, to classify geological objects taking into account the fuzziness of boundaries, and to correctly assess the risks of emergency situations in drilling [2, 8, 9].

It should be noted that while being very useful in solving specific problems, existing methods and tools for studying the sections in the drilling process due to the lack of comprehensive studies and insufficient program and methodological support still make it difficult to control the drilling process, optimize and accurately estimate productive intervals, ecological situation, etc. This is also caused by the fact that when setting a goal, in addition to tasks solved at one or another stage, there are also unnoticed ones, that

should consider diversity, different kind of uncertainty of conditions for obtaining the information and decision-making.

Analysis of geological and technological information about drilling wells. The system of obtaining and using geological and technological information [14], including three main aspects (geological, technical and technological, ecological), also provides: data collection and processing (information retrieval); construction of models expressing the relationship between drilling performance and natural, technical and technological characteristics, forecasting of drilling parameters and the situation of drilling operations using that; evaluation and provision of optimal values of drilling performance indicators (information use).

When collecting and processing data, it is necessary to strive to obtain and use the most complete information, and this work is carried out throughout the decision-making process. As the transition from one stage to another, if necessary, the need for information can be clarified. The results of the work performed in the previous stages serve as initial information for the subsequent stages. Wherein, the nature of the initial information can be different (from previously drilled wells or information coming in during drilling). Depending on this, the approach to decision-making will be different. Therefore, the obtaining and proper use of complex geological and technological information for the purpose of prompt decision making while drilling wells and the problem of the performance of the bits, depending on its nature, is actual and requires appropriate attention. Very often, there are difficulties associated with the lack of information about the properties of rocks and its fuzzy nature. In the absence of the corresponding core material, it is often necessary to use information that is descriptive in nature, i.e. to evaluate the mechanical properties of rocks on the basis of their geological and petrographic description. Such methods exist. In particular, the well-known technique of VNIIBT [7] allows, using the noted information, to estimate the parameters of rock properties.

In recent years, the assessment of the properties of rocks and their impact on drilling performance, as well as the intervals of possible complications, are carried out with the help of geological and technological studies. As can be seen from the above review, over this period, and especially over the past 20 years, researchers have accumulated considerable experience and proposed various criteria [16], taking into account also the stressed state of the rocks composing the walls of the drilling well.

Based on the results of the assessment of the influence of these factors on the drilling performance, a corresponding model is constructed. This model, along with parameters that take into account the properties of rocks, also includes technological factors and parameters that take into account the type of bit. In the construction of the model, it should be noted that due to the complexity of the drilling conditions it is impossible to construct such a universal model that could successfully describe the process in different geological and technological conditions. The presence of a large number of factors, including factors that are of a random nature and thus not amenable to recording, clearly demonstrates the difficulty in constructing a model of rate of penetration. Taking into account that the models constructed up to the present time were constructed for different conditions, we previously carried out their comparative analysis, during which parameters for the same interval were determined by the random search method. When considering the methodology for selecting bits and regime parameters, it is necessary, as already noted, to take into account the nature of the initial information, which can be different. The choice of bits and parameters depends on the nature of this information. If preliminary information is available from previously drilled wells, complex information is generated based on the collection and processing of well drilling data, field observations, and information on rock properties, which is used to identify models. The model is constructed within each homogeneous interval. First, private dependencies are constructed, which subsequently include unaccounted factors. One of the known basic models, as, for example, in [11, 13, 19], is used as a basis. Next, the corresponding cost of 1m of penetration is calculated. The best mode parameters and types of bits are refined (selected) by variant calculations using the provisions of the theory of fuzzy sets. If such data on previously drilled wells are not available or if they are available in an insufficient amount, the calculations are carried out according to the data of geological and technological studies in the process of drilling as they are received. According to this algorithm, the decision-making process is implemented depending on the nature of the initial information. The characteristics of the geological section, estimated with the help of the above program, allow solving a number of tasks in the drilling process, in particular, the problem of selecting bits and regime parameters, assessing complications and making

decisions in complicated conditions. At the same time, the results of geological and technological studies are of great importance for quick determination of the characteristics of geological sections in the process of drilling wells [1, 4, 16-18]. Based on the data of geological and technological studies on several wells with the application of the corresponding program, physico-mechanical and baric characteristics of the sections of some deposits were obtained. In addition, according to geological and technological studies, stresses are calculated around the well. Figure 1 shows the change in the indices of physico-mechanical properties of the rocks of the Karabagly deposit. The figure shows the lithologic-stratigraphic characteristics of the section, the graphs of the change of petrophysical (porosity, permeability), strength (hardness, abrasiveness) and elastic (Young's modulus, Poisson's ratio) rock characteristics with the depth. As a result of the statistical analysis of geological and technological information on drilling wells at the Karabaghli (Azerbaijan), Aktum, Kokmai, Karamandybas, and South Koktau (Kazakhstan), we constructed models of rate of penetration [14]. The complex of geological-technological and geophysical studies performed in the wells under consideration allows to have a complete picture of the conditions, technology and indicators of the drilling process. To make decisions, first, it is necessary to create the initial array.

The approach to decision-making depends on the nature of the initial information (figure 1).

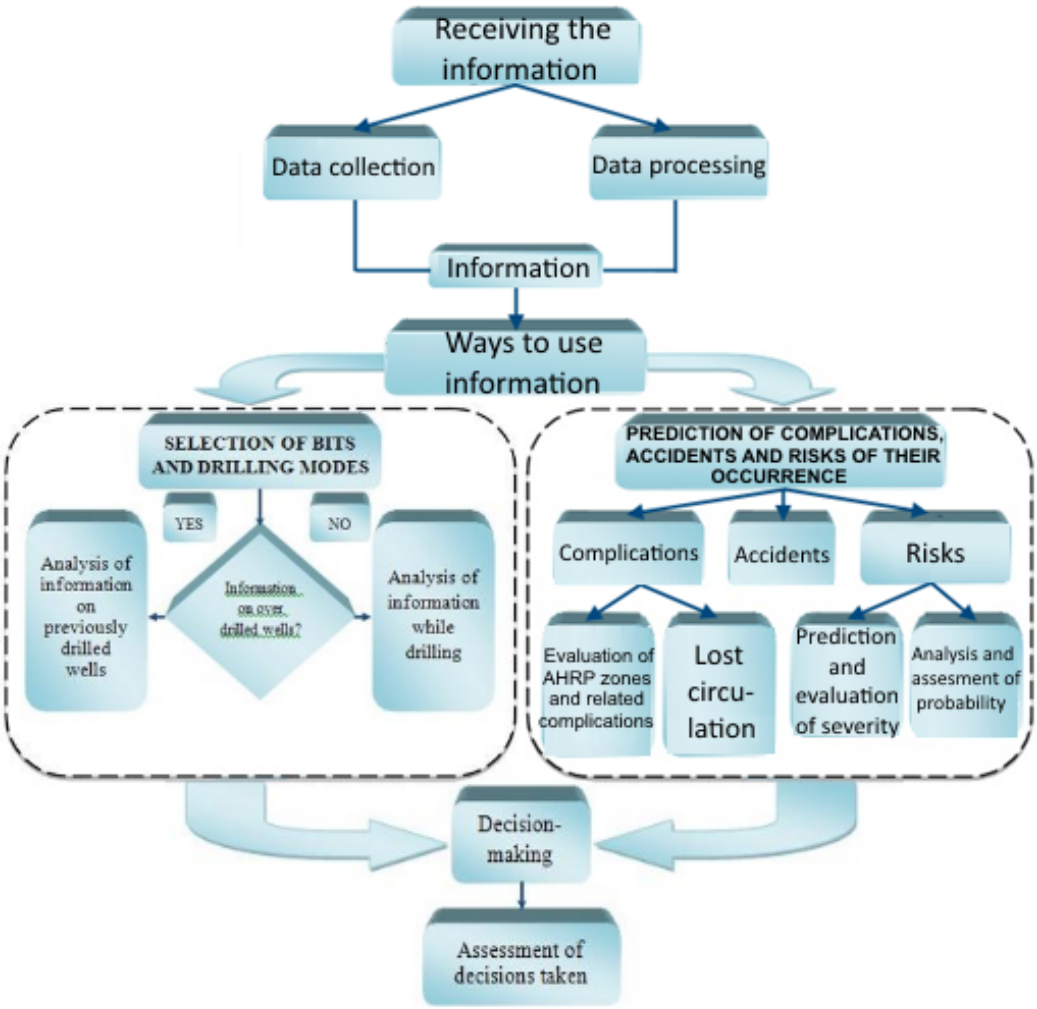

Figure 1 – Block diagram of obtaining and using information about drilling wells

In the process of analysis, equations for the corresponding bit types in the considered rock were obtained, expressing the dependence of the initial rate of penetration on the regime parameters and rock properties, the parameters of which were refined in the course of processing by the random search method [14].

The choice of bits and parameters is made by two criteria – the rate of penetration and the cost per meter of penetration. The solution of this problem is hindered by the presence of uncertainty. In general, t is often needed to build models in drilling [20], make decisions under conditions of uncertainty [10]. In the presence of models of rate of penetration, variant calculations are carried out in the same way as was done in [1, 4, 12]. For the purpose of carrying out variant calculations, the boundaries for changing the value of the regime parameters and their steps were set. For all these options, calculations of the run speed and the cost per meter of penetration were made. The best regime parameters according to predictions were determined using the above two criteria via the theory of fuzzy sets.

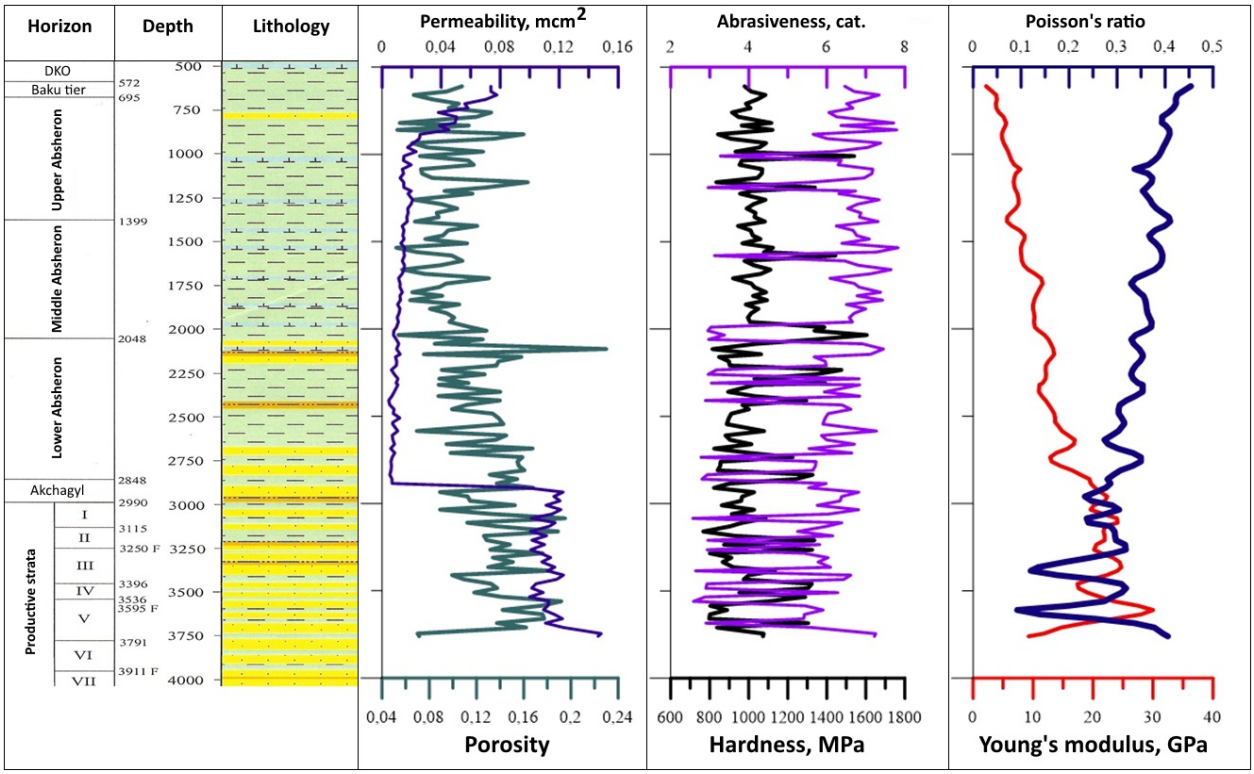

Figure 2 – Changes in the indices of physical and mechanical properties of the rocks of the Karabagli deposit

According to this, the set of solutions is the intersection of sets of goals (to achieve the highest run speed) and restrictions (with the lowest cost of 1 m penetration). For this purpose, the form of the membership function of the sets of goals and constraints was chosen. In this case, the membership function for the run speed increases with the increase in the run speed, which expresses the desire of the person making the decision to achieve high run speed, that is, the maximum value of the run speed of drilling corresponds to the value of the membership function close to one, and the minimum value of the run speed corresponds to the smallest value of the membership function, close to zero. The membership function of the cost per meter of penetration, on the contrary, decreases with the increase in the cost of the penetration meter, since in this case we are striving to achieve a low cost per meter of penetration. That is, in all cases, our aspiration is expressed by a result corresponding to the largest value of the membership function, close to one, and the lowest value of the membership function, close to zero, corresponds to the largest value of the penetration meter. The membership function of the solution set according to the noted theory was estimated as min (μ_v, μ_c). The greatest value of the membership function of the solution set in the totality of calculated data corresponds to the best solution. In the same sequence, the algorithm was implemented for another homogeneous group of rocks. As a result of calculations on models, the distribution surfaces of the values of the run speed and the cost of the penetration meter depending on the mode parameters are also constructed, [21]. As an example, figure 3 shows the surface of the change in the membership function. Via this figure, it is possible to track the change in drilling performance in three-dimensional space, as well as determine their optimal values.

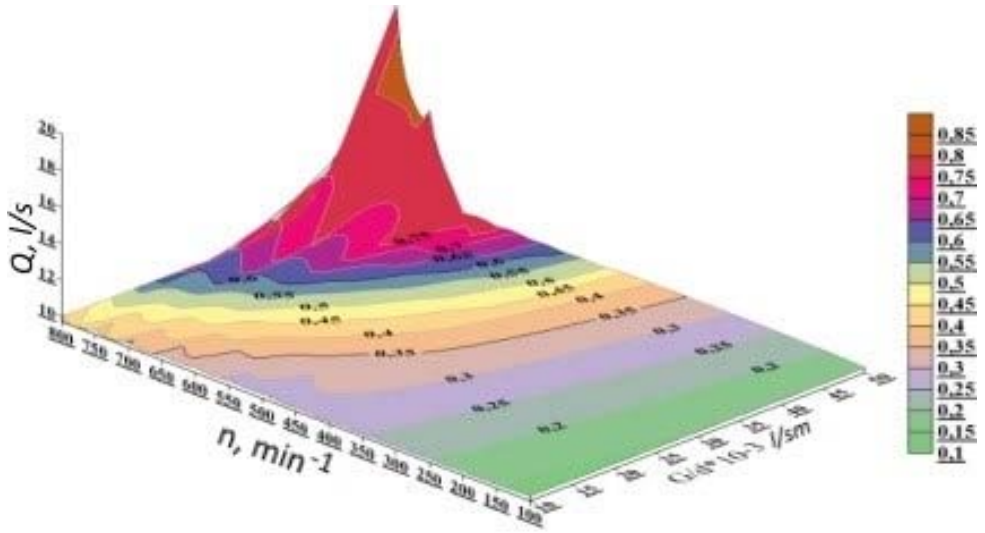

Figure 3 – The distribution surface of the membership function of the solution set depending on the regime parameters.

Conclusion. Over the past decades, a large number of studies and data on the interaction of the tool with the rock have been accumulated, methods and means for determining the physico-mechanical properties and abrasiveness of rocks have been proposed. The mechanism of destruction of rocks was studied, the influence of various factors on it, attempts of the mathematical description were made [1, 17, 19]. In this regard, mathematical models of the drilling process are proposed, the main elements of which are the rate of penetration, as well as the factors that influence its values; the possibility of using these models to study the main integral indicators of the drilling process efficiency is shown: the run speed, the cost of one meter of penetration and bit footage; an improved scheme of predictive calculations of drilling performance and decision-making in the selection of bits and regime parameters, taking into account the rock properties, depending on the nature of the initial information has been proposed; by analyzing and studying the drilling process, an algorithm has been proposed for predicting the parameters of drilling wells and making optimal decisions based on data of geological and technological research in the drilling process, the use of which makes it possible to find the optimum values of the regime parameters from the condition of ensuring the maximum of the run speed and the minimum cost of 1 meter of penetration. When making decisions it is very important to take into account the conditions under which the drilling process takes place, namely: the heterogeneity, fuzziness and random nature of the factors, for which the development of methods of control theory and decision-making with insufficient information in recent years can serve as a reliable basis.

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МОДЕЛДЕУ ҮДЕРІСІН ТАЛДАУ ЖӘНЕ ҰҢҒЫЛАРДЫ БҰРҒЫЛАУДА АЙҚЫН ЕМЕСТІКТІ ЕСЕПКЕ АЛА ОТЫРЫП ШЕШІМ ҚАБЫЛДАУ

Аннотация. Моделдеу мен ұңғыларды бұрғылауда шешім қабылдауға арналған соңғы жылдарда жинақталған зерттеулерге шолу орындалған. Шолу барысында назарды баса аудару қажет сұрақтар аясын анықтау мүмкін болды. Соның ішінде, оңтайландыру міндеттерін шешу үшін бірінші кезекте қажет мәліметтердің болуы атап көрсетілген. Бұл кезеңнен соң мәліметтерді өңдеу, бұрғылау моделін тұрғызу жасалады. Одан соң нұсқалық есептеулер жасалып, шешім қабылдау кезеңі келеді.

Бұрғылау үдерісін қолайландыру міндеттерін шешу шешім қабылдау жағдайларының айқындалмауы, көпфакторлық, көпталаптылық, дәлдіктің болмауы, біржақтылық болмауы себептерінен күрделенеді. Мәселені табысты түрде шешу үшін анықталған айқын еместіктіктерді есепке ала отырып сәйкес әдістерді қолдану қажет. Бұл әдістерде айқын еместікті есепке алу керек. Бұдан басқа, олар соңғы жылдарда белең алған геологиялық технологиялық зерттеулер нәтижесіне де негізделуі тиіс. Осыған байланысты, осы мақалада қашауларды және режимдік көрсеткіштерді таңдау әдістерін жетілдіру жолдары, сонымен қатар, геологиялық технологиялық зерттеулер нәтижесін интерпретациялау қарастырылады. Геологиялық технологиялық зерттеулерді өңдеу және талдау негізінде моделдер тұрғызылған. Айқын еместікті ескере отырып шешім қабылдау жолдары көрсетілген. Шешімдер дәл емес көпшелер теориясы ережелерін қолданып қабылданады.

Геологиялық технологиялық зерттеулер негізінде бірнеше ұңғылар бойынша есептеулер жүргізілді. Ол үшін тиісті бағдарлама қолданылды. Нәтижесінде қималардың физикалық механикалық және қысымдық сипаттамалары алынды. Есеп жұмыстары Әзірбайжан мен Қазақстанның бірнеше кенорындары мысалымен орындалған. Мақалада Қарабаглы кенорны қимасындағы тау жыныстарының физикалық механикалық қасиеттерінің өзгеруі көрсетілген. Қиманың литологиялық стратиграфиялық сипаттамасы келтірілген. Тау жыныстарының тереңдігіне қарай петрофизикалық(кеуектілік, өткізгіштік), беріктік (қаттылығы, абразивтілігі), серпімділік (Юнг модулі, Пуассон коэффициенті) қасиеттерінің өзгеру қисық сызықтары салынған. Талдау қортындысында ұңғыларды бұрғылау көрсеткіштерін болжау және бұрғылау үдерісінде геологиялық технологиялық зерттеулер мәліметтері бойынша ұтымды шешімдер қабылдау жолдары көрсетілген. Бұл 1 метр қашау жүрісі құнын төмендету және рейстік жылдамдықтың ең жоғары мәнін қамтамасыз ету шарттары арқылы режимдік көрсеткіштердің оңтайлы мәндерін табуға мүмкіндік береді.

Түйінді сөздер: механикалық жылдамдық, рейс жылдамдығы, ену көрсеткішінің құны, режим параметрлері, мүшелік функция, белгісіздік.

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АНАЛИЗ ПРОЦЕССОВ МОДЕЛИРОВАНИЯ И ПРИНЯТИЯ РЕШЕНИЙ ПРИ БУРЕНИИ СКВАЖИН С УЧЕТОМ НЕОПРЕДЕЛЕННОСТИ

Аннотация. Выполнен обзор исследований, посвященных моделированию и принятию решений в процессе бурения скважин, накопившихся за последние годы. Обзор позволил определить круг вопросов, на которых необходимо сосредоточить внимание. В частности, отмечается, что для решения задач оптимизации в первую очередь необходимы данные. За этим этапом следует обработка данных, построение модели бурения. Затем проводятся вариантные расчеты и наступает этап принятия решений.

Решение задач оптимизации процесса бурения усложняется неопределенностью ситуации принятия решений, выраженной многофакторностью, многокритериальностью, неточностью, неоднозначностью. Для успешного решения проблемы с учетом отмеченных неопределенностей необходимо применять соответствующие методы. Эти методы должны учитывать неопределенность. Кроме того, они должны основываться также на результатах, получивших в последние годы широкое распространение геолого-технологических исследований. Исходя из этого, в настоящей статье рассматриваются пути совершенствования методов выбора долот и режимных параметров, а также интерпретации результатов геолого-технологических исследований. Построены модели на основе обработки и анализа данных геолого-технологических исследований. Показаны пути принятия решений с учетом неопределенности. Решение принимается с применением положений теории нечетких множеств.

На основе данных геолого-технологических исследований по нескольким скважинам проводились расчеты. Для этого применялась соответствующая программа. В результате получены физико-механические и барические характеристики разрезов. Расчеты выполнены на примере некоторых месторождений Азербайджана и Казахстана. В статье показано изменение показателей физико-механических свойств пород разреза месторождения Карабаглы. Приведены литолого-стратиграфические характеристики разреза. Построены графики изменения с глубиной петрофизических (пористости, проницаемости), прочностных (твердости, абразивности) и упругих (модуль Юнга, коэффициент Пуассона) характеристик пород. В результате анализа показаны пути прогнозирования показателей бурения скважин и принятия оптимальных решений по данным геолого-технологических исследований в процессе бурения. Это позволяет найти оптимальные значения

режимных параметров из условия обеспечения максимума рейсовой скорости и минимума стоимости 1 метра проходки.

Ключевые слова: механическая скорость, рейсовая скорость, стоимость метра проходки, долото, режимные параметры, функция принадлежности, неопределенность.

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