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ANALYSIS OF THE PERFORMANCE OF THE REMOVABLE DIAMOND TOOLS OF NEW DESIGN

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ДОСЛІДЖЕННЯ РОБОТИ НОВИХ КОНСТРУКЦІЙ ЗНІМНИХ АЛМАЗНИХ ІНСТРУМЕНТІВ

Purpose. Modernization of the technical solutions to improve the removable diamond rock-breaking tools taking into account the various stages of wear out of diamond bits.

Methodology. The methods of mathematical modelling and comparative analysis were employed in the research, experimental study was carried out.

Findings. The bar rigged shell has been proposed that contains an outer pipe, a shoe with grooves, a retrievable core receiver with a core catcher adapter linked with the removable telescoping drill bit consisting of drill bit members, arranged according to the collet's sectors, there are cants on its internal surfaces. The lugs have been made on the outer cone of core catcher, and there are longitudinal grooves on an internal surface of cants sectors. When changing the position of the drill bit from transport to operational position, the lugs and grooves interact with each other, and in the working position of the drill bit lugs through grooves on collet sectors interact with the shoe grooves.

Originality. The analysis of the research showed the following:

- The greatest efforts for rotation of drill bit from the transport to operational position and back are in the angular range of 75–90°, i.e. in the final and the initial stages of the corresponding operations.

- The bearing springs influence greatly on the effort of the drill bit rotation. Because of their consecutive operation, the efforts step change depending on the turn angle of the drill bit.

Practical value. The values of the calculated efforts suggest a possible mechanism for the implementation of the structural removal and installation of a removable diamond drill bit with the diameter of 59 mm inside the drill. To expand the rational use of removable bits it is necessary to complete the SRK-76 with the pilot drill bits and sectors, which are similar to the type of the diamonds grains, matrix and geometry of the end to the diamond bit of serial-type SSK, and special attention should be paid to increasing the wear resistance of the pilot part of the sectors at greatest wear out.

The use of removable bits is the most expedient as the shells part with removable core receivers.

Keywords: *modular of elasticity, bottom, drilling, diamond bit, hole, tension, strain, finite-element method*

The summary. The questions of the creation removable rock cutting tools used at boring of the geology-prospecting wells are considered in the article. The authors offer a technological solution on retrofit and perfection of the removable rock cutting drill bit, taking into account various stages of diamond bits` wear out. The calculations of unit loads and the concentrated forces representing a shoe core barrel are resulted. And the efforts calculation of bits moving from the transport into the working position. The construction of the new bar-rigged bullet is considered.

Introduction. In recent years there has been increasing business activity in the industrial sphere of the Russian Federation and Kazakhstan that can`t help touching the geological exploration, where also there has been a growing trend to increase the volume of drilling. There are all grounds to consider that soon again the most advanced facilities and technologies of exploration drilling will be demanded, primarily, complexes of bullets with removable core barrel, one of the varieties are bar rigged sets with removable diamond bit of types SRK-76, KRK-59, SCK-59. The first two types are serial products pumped into production of the highest quality, and SCK-59 is the cobbled unit protected by a number of copyright certificates and the patent of the Russian Federation №2158344 from 10/27/2000 [1]. The removable drill bit in the future won`t be only a base for the second generation of complexes SSK used at boring of geology-prospecting wells, but it will be able to be widely applied for technical boring, in particular, at drilling out of cylindrical products from rock, such as press granite shafting for paper making machine, a string, pedestals for monuments and etc.

The method of the research. Taking into account that circumstance that for a number of years full production of column sets SRK-76 and KPK-59 has not been carried out, and research works on the development SCK-59 have not been held, it is necessary in the shortest terms before full production resumption to make every effort to improve and upgrade the product, despite the fact that many technical solutions, applied in this instrument to date are at a high level and do not have foreign analogues.

As a basis of retrofit and perfection of bar rigged set SRK-76 can serve the data on gathering and automatic processing of results of its acceptance testing, and also the data of the bench tests held by the firm "Terra-Tec" (Salt-Lake City, USA) in 1995 [2]. The source information on boring has been partitioned on two packages where the first represented the information assembled in unpowered mode (fixation of boring parameters set by the driller), and the second – the information assembled in an active mode under expressly developed programs.

The baseline alternative of bar rigged set SRK-76 is completed with a pilot drill bit and four stage sectors, armor diamonds of the XV group, granularity 50–30 pieces /carat, intended for boring of law seamy formations of VIII–IX categories according to drill ability.

In order to expand the rational application fields of removable drill bits it is necessary to complete SRK-76 with pilot drill bits and sectors, that are similar as a matrix, granularity of diamonds and end geometry to serial diamond bits of type SSK, and special attention should be given to increasing the wear resistance of the sectors` pilot part at greatest wear. Groove wear out begins to emerge from the interior of the sector, increasing as long as the pilot is not completely disappeared. Fig. 1 shows the pilot wear out stages of the sectors having the average tunneling in the geological resource that is within 12–15 meters.

Fig. 1. Various stages of sector wear out of a telescoping drill bit

Taking into account that in bar rigged set SRK-76 the removable drill bit is extracted together with a core receiver and its substitution does not introduce special complication, there is no necessity to reinforce sectors with high-quality diamonds. To enhance stability of sectors probably by manufacturing of their pilot part in the form of the impregnated matrix alike to a matrix of the drill bits K-08.

The quantity of sectors of telescoping drill bit also exercises influence over technical and economic indexes of the work SRK-76. It should be noticed that at the same modes, middle mechanical drilling rate of the removable drill bit with three sectors in 1,7 times above, than with six sectors that explains, first of all, higher unit pressure on a slope back at the expense of reduction of the floor space end of the drill bit. Without changing the basic diagram of the driven end, it is possible to construct a three-sector removable drill bit with larger and stronger sectors raising reliability of the product.

The occurrence of erosive tracks on some pilot drill bits (Fig. 2) is linked or to insufficient quantity of flush fluid, or with bad tuning up of the capping flap, which distinctive features of operation are in detail stated in the work [3].

More difficult works should be executed on adjusting pressure of mock-up samples of removable diamond bits for holes in diameter of 59 mm. The preference during the last years at creation of small-sized removable drill bits is given to all hollow drill bits, as to constructions more rigid and strong.

All hollow drill bit representing a truncated cone with cut off edges which on the transporter is drained off on the internal channel of drill-pipes below a string shoe is known, then turns on 90° and is fastened in a shoe. Besides constructive complication the alike alternative possesses technological difficulty of performance of manipulations on the drill bit rotation which are outside of an auger system, especially in case the shell concerns a lying hole wall. This difficulty can be avoided, turning drill bit directly in a string shoe.

Fig. 2. The kind of the pilot drill bit with erosive track on the matrix

The removable part, moving downwards, stops, having reached a core barrel shoe. Under the influence of force P on two contact surfaces of the drill bit and a shoe there are unit loads p and concentrated efforts N' and N'', representing reaction of shoe of a core barrel. In connection with offset of a hanger place of drill bit from a shell axis on magnitude a, unit loads will be distributed on a contact plane symmetrically shell axis according to some law. Designating through magnitude $2a$ angular co-ordinate of a contact line in a horizontal plain, we will notice that $p = f(a)$.

Then the elementary effort of reaction will be equal

$$dN = pdl = p \cdot rda, \quad (1)$$

where l – length of a contact line ; r – drill bit radius.

Efforts N' and N'', and also communal effort of reaction N we will record in the form

$$N` = N`` = \frac{N}{2\cos\beta}, \quad (2)$$

where β – lean angle of shoe contact surfaces.

In turn

$$dN' = dN\cos a;$$

$$N` = \int_{-\alpha}^{+\alpha} dN\cos\alpha = \int_{-\alpha}^{+\alpha} p\cdot 2\cos\alpha\, d\,\alpha.$$

Substituting the formula (2) in the formula (1), we will have

$$N = 2\cos\beta \int_{-\alpha}^{+\alpha} p\cdot 2\cos\alpha\, d\,\alpha.$$

The drill bit rotation will be precluded into position by friction forces *F '* and *F ''*in the applicable zones of contact.

By analogy to the formula (1) we will record

$$dF = f\cdot p\cdot rd\alpha,$$

where *f* – a friction coefficient in a contact zone.

As $F` = F`` = f\cdot r\int_{-a}^{+a} pd\alpha$, then total friction force will be equal

$$F = F`+F`` = f\cdot r.$$

The resulted coefficient of friction force *f* we will find from expression

$$f = \frac{F}{N} = \frac{f}{\cos\alpha} = \frac{\int_{-a}^{+a} d\,\alpha}{\int_{-a}^{+a}\cos\alpha\, d\,\alpha} = f\cdot\pi\cdot\frac{a}{180}\cdot\frac{1}{\sin\alpha\cdot\cos\beta}.$$

Presence of the bearing springs indispensable for supply of the guaranteed gap with a view of free turning of the drill bit in a shoe, will affect also on the effort of recalculation of the drill bit from transport position to the working one and back. This effort can be determined proceeding from a bending flexure of springs δ. Considering the work of springs as a bending flexure of a girder with the pinched end, we have

$$\delta = \frac{N_n l_n^3}{3EJ};$$

$$N_n = \frac{3\delta EJ}{l_n^3},$$

where N_n – the effort arising at a bending flexure of a spring on magnitude δ; l_n – Length of a spring; E – modulus of elasticity; J – inertia moment.

As well as in a case of affecting of a removable drill bit on a shoe, efforts from strain of springs will be distributed symmetrically in relation to the drill bit body, and in dots of contact to a spherical part of a shoe there will be identical efforts of reaction which will be equal

$$N_n^{'} = N_n^{''} = \frac{\text{N}}{2\cos\beta_n},$$

where β_n – angle between a direction of forces.

Friction forces *F '* and *F ''*, as well as in the previous case, we will determine proceeding from a condition: *F '= F''*

$$F` = F`` = f\frac{N_n^{''}}{2\cos\beta_n};$$

$$F_n = F_n^{'} + F_n^{''} = f\frac{N_n}{\cos\beta_n}.$$

The resulted friction coefficient will be determined as

$$f_n^{'} = \frac{F_n}{N_n} = \frac{f}{\cos b_n}.$$

The total active moment indispensable for rotation of the drill bit

$$M = P\cdot\alpha.$$

Reaction torque of resistance to the drill bit rotation will be determined as

$$M_R = Fk + F_n R,$$

where *k* – arm of friction force *F* (the maximum spacing interval from a pivot centre of drill bit to working point *F*); *R* – a force arm F_n (spacing interval from rotation centre of drill bit to a dot of spring contact with a shoe).

Taking over $M = M_R$, after some transforming we will find

$$P = \left[\frac{f\,\pi\alpha}{180}\cdot\frac{Q + \frac{G\delta EJ}{l_n^3\cos\beta_n}}{\sin\alpha\cdot\cos\beta} + \frac{Gf\,\delta\, EJR}{l_n^3}\right],$$

where *Q* – force of gravity of a removable diamond bit.

Fig. 3 shows the dependence of force *P* on the turn angle of the drill bit and arm force applying *Q*

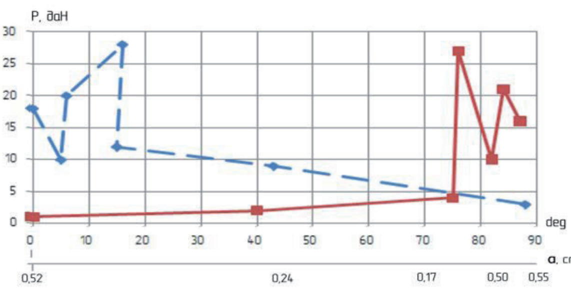

Fig. 3. Dependence of force P on turn angle of drill bit and arm force applying α: while turning drill bits in a transport position; into working position

The analysis of these efforts has demonstrated the following:

- the greatest efforts for rotation of drill bit from a transit condition in working one and conversely are in the angular range of 75–90º, and. e. in the final and the initial stages of the corresponding operations;

- bearing springs influence greatly on effort of drill bit rotation as a result of consecutive operation for each of them there is a jumplike change in the nature of these efforts, depending on the turn angle of the drill bit;

- the minimum effort is expended by the turn angle of the drill bit to the working position during its rotation under the action of gravity until the moment of contact with the shoe bearing springs.

The quantities of calculated efforts suggest a possible mechanism for the implementation of the structural removal and installation of a removable diamond drill bit, having diameter of 59 mm inside the drill.

Experimental researches. Under the investigations conducted in TulNIGP the bar rigged shell has been proposed that contains an outer pipe, a shoe with grooves, a retrievable core receiver with a core catcher adapter linked with the removable telescoping drill bit consisting of drill bit members, arranged according to the collet`s sectors, there are cants on its internal surfaces, lugs have been made on the outer cone of core catcher, and there are longitudinal grooves on an internal surface of cants sectors, and during moving process of the drill bit from the transport position into the working one the lugs and grooves interact with each other, and in the working position of the drill bit lugs through grooves on collet sectors interact with the shoe grooves.

Fig. 4 shows the offered bar rigged shell with a removable drill bit in the working position.

Fig. 5 shows bar rigged shell with a removable drill bit in the transport position;

Fig. 6. shows a type of the bar rigged set`s end without a removable drill bit.

The bar rigged shell contains a collet *1*, drill bit members *2*, an outer barrel with a shoe *3*, a retrievable core receiver *4*; a core catcher adapter *5* has: the outer cone *6* with lugs *7*. The collet *1* is connected with a core catcher adapter *5* by means of limiting devices *8* and the screws *9* placed in grooves of *10* collets *1*. The shoe *3* has grooves *11.* The collet 1 on the inner cone *12* has grooves *13.* In the transport position of the drill bit spacing interval *h* from an end *14* core catcher adapters *5* to a working end *15* drill bit members *2.* Grooves 11 in a shoe *3* are separated from each other by cuneiform drill bits *16.* The device works as follows.

The retrievable core receiver *4* with a collet *1* drill bit members *2* in a transport position is pulled down in a shoe *3.* Then drill bit members *2* rest against a slope back and move apart the outer cone *6*, turning thus a shell for combination of grooves *11* shoes *3* with sectors of a collet *1*. After complete recalculation, thus, drill bit members *2* from a transport position in the working one begin a drilling process. After run out of drill bit members *2* or fillings up of a core receiver by *4* core effect withdrawal of the retrievable core receiver *4* with a collet 1 and drill bit member *2* catcher.

Experimental samples of such bar rigged shell have been successfully tested in the drilling of deep wells in Norilsk GRE.

Open Joint Stock Company «Tula NIGP» has found [4–5] that boring by shells with retrievable core receivers of directional wells is possible with application of drill bits with a various profile of matrixes. Thus updating of traces of holes is effected by means of alternation of drill bits with the various form of their working end. Especially great value a way of the hole trace control by application of drill bits of the various geometry gets in connection with progressing of a boring method with the usage of the removable drill bit allowing essentially to enhance output of boring due to reduction of time for lowering and lifting operations. Using removable drill bits with the plane, rounded off or edge form of a diamond-bearing matrix it is possible to operate a hole trace and without lifting the drill string.

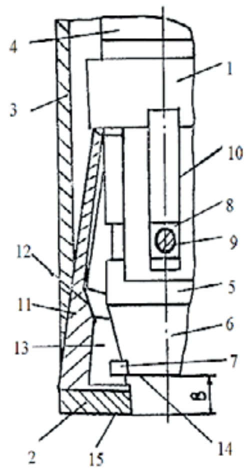

Fig. 4. Bar rigged shell in the working position

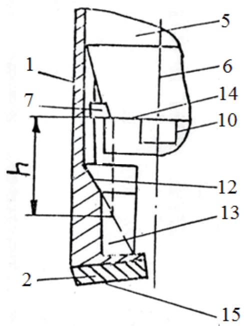

Fig. 5. Bar rigged shell in the transport position

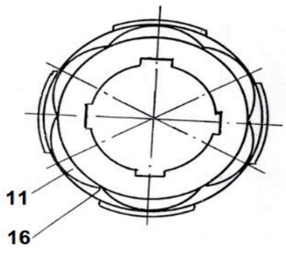

Fig. 6. A type of the bar rigged set`s end without a removable drill bit

Taking into account that application of removable drill bits most expediently as a part of shells with retrievable core receivers, we will conclude following the work [4] limit of application rationality of the removable drill bits for time spent on drilling (interval), using for these purposes coefficient of rationality of removable drill bits.

$$K_p = \frac{T_1}{T_2}, \tag{3}$$

where T_1, T_2 – overall time of drilling wells SSK (KSSK) and removable drill bit as a part of a shell with a retrievable core receiver, *h*.

The total overall time spent on drilling the same depth by retrievable core receivers (T_1) and a removable drill bit (T_2) according to operations (Isaeva M.I, Onishchina V.P) [5] will be the following

$$T_1 = K \cdot \frac{H}{V_1} + 2\frac{H}{S_1}\left(a\frac{H}{2}+b\right) + H\left(a\frac{H}{2}+b\right)\cdot\left(\frac{1}{P_K}-\frac{1}{S_1}\right); \tag{4}$$

$$T_2 = K\frac{H}{V_2} + 2\frac{H}{S_2}\left(a\frac{H}{2}+b\right) + H\left(a\frac{H}{2}+b\right)\cdot\left(\frac{1}{P_K}-\frac{1}{S_2}\right), \tag{5}$$

where K – the coefficient considering the additional time spent on work capacity and lashing tubes during lowering and lifting operations(=1,06) K; H – well depth, m; V_1, V_2 – mechanical drilling rate SSK (KSSK) and a removable drill bit accordingly, m/hour; S_1, S_2 – length of run at boring SSK (KSSK) and a removable drill bit accordingly, m; a and b – skilled coefficients (a =1,7·10-3 ч/м, b =0,35); P_K – a penetration for run by core receivers, m.

Taking into account the equations (4, 5) after transforming we will result expression (3) in a kind

$$K_p = \frac{\frac{K}{V_1}\left(a\frac{H}{2}+b\right)\cdot\left(\frac{1}{P_K}+\frac{1}{S_1}\right)}{\frac{K}{V_2}\left(a\frac{H}{2}+b\right)\cdot\left(\frac{1}{P_K}+\frac{1}{S_2}\right)}. \tag{6}$$

It is obvious that application of removable drill bits at boring SSK (KSSK) is rational in the case, when $K_p \geq 1$ if K_p<1 because expenditures for manufacturing of removable drill bit and its operation above, are higher than on manufacturing of traditional diamond drill bit, and are not countervailed by reduction of the discharge rate of the electric power and reduction of run out boring, pipe handling tool and tackle system, an application of a removable drill bit is not rational.

The analysis of the formula (6) demonstrates that on a range of application of removable drill bits essential influencing renders stability of injection drill bits at boring SSK (KSSK), boring by a removable drill bit, is more effectively, than less stability of the drill bit is (S_1).

At boring in standard conditions (without emergencies and complications) it is possible to take over that the length of run of a removable drill bit (S_2) is equal to well depth *(H)*. Apparently from the formula (6), at equal drilling rates V_1 and V_2, than more depth of passable hole, application of a removable drill bit is especially effective.

Thus, the national experience of creating of removable drill bits leads to the conclusion about the need to intensify research, experimental design and technological works in order to create innovative constructions of removable drill bits, the use of which is qualitatively new, higher level of exploration drilling, can significantly reduce the duration of the lowering and lifting operations and, accordingly, increase the efficiency and safety of drilling operations.

1. The application of removable drill bits is the most expediently as a part of shells with retrievable core receivers, we will conclude following the work limit of application rationality of the removable drill bits for time spent on drilling (interval), using for these purposes coefficient of rationality of removable drill bits that application of removable drill bits at boring SSK (KSSK) is rational in a case, when $K_p \geq 1$;

2. On the range of application of removable drill bits essential influencing renders stability of injection drill bits at boring SSK (KSSK), boring by a removable drill bit, is more effectively, than less stability of the drill bit is (S_1).

3. At boring in standard conditions (without emergencies and complications) it is possible to take over that the length of run of the removable drill bit (S_2) is equal to well depth (at equal drilling rates V_1 and V_2, than more depth of a passable hole, application of the removable drill bit is especially effective.

4. It is necessary to intensify research and development, experimentally-design and technological operations for the purpose of creating progressive constructions of removable drill bits.

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Мета. Технічні рішення з модернізації знімного алмазного породоруйнуючого інструменту з урахуванням різних стадії зносу алмазних коронок.

Методика. Застосовані методи математичного моделювання, порівняльного аналізу, виконані експериментальні дослідження.

Результати. Запропоновано колонковий снаряд, що містить зовнішню трубу, черевик з пазами, знімний керноприймач з корпусом кернорвателя, до якого приєднана знімна роздвижна коронка. Вона складається з породоруйнуючих елементів, розміщених за секторами цанги, на внутрішніх поверхнях яких є скоси. На зовнішньому конусі кернорвателя виконані виступи, а на внутрішній поверхні скосів секторів виконані поздовжні пази. У процесі переводу коронки з транспортного положення в робоче виступи й пази взаємодіють між собою, а в робочому положенні коронки виступи через пази на секторах цанги взаємодіють з пазами черевика.

Наукова новизна. У результаті досліджень встановлено, що:

- найбільші зусилля для повороту коронки з транспортного положення в робоче й назад виникають в інтервалах кутів 75−90º, а саме в заключній і початковій стадіях відповідних операцій;

- опорні пружини мають істотний вплив на зусилля повороту коронки, а в результаті послідовної роботи кожної з них спостерігається стрибкоподібний характер зміни цих зусиль у залежності від величини кута повороту коронки.

Практична значимість. Величини розрахункових зусиль свідчать про можливу конструктивну реалізацію механізму зняття й установки знімної алмазної коронки діаметром 59 мм усередині бурового снаряда. З метою розширення областей раціонального застосування знімних коронок необхідно комплектувати СРК-76 пілотними коронками й секторами, аналогічними за типом матриці, зернистості алмазів і геометрії торця серійним алмазним коронкам типу ССК, причому особливу увагу слід приділяти підвищенню зносостійкості пілотної частини секторів, схильної до найбільшого зносу.

Ключові слова: *знімний кернoприйомник, алмазна коронка, колонковий набір, забій, метод кінцевих елементів, модуль пружності, деформація*

Цель. Технические решения по модернизации съемного алмазного породоразрушающего инструмента с учетом различных стадий износа алмазных коронок.

Методика. Применены методы математического моделирования, сравнительного анализа, выполнены экспериментальные исследования.

Результаты. Предложен колонковый снаряд, содержащий наружную трубу, башмак с пазами, съемный керноприемник с корпусом кернорвателя, к которому присоединена съемная раздвижная коронка. Она состоит из породоразрушающих элементов, размещенных по секторам цанги, на внутренних поверхностях которых имеются скосы. На наружном конусе кернорвателя выполнены выступы, а на внутренней поверхности скосов секторов выполнены продольные пазы. В процессе перевода коронки из транспортного положения в рабочее выступы и пазы взаимодействуют между собой, а в рабочем положении коронки выступы через пазы на секторах цанги взаимодействуют с пазами башмака.

Научная новизна. В результате исследований установлено, что:

- наибольшие усилия для поворота коронки из транспортного положения в рабочее и обратно возникают в интервалах углов 75−90º, т. е. в заключительной и начальной стадиях соответствующих операций;

- опорные пружины оказывают существенное влияние на усилие поворота коронки, а в результате последовательной работы каждой из них наблюдается скачкообразный характер изменения этих усилий в зависимости от величины угла поворота коронки.

Практическая значимость. Величины расчетных усилий свидетельствуют о возможной конструктивной реализации механизма снятия и установки съемной алмазной коронки диаметром 59 мм внутри бурового снаряда. В целях расширения областей рационального применения съемных коронок необходимо комплектовать СРК-76 пилотными коронками и секторами, аналогичными по типу матрицы, зернистости алмазов и геометрии торца серийным алмазным коронкам типа ССК, причем особое внимание следует уделять повышению износостойкости пилотной части секторов, подверженной наибольшему износу.

Ключевые слова: *съемный керноприемник, алмазная коронка, колонковый набор, забой, метод конечных элементов, модуль упругости, деформация*

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