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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

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ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК
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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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INNOVATIVE DRILL BIT TO IMPROVE THE EFFICIENCY OF DRILLING OPERATIONS AT URANIUM DEPOSITS IN KAZAKHSTAN

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Abstract. The Republic of Kazakhstan is the world leader in proven uranium reserves. Most of the deposits are concentrated in the Shu-Sarysu uranium-ore geological province and are developed by underground borehole leaching. Therefore, drilling operations account for 60–70 % of the total cost of field development. A typical geological section from wells is represented by an upper unit of soft, soft rocks lying to a depth of 300–500 m and a lower unit of medium and hard rocks to a depth of 350–800 m. These units are separated by a layer of dense clays. Currently, the first geological unit of soft rocks is drilled with spud bits with carbide cutters, and the second with blade bits equipped with PDC cutters. The main disadvantage of this technology is the unproductive loss of time on tripping operations necessary to lift a spud bit with carbide cutters and replace it with a bladed PDC bit to continue drilling the well to the designed depth. The research was based on the idea of combining in one bit design the advantages of carbide and PDC bits, which have proven themselves well in the geological conditions under study. To solve the problems, a comprehensive research method was used. It included a review and synthesis of literature sources, patent research, analysis of geological conditions, as well as the scope, advantages and limitations of existing designs of cutting drill bits. As a result of the work, a technical solution was proposed and patented that allows the most effective use of two types of cutters in a single design of a rock-cutting tool: cheap carbide cutters used in the upper part of the rock section, and more expensive PDC cutters with high productivity in the lower part of the rock section, represented by harder ones. The fullest use of cutter use is achieved when the edges of the carbide cutters rise below the edges of the PDC cutter blades, i.e. when the former are closer to the bottom of the well when drilling the upper interval of soft rocks, and the bit has a split ring pilot equipped with mixed cutters in its end part. Rock-cutting PDC cutters should be made from the new super-hard composite material $25C_{diamond}$-70.5WC-4.5Co with the addition of 10% zirconium dioxide micropowder (ZrO_2). The developed innovative combined bit will be effective in the practice of drilling geotechnological wells in the conditions of the Shu-Sarysu uranium-ore geological province.

Keywords: well drilling, blade bit, combined bit, PDC cutter, in-situ leaching

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ҚАЗАҚСТАННЫҢ УРАН КЕН ОРЫНДАРЫНДА БҰРҒЫЛАУ ЖҰМЫСТАРЫНЫҢ ТИІМДІЛІГІН АРТТЫРУҒА АРНАЛҒАН ИННОВАЦИЯЛЫҚ ҚАШАУ

Аннотация. Қазақстан Республикасы уранның дәлелденген қоры бойынша әлемде көшбасшы болып табылады. Кен орындарының басым бөлігі Шу-Сарысу уран-кенді геологиялық провинциясында шоғырланған және жерасты ұңғымаларын шаймалау арқылы игерілген. Сондықтан бұрғылау жұмыстары кен орнын игерудің жалпы құнының 60–70 % құрайды. Ұңғымадан алынған типтік геологиялық қима 300–500 м тереңдікте жатқан тасты, жартылай тасты таужыныстарының жоғарғы бірлігімен және 350–800 м тереңдіктегі орташа және қатты таужыныстардың төменгі бірлігімен ұсынылған тығыз саздар қабаты. Қазіргі уақытта жұмсақ таужыныстардың бірінші геологиялық қондырғысы карбидті ұштары бар пикобұрғылармен, ал екіншісі PDC кескіштермен жабдықталған қалақ қашауларымен бұрғыланады. Бұл технологияның негізгі кемшілігі - ұңғыманы жобаланған тереңдікке дейін бұрғылауды жалғастыру үшін карбидті кескіштері бар пикобұрғыны жоғарыға көтеру және оны қалақшалы PDC қашаумен ауыстыру үшін қажет операцияларындағы уақыттың өнімсіз жоғалуы. Зерттеу қаттықорытпалы мен PDC қашаулардың артықшылықтарын бір құрылымда біріктіру идеясына негізделген, ол зерттелетін геологиялық жағдайларда жақсы жұмыс істеді. Қойылған міндеттерді шешу үшін зерттеудің кешенді әдісі қолданылды. Оған әдеби дереккөздерге шолу және жалпылау, патенттік зерттеулер жүргізу, геологиялық жағдайларды талдау және қолданыстағы бұрғылау қондырғыларының конструкцияларының қолданылуы, артықшылықтары мен шектеулері кірді. Жұмысты орындау нәтижесінде таужыныстарын бұзатын құралдың бірыңғай дизайнында кескіштердің екі түрін тиімді пайдалануға мүмкіндік беретін техникалық шешім ұсынылды және патенттелді: кесудің жоғарғы жағында қолданылатын арзан карбидті кескіштер және қатты таужыныстармен ұсынылған кесудің төменгі бөлігінде жоғары өнімділікке ие қымбат PDC кескіштері. Аталған құралдардың ресурсын ең толық пайдалану карбидті кескіштердің жиектері PDC кескішті жиектерінің астында көтерілгенде, яғни біріншісі жұмсақ таужыныстардың жоғарғы аралығын бұрғылау кезінде ұңғыманың кенжарына жақын болғанда және құралда оның соңғы бөлігінде аралас кескіштермен жабдықталған ажыратылатын сақина ұшқышы болған кезде пайда болады. Таужыныстарын бұзатын PDC кескіштерін жаңа 25 қатты композициялық материалдан жасау керек алмаз-70,5 4,5 Co, 10 % цирконий микроұнтағы (ZrO_2) қосылған. Әзірленген инновациялық аралас қашау Шу-Сарысу уран-кен геологиялық провинциясы жағдайында геотехнологиялық ұғымаларды бұрғылау тәжірибесінде тиімді болады.

Түйін сөздер: ұңғымаларды бұрғылау, қалақша қашау, аралас қашау, PDC кескіш, жерасты ұңғымаларын шаймалау

Алғыс: зерттеуді Қазақстан Республикасы Ғылым және жоғары білім министрлігінің Ғылым комитеті (грант №AP14869271) қаржыландырады.

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ИННОВАЦИОННОЕ ДОЛОТО ДЛЯ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ БУРОВЫХ РАБОТ НА УРАНОВЫХ МЕСТОРОЖДЕНИЯХ КАЗАХСТАНА

Аннотация**.** Республика Казахстан является мировым лидером по разведанным запасам урана. Большинство месторождений сосредоточено в Шу-Сарысуской ураново-рудной геологической провинции и разрабатываются методом подземного скважинного выщелачивания. Поэтому буровые работы составляют 60–70 % от общей стоимости разработки месторождений. Типичный геологический разрез по скважинам представлен верхней пачкой мягких пород, залегающей до глубины 300–500 м и нижней пачкой средних и твердых пород – до глубины 350–800 м. Эти пачки разделены слоем плотных глин. В настоящее время первая геологическая пачка мягких пород бурится пикобурами с твердосплавным вооружением, а вторая – лопастными долотами, оснащенными резцами PDC. Основной недостаток такой технологии – непроизводительные потери времени на спускоподъемные операции, необходимые для подъема пикобура с твердосплавными резцами и замену его на лопастное PDC долото для продолжения бурения скважины до запроектированной глубины. Исследования базировались на идее соединения в одной конструкции долота достоинств твердосплавных и PDC-долот, которые хорошо себя зарекомендовали в исследуемых геологических условиях. Для решения поставленных задач был использован комплексный метод исследований. Он включал обзор и обобщение литературных источников, проведение патентных исследований, анализ геологических условий, а также области применения, преимуществ и ограничений существующих конструкций режущих буровых долот. В результате выполнения работы предложено и запатентовано техническое решение, позволяющее наиболее эффективно использовать в единой конструкции породоразрушающего инструмента два типа резцов: дешевые твердосплавные резцы, применяемые в верхней части разреза, и более дорогие резцы PDC, обладающие высокой производительностью в нижней части разреза, представленного более твердыми породами. Наиболее полное использование ресурса вооружения наступает, когда кромки твердосплавных резцов возвышаются под кромками лезвий резцов PDC, т.е. когда первые находятся ближе к забою скважины при бурении верхнего интервала мягких пород, а инструмент имеет разъемный кольцевой пилот, оснащенный смешанными резцами в его торцевой части. Породоразрушающие PDC резцы следует выполнять из нового сверхтвердого композиционного материала $25C_{алмаз}$-70,5WC-4,5Co с добавкой 10 % микропорошка диоксида циркония (ZrO_2). Разработанное инновационное комбинированное долото будет эффективно в практике бурения геотехнологических скважин в условиях Шу-Сарысуской уранaво-рудной геологической провинции.

Ключевые слова: бурение скважин, лопастное долото, комбинированное долото, резец PDC, подземное скважинное выщелачивание

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Introduction

The Shu-Sarysu uranium-ore geological province, located in Southern Kazakhstan, was discovered in the late 1960s and is recognized as the largest uranium ore reserve in the world.

This province includes two metallogenic zones: Kentse-Budennovskaya, where uranium mineralization is found in Upper Cretaceous deposits, and Uvanas-Kanzhuganskaya, with mineralization in Paleogene deposits. The total uranium resources in these zones are estimated at 1 million tons (Xayitov, 2022: 7).

Currently, 14 out of 56 explored deposits with balance uranium reserves are being developed in Kazakhstan, with the remaining 42 on reserve. Due to this province's discovery, Kazakhstan now holds 67 % of the world's proven uranium reserves, making it the global leader in this sector (Xayitov, 2022: 7). Most uranium deposits, such as Budenovskoye, Kanzhugan, Inkai, Zhalpak, and Uvanov, are developed through underground borehole leaching.

This method necessitates extensive drilling of technological, exploration, and auxiliary wells, making drilling operations a major expenditure, accounting for about 60-70% of the total development cost of uranium deposits (Khaitov, 2022: 12). The productive formations in most deposits of the Shu-Sarysu province typically range from 500 m to 650–800 m in depth. The geological sections of the wells generally feature an upper unit of soft, easily drillable rocks (sands, clay fractions) extending to depths of 300–500 m, and a lower unit of more difficult-to-drill rocks (dense clays, gypsum, anhydrites, sandstones, siltstones) reaching depths of 350–800 m, separated by a layer of dense clays (Nazirova, 2019). Drilling the upper rock unit, averaging 540 m thick, takes about 70–80 hours, whereas drilling the lower unit (540–680 m) with bits equipped with polycrystalline diamond cutters (PDC) takes approximately 40–50 hours (Togasheva, 2023).

Currently, due to economic considerations, a mixed drilling technology is employed at the sites:

– The first geological unit (0 to 300–500 m) of soft rocks is drilled using spud bits with carbide drills.

– The second geological unit, ranging from 350–500 m to 700–800 m (to the design depth) of medium and hard rocks, is drilled with blade bits equipped with PDC cutters (Khaitov, 2022: 12).

This mixed technology maximizes the capabilities of spud bits with carbide cutters for efficiently drilling soft rocks, while significantly enhancing productivity and bit life in harder rocks with the use of blade PDC bits, despite their higher cost. However, the primary drawback of this method is the unproductive time lost during tripping operations needed to switch from a spud bit with carbide cutters to a blade PDC bit to continue drilling to the designed depth.

The purpose of this work is to develop a bit design capable of efficiently drilling through the entire geological section characteristic of the Shu-Sarysu uranium-ore geological province in Kazakhstan.

To achieve this purpose, the following tasks were undertaken:

– Conducting a detailed study of the geological features of the Shu-Sarysu uranium-ore geological province, including rock types, mineral composition, and strata structure.

– Identifying specific problems associated with drilling in this region.

– Reviewing existing literature on drill bit technologies and their effectiveness in similar geological conditions.

– Performing patent research to examine innovations and patented technologies in drill bit design.

– Identifying and selecting materials for bit reinforcement that would be effective in the specific conditions of the Shu-Sarysu uranium-ore geological province.

Materials and basic methods

The research was based on the idea of combining in one bit design the advantages of carbide and PDC bits, which have proven themselves well in the geological conditions under study.

To solve the problems, a comprehensive research method was used. It included a review and synthesis of literature sources, patent research and analysis of the scope, advantages and limitations of existing designs of cutting drill bits.

The creation of a combined drill bit for drilling technological wells in Kazakhstan began with an in-depth design stage. This phase included a thorough analysis of the geological characteristics of the drilling sites, including rock types, formations and specific drilling problems. Based on these ideas, a conceptual design was developed that combines PDC and carbide cutters into a single bit design.

Once the conceptual design was completed, the manufacturing process began. High quality materials were used, selected for their suitability to different geological conditions. The manufacturing process included precision machining and assembly techniques to ensure smooth integration of the PDC and carbide cutters onto the bit blade. The location and orientation of the cutters have been carefully optimized to improve cutting efficiency and overall drilling performance.

A series of laboratory tests will be conducted to evaluate the newly developed combination drill bit. These tests will replicate drilling conditions typical of geological formations in Kazakhstan. Test reports will measure rate of penetration, cutting efficiency and wear resistance of PDC and carbide cutters under various drilling parameters.

Results

For initial attempts at drilling technological wells with a single rock-cutting tool in the Shu-Sarysu uranium-ore geological province, two-, three-, or four-bladed hydraulic monitor spud bits designed by JSC Volkovgeology were used, with the four-blade bit being the most common (Abdoldina, 2020: 5). These bits feature stepped blades and a central pyramidal section equipped with carbide cutters. The bit body includes channels between the blades, each 140 mm in diameter, to supply drilling fluid to the bottom.

Long-term use of this spud bit demonstrated high productivity when drilling the upper geological section. However, upon encountering dense clays, there is a sharp decline in the rate of penetration (ROP), significant cutter wear, and the necessity to lift the spud bit to the surface for replacement (Abdoldina, 2021: 9).

Efforts have been made to reduce wear on the central pyramidal part of the bit. In 2017, tests of a spud bit (three samples) produced by the Republic of Uzbekistan were conducted at the Budenovskoye and Khorosan fields (Piriverdiyev, 2019: 9).

The spud bit features three blades reinforced with carbide cutters. Unlike the peak-shaped spud bit from JSC Volkovgeology, this bit ends with a flat top part equipped with three cylindrical teeth cutters. The bit has a popular diameter of 161 mm, with three channels each measuring 9 mm in diameter.

Testing of the spud bit was primarily conducted on the upper member of soft rocks (0–370 m), consisting of sands, clays, sandy sediment layers, pebbles, and loams, categorized under drillability I-IV. The penetration per bit ranged from 330–350 m. However, when drilling the 370–450 m interval (clay deposits), penetration sharply decreased to 80–100 m, and the rate of penetration (ROP) dropped by 30 % compared to the JSC Volkovgeology spud bit, becoming ineffective in dense clays (Biletsky, 2019: 7).

Tests highlighted the following disadvantages of the spud bit from Uzbekistan:

– The ROP through clay deposits was on average 30 % lower than with the JSC Volkovgeology spud bit.

– The 9 mm diameter channels were insufficient, leading to clogging with rock and clay during drilling.

– Increased weight on the spud bit resulted in drill string vibration, jamming, and intense wear of the calibrating cutters (Borash, 2023: 7).

Kazakh National Research Technical University named after K.I. Satbayev has conducted extensive research and development to enhance the efficiency of drilling operations for technological wells. These studies focused on the forces affecting the cutters placed on the spud bit blades at varying distances from the axis of rotation (Biletsky, 2019: 7). The research revealed that near-axial regions of rotation experience zero speeds, causing the weight on the bit (WOB) to increase sharply (8–10 times or more). This leads to a halt in the bit's rotation and slow rock destruction, complicating the drilling process, accelerating wear on the bit's central part, and reducing overall productivity even in the upper section interval.

To address these issues and improve drilling efficiency under such conditions, a technical solution was proposed. This solution was implemented in a simple design of a patented spud bit in the Republic of Kazakhstan (Biletsky, 2019: 7). The design features stepped blades with cutters uniformly welded to a tubular body that has external threads for connection to the drill string. Additionally, to increase structural rigidity, the lowest cantilevered steps are welded to a ring equipped with carbide cutters.

The operating principle of this spud bit involves creating an annular cut with cutters soldered to the steps. The resulting core is either washed away by the central flow of drilling fluid passing through the annular body or destroyed by the cutters of the stiffening ring and bit vibration when encountering harder rocks. This design significantly reduces the weight on the blades, prevents spud bit sticking, and increases wear resistance. Production tests of the PK-2 spud bit at the Budenovskoye field demonstrated its superior efficiency compared to previously used blade bits with carbide cutters (Ratov, 2020: 6). In the upper section, the rate of penetration (ROP) ranged from 18–20 m/hour to 10–12 m/hour, gradually decreasing to 3 m/hour and even zero when drilling dense clays. The decrease was due to the bending of the lower stages of the blades forming an annular cut as the weight on bit (WOB) was increased. Overall, the PK-2 spud bit covered an interval of 0–436 m, setting a record for carbide blade bits used.

Analysis of the spud bits' industrial use indicated their ineffectiveness in drilling the harder rocks of the lower section, with productivity dropping to an average of 2–3 m/h and wear resistance declining to 50-80 m of penetration (Ratov, 2020: 6).

The introduction of blade bits equipped with PDC cutters presents a significant opportunity to increase drilling productivity in the harder rocks of the lower geological section, potentially replacing previously used carbide-tipped bits. Despite the higher cost of PDC bits, their use is justified by a considerable reduction in the construction time of geotechnological wells.

As a result of synthesizing scientific, technical, and patent literature, and critically analyzing the use of various rock-cutting tools in the Shu-Sarysu uranium-ore geological province, the following requirements for drill bits for in-situ leaching wells were established:

– Combine the advantages of carbide cutters (low cost) and PDC cutters (high destructive ability and wear resistance), with each type being effectively used depending on the rock properties.

– Ensure calibrating elements can maintain the well diameter to the designed depth (700–800 m).

– Maintain the optimal ratio of technological parameters (ROP, WOB, rpm).

A technical solution meeting these requirements for drilling technological wells in the Shu-Sarysu uranium-ore geological province was developed and patented in the Republic of Kazakhstan (Ratov, 2023: 15). Figure 1 illustrates a general view of the proposed combined bit.

The annular housing 1 features an upper thread 2 for connection to the drill string and a lower thread 3 for connection to the annular blade pilot 4. Stepped blades 5 are welded to the side surface of housing 1, with the steps alternately armed with carbide cutters 6 and PDC cutters 7. Blades 8 are also welded to the side surface of pilot 4, continuing the blades 5 of the housing and decreasing in transverse size with each step.

The pilot body includes inclined channels 9 for the passage of drilling fluid and has four carbide cutters and an equal number of PDC cutters at its end. In the upper interval of the geological section, which consists of soft rocks, drilling is performed with carbide cutters. Consequently, their edges should be positioned closer to the bottom of the well at a distance h relative to the edges of the PDC cutters (Fig. 2).

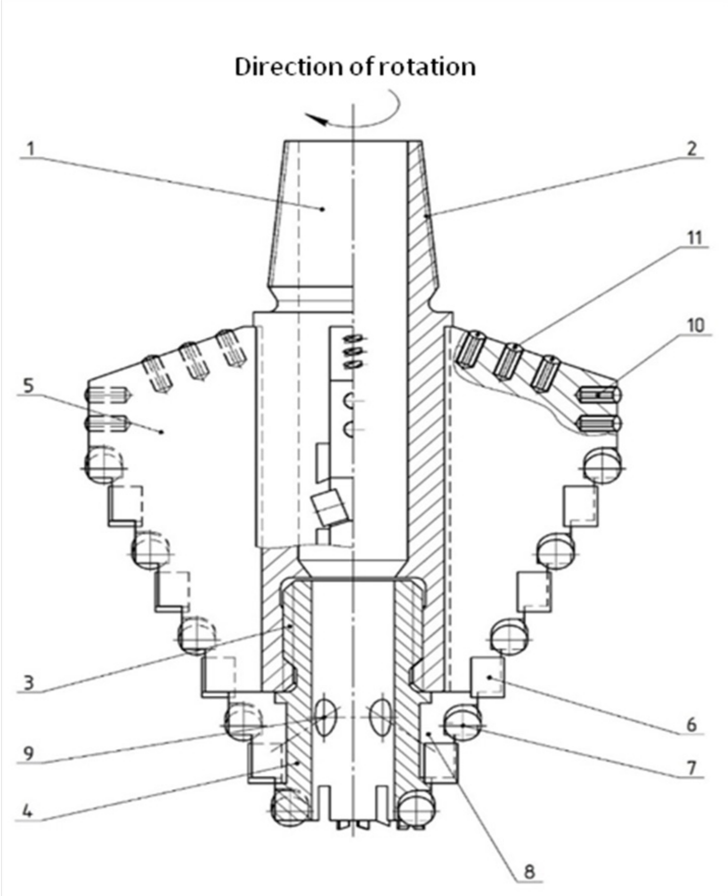

Fig. 1. Combined spud bit (according to RK patent No. 35606)

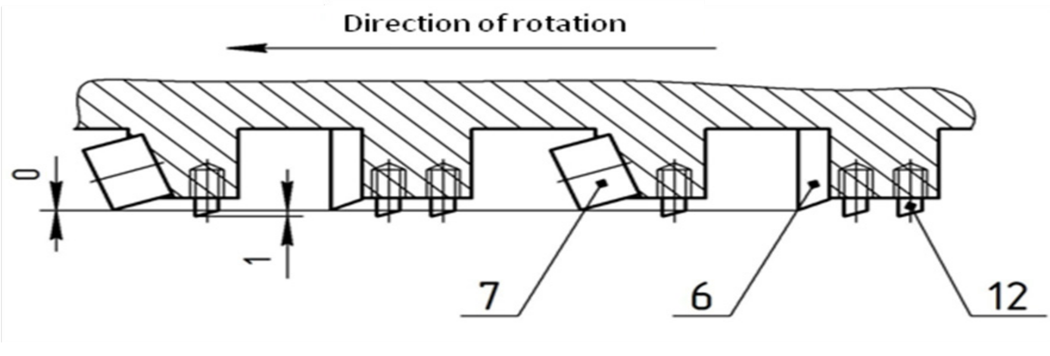

Fig. 2. Development along the middle circle of the end of the annular pilot

7 – PDC cutter; 6 – main carbide cutter; 12 – auxiliary carbide cutters

To address complications during drilling, such as rock falls onto the bit, the rear part of the blades is equipped with emergency carbide bits 11. Additionally, carbide cutters 12 are used to enhance the formation of the annular bottom.

A key aspect of the combined spud bit drilling technology is that at the start of the soft rock drilling interval (Fig. 3, A), the transverse size of the carbide cutter's blunting area is equal to bi (initial, factory blunting). As drilling progresses, even in soft rocks (Fig. 3, B), the cutter blunting size increases due to abrasive wear, reaching bf when encountering harder rocks (Fig. 3, B).

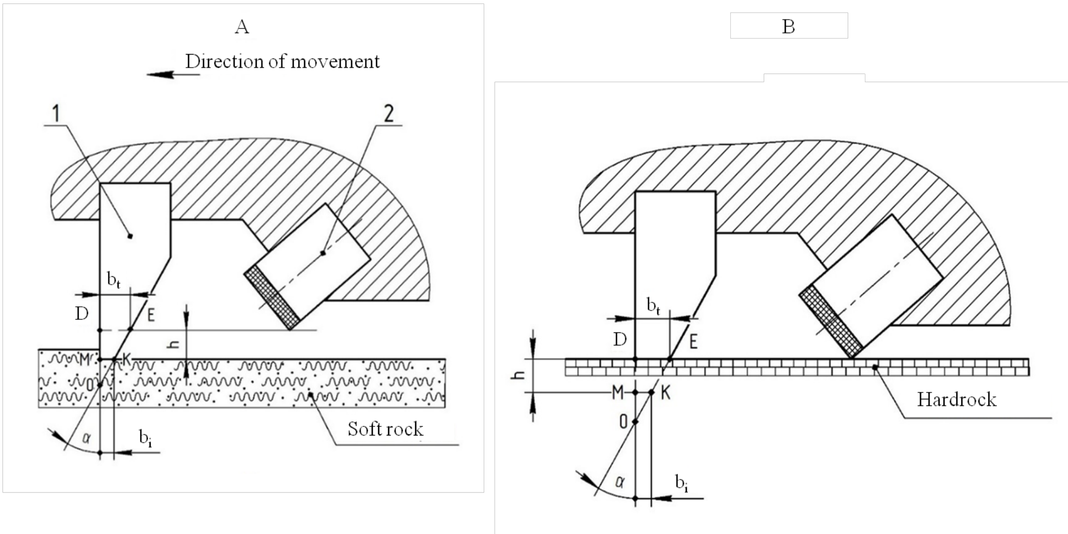

Fig. 3. Determination of the amount of wear of a carbide cutter
1 – carbide cutter; 2 – PDC cutter; b_i – initial blunting of the incisor; b_f – final blunting of the cutter when encountering a formation with increased drilling difficulty

From triangles ODE and OMK (Fig. 4, A) we can determine the height h (h = MD), which is equal to:

$$h = \frac{b_f - b_i}{tg\alpha} \quad (1)$$

where α is the sharpening angle of the carbide cutter.

The size h represents the initial offset between the edges of the carbide cutters and the edges of the PDC cutter blades at the end of the spud bit prior to well drilling.

The value of h is influenced by several factors: the rate of carbide cutter wear during drilling in the upper section, the thickness of rocks requiring drilling with carbide cutters, and the reduction in ROP when transitioning from carbide-tipped spud bits to PDC cutters. For specific uranium deposits like Budenovskoye, Inkai, etc., h is determined experimentally with precision by repeatedly measuring the initial bi and resulting bf values after using a spud bit.

Once wear causes the edges of the carbide cutters and PDC cutter blades to align, the PDC cutters begin exerting significant force on the bottom, enabling the well to deepen to its designed depth due to the functioning of these components.

The blade pilot 4 is designed to be detachable from the bit body. This is crucial because rock-cutting elements closer to the rotation axis endure higher loads and wear out more rapidly compared to the stepped blades on the body (Dreus, 2016a, 2016b). Consequently, the bit often needs removal from operation due to central cutter wear, even though the remaining cutters are still functional. The proposed technical solution allows for replacing the worn pilot in case of abnormal cutter wear in the central part, promoting uniform wear across all cutters – both on the blades and the pilot. This approach ensures thorough utilization of the spud bit's expensive equipment and enhances its technical and economic performance metrics.

Maintaining the nominal diameter during well drilling is crucial for ensuring the efficiency and success of drilling operations. The planned borehole diameter is essential for the accurate placement and functioning of drilling equipment and pipes. Deviations from the intended diameter can lead to complications during tripping, casing installation, in-situ leaching equipment setup, or reservoir stimulation (Abdeli, 2023: 7). Such deviations prolong the duration and increase the cost of well construction and equipment installation.

Furthermore, a narrowed wellbore increases mechanical resistance and friction during tripping, accelerating wear on drilling equipment and raising the risk of damage. Unevenness and narrowing of the wellbore also heighten the chances of emergencies, such as drill string jamming or well wall collapses, necessitating costly and intricate operations for resolution (Ihnatov, 2021b; Abirov et al., 2022: 159–173; Abakumov et al., 2014: 209–218).

To address these challenges, wear-resistant calibrating elements 10 with diameter d are installed on the stepped blades at their maximum transverse size, protruding from the blades by amount b. This arrangement ensures the well diameter is maintained consistently throughout its entire depth (Fig. 4).

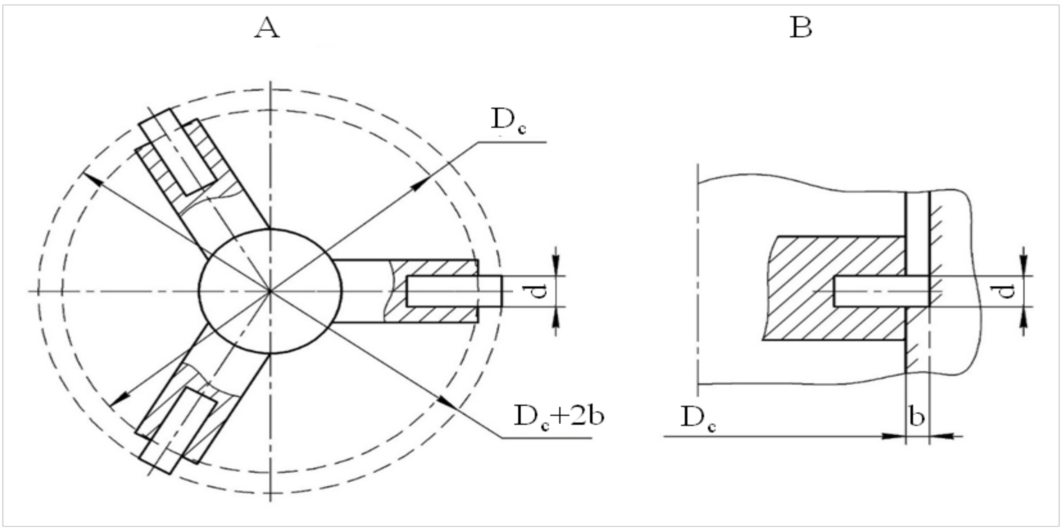

Fig. 4. Reinforcement of the calibrating part of the bit

D_c is the diameter of the circle described by the body blades, excluding the release of calibrating elements; d – diameter of calibrating cutters; b – protrusion of calibrating cutters from the blades

To assess the force interactions of the spud bit's working elements with the well bottom and walls, understanding the strength characteristics of the rocks being drilled and the technical capabilities of drilling rigs is essential (Ihnatov, 2021a: 8; Ratov, 2022; Kuanbayeva et al., 2024: 1640–1647).

The development of PDC cutter materials involved collaboration with the Bakul Institute of Superhard Materials of the National Academy of Sciences of Ukraine (Ratov, 2023: 15). Research has demonstrated that incorporating zirconium dioxide micropowder (ZrO_2) into the $25C_{diamond}$-70.5WC-4.5Co composite, produced via spark plasma sintering, significantly enhances the material's mechanical and operational properties.

The addition of ZrO_2 micropowder into the $25C_{diamond}$-70.5WC-4.5Co composite results in a structure with finer carbide matrix grains and denser diamond-matrix interfaces. This improves the material's resistance to elastic and plastic deformations and enhances its resistance to abrasive wear simultaneously.

Incorporating zirconium dioxide micropowder (ZrO_2 = 10%) into the $25C_{diamond}$-70.5WC-4.5Co composite increases the calculated resistance values to elastic deformation from 0.043 to 0.057 GPa, resistance to plastic deformation from 0.056 to 0.075 GPa, and abrasive wear resistance from $0.75 \cdot 10^{-7}$ to $2.75 \cdot 10^{-7}$ GPa^{-3}.

This newly developed composite material will be employed to manufacture rock-cutting elements that promise exceptional effectiveness in the challenging conditions of the Shu-Sarysu uranium ore geological province.

Discussion

Combination bits, featuring both PDC (polycrystalline diamond compact) and carbide cutters, excel across a broader spectrum of formations. While carbide cutters perform exceptionally in softer formations, PDC cutters are optimized for harder formations. This dual capability allows for uninterrupted drilling through varying geological conditions, reducing the need for frequent bit changes.

The synergy of PDC and carbide cutters in combination bits results in higher ROP and increased efficiency. PDC cutters offer superior cutting in hard formations, whereas carbide cutters facilitate smoother drilling in softer formations. This integration improves overall drilling performance and decreases drilling time.

Incorporating carbide cutters into combination bits helps balance the cutting workload, reducing wear and extending the bit's life. Carbide cutters are more resistant to impact and abrasion than PDC cutters, making the bits more durable and better suited for challenging drilling conditions.

Although PDC cutters are highly effective, they are also more expensive. Combination bits present a cost-effective solution by utilizing carbide cutters in softer formations, where the benefits of PDC cutters are not as critical. This approach optimizes drilling costs while maintaining high performance across different rock types.

Drilling operations can face stalling or slowdowns when encountering sudden changes in formation hardness, especially with bits equipped only with PDC cutters. Combination bits mitigate this risk by incorporating carbide cutters, which handle softer formations more effectively, ensuring continuous drilling and improved efficiency.

Combination bits with both PDC and carbide cutters provide significant advantages over bits with only PDC cutters, including versatility, enhanced performance, improved durability, cost-effectiveness, and reduced stalling risk. These benefits make combination bits an ideal choice for drilling operations across diverse geological formations and conditions.

Conclusion

1. A patented technical innovation enables optimal utilization of two types of cutters within a single rock-cutting bit design: economical carbide cutters are employed in the upper section of uranium deposits composed of soft, easily drillable rocks, while more expensive PDC cutters with superior productivity are utilized in the lower sections containing harder rocks.

2. Optimal utilization of the bit's capabilities is achieved when the edges of the carbide cutters are positioned slightly below those of the PDC cutter blades. This configuration ensures the carbide cutters operate closer to the well bottom during drilling of the upper interval of soft rocks. The bit includes a split ring pilot equipped with a combination of these cutters at its end.

3. The rock-cutting PDC cutters are fabricated from a novel super-hard composite material, $25C_{diamond}$-70.5WC-4.5Co, enhanced with zirconium dioxide micropowder (ZrO_2 = 10 %). This material was developed through collaboration with the V. Bakul Institute for Superhard Materials and is tailored to withstand the demanding conditions encountered in drilling operations.

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