UDC 622.24.05 (031)
DOI: 10.15587/1729-4061.2022.265304

DESIGN OF DIAMOND DRILL HEADS WITH A HYDROJET EFFECT OF ROCK DESTRUCTION

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It follows from the analysis of materials related to the design and operation of drilling equipment that an important direction in the search for effective solutions appears to be the improvement of the structure of the working matrix of diamond drilling heads and the enhancement of their technological capabilities by using in their schemes physical effects that are unconventional in the field of well drilling technology.

The tasks to be solved are to reduce the energy costs of the process of deepening wells, to obtain a structurally integral, informative core, and to ensure the stability of well walls.

Following the concept, diamond drill heads with a separate system of washing channels and a hydrojet effect of rock destruction were designed and tested during the drilling of wells.

The novelty of the structure of drill heads is the direction of the pressure flow of liquid to the steps of the bottom of the wells, repeating the shape of the matrix, the removal of sludge along the grooves and radial grooves, the treatment of the well wall.

A special technology for the manufacture of diamond drill heads with a complex geometry of the matrix has been devised.

The performance of diamond drill heads of various designs was tested under the industrial conditions of drilling wells for water and at polymetal deposits. It has been established that in terms of the quality of the tasks to be solved and technical and economic indicators, they have a significant advantage in comparison with standard equipment in terms of the mechanical speed of drilling wells, energy costs, and structural integrity of the core.

The comparative states of the shape, the transverse size of the hydrogeological well, the purity of the treatment of the wall of the latter, drilled by diamond drill heads and standard equipment with ball bits, are indicative. The structural integrity of the core selected by the regular column set HQ in an assembly with drill heads with a hydrojet effect of rock destruction is ensured

Keywords: drill heads, hydraulic jet destruction, informative core, diamond matrix, stepped, multistage

Received date 04.07.2022
Accepted date 21.09.2022
Published date 31.10.2022

How to Cite: *Mendebaev, T., Smashov, N. (2022). Design of diamond drill heads with a hydrojet effect of rock destruction. Eastern-European Journal of Enterprise Technologies, 5 (1 (119)), 36–43. doi: https://doi.org/10.15587/1729-4061.2022.265304*

1. Introduction

Along with increasing the reliability and informativeness of geological materials, a significant task of modern geological exploration of mineral deposits is to reduce the energy costs of the well drilling process. The task is dictated by an irreversible trend of increasing the depth of search, exploration, and extraction of natural resources, which places high demands on the methods and means of constructing wells, on the integrity of the design and structure of the core. There is a task of preserving the shape and stability of the walls of wells.

To solve problems, new ideas and resources are needed to improve equipment and technology based on physical principles that are not used in the means of drilling wells. The results of scientific research and development on this topic, the structural features and technological capabilities of the means of constructing wells, promising ways to improve them are analyzed. The main geological, technical, and technological factors that determine the success of solving the problems of drilling deep wells have been established. The main aspect is the compatibility of the mining environment with the applied equipment and technology of drilling wells.

The initial requirements for the design of means for the construction of deep wells are the creation of conditions for the manifestation of the hydrodynamic effect of volumetric destruction of rocks and favorable core formation, a separate system for supplying washing liquid and removing sludge from the face. At the same time, the objects of research are drill heads, which directly conduct the process of destruction of rocks and the formation of wells.

A relevant scientific issue of geological exploration on the deep horizons of the bowels of the earth is the design of drill heads with structural features and technological capabilities focused on solving the problems of building deep wells.

2. Literature review and problem statement

Technologically, the bottleneck in the construction of deep wells is to enable the stability of the walls against landslides, crumbling, and narrowing by changing the cross-sectional profile of the well wall.

Study [1] highlights the crumbling of weakly bound mudstones, shale clays, sands, fractured and crumpled rocks, as well as narrowing caused by the current, creep of floaters, and swelling of clay-containing rocks. According to researchers engaged in solving the problems of ensuring the stability of the walls of wells, it was found that the collapse of shale clays is controlled by weak layer planes, and the walls of the well are more stable when drilling with a lower angle of inclination. On this basis, a targeted safe drilling project was carried out. The unsolved part of the general problem is that at zenith angles of inclination from 42–45 to 68–78 degrees, the process of crumbling clays in time becomes progressive. The rate of deformation destruction of well walls in shale clays is 2–3 times higher compared to other clay rocks.

Despite the ongoing research, the problem of maintaining the stability of the walls of inclined wells in clay rocks has not been solved; the effectiveness of the recommended solutions is low.

Paper [2] indicates that in order to ensure the safety of drilling and maintain the stability of the walls of wells, the density of drilling fluid within a safe window is necessary, without taking into consideration other parameters of the solution.

The effectiveness of the use of drilling fluids to prevent collapse and leakage of the well wall is more widely studied in work [3]. It states that the preservation of the stability of the walls of wells is possible with the correct choice of the type, composition, and parameters of drilling fluids such as density, water yield, static shear stress, viscosity. It should be noted that increasing the density of drilling fluid cannot always ensure the stable state of the well walls. There are cases when an increase in the density of drilling fluid led to cavern formation, hydraulic erosion of the rock, and collapse. The reason for this is the variety of complex, often changing geological and technical conditions for drilling wells, difficulties in selecting drilling fluids for each interval of rock occurrence, ensuring maximum stability of the well walls.

Study [4] summarizes and analyzes the processes associated with the stability of the well wall when drilling in clay rocks. The choice of drilling fluids is proposed in order to stabilize the well wall, taking into consideration the geomechanics of clay rocks. According to the researchers, the reasons for the low efficiency of stabilizing the walls of the well with the recommended drilling fluids are subjective. Mistakes made in laboratory studies are mainly related to an attempt to simplify or speed up the experiment, or to the failure to take into consideration any properties.

A common drawback of studies aimed at solving the problems of stability of well walls is that they do not consider the effect of drill heads on the formation of the shape, transverse size, and purity of surface treatment of well walls.

It follows from the review of research papers aimed at solving the problems of safe drilling of deep wells and preserving the wellbore from collapses that the measures taken are mainly reduced to the choice of drilling fluids. Measures may also be limited to clarifying their composition and parameters in relation to the geological and technical conditions of a particular well depth interval.

It appears that a qualitative solution to the problems of trouble-free construction of deep wells is possible when taking into consideration the structural features of the drill heads used, which determine the type of destruction of rocks and the treatment of well walls.

Another issue in building deep wells is to obtain highly informative geological material in the form of a structurally solid core.

Selection of high-quality core is the main purpose of drilling wells, the ability to reliably establish the intervals of the location of ore bodies, the elements of occurrence, and the content of useful components of industrial interest. It is also necessary to identify the type of rocks, features of the development of intervals of cracking, permeability, and porosity.

Obtaining a highly informative core when drilling wells is due to the state of the mining environment, technical and technological factors. When assessing the state of the rock environment, the mineral composition, structure and texture, resistance of rocks to deformation and destruction are taken into consideration.

Core drilling has been a central part of exploratory oil and gas drilling for decades, however there are challenges still associated with traditional core extraction methods and technologies. To obtain a high-quality core, the Norwegian technology company CorelJJ and the company Intelligent Coring System (ICS) have put forward a joint project – to design a fully equipped core drilling assembly. In the process of deepening wells, the assembly can record the main parameters of the reservoir and fluid together with downhole diagnostics [5]. At the same time, there is no information in the cited work on how in the bottom hole part of the core assembly the core will be isolated from the effects of the washing fluid.

The main means of increasing the uplift of the core are units with removable core receivers of the SSK type; NQ and HQ, double and triple core pipes, downhole assemblies with backwashing. Significant disadvantages of units with removable core receivers are as follows: in the cavity of the drill bit, the side walls of the core are affected by the pressure flow directed to them, undergoing destruction and erosion.

There are difficulties in moving the core in the core receiving pipe due to the lack of liquid lubrication between their rubbing surfaces.

For core extraction drilling in medium hard rocks such as soft sandstones, salts, limestones, and marls, the Grad 126/S 2 multi-stage diamond drill head is produced. However, the design does not provide for the use of hydro-jet destruction of rocks.

With regard to the safety of core columns, the most promising are drill heads containing longitudinal channels for the supply of washing fluid outside the core formation zone. This ensures a high percentage of core yield even in destroyed rocks.

Disadvantages are as follows: the lack of a separate system for supplying washing liquid and removing sludge; longitudinal channels are located in radial grooves and the ingress of sludge into them eliminates the effect of hydrojet destruction of rocks.

Another challenge of successfully operating deep wells is to reduce the energy costs of the well deepening process by increasing the efficiency of rock destruction. The regime of volumetric destruction, which is possible with an optimal combination of technological modes of drilling wells corresponding to the physical and mechanical properties of rocks, is considered advantageous in all respects.

Based on the results of studies into the influence of rotation speed and the intensity of penetration, it has been established that with an increase in the speed of rotation of a rock-destroying tool and a decrease in the intensity of its introduction into the rock, the energy intensity of its destruction decreases [6].

Study [7] investigated the effect of the rotation speed of the rock-breaking tool on the cutting force of the rock. The average values of the constituent forces were established, as well as the amount of work spent in the cutting process, and the amount of specific energy during the destruction of the rock. The scope of use of the research results is limited since they are based on parameters characteristic of the process of drilling wells (holes) using RS-140 milling cutters; cutting depth, 0.5; 1.0; 1.5; and 2.0 mm; linear cutting speed, 0.523–0.561 m/s.

An increase in the energy costs of the process of rock destruction is also possible with an imperfect system for removing sludge from the bottom of wells.

In order to increase the intensity of sludge removal from the bottom of wells, studies of the culvert system of the drill bit were carried out [8]. It was found that the flow field of the washing fluid at the bottom becomes more turbulent while the efficiency of removal of the bearing sludge decreases as the height of the bit penetration increases. At the same time, the optimal speed of rotation of the bit should be in the range of 250–400 rpm, the flow rate of washing fluid is 50–80 l/min.

According to [9], the deterioration of the removal of the products of destruction leads to the re-grinding of the sludge and increased wear of the matrix of the rock-destroying tool, which causes an increase in the energy intensity of drilling wells.

Increasing the wear resistance of the matrix of the rock-destroying tool is possible with the improvement of the technology of their manufacture.

Work [10] describes the manufacture of diamond bits with a diameter of up to 212 mm at a pressure of up to 1.5 GPa and a temperature of up to 1250°. This technology involves sintering by electric heating inside heat and an electrically insulating shell in a high-pressure steel chamber for 120 min. It is noted that such high-pressure sintering is a relatively fast process. The disadvantages of the technology are the high cost of the steel chamber, even if it is used repeatedly, as well as the fact that the degradation of diamond grains begins at a temperature of 1000 °C.

For the operation of directional and horizontal wells on solid and heterogeneous rocks, a conical hybrid bit equipped with polycrystalline diamonds of a compact ball type has been developed. The results of the test showed that the conical shape helps increase the penetrating power of compact cutters made of polycrystalline diamond in hard rocks, increasing the efficiency of destruction [1]. Disadvantages are as follows: the torque of the hybrid bit is approximately equal to the torque of the ball bit, which explains the increase in energy costs of the well deepening process.

Works [11, 12] describe the conditions and results of experiments to study the technological capabilities of the method of drilling rock using a jet of water. It has been proven in practice that the permeability of the rock environment is a decisive factor in increasing the efficiency of hydrojet destruction of rocks.

Scientific research is being conducted in the world aimed at finding ways and means to increase the cutting capacity of high-speed water jets without increasing the hydraulic power of equipment, as well as to increase the efficiency of slot failure [13].

The most promising is the waterjet cutting of rocks, which is based on the joint effect on the material of continuous high-speed jets of water and abrasive parts. At the same time, the abrasive water jet is a new technology where the two-phase medium «liquid-solid» is characterized by a high water velocity. All other things being equal, the impact force of an abrasive jet is much greater than that of high-pressure water jets since the strength of abrasive particles with sharp pointedness is greater than that of water.

It was found that the depth of cracks formed under the influences of an abrasive mixture was 5–8 times higher than the depth of cracks obtained by cutting with conventional high-speed water jets without adding an abrasive component [14].

Hence the conclusion: an abrasive jet of high-pressure water can be used especially effectively when drilling rocky, fractured, weakly bound rocks. This is also possible when drilling dense rocks if a leading network of cracks and furrows appear on their surfaces.

It follows from the sources of information [15, 16] tackling the means of drilling wells that the problems of preserving the shape, size, and wall of wells, obtaining an informative core and reducing the energy costs of well depth are linked via the design of drill heads.

To successfully solve the problems of drilling deep wells, a new generation of drill heads will be required, designed under conditions for introducing into their structure of physical effects and resources that are uncharacteristic of traditional drilling equipment.

It follows from the analysis of trends in the development of equipment and technology of drilling wells that in order to solve the problems of drilling deep wells, an unused resource in rock-destroying tools, hydrojet destruction of rocks, seems promising.

The effect of hydrojet rock fracture can be realized by the structural features of diamond drill heads, aimed at maximizing the use of the potential energy of the washing fluid.

Structural features are manifested in the form of increasing the intensity and reducing the energy cost of the process of rock destruction, protecting the core from erosion, preserving the shape of the transverse size and stability of the walls of wells.

3. The aim and objectives of the study

The purpose of this study is to design diamond drill heads with a hydrojet effect of rock destruction. This will make it possible to drill deep wells without complications, reduce energy costs, and obtain an informative core.

To accomplish the aim, the following tasks have been set:

– to establish the structural features and technological capabilities of diamond drill heads with a hydrojet effect of rock destruction;

– to devise a manufacturing technology and master the production of prototypes of diamond drill heads with a hydrojet effect of rock destruction;

– to test the applicability of prototypes of diamond drill heads in the practice of drilling wells, to assess their effectiveness in comparison with standard rock-breaking tools.

4. The study materials and methods

Prerequisites for the formation of structural schemes of diamond drill heads are as follows: a directed flow of washing fluid to the bottom of the well outside the core formation zone, a separate washing system for removing sludge, well-forming inserts.

On these premises, a structure of the diamond drill heads with a stepped and multi-stage matrix was designed. According to the structural execution, the stepped matrix of the diamond drill head consists of a part that is ahead of the face (cut) and a lagging, well-forming base.

Distinctive features are as follows: the cut part can be removable or solid with a lagging base, longitudinal channels – going above concentric grooves, crossed by radial grooves, dividing the matrix into sectors.

Between the sectors, the concentric grooves are shifted horizontally on the end surface of the matrix; the radial flushing grooves of the cut part and the base are linearly connected.

The multistage matrix of the diamond drill head also consists of a removable cut part and a base equipped with replaceable diamond cutters. On the outer surface of the base, there are vertical, well-forming inserts, saturated with small, impregnated diamonds.

Diamond drill heads with a multistage matrix are universal in structure, designed for drilling wells with both solid bottom and core selection. In the latter version, the cut part is a diamond crown with a diameter of 75.6 mm or 95.6 mm, built respectively into the NQ and HQ column set system with a non-rotating core intake pipe.

When switching to drilling wells with a solid bottom, the crown is changed to a bit with longitudinal channels and concentric grooves.

The stepped shape of the matrix of diamond drill heads has a complex geometry, which required the development of a special technology for their manufacture.

One of the determining factors in the effectiveness of diamond rock-breaking tools is the hardness of the matrix. The harder the rock and the less abrasive it is, the softer the matrix should be, since in it the layers of diamond grains are completely opened, there is no polishing, the reason for the decrease in drilling speed.

The hardness of the matrix in a wide range of 15–50 HRC, in the absence of tungsten carbide, can be enabled by the use of hot pressing technology of the matrix. In addition, a significant advantage of the hot pressing technology of the matrices is the preservation of the properties of diamond grains. This is due to the fact that the combined process of pressing and sintering takes place at a temperature of 900–950 °C while the degradation of diamond grains begins at a temperature of 1000 °C.

Devising a technique for hot pressing the matrices of diamond drill heads with a separate system of washing channels and the hydrojet effect of rock destruction required significant changes in the production process. Difficulties were associated with the complex geometry of the matrix, determining its composition, the accuracy of calculating the ratios of the norm of antifriction and other additives that increase the wear resistance of the matrix.

As a result, the most rational scheme of the technological process of manufacturing diamond drill heads with a separate system of washing channels and the hydrojet effect of rock destruction was chosen.

For the design of 3D models of drill heads and graphite mold, a simplified version of the Kompas 3DV14 Home CAD program, compatible with EVRAZESEC standards, was used.

The ARTCAM work program was used to manufacture parts on the 4PUREMAX40302 machine. The software makes it possible to set trajectories for material processing with high accuracy (up to 0.024 mm) while the system is able to automatically recognize the shape of the drawn 3D model and repeat it. Thereby forming complex forms of bases for molds in which crown dies are sintered. Using the 3D modeling of the milling process makes it possible to optimally select the tool or group of tools necessary for processing, see possible difficulties and shortcomings in processing and correct them at the stage of creating a control program.

Technological operations of manufacturing involved the following stages. Assembling the mold, filling it with a mixture of VK-8 powder and bulk diamonds in accordance with the established procedure. The process of hot pressing the product on a specially assembled induction unit for the task to a temperature of 950 °C with simultaneous pressing under a load of 15–20 tons and cooling under load at a temperature of 200–300 °C.

The final part of the diamond drill head manufacturing operation is mechanical stripping, threading, and painting.

In-depth video recordings of the walls of hydrogeological wells were shot using the downhole video surveillance system (SSV-01), certified in the Republic of Kazakhstan.

The objects of our study are the state of the wall of wells, contacts of rock layers, cracks, veins, elements of occurrence.

5. Results of studying the structural schemes of diamond drill heads with a hydrojet effect of rock destruction

5. 1. Structural features and technological capabilities of diamond drill heads with hydrojet rock destruction

Fig. 1 shows the structure of a diamond drill head with a diameter of 215.9 mm with a separate system of flushing channels and a hydrojet effect of rock destruction, designed for drilling wells with a continuous bottom.

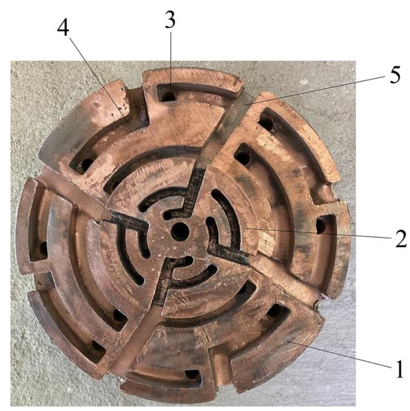


Fig. 1. Diamond drill head with a stepped matrix with a diameter of 215.9 mm with a separate system of washing channels and a hydrojet effect of rock destruction: 1 – base; 2 – cut part; 3 – longitudinal channels; 4 – concentric grooves; 5 – radial grooves

Fig. 2 shows diamond drill heads with a diameter of 75.6 mm for drilling wells with a solid bottom and with core selection.

Fig. 2. Diamond drill heads with a diameter of 75.6 mm for drilling wells with solid bottom and core extraction

Fig. 3 demonstrates the structure of a multi-stage, universal diamond drill head with a diameter of 215.9 mm, designed for drilling wells with a solid bottom and with core selection.

a *b*

Fig. 3. Multi-stage, universal diamond drill head with a diameter of 215.9 mm designed for: *a* – core selection; *b* – drilling wells with continuous bottom

Fig. 4 shows diamond drill heads (crowns) used as part of regular NQ and HQ core kits for core selection.

Fig. 4. Diamond drill heads (crowns) used in NQ and HQ core kits

Diamond drill heads (crowns) with a working matrix saturated with impregnated diamonds as part of the HQ and NQ core sets were worked out at the polymetal deposit of Central Kazakhstan.

5. 2. Technology of manufacture and production of diamond drill heads for the hydrojet destruction of rocks

Fig. 5 shows a diagram of the technological process of manufacturing diamond drill heads with a hydrojet effect of rock destruction.

A significant advantage of the technology of hot pressing of diamond drill heads matrices is the preservation of their shape, size, and properties of diamond grains.

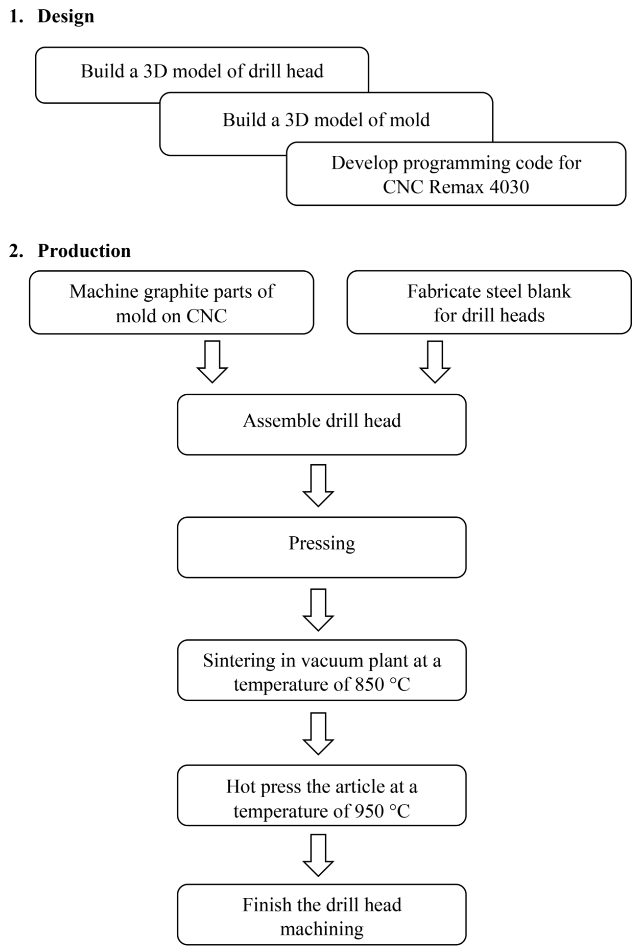


Fig. 5. Scheme of the technological process of manufacturing diamond drill heads with a hydrojet rock destruction effect

5. 3. Applicability of diamond drilling heads in well drilling and efficiency evaluation

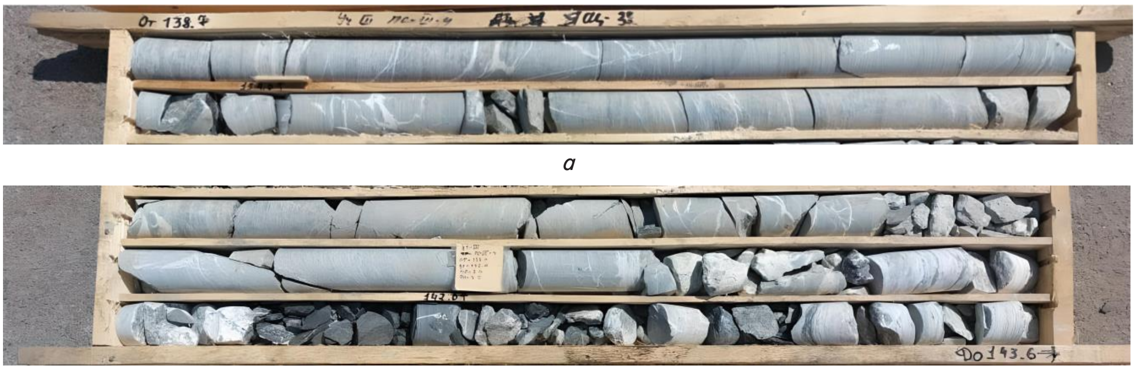
The applicability and efficiency of diamond drill heads in solving the problems of deep well drilling were evaluated.

Fig. 6 shows deep video footage of the walls of the hydrogeological well, drilled with a Sh-190.5ST ball bit and a multi-stage universal diamond drill head with a diameter of 190.5 mm.

a *b*

Fig. 6. Deep video recording of the walls of a hydrogeological well: *a* – drilled with the ball bit Sh-190.5ST; *b* – drilled using a multi-stage, universal diamond drill head with a diameter of 190.5 mm

Fig. 7 shows the states of the core samples taken by the HQ core set when drilling wells with a diamond drill head with a diameter of 95.6 mm and the standard KB-I3AT diamond crowns with a diameter of 95.6 mm.



a

b

Fig. 7. State of the core samples taken by the HQ core set:
a — using a diamond drill head ∅95.6 mm; *b* — using the standard diamond crowns KB-I3AT ∅95.6 mm

According to the state of the specific clump of the core per linear meter of drilling wells under comparable geological and technical conditions, it is clear how effective diamond drill heads are in ensuring the structural integrity of the core.

Table 1 gives comparative data on drilling wells with a multi-stage, universal drill head equipped with replaceable cutters saturated with impregnated diamonds and the regular Sh-190.5ST ball bit.

The results of average timekeeping observations and indicators of control and measuring devices for the performance of regular diamond drill bits and diamond drill heads as part of the NQ and HQ core sets under the industrial conditions of drilling wells are given in Table 2.

According to the results of tool operation, it was established that the resource capabilities of regular diamond crowns and diamond drill heads are approximately the same, within the range of 180–220 meters.

6. Discussion of structural features and technological capabilities of diamond drill heads

The results obtained, specifically reducing the energy costs of the process of destruction of rocks to obtain a structurally solid core, ensuring the stability of the walls of wells are explained by the structural features of the matrix of drill heads. Due to this, the shape of well bottom and the type of destruction of rocks, the sludge removal system, the conditions of core formation change; it becomes possible to switch to low values of the drilling mode parameters. The results are confirmed by the types of diamond drill heads (Fig. 1–4), the technological scheme of their manufacture (Fig. 5), the practice of mining (Fig. 6, 7), comparative indicators with standard equipment (Tables 1, 2).

The peculiarity of the method is the use of directed, potential energy of the washing fluid to increase the intensity of rock destruction and reduce the energy costs of well deepening, maintaining the integrity of the core and the stability of wells.

Table 1

Comparative data on drilling wells with a continuous bottom using a multistage universal drill head with replaceable diamond cutters and the standard Sh-190.5ST ball bit

Well drilling equipment	Well drilling mode			Energy consumption, kW/h at well depth, m			Mechanical drilling rate, m/h
	Axial load, kgf	Fluid flow rate, l/min	Rotation speed, rpm	100	300	500	
1. Multi-stage, universal drill head with replaceable diamond bits, 190.5 mm diameter	500–800	100–160	70–150	2.1–3.0	2.8–4.2	3.7–5.3	3.6
2. Standard Sh-190.5ST ball bit	1200–2500	110–180	110–230	4.6–8.5	6.2–10.6	7.9–12.4	1.4

Table 2

Averaged performance data on the regular diamond drill bits and diamond drill heads as part of NQ and HQ core sets under comparable rock environment conditions

Types of rock cutting tools	Drilled, m	Well drilling mode			Mechanical drilling rate, m/h	Core extraction, %	Energy costs, kW/h
		Axial load, kgf	Rotation frequency, rpm	Flushing fluid flow rate, l/min			
1. Standard: (KB-I3AT) diameter 75.6 mm (NQ)	300	1800–2000	600–700	60–70	3.1–3.3	93	1.6–1.8
diameter 95.6 mm (HQ)	242	2200–2500	500–600	80–90	2.8–3.0	93	2.1–2.4
2. Diamond drill heads: diameter 75.6 mm (NQ)	275	400–600	400–500	35–40	2.7–3.0	95	0.7–0.9
diameter 95.6 mm (HQ)	181	700–900	300–400	60–70	2.5–2.7	95	1.2–1.5

The design of diamond drill heads makes it possible to form a directional flow, thanks to which the formation of loosening zones on the steps of the well face and an increase in the permeability of the media is ensured.

The following structural features of diamond drill heads are realized:

– a hydrojet effect of rock destruction by the pressure flow of washing fluid directed through the longitudinal channels to the steps of the well face, repeating the shape of the matrix;

– the appearance of a leading zone of cracks on the steps of the well face; there are prerequisites for the volumetric destruction of rocks, which is facilitated by the displacement of concentric grooves horizontally between sectors;

– making concentric grooves at the end of the matrix, crossed by radial grooves, excluding the ingress of sludge from one sector of the matrix into another, a hydraulic support under it and increasing the intensity of sludge removal;

– protection of the core from the effects of the flow of pressure washing fluid, creating conditions for liquid lubrication between the core and the core receiver;

– reducing the value of well drilling modes of axial load on the face and rotational speed; when using diamond drill heads, the walls of wells are less susceptible to destruction than when using ball bits;

– the use of diamond drill heads, which ensure the preservation of the shape and transverse dimensions of wells, the smoothbore of the wall by the latter treatment with well-forming inserts of drill heads, saturated with impregnated diamonds;

– treatment of the walls of wells to the state of smoothbore excludes the appearance of whirlpool zones of the upward flow with sludge, forming conditions for erosion and destruction of the walls of wells.

By the set of structural features, and the consequences of their manifestation in the process of drilling wells, diamond drill heads, representing the objects of this research, differ significantly from the design of regular rock-destroying tools.

Diamond drill heads with a hydrojet effect of rock destruction find limited use in drilling wells on dense clays, loams, where it is possible to block the longitudinal channels and block the movement of the pressure flow.

The disadvantage can be eliminated by selecting the transverse dimensions of the longitudinal channels corresponding to the properties of the rocks and increasing the consumption of washing fluid.

A promising direction in expanding the scope of application of diamond drill heads with a hydrojet effect of rock destruction is their use in drilling the shafts of mines, pits, the development of mineral deposits by the method of borehole hydraulic production.

7. Conclusions

1. The structural features of diamond drill heads are a stepped and multi-stage matrix. In a stepped matrix, the longitudinal channels are made extending to concentric grooves at the end of the matrix, intersected by radial grooves dividing the matrix into sectors. In this case, the concentric grooves between the sectors are shifted horizontally, the radial grooves of the cut and the lagging part of the stepped matrix are linearly connected. The multi-stage matrix is equipped with replaceable diamond cutters, well-forming vertical inserts saturated with small impregnated diamond grains are placed along the diameter.

Technological capabilities are as follows: the volumetric destruction of rocks, a separate system for removing sludge from the bottom of wells, favorable bottomhole conditions of core formation by supplying washing liquid outside the core formation zone. The transition to low values of the axial load and rotational speed, therefore, reducing the impact of torsional oscillations of the drill string on the walls of the wells, the purity of the processing of the latter.

2. A manufacturing technology has been devises and the production of prototypes of diamond drill heads with a hydrojet effect of rock destruction has been mastered. The manufacturing process was carried out according to the program of 3D models by developing a program code for a CNC machine. The manufacture of diamond drill heads is carried out according to the scheme: the processing of graphite parts of molds and the manufacture of a steel billet for a drill head. Next, the assembly of the drill head – cold pressing-sintering in a vacuum installation – hot pressing – finishing.

3. Verification of the applicability of structural schemes of diamond drill heads with a hydrojet effect of rock destruction was carried out under the industrial conditions of drilling wells for groundwater and solid mineral deposits.

The efficiency of diamond drill heads in comparison with regular rock-destroying tools is expressed in a reduction in energy costs by 40–50 %, obtaining a structurally solid core, and an increase in mechanical velocity by 8–9 %, the preservation of the shape, transverse dimensions, and stability of the walls of wells.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Acknowledgements

The research was conducted involving grant financing for the implementation of scientific and scientific and technical projects on the topic No. IRN AP08855657 «Development and introduction into production of energy-saving, universal downhole well drilling assembly with a hydrojet effect of rock destruction».

The source is the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan.

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