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FEATURES OF DRILLING HORIZONTAL WELLS WITH GAS-LIQUID SHOCK-EJECTOR SHELLS IN DIFFICULT MINING AND GEOLOGICAL CONDITIONS



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This article examines the features of drilling horizontal wells with gas-liquid shock-ejector shells in difficult mining and geological conditions, namely in boulder-pebble deposits. The technology of drilling large boulders is considered. In addition, to study the processes of energy transfer and shock pulses from the drilling shell to the bottom of the well during the sinking of boulders, the authors conducted appropriate theoretical studies and provided calculations of the stages of the introduction of the tool into the rock. Based on theoretical studies, drilling analysis, calculations of the dependence of boulder movements, several conclusions were obtained on the technology of drilling wells in boulder-nut deposits.

KEY WORDS: *drilling, boulder-pebble deposits, soil, ejector projectile.*

КҮРДЕЛІ ТАУ-КЕН-ГЕОЛОГИЯЛЫҚ ЖАҒДАЙЛАРДА ГАЗ-СҰЙЫҚ СОҚҚЫЛЫ-ЭЖЕКТОРЛЫ СНАРЯДТАРМЕН КӨЛДЕНЕҢ ҰҢҒЫМАЛАРДЫ БҰРҒЫЛАУ ЕРЕКШЕЛІКТЕРІ

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Бұл мақалада күрделі тау-кен-геологиялық жағдайларда, атап айтқанда, тасты-қиыршық тасты кен орындарында газ-сұйық соққылы-эжекторлы снарядтармен көлденең ұңғымаларды бұрғылау ерекшеліктері қарастырылады. Ірі тастарды бұрғылау технологиясы қарастырылған. Сонымен қатар, тастарды айдау кезінде бұрғылау тізбегінен ұңғыма түбіне энергия мен соққы импульстарының берілу процестерін зерттеу мақсатында авторлар тиісті теориялық зерттеулер жүргізіп, құралды енгізу кезеңдерін есептеді. жартасқа. Теориялық зерттеулер, бұрғылауды талдау, тастардың қозғалысына тәуелділікті есептеу негізінде ұңғымаларды бұрғылау технологиясы бойынша тас-жаңғақ шөгінділеріне бірнеше тұжырымдар алынды.

ТҮЙІН СӨЗДЕР: *бұрғылау, тасты-малтатас шөгінділері, топырақ, эжекторлық снаряд.*

ОСОБЕННОСТИ БУРЕНИЯ ГОРИЗОНТАЛЬНЫХ СКВАЖИН ГАЗОЖИДКОСТНЫМИ УДАРНО-ЭЖЕКТОРНЫМИ СНАРЯДАМИ В СЛОЖНЫХ ГОРНО-ГЕОЛОГИЧЕСКИХ УСЛОВИЯХ

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Рассмотрены особенности бурения горизонтальных скважин с газожидкостными ударно-эжекторными снарядами в сложных горно-геологических условиях, а именно в валунно-галечных отложениях.

Рассмотрена технология бурения крупных валунов. Кроме того, для изучения процессов передачи энергии и ударных импульсов от бурового снаряда к забою скважины при проходке валунов авторами были проведены соответствующие теоретические исследования и приведены расчеты этапов внедрения инструмента в породу.

На основании теоретических исследований, анализа бурения, расчетов зависимости подвижек валунов было получено несколько выводов по технологии бурения скважин на валунно-ореховые отложения.

КЛЮЧЕВЫЕ СЛОВА: *бурение, валунно-галечные отложения, грунт, эжекторный снаряд.*

Introduction. The analysis of the state of core pneumatic impact drilling in the fields of the country indicates the high productivity of the method and, in general, the low yield of the core material. The reasons influencing this factor are very diverse.

The analysis of previous works shows that the mechanism of core formation during pneumatic impact drilling is influenced by a combination of geological, technological, and technical factors.

Some researchers, believe that the process of core formation is primarily influenced by the geological structure of the deposit, the physical and mechanical properties of passable rocks and mainly fracturing, brittleness and shale. Therefore, after the core column enters the crown, it is separated by a weakened section. In the core pipe, the rock discs are worn away from each other and against the pipe, because of which the core pieces have a rounded character.

Other researchers of core preservation have tested several technical means in which the airflow does not have a direct effect on the core or is generally isolated from it, that is, double core pipes. However, these tools only ensure the preservation of the linear output of the core.

Materials and research methods. Based on the analysis, the issues of core selection during drilling with pneumatic impact machines have not been sufficiently investigated. At the same time, further expansion of the scale of impact-rotational drilling is being held back due to the lack of reliable means of obtaining core material [1-3].

Results and discussion. During the construction of the Almaty metro, a large amount of work falls on the construction of horizontal approach workings. The latter is carried out in very difficult geological conditions, which consist of the fact that the work is carried out in extremely unstable boulder-pebble deposits. To temporarily strengthen the arch of workings, under the protection of which a permanent reinforced concrete support is installed, the ARR Design Institute (Belgorod) proposed a technology consisting of the sequential conduct of the following operations [4]:

– drilling along the contour of the bottom of the production of wells with a depth of 1m by a shock-rotational method with water flushing or purging;

– injection of the cement-silicate solution under pressure into a drilled well, which, due to the permeability of boulders, penetrates the near-barrel space and closes with the solution injected into adjacent wells;

– exposure for a certain period set the grouting solution and obtain cement stone;

– drilling on the cement stone that filled the borehole, and further deepening of the face into the loose rock again by 1m;

– repetition of injection and drilling cycles (well drilling intervals of the design depth (8-12 m);

– drilling of grouting stone in wells that have reached the design depth, installation of steel anchors in them with subsequent cementing;

– excavation of the rock under the protection of the created vault to the full cross-sectional area and the creation of a work-out, which is further reinforced with permanent reinforced concrete support.

Tests of the proposed technology at the facilities of Almatymetrostroy (Baikonur station) revealed the following:

– low productivity and high accident rate of drilling operations caused by the collapse of the walls of wells in unstable boulder-pebble deposits;

– for this reason, none of the drilled wells was drilled to the design depth (the maximum depth of the well reached was 6 m);

– a large volume of drilling on cement stone, due to the small size of the approaches (drilling interval on loose rock), amounting to only 1m. For example, at a depth of 6 m it is 21 m, at a depth of 8 m-36 m, and at a depth of 12 m – already 78 m;

– drilling on cement stone is an unproductive waste of time and money, and a large volume of this work dramatically reduces the efficiency of the construction of temporary support.

Tests have shown that the proposed technology does not solve the main problem– achieving satisfactory performance in strong unstable rocks while ensuring the stability of the walls of wells and preserving the natural permeability of the surrounding massif for its high-quality cementing.

The authors analyzed modern drilling methods suitable for the construction of wells in boulder-pebble deposits.

In these conditions, the following drilling methods are used: shock-rotational, rotary and shock-rope.

For specific conditions, the use of shock-rope drilling is excluded,since this method is used only for drilling vertical wells.

Rotary drilling with flushing with clay solution, although it ensures the stability of the borehole, however, leads to colmatation of the latter and, consequently, to a sharp decrease in soil permeability. When switching to drilling with water flushing in this way, the walls of the well collapse.

Special attention should be paid to a kind of shock-rotational method – gas-liquid shock-ejector projectiles.

The essence of the latter lies in the transmission of rock-crushing tools, in addition to static axial load, shock pulses with a frequency of 1000-1500 hits/min. the shock pulse generators are downhole machines – pneumatic hammers using compressed air as a working fluid, the energy of a single impact of pneumatic hammers is 100-300 J, which is 2.5 times higher than that of hydraulic hammers.

At the Baikonur station of Almatymetrostroy, experimental work was carried out by drilling horizontal wells to contructtemporary support for the approach production of SC-2. As a result of experimental work, it was found that the penetration of horizontal wells is provided using hydraulic pulse generators in combination with gas-liquid shock-ejector projectiles. Technological operations for the construction and plugging of wells were divided into 2 periodically recurring stages:

Stage I–drilling of wells up to 4 m deep with the cleaning of the bottom with foam, which ensured the stability of the trunk for up to 1-5 days;

Stage II–injection of cement mortar under pressure up to 2-4 MPa through a conductor fixed at the wellhead.

After 6-8 hours after setting the cement mortar, the drilling process resumes, i.e. the cement stone was drilled and wells were drilled into the loose rock repeatedly for 4 m, followed by tamponing of the near-barreled array.

71.5 m wells were drilled using this technology. The maximum drilling depth was 14 m with a replaceable capacity of 2-3 m/shift.

The experimental work carried out showed that pneumatic impact drilling with gas-liquid shock-ejector projectiles with foam flushing is more effective than the method of well construction proposed by ARR Design Institute (Belgorod):

– due to an increase in approaches from 1 m to 4 m, unproductive time and money spent on drilling the grouting stone filling the borehole after its cementation decreased, drilling productivity and the depth of drilled wells increased.

However, the tests revealed several shortcomings, the main of which is the insufficient development of drilling technology in soils of different granulometric composition, especially great difficulties arose when drilling small boulders. When drilling intervals were stacked with sand aggregate with small pebbles, jamming (jamming) of the tool was repeatedly observed due to insufficient cleaning of the well. However, there is no alternative to this method of drilling in these conditions. Only this method can solve the contradictory task of ensuring the stability of the walls of the well and maintaining the permeability of the near-well array [5-7].

To develop drilling technology in soils of different granulometric composition, experimental work was continued at the Zhetysu station of Almatymetrostroy.

The set of drilling equipment includes: the DR-100 drilling rig, a metering device (foam generator) for the preparation of foam solution, and hoses with valves. Sulfanol was used as a foaming agent.

The task of drilling operations was to delineate the bottom of the horizontal workings with SC-1 cross-section wells, followed by tamponing to create a temporary support.

Before drilling, a concrete bridge was constructed in the bottom with installation along the contour with a certain step of conductors serving to direct wells and pump grouting mortar.

Drilling modes were determined by the pressure and flow rate of compressed air, the concentration of the foaming agent in the solution, the rotational speed of the projectile and the axial load on the face.

During the experimental work, three types of soils were identified that require the development of special technological measures for their effective drilling:

– drilling of large boulders larger than 25 cm.;

– drilling of small boulders up to 20-25 cm in size;

– drilling on a sand aggregate with small pebbles.

In all three types of soils, ring face drilling with core sampling was used, as only core drilling ensures the straightness of the borehole in these conditions and eliminates the jamming of the projectile between boulders (*Fig.1*).

The technology for drilling large boulders was the same as when drilling rocks. The compressed air pressure in the network was maintained as high as possible and was 0.5-0.6 MPa. The consumption of the foam solution was 1-1.5 l/min at a concentration of 0.5%sulfanol. The rotational speed ofthe projectile varied from 10 to 20 rpm. The axial load on the face when drilling boulders should ensure tight contact of the crown with the face and approximately amounted to 1-4 kN. However, the DR-100 drilling rig was not equipped with an axial load indicator, so this parameter was not measured during drilling [8].

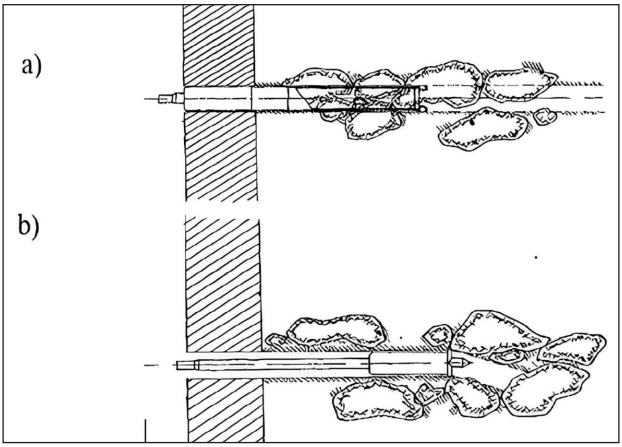

Figure 1 – **The direction of the well route by gas-liquid shock-ejector shells drilling**
a – ring face; b – solid face

Measurements of the crowns by the outer diameter showed that the intensity of their lateral wear when drilling large boulders is 0.12-0.15 mm per 1 m of the well. Lateral wear of the crown causes its clamping by the walls of the well, which reduces the energy of transmitted shock pulses, and drilling speed and causes jamming of the projectile.

In this regard, the crowns were worked out in a circular pattern. The alternating circle included crowns of the same diameter in the amount necessary for drilling a given interval of wells, considering the hardness and abrasiveness of rocks. The crowns were grouped by diameter with a difference of 0.2 mm. The permissible reduction in the diameters of consistently applied crowns is 0.1-0.15 mm.

The drilling of small boulders causes the greatest difficulties. During the penetration of such soils, the deepening of the face was suspended. Regulation of the operating parameters did not give tangible results.

To study the processes of energy transfer and shock pulses from the drilling shell by the bottom of the well during the sinking of boulders, appropriate theoretical studies were carried out. We denote the mass of the boulder encountered by the face of the wells, ml, the mass of the projectile part (crown, core tube adapter) involved in the transfer of shock loads to the face (boulder)– through m_2, and the pre-impact velocity of the projectile at each impact pulse *0* through V_0. The stiffness of the «crown-boulder» and «boulder-sand filler» contacts are indicated by C_2 and C_1, respectively, and the movement of the crown is indicated by α_1 and α_2.

The equation of motion of the elements of the shock system has the form:

$$\alpha_1 = a_{1\text{-}1} \sin(f_1 t + \phi_1) + a_{1\text{-}2} \sin(f_2 t + \phi_2),$$
$$\alpha_2 = X_{2\text{-}1}\, a_{1\text{-}1} \sin(f_1 t + \phi_1) + X_{2\text{-}2} a_{1\text{-}2} \sin(f_2 t + \phi_2) \quad (1)$$

where, the natural frequency of oscillations is determined from the ratio:

$$f_1 = \sqrt{\frac{1}{2}\frac{C_1 + C_2}{m_1} + \frac{C_2}{m_2} - \sqrt{\frac{1}{4}(\frac{C_1 + C_2}{m_1} + \frac{C_2}{m_2})^2 - \frac{C_1 C_2}{m_1 m_2}}},$$
$$f_2 = \sqrt{\frac{1}{2}\frac{C_1+C_2}{m_1} + \frac{C_2}{m_2} - \sqrt{\frac{1}{4}(\frac{C_1+C_2}{m_1} + \frac{C_2}{m_2})^2 - \frac{C_1 C_2}{m_1 m_2}}} \quad (2)$$

The ratio of amplitudes is equal to the:

$$\chi_{2\text{-}1} \frac{a_{2-1}}{a_{1-1}} = \frac{C_1 + C_2 - m_i f_i^2}{C_2}$$
$$\chi_{2\text{-}2} \frac{a_{2-2}}{a_{1-2}} = \frac{C_1 + C_2 - m_i f_i^2}{C_2} \quad (3)$$

The oscillation amplitudes are equal:

$$a_{1\text{-}1} = \frac{V_0}{f_1} \times \frac{1}{\chi_{2\text{-}1} - \chi_{2\text{-}2}}$$
$$a_{1\text{-}2} = \frac{V_0}{f_2} \times \frac{1}{\chi_{2\text{-}2} - \chi_{2\text{-}1}} \quad (4)$$

The process of impact interaction of a projectile with a boulder consists of two stages. At the first (active) stage, the crown is embedded in the boulder, and the depth of the embedding increases α_2. At the second (passive) stage, elastic deformations of the rock and the tool are restored, α_1 decreases until the contact between the crown and the boulder is broken [9-12].

Let's consider the stages of introducing the tool into the breed. The contact between the crown and the boulder can be maintained throughout the entire impact stage, in which case the movement of the projectile and the boulder are described by the equation. However, at certain ratios of stiffness C_1 and C_2 and mass t, and t, the contact between the crown and the boulder is broken before the completion of the stage of the tool introduced into the rock. Then the equation of motion of the projectile from the moment of violation of its contact with the boulder takes the form:

$$\alpha_1 = a'_{1\text{-}1} \sin(f'_1 t + \phi_1) \quad (5)$$

where: f – the oscillation frequency of the instrument; $a'_{1\text{-}1}$ – the displacement amplitude; ϕ_1 – the initial phase.

Variation frequency:

$$f'_1 = \sqrt{\frac{C_1}{m_1}} \quad (6)$$

The displacement amplitude is determined from the condition of equality of the kinetic energy of the tool to the work of the elastic force:

$$\frac{m(V_i)^2}{2} = \frac{(\alpha'_2+\alpha'_2)(P'_1-P_1 m)}{2} \quad (7)$$

where: V and α_1 – the speed of movement of the tool at the moment of violation of its contact with the rock; P'_1 – the value of the force on the crown-boulder contact at the time of violation of this contact; P_{1m} – the maximum force acting on the crown-boulder contact.

Hence, taking into account the fact that $P_1 \times m = C_1 {*} m \times a'_{1\text{-}1}$ we get:

$$a'_{1\text{-}1} = \sqrt{\frac{m(V'_1)^2 + C_1 \alpha_1{}^2}{C_1}} \quad (8)$$

The initial phase is determined from equation (5) by the known value a, at the time of breaking the contact between the crown and the boulder. Denote this value by a'_1 then:

$$\alpha'_1 = \alpha_m \sin\phi \quad (9)$$

Where: $\phi_1 \arcsin\frac{\alpha'_1}{\alpha_m}$

Thus, equation (2) and (5) allow us to calculate the dependence of the movements of boulder 2 and projectile a, on time t for different parameters of the shock system. The corresponding dependences of the contact forces P_2 and P_1 are obtained from the relations:

$$P_1 = C_1 \alpha_1 \quad (11)$$

$$P_2 = C_2 \alpha_2 \quad (12)$$

The analysis of the obtained dependences allows us to conclude that the value of contact forces and the proportion of energy transmitted to the face (boulder) depend on the ratio of the masses of the projectile and the boulder $m/m.$, and the stiffness at the crown-boulder contacts C_2/C_1 sand filler. The maximum energy transferred to the rock is observed at:

$$\frac{m_2}{m_1} 2uC_1 = C_2 \tag{13}$$

At these ratios, up to 90% of the energy is transferred to the boulder. With an increase in the C_2/C_1ratio, the share of transmitted energy decreases. So, at C_2/C_1=6, it decreases to 55%, and at C_2/C_1= 10 to 30%.

In real conditions, the stiffness of the sand aggregate is significantly less than the stiffness at the crown-boulder contact (C_1<<C_2). Therefore, the share of energy transmitted to a small boulder by shock pulses is extremely small. The impact energy is spent mainly on crushing the sand aggregate, and not on destruction (deepening of the face in the boulder). Shock pulses are damped, transmitted as if «into a pillow».

The most rational, technological method for drilling small boulders is to increase the hardness of the sand aggregate by plugging the bottom-hole part of the well. The grouting solution, penetrating the sand aggregate and seizing with it, forms a single monolith behind the face, which is further drilled. If the cementation interval is drilled, and the zone of small boulders continues, it is necessary to re-tampon the space behind the face and continue drilling. These operations should be continued until the interval of small boulders is completely passed [13].

To save time during the setting of the grouting material, it is necessary to move the drilling rig and drill adjacent wells of the arch.

This technological technique has received its full experimental confirmation. Other parameters of the drilling process mode (axial load, projectile rotation frequency, foam consumption, frequency, and height («pacing») the same as when drilling large boulders.

When drilling wells, soils were repeatedly encountered, represented by a sandy aggregate with small pebbles. The main difficulty of drilling sand and gravel soils was the partial jamming of the well. This phenomenon occurred due to a large amount of sludge accumulating on the recumbent wall of the well. Under such conditions, the energy of the reverse flow of the foam solution was not enough to clean the well. To remove the sludge, the shell layout was used, the distinctive feature of which was the presence of a screw rib on the drill pipes. Thus, when drilling sands with pebbles, it is rational to use a combined well cleaning method: the bottom-hole part of the latter at the location of the core pipe having transverse dimensions approaching the diameter of the well is successfully cleaned with foam solution, and the rest of the trunk is mechanically cleaned using a screw conveyor. To avoid jamming of the projectile, drilling was carried out with «pacing». To increase the productivity of the screw conveyor, the rotation speed of the projectile was increased to 30-40 rpm. The consumption of the foam solution was 1.5-2 l/min at a concentration of up to 1% surfactant [14.]

Conclusion. The analysis of the drilling results shows that the highest indicators of shift productivity of the order of 3.5-6.0 m/shift are achieved in the intervals from 0 to 6.0 m, provided the correct application of drilling technology. With an increase in the depth of the well, the indicators of shift productivity decrease due to an increase in the share of auxiliary work, the number of descent operations and adecrease in the voyage penetration, which is 1.5-2.5 m/shift. At the same time, the data obtained when drilling wells at intervals of more than 6.0 m should be considered preliminary, since there are significant reserves for increasing productivity, i.e.:

a)the choice of rational drilling technology depending on the mining and geological conditions of the traversed rocks;

b) drilling of the well with shortened (up to 1.0-1.5 m) flights, which will make it easier to carry out descent operations in an unclaimed well;

c) the use of foaming substances with a small concentration of up to 0.5% and a flow rate of 1.0-1.5 l/min, which will facilitate the removal of slurry from the well with special drill pipes.

The analysis of the experimental work carried out allows us to draw the following conclusions:

1.Column pneumatic shock-ejector complex with face cleaning foam provides satisfactory performance, stability, and permeability of the walls of wells, therefore it is suitable for industrial use in the construction of temporary support of underground workings at the facilities of Almatymetrostroy.

2. A rational technology for drilling soils of various compositions (large and small boulders, sand aggregate with pebbles) has been developed, providing trouble-free drilling of wells with satisfactory productivity.

3. The use of an ejector projectile and a screw rib normalizes the drilling process by preventing accidents associated with the jamming of the drill string in the well [15-16].

Gratitude. BR21881822 related «Development of technical solutions to optimize geological and technical operations during drilling and oil production at a late stage of field operation» according to Agreement No. 394-TFP-23-25 dated 11/15/2023 with the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

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