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Satbayev University

# Х А Б А Р Л А Р Ы

# ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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# DOUBLE-CHAMBER ROTARY TYPE DOWNHOLE HYDRAULIC MOTOR FOR DRILLING MULTIBRANCH WELLS

**Abstract.** Importance of wells drilling method in subsoil use is stated. In general, reliable geological material can be obtained by the method of multibranch wells construction. By technological capabilities, the most effective means -downhole hydraulic motors performing wells drilling without drill string rotation. According to analysis of information sources containing data about downhole motors in the world, among all of them (propeller, turbodrills, rotors), the corresponding to conditions of drilling wells with offshoots are rotor type hydraulic motors, small-size longwise, fitting into the curvature of deviation from the parent well.

Based on the new physical principle, structural layout of double-chamber rotary type downhole hydraulic motor was formed with multilayer reactive force moment that became the subject of research. Methodology of calculating hydraulic motor output parameters was developed, technical characteristics were identified: length –0.80 m, weight – 40 kg with housing diameter 88 mm.

Prototype model was manufactured, test was performed to check reproducibility of calculations and test data. By output parameters and technical characteristics, the prototype model has significant advantage over abroad analogue.

Introduction of hydraulic motor into the execution of drilling operations, scope of application of wells drilling is extended, cost of minerals prospecting and mining is reduced.

**Key words:** geology, prospecting, drilling, well, multi-hole, hydraulic motor, layout, parameters, characteristics.

In today's subsoil use, detection of mineable mineral depositsis possible at depths only, which raises exclusive standards to methods and means of geological exploration works execution.

The main method of geologic exploration – wells drilling identifying the accuracy of study objectsevaluation, selection of optimum schemes of subsequent development and cost of works.

In the paper [1] it was noted that the solution of task of drilling process optimization is complicated by uncertainty of decision-making situation expressed in multivectorness, multicriteriality, inaccuracy and many-valuedness. In the opinion of authors, to resolve such problems, it is necessary to use respective methods that are based on the results of geological-technical studies. The most remarkable of them is the method of obtaining generally reliable geological information by construction of multibranch wells with drilling of offshoots along the strike of productive strata.

In the area of hydrocarbons, opening of productive series by horizontal offshoots increases the filtering area and flow rate as compared to vertical by 2-4 times more at oil and 3-8 times at gas fields [2].

Comparatively safe and less costly means of drilling offshoots– downhole hydraulic motors fitting into the curvature of deviation from the parent well and performing the drilling process without drill string rotation. Experiments proved by practice showed that capacity losses for blank drill string rotation amount to 65-85% of the total power spent for drilling [3].

Known are hydraulic turbine downhole motors manufactured by Neyrfor (Schlumberger) and TurboPower (Halliburton): their turbodrills 10-15 m long comprise one or two turbine sections [4].

Also abroad the use was made of the driven rotor configurations and specifically designed PDC drill bits manufactured by BakerHughes, Halliburton and Schlumberger, which allow successful drilling of deviant directional and horizontal offshoots. Their disadvantage include the structural complexity and high cost of maintenance, and their price is comparable to rocket-and-space equipment [5].

Interesting technical solution was reflected in a patent of UK "Downhole hydro turbine motor with regulated bend angle" [6]. Its advantage is in the creation of favorable downhole conditions for offshoot kickoff and displacement from parent hole.

US patents [7-10] give schematic diagrams of downhole hydraulic motor components force interaction ensuring life prolongation and reliability of their work while drilling directional wells, especially turbo drills with improved performance characteristics.

Designers of Neftegazotekhnika research and development enterprise (Russia) managed to reduce the turbodrill length for drilling wells with drill bits with diameter of 215.9 mm from 25.7m to 8.8m, which allowed improvement of well and offshoots walls formation conditions [11].

Practice of downhole hydraulic motors operation in drilling of wells around the world [12-17] shows that main ideas for improvement of their design (propeller, turbodrills and rotor type) are aimed at the simplification of structure, extending of elements' functions, ensuring high accuracy of their interaction.

Analysis of known schemes and conditions of various types downhole hydraulic motors usability allowing making a conclusion that by design and technological capabilities, the most suitable for the construction of multibranch wells are hydraulic motors of rotor type, small-size longwise, low-consuming operating fluid.

However, the paper [18] notes that the main disadvantage of rotor type machines – vibration arising due to rotor rotation.

Based on analysis results and with account of the possibility of vibration occurring, on the basis of a new physical principle, design of double-chamber rotor hydraulic motor with multilayer reactive force moment [19,20] was formed. Hydraulic motor comprises internal nonrotating rotor 1 which is interacted with a power unit through bearing boxes, such power unit comprising upper (figure 1) and lower (figure 2) parts, disconnectably-rigidly connected with each other. The upper part of the power unit represents a housing 2, inside of which and with formation of external chamber a shaft 3 is hard-mounted set with hemispheric blades 4 and side ports 5 for feeding operating fluid to internal chamber. In the housing body 2, channels 6 are made for jet exhaust of operating fluid to hole annuity.

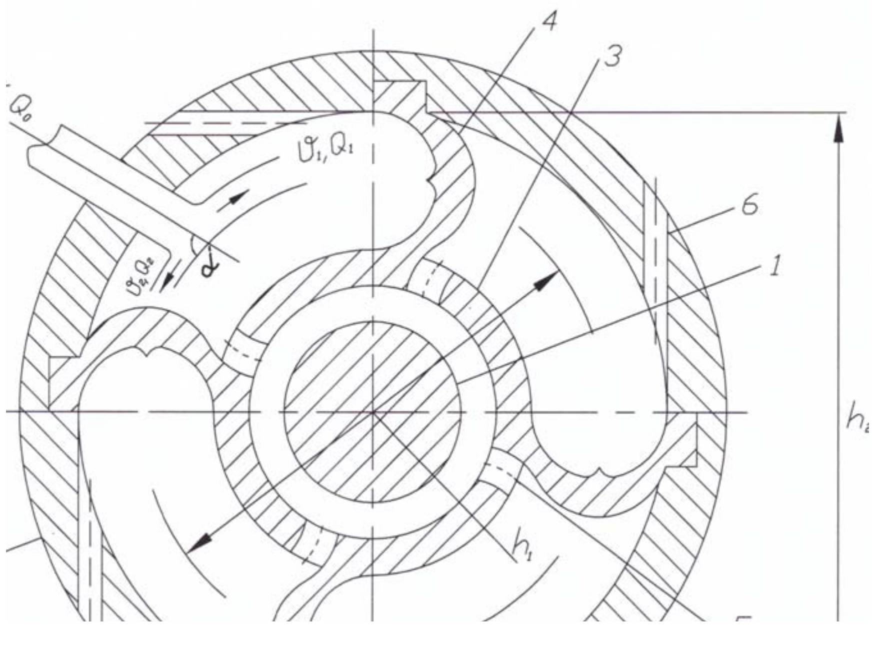


Figure 1 – Power unit upper part

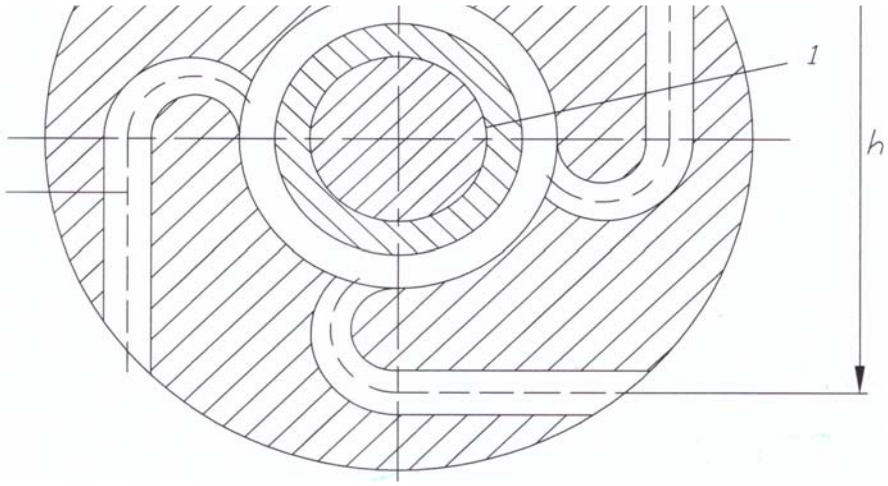


Figure 2 – Power unit lower part

On housing 7 of the power unit lower part, made are horizontal grooves8 departing from the internal chamber and with the turn entering to hole annuity oppositely to corotation of housings 2 and 7.

Principle of operation and calculation of double-chamber downhole rotor type hydraulic motor output parameters. Motor housing with diameter of 88 mm was chosen as an example.

When feeding along inclined channels at an angle αto horizontal,operating fluid downstream falls on the bottom of the external chamber along the direction of housing rotation 2. The apprise flow has a flow of $Q_0$, velocity $\vartheta_0$, and the flows diverging in opposite directions $Q_1$, $\vartheta_1$ and $Q_2$, $\vartheta_2$. to find excess pressure equivalent force Rlet's write down Euler theorem [21] in force projections on coordinate axes OXand OУ:

$$\begin{cases} P_0 * cos \propto = P_1 - P_2 \\ P_0 * sin \propto + R = 0 \end{cases} \quad (1)$$

where $P_0 = \rho * Q_0 * \vartheta_0$; $P_1 = \rho * Q_1 * \vartheta_1$; $P_2 = \rho * Q_2 * \vartheta_2{}'$

With account to $P_0$, $P_1$, $P_2$ and having assumed that flow velocity does not change, that is $\vartheta_0 = \vartheta_1 = \vartheta_2$:

$$\begin{cases} \rho * Q_0 * \vartheta_0 * cos \propto = \rho * Q_1 * \vartheta_1 - \rho * Q_2 * \vartheta_2 \\ \rho * Q_0 * \vartheta_0 * \sin \propto + R = 0 \end{cases} = \begin{cases} Q_0 * \cos \propto = Q_1 - Q_2 \\ R = -\rho * Q_0 * \vartheta_0 * \sin \propto{}' \end{cases} \quad (2)$$

where R – reaction of external chamber bottom, oppositely directed, but in value equal to $-P_0$;

It is known that $Q_0 = Q_1 + Q_2$. Let's make and solve system of equations with twounknowns:

$$\begin{cases} Q_0 = Q_1 + Q_2 \\ Q_0 * \cos \propto = Q_1 - Q_2 \end{cases} = \begin{cases} Q_1 = \frac{Q_0}{2} * (1 + \cos \propto) \\ Q_2 = \frac{Q_0}{2} * (1 - \cos \propto) \end{cases} \quad (3)$$

Oncoming fluid flow velocity depending on height Hof fluid feed can be written as follows:

$$\vartheta_0 = \sqrt{2 * q * H} \quad (4)$$

Force of flow impact on the external chamber bottom shall be as follows:

$$P_0 = \rho * Q_0 * \sin \propto \quad (5)$$

Depending on value of angle $\propto$, the major part of flow $Q_1$impacts a blade with bent surface, symmetrical with relation to line center of the external chamber in a circumferential direction. Form of blades execution in the form of hemisphere condition the turn of operating fluid flow by angle 180□, thus, doubled dynamic impact can be obtained [22].

$$P_1 = 2 * \rho * Q_1 * \vartheta_1 \quad (6)$$

When the operating fluid flow impacts on a series of alternating hemispheric blades, oncoming fluid flow rate will be

$$\vartheta_1 = \vartheta_0 - \vartheta_л , \qquad (7)$$

where $\vartheta_л = \frac{\pi * D * n}{1000*60}$ – blade speed ($D$ = housing diameter, $n$ – housing rotation frequency, deduced from experiments – 800 *r/min*).

With account to (3) and (7), expression (6) will be as follows:

$$P_1 = 2 * \rho * \frac{Q_0}{2} * (1 + \cos \propto) * (\vartheta_0 - \vartheta_л) \qquad (8)$$

Moment of force of operating fluid flow impact on the external chamber bottom, subsequently converted into rotation torque:

$$M_0 = P_0 * h_1, \qquad (9)$$

where h1 – distance between external chamber median lines in circum ferential direction.

Rotating blade torque:

$$M_1 = P_1 * h_1, \qquad (10)$$

Moment of operating fluid jet exhaust through channels 6 in the upper part of the power unit:

$$M_2 = P_1/2 * h_2, \qquad (11)$$

where $h_2$ - distance between opposite channels of the power unit upper part.

The remaining part of the flow enters the internal chamber through side ports 5:

$$P_2 = \rho * Q_2 * \vartheta_2 \text{or } P_2 = \rho * \frac{Q_0}{2} * (1 - \cos \propto) * \vartheta_0 \qquad (12)$$

Moment of operating fluid jet exhaust through grooves 8 of the power unit lower part:

$$M_3 = P_2 * h_3 \qquad (13)$$

where $h_3$ – distance between opposite grooves.

Cumulative torque of the housing with account of the number of sections of external and internal chamber and channels of the lower power unit:

$$\sum M = (M_0 + M_1 + M_2 + M_3) * 4 \qquad (14)$$

Baseline data for recalculation:

Inclination angle of operating fluid feeding channels, α = *45°*

Operating fluid density (water), ρ [kg/m$^3$] *1000*

Acceleration of gravity, g [m$^2$/s] *9,8*

Operating fluid flow rate, [m/s]

with H=100 m *44,27*

with H=300 m *76,68*

with H=500 m *99*

Length force lever, m

$h_1$ *0,057*

$h_2$ *0,07*

$h_3$ *0,064*

Results of calculating values of double-chamber downhole rotary type hydraulic motor output parameters are summarized in table 1.

Table 1 – Values of downhole hydraulic motor output parameters

| Output parameters | *H=100m* | | | *H=300m* | | | *H=500m* | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Q_0$, l/min | | | $Q_0$, l/min | | | $Q_0$, l/min | | |
| | *40* | *60* | *80* | *40* | *60* | *80* | *40* | *60* | *80* |
| $P_0$, *H* | 19.13 | 28.70 | 38.26 | 34.41 | 51.61 | 68.81 | 44.92 | 67.38 | 89.85 |
| $P_1$ | 46.19 | 69.28 | 92.38 | 83.07 | 124.61 | 166.14 | 108.46 | 162.70 | 216.93 |
| $P_2$ | 7.93 | 11.89 | 15.86 | 14.26 | 21.39 | 28.52 | 18.62 | 27.93 | 37.23 |
| $M_0$, *H*m* | 1.10 | 1.65 | 2.20 | 1.98 | 2.97 | 3.96 | 2.58 | 3.87 | 5.17 |
| $M_1$ | 2.66 | 3.98 | 5.31 | 4.78 | 7.16 | 9.55 | 6.24 | 9.35 | 12.47 |
| $M_2$ | 1.62 | 2.42 | 3.23 | 2.91 | 4.36 | 5.81 | 3.80 | 5.69 | 7.59 |
| $M_3$ | 0.51 | 0.76 | 1.01 | 0.91 | 1.37 | 1.83 | 1.19 | 1.79 | 2.38 |
| $\Sigma M$ | 23.56 | 35.24 | 47.0 | 42.32 | 63.42 | 84.60 | 55.24 | 82.40 | 110.44 |

With the purpose of checking the results of output parameters calculations, a prototype model of double-chamber hydraulic motor was tested on testing drilling bench equipped with twin circulation pump NB 320/63, flow meter PROMASS 40, tachometer IT-371 and pressure gauge MP-2. Obtained was satisfactory reproducibility of calculations and test data.

Table 2 below gives comparative characteristics of the prototype model of double-chamber hydraulic motor with series-produced propeller hydraulic motors Dyna-Drill of Smith Tool.

Table 2 – Comparative characteristics of series produced hydraulic motor prototype model

| Motor nominal size | Housing diameter, mm | Fluid flow rate, l/s | Differential pressure, MPa | Rotation frequency, rpm | Force moment, N*m | Length, m | Weight, kg |
|---|---|---|---|---|---|---|---|
| MS-98 Dyna-drill | 98 | 8,2 | 3,45 | 460 | 47,5 | 5,85 | 220 |
| Prototype model | 88 | 6-7 | 4,0 | 600-800 | 110,44 | 0,80 | 40 |

The data given prove that hydraulic motor prototype model with lower weight and length has considerable advantage over series-produced downhole motor.

Be values of output parameters and technical characteristics, a double-chamber downhole rotary type motor may become an effective means for the construction of multibranch wells for oil and gas, underground water, opening of geothermal fields. There are also preconditions that it will give a high-power impulse to the development of hydraulic borehole mining method, making process-oriented mine openings.

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## КӨПОҚПАНДЫ ҰҢҒЫЛАР БҰРҒЫЛАУҒА АРНАЛҒАН ҚОСКАМЕРАЛЫ АЙНАЛМАЛЫ ТҮПКІ ГИДРОҚОЗҒАЛТҚЫШ

**Аннотация.** Жер қойнауын пайдалану шаруасында ұңғы бұрғылау – айрықша маңызды. Көлемді, шынайы геологиялық ақпарат алу, көпоқпанды ұңғы жүргізу әдістемесі арқылы іске асырылады. Технологиялық мүмкіндігіне орай, олардың құрылысын жүргізуге ең тиімді құрал-ұңғыдағы гидроқозғалтқыштар, бұрғы жұмысын құбыр тізбегін айналдырмай іске асырады. Әлемдегі ұңғы қозғалтқыштар туралы мәлімдеме беретін ақпарат көзіне жасалған таңдау бойынша олардың ішіндегі (винтті, турбина және ротор) көпоқпанды ұңғылар жүргізу шартына сай келетіні – ротор түріндегісі ұзындығы қысқа, негізгі ұңғыдан бұралатын бүйірлі оқпанның радиусына енеді.

Жаңа физикалық заңдылықтар негізінде қоскамералы, ұңғыдағы гидроқозғалтқыштың айналмалы түрінің көпдеңгейлі кері тебу күші бар сызбасы анықталды, зерттеу нысаны болып белгіленді. Оның жұмыс көрсеткішін, құрылымын есептейтін әдістеме дайындалды: ұзындығы – 0,80 м, салмағы 40 кг, сыртқы бел сызығы 88 мм болатын тәжірибе үлгісіндегі гидроқозғалтқыш жасалды.

Теориялық есептеу нәтижесі, зертханадағы сынақ көрсеткіштері арқылы дәлелденді. Негізгі жұмыс көрсеткіштері жағынан үлгідегі гидроқозғалтқыш әлемдегі жаппай қолданыстағы өзі теңдес гидроқозғалтқыштардан әлдеқайда басым, тиімді.

Үлгідегі гидроқозғалтқыштарды бұрғы жұмысына енгізу арқылы ұңғы бұрғылау аясын кеңейтіп, барлау жұмыстарының пайдалы қазба байлықтарды өндірудің шығынын азайтады.

**Түйін сөздер:** геология, барлау, бұрғы, ұңғы, көпоқпанды, гидроқозғалтқыш, сызба, көрсеткіштер, мінездеме.

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## ДВУХКАМЕРНЫЙ ЗАБОЙНЫЙ ГИДРОДВИГАТЕЛЬ РОТОРНОГО ТИПА ДЛЯ БУРЕНИЯ МНОГОЗАБОЙНЫХ СКВАЖИН

**Аннотация.** Изложена значимость способа бурения скважин в сфере недропользования. Объемный, достоверный геологический материал можно получить посредством метода сооружения многозабойных скважин. По технологическим возможностям наиболее эффективное средство-забойные гидродвигатели осуществляющие бурения скважин без вращения бурильной колонны. По анализу источников информации, содержащих сведения о забойных двигателях в мире, из всех них (винтовые, турбобуры, роторы), соответствующими условиями проведения скважин с боковыми стволами являются гидродвигатели роторного типа, малогабаритные по длине, вписывающиеся в радиус кривизны отхода от основной скважины.

На основе нового физического принципа сформирована конструктивная схема двухкамерного забойного гидродвигателя роторного типа, с многоуровневым моментом реактивных сил, ставшая объектом исследований. Разработана методика расчета выходных параметров гидродвигателя, определены технические характеристики: длина – 0,80 м, масса 40 кг при диаметре корпуса 88 мм.

Изготовлен опытный образец, проведены эксперименты с целью проверки сходимости результатов расчета и данных эксперимента. По выходным параметрам и техническим характеристикам опытный образец имеет значительное преимущество над зарубежным аналогом.

Внедрением гидродвигателя в производство буровых работ, расширяется сфера применения бурения скважин, снижается стоимость разведки и добычи полезных ископаемых.

**Ключевые слова:** геология, разведка, бурение, скважина, многозабойное, гидродвигатель, схема, параметры, характеристики.

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