DNIPRO UNIVERSITY of TECHNOLOGY 1899

Mining of Mineral Deposits
Volume 14 (2020), Issue 3, 128-133

MMD JOURNAL / MINING.IN.UA

UDC 622.243.25 https://doi.org/10.33271/mining14.03.128

Design of bottom hole assemblies with two rock cutting tools for drilling wells of large diameter

Vasyl Moisyshyn[1]✉, Igor Voyevidko[1]✉, Vasyl Tokaruk[1*]✉

[1]*Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, 76019, Ukraine*

**Corresponding author: e-mail vasyl.tokaruk@gmail.com, tel. +380994854491*

Abstract

Purpose. A methodology development for calculating the bottom hole assemblies (BHA) with two rock cutting tools for drilling the wells of large-diameter with an ability to manage the trajectory.

Methods. A mathematical model has been developed for calculating the assemblies for drilling wells of large-diameter using two rock cutting tools – a bit and a reamer. The main technical and geological factors have been modelled, which influence the assembly elements (stress-strain state of the BHA, deflecting forces arising due to the rock influence). An algorithm for determining the distribution of axial load between the bit and the reamer has been developed. It has been modelled the formation of the reamer eccentrical displacement relative to the pilot wellbore and the change in the intensity of the wellbore curvature in the process of deepening. Further on, a practical calculation according to the developed methodology is given.

Findings. It has determined that an increase in the resource coefficient of cutting structure (that is, an increase in the total number of teeth on a bit, or a decrease in teeth on a reamer) leads to a decrease in the load on the bit. With an increase in the coefficient of destruction areas, the load on the bit decreases. It has been revealed that when drilling with assemblies, a significant influence on the stress-strain state of the BHA and on the change in deflecting forces, has an eccentricity on the reamer, while the intensity of the well curvature changes. It has been proven that the same assembly allows the well to be drilled with different curvature intensities, which can be adjusted by placing a restrictor under the reamer.

Originality. A new comprehensive approach is proposed to the calculation of assemblies with two rock cutting tools, which is different in that it allows to perform an iterative cyclic calculation with constant refinement of the main parameters and the creation of a data set for constructing a well trajectory.

Practical implications. The developed methodology for calculating the bottom hole assemblies with two rock cutting tools makes it possible to determine a rational design of the BHA for drilling a well in a specified direction by changing the design parameters of the drill collar (DC), supporting-centering elements (SCE), a bit, a reamer and an eccentricity restrictor.

Keywords: *well, rock cutting tools, reamer, drilling, pilot wellbore, eccentricity*

1. Introduction

1.1. Setting of a problem

Recently, the drilling of deep wells in Ukraine is an increasing part of the total volume of drilling operations. In the process of constructing deep wells, a significant part is accounted for drilling large-diameter wellbores, which is carried out by step-shaped assemblies using reamers.

Complex well designs involve inserting one- or two-dimensional large diameter strings to significant depths. Thus, at well No. 109 of the Tymofiiske Oil and Gas Condensate Field, it was planned to insert a conductor with a diameter of 508 mm to a depth of 350 m, and a string with a diameter of 340 mm to a depth of 2350 m. The drilling and inserting of large diameter strings at well No. 17 of the Semyrenkivske Gas Condensate Field (426-mm string to a depth of 240 m and 324-mm string to a depth of 3600 m) were approximately the same difficult. Thus, the problem arose of shaping wellbores with a diameter of 660 mm and 394 mm to great depths, and later inserting the strings with a diameter of 426 and 324 mm into these wells.

The lack of upgraded rock cutting tools and bottom hole assemblies to manage the well trajectory resulted in low drilling velocities. Therefore, when designing the technologies for drilling the upper intervals using large-diameter rock cutting tools, the task arose of how to combine effective drilling with the formation of the design well trajectory.

1.2. Recent research analysis

For drilling large-diameter wellbores in foreign practice, step-shaped bits are widely used [1], as well as drilling with the use of eccentric reamers set in the BHA, which allow to make an underreaming in certain areas, since their functional diameter can be changed [2]. It is expedient to use this method when drilling in salt deposits or intervals where the wellbore can be narrowed for other reasons. If it is necessary to expand to large diameters, it is possible to use several eccentric reamers at the same time or combinations of such reamers with conventional and hard-alloy teeth [3][4]. However, for the construction of a wellbore with a diameter of more than 393.7 mm with the ability to manage the well trajectory, it is rational to use an option with two or more rock cutting tools included in the BHA – a pilot bit and a pin-and-roller type reamer [5]-[7]. In the existing methodology for calculating this type of BHA, developed by L.A. Raikhert and I.M. Friz [8], the deflecting forces acting on the rock cutting tools due to the bending of the assembly axis, the angle of lack of axes coincidence of the pilot and main sections of the step-shaped assembly and the effect of the eccentricity value on the stress-strain state of the assembly are not taken into account. Therefore, the results of calculating the step-shaped BHA according to the specified methodology only in the first approximation reflect their operation.

When constructing large-diameter wellbores, other methods are often used to form the wellbores of the final diameter. One of such methods is the use of bicentric bits or pilot eccentric reamers for drilling with a simultaneous underreaming the area of angle buildup in medium-hard rocks.

Using the experience of drilling with eccentric bits, concentric hard-alloy bits have been developed, which, due to the setting of teeth on the entire annular surface, provide a higher drilling velocity, allow for increased advance per bit and drill the wellbore with greater accuracy. The pilot part of the bit is 75-80% of its entire surface area [1].

The advantages of using this type of bits include the drilling velocity, which is equal to the drilling velocity of standard hard-alloy bits, drilling with simultaneous wellbore underreaming, and reduction of well construction costs by saving round-trip time. The main disadvantage is the high cost of bicentric bits compared to standard bits.

Previously, the authors studied the specifics of drilling large-diameter wellbores using two rock cutting tools [9] with the ability to control eccentricity during drilling, as well as an analysis of the process of deepening a well when drilling conventionally vertical and inclined-directed wells [10][12].

1.3. Identifying previously unresolved parts of a common problem

When drilling with two rock cutting tools, deflecting forces arise, leading to lateral drift of the assembly, and, accordingly, to wellbore curvature. Since drilling with step-shaped assemblies is mainly carried out in intervals of low- to medium-hard rocks, the curvature intensity can reach values that, ultimately, cause complications. Therefore, when choosing an assembly that will ensure that the well trajectory meets the design requirements, all factors affecting the drilling process should be taken into account.

1.4. Formulation of the work purpose and setting objectives

The purpose of the paper is to develop a new methodology for calculating the BHA with two rock cutting tools and supporting-centering elements, which makes it possible to take into account a complex of deflecting factors of a geological and technical nature.

To achieve this purpose, the following main research objectives should be solved:

1. Development of a methodology for designing the bottom hole assemblies with two rock cutting tools.
2. Development of a method for calculating the axial load distribution between the bit and the reamer.
3. Designing a BHA which includes a bit, a reamer and a different number of supporting-centering elements at several ratios of the diameters of the pilot wellbore and main wellbore, for various tasks of directional (prevention-of-curvature) drilling, under various geological conditions.

2. Methods

According to the methodology developed by the authors, the BHA calculation cycle (at a certain interval) is divided into four stages:

1. The axial load distribution between the bit and the reamer is calculated.
2. The stress-strain state of the bottom hole assembly with two rock cutting tools, as well as the deflecting forces on the rock cutting tools formed by geological factors are calculated, and the resulting deflecting forces on the bit and the reamer are determined.
3. The eccentricity on the reamer and the bit is calculated.
4. The intensity of well curvature is determined.

At the first stage, the distribution of the axial load between the bit and the reamer is calculated. When predicting the axial load distribution, some basic research results of the rocks destruction process have been adopted [13][14]:

– volumetric rock destruction occurs with a good face cleaning;
– cutting structure of a bit and a reamer is of the same type;
– the rock volume of the destruction zone is directly proportional to the load on the tooth.

Theoretical studies are conducted using a deterministic approach for predicting the oriented rate values of the rolling bits penetration.

Figure 1 shows the scheme of assembly with two rock cutting tools. For a certain number of revolutions, rock cutting elements destroy the different volume of rock. If at the beginning of drilling the cutting capacity of the bit and the reamer is different, then over time the axial load is automatically redistributed between them until they start to work synchronously, that is, the lateral displacements of the bit h_b and the reamer h_{ho} will be equal.

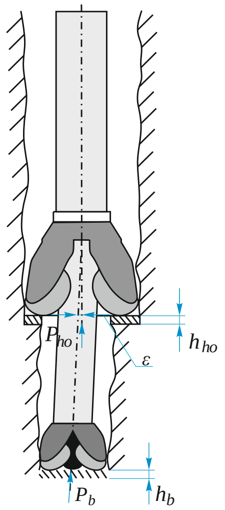

Figure 1. Scheme of assembly with two rock cutting tools

The load on the bit is determined by the formula:

$$P_b = \frac{P}{1 + n_r \cdot k_d \cdot a_i \cdot k_f \cdot k_\sigma}, \quad (1)$$

where:

P – the total axial load;

n_r – resource indicator of the cutting structure of rock cutting tools;

k_d – coefficient of operational dynamics of rock cutting tools;

a_i – kinematic coefficient of rock cutting tools;

k_f – coefficient of the destruction areas of the step and the face;

k_σ – mine rock hardness ratio under bit and reamer.

In its turn:

$$n_r = \frac{z_{tb} \cdot n_{cb}}{z_{tho} \cdot n_{cho}}, \quad (2)$$

where:

z_{tb}, n_{cb}, z_{tho}, n_{cho} – the number of teeth and rollers of the bit and the reamer, respectively.

$$a_i = \frac{i_b}{i_{ho}}, \quad (3)$$

where:

i_b, i_{ho} – gear ratios of the bit and the reamer.

$$k_f = \frac{F_{ho}}{F_b}, \quad (4)$$

where:

F_{ho}, F_b – area of rock destruction by a bit and a reamer.

$$k_d = \frac{k_{db}}{k_{dho}}, \quad (5)$$

where:

k_{db}, k_{dho} – coefficients of applied loads dynamism (depends on the time of the tooth contact with the rock).

$$k_\sigma = \frac{\sigma_{rho}}{\sigma_{rb}}, \quad (6)$$

where:

σ_{rho}, σ_{rb} – rock hardness under reamer and bit, respectively.

3. Results and discussion

Having analyzed equations (1), it can be concluded that the design peculiarities of these rock cutting tools, namely, the number and diameter of rollers, the number of teeth on the roller, have a significant influence on the distribution of the axial load between the bit and the reamer, which is actually taken into account in the resource indicator of the cutting structure. The dependence of the load distribution on the change in this indicator is shown in Figure 2.

This graph shows that an increase in the resource coefficient of cutting structure, that is, an increase in the total number of teeth on a bit, or a decrease in teeth on a reamer leads to a decrease in the load on the bit. Figure 3 shows a dependency graph of the load distribution on the ratio of the destruction areas of the bit and reamer.

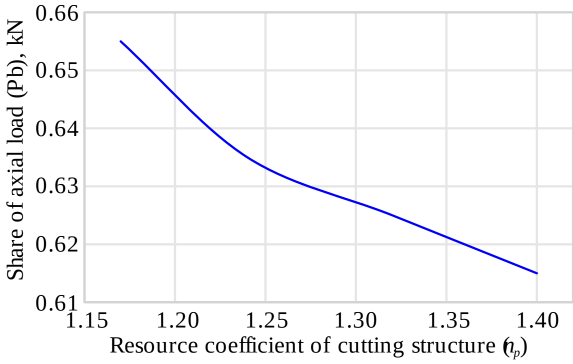

Figure 2. Dependency graph of the load distribution between the bit and the reamer on the change in the resource coefficient of cutting structure

Figure 3. Graph of dependence between the bit and the reamer on the change in the ratio of the destruction areas

Based on this graph, it can be concluded that with an increase in the coefficient of destruction areas, the load on the bit decreases.

At the second stage, based on solving the differential equations of the bent axis of the assembly, the stress-strain state of the BHA with two rock cutting tools is calculated, and the technical deflecting forces on the contact elements are determined [15]-[17].

In addition, the geological components of the deflecting forces on rock cutting tools are calculated taking into account the rock hardness, drilling anisotropy index and the angle of the seams incidence [8]:

$$F_{g.l.b} = 0.5 \cdot \sigma_r \cdot S_b \cdot h_b \cdot \sin 2(\gamma - \alpha); \quad (7)$$

$$F_{g.l.ho} = 0.5 \cdot \sigma_r \cdot S_{ho} \cdot h_b \cdot \sin 2(\gamma - \alpha), \quad (8)$$

where:

σ_r – rock hardness according to a stamp;

S_b, S_{ho} – the contact surface area of the bit and the reamer with the face, respectively;

h_b – drilling anisotropy index of the mine rock;

γ – angle of the rock incidence;

α – zenith angle of the well inclination.

The resulting deflecting forces on the bit and the reamer are determined by the difference between the technical and geological components acting on the corresponding element:

$$F_{r.l.b} = F_{g.l.b} - F_{t.l.b}; \quad F_{r.l.ho} = F_{g.l.ho} - F_{t.l.ho}, \quad (9)$$

where:

$F_{t.l.b}$, $F_{t.l.ho}$ – technical components of the deflecting force on the bit and the reamer.

At the third stage, the eccentricity on the reamer is calculated by determining the lateral displacements on the rock cutting tools, taking into account the data obtained using the formulas (9) [18]:

$$h = \frac{V}{S} = \frac{0.5 \cdot L_{pt} \cdot n_{tp} \cdot n_c \cdot F_{r.l.} \cdot K_P \cdot n}{R \cdot h_{sh}}, \quad (10)$$

where:

L_{pt} – tooth diameter and length of its movement trajectory;

n_{tp}, n_c – the number of teeth on the peripheral rim of the roller and the number of rollers on the rock cutting tool;

$F_{r.l.}$ – resulting deflecting force;

K_p – slope coefficient, inversely proportional to the rock hardness according to a stamp;

n – number of rollers revolutions;

R – rock cutting tool radius;

h_{sh} – support surface height.

The eccentricity value is determined by the formula:

$$\varepsilon = h_{ho} - h_b, \quad (11)$$

where:

h_b, h_{ho} – lateral displacement on bit and the reamer, respectively.

At the fourth stage, the intensity of the well curvature and its direction are determined [19][20]:

$$\frac{d\alpha}{dS} = \frac{2}{L}\Phi_\alpha = \frac{2}{L}\left(\beta_0 + k\frac{F_{t.l.}}{P}cos\rho + \frac{h}{2}\sin 2\omega \cos\sigma\right), \quad (12)$$

where:

L – length of the guide section from the bit to the first point of the BHA contact with the well wall;

$\beta_0 = \frac{D_b - D_C}{2 \cdot L}$ – angle of lack of axes coincidence;

D_b, D_C – diameter of the bit and supporting-centering element, respectively;

k – coefficient of bit milling capacity;

$F_{t.l.}$, P – deflecting force and axial load on a bit, respectively;

h – drilling anisotropy index;

$\omega = \arcsin\left\{\frac{\cos\left[\alpha - arctg\left(tg\gamma\cos\phi_n\right)\right]\cos\gamma}{\cos\left[arctg\left(tg\gamma\cos\phi_n\right)\right]}\right\}$ – the angle of bit meeting with the seam plane of the geological structure;

γ – the angle of the seams incidence;

φ_n – well direction in relation to the rise of the seams;

$\sigma = \arcsin\left(\frac{\sin\gamma \cdot \sin\phi_n}{\cos\omega}\right)$ – the angle between the apsidal plane and the plane of action of the deflecting anisotropy factor.

Having made these calculations, the refined values of the eccentricity and intensity of the well curvature can be obtained, and hence the zenith angle. In the initial BHA calculation, it is assumed that the eccentricity value ε is equal to 0. To calculate the next interval, the value is used of the last calculation cycle, which allows to perform interval modelling of the well deepening process and track the change in the main parameters (when choosing the appropriate average rate of penetration in certain rocks, obtained by analyzing industrial data and using the number of the drill string revolutions over a certain period).

Using the described above methodology, the calculations have been made of the BHA with two rock cutting tools at various ratios of bit and reamer diameters.

Figures 4 and 5 show the graphs of changes in the intensity of the wellbore curvature with deepening of the well and with a change in eccentricity. The calculation was made for different values of the destruction areas coefficients:

– 0.78 – for an assembly: bit Ø295.3 mm, DC-203, SCE Ø295 mm, DC-203, reamer Ø393.7 mm, DC-203 – 5 m, SCE Ø393 mm, DC-203;

– 0.99 – for an assembly: bit Ø393.7 mm, DC-203, SCE Ø393 mm, DC-203, reamer Ø555 mm, DC-229 – 5 m, SCE Ø554 mm, DC-229.

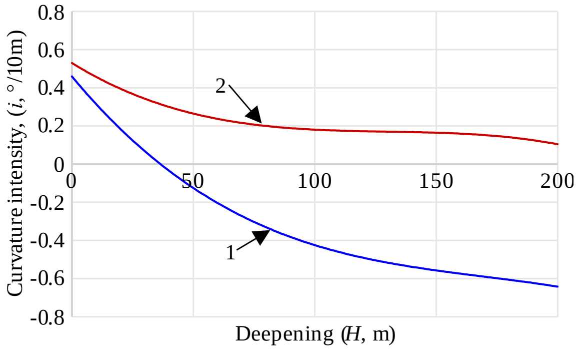

Figure 4. Graphs of a change in the curvature intensity with deepening the well: 1 – bit Ø393.7 mm, reamer Ø555 mm; 2 – bit Ø295.3 mm, reamer Ø393.7 mm

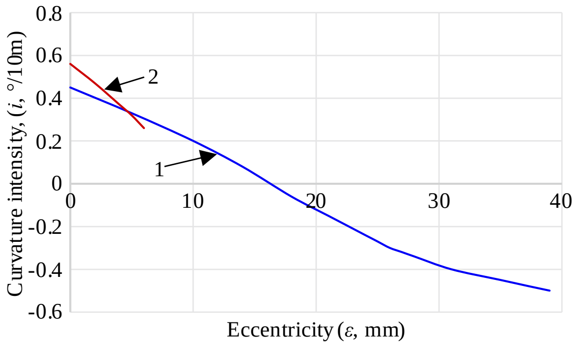

Figure 5. Graphs of a change in the curvature intensity with a change in eccentricity: 1 – bit Ø393.7 mm, reamer Ø555 mm; 2 – bit Ø295.3 mm, reamer Ø393.7 mm

Geological conditions: zenith angle – $\alpha = 2°$, anisotropy index $h_b = 0.015$; angle of the seams incidence – 30°, rock hardness according to a stamp σ_r – 1500 MPa. Based on the analysis of industrial data, the average rate of penetration in medium-hard rocks is taken equal to 1 m/h.

Based on the directional drilling tasks, the assemblies with two rock cutting tools can be divided into two types:

– assemblies for drilling conventionally vertical wells with the zenith angle stabilization;

– assemblies for drilling the wells with a change in the zenith angle (increase or decrease).

Since when drilling with these assemblies, the eccentricity on the reamer has a significant influence on the stress-strain state of the BHA and, as a result, on the change in deflecting forces, the intensity of the curvature will change accordingly. That is, the same assembly allows the well to be drilled with different curvature intensities, which can be adjusted by placing a restrictor under the reamer.

Analyzing the graphs in Figures 4 and 5, it can be concluded that, in the general case, for this type of assemblies with an increase in eccentricity, the curvature intensity reaches zero, after which it begins to grow in the opposite direction. For the 2nd type of BHA, this value is stabilized at 0.13°/10 m with an eccentricity value of 6 mm, and with further deepening, there is a tendency to a slight decrease in the curvature intensity. For the 1st type of BHA, the increase in eccentricity leads to a decrease in the value of the curvature intensity to 0°/10 m (at $\varepsilon = 17$ mm), which allows to achieve stabilization of the drilling direction. A further increase in eccentricity will be accompanied by a well curvature in the direction opposite to the initial, that is, with a change in azimuth by 180°.

Figure 6 shows the graphs of a change in the zenith angle during the well deepening for assemblies with different standard sizes of rock cutting tools.

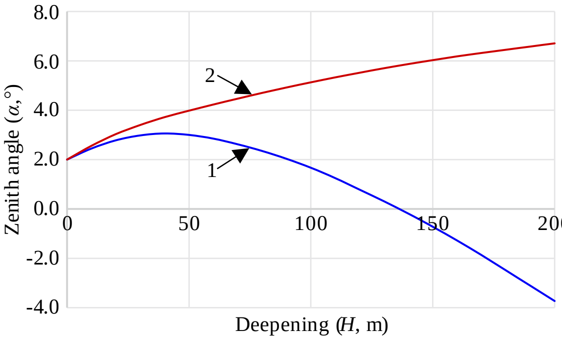

Figure 6. Graphs of a change in the zenith angle with deepening the well: 1 – bit Ø393.7 mm, reamer Ø555 mm; 2 – bit Ø295.3 mm, reamer Ø393.7 mm

For the 2nd type of assembly, an increase in the zenith angle is observed with an intensity that decreases with the well deepening. For the 1st type of BHA, at first, the zenith angle increases up to 3°, after which the inclination angle decreases, that is, the well is curved in the direction opposite to the initial direction. This effect is observed due to a change in the difference between the geological and technical components of the deflecting force on rock cutting tools. An increase in the eccentricity value leads to an increase in the technical components of the deflecting force, which in turn leads to a decrease in the resulting forces. The value of the geological component of the deflecting force changes insignificantly during the drilling process, since the main factor that has an influence on its value is the zenith angle, the values of which are in a quite narrow range.

4. Conclusions

1. A new methodology is proposed for calculating the BHA during the drilling process, which takes into account the ratio of technical and geological factors acting on the rock cutting tools and causing eccentric displacement of the reamer relative to the pilot wellbore.

2. A new methodology has been developed to determine the distribution of the axial load between the bit and the reamer in the process of deepening the well, and the main factors impact has been determined on the share of loading on each of the rock cutting tools.

3. A practical calculation has been made of assemblies with different ratios of destruction areas under the same geological conditions, which makes it possible to choose the rational BHA options for various tasks of directional drilling.

Acknowledgements

The experimental results have been obtained without any support of grants or projects. The authors express their gratitude to Doctor of Technical Sciences, Professor I.I. Chudyk for advice and support in the process of obtaining research results.

References

[1] Al-Mayyan, H., Malik, A., Sumait, B., Fayed, M., Khalil, K., & Khalil, A. (2016). New concentric dual diameter fixed cutter technology bit drills 56 faster and saves operator drilling time in directional application through challenging abrasive sandstone in one of the largest reservoirs in the Middle East. In *Abu Dhabi International Petroleum Exhibition & Conference* (p. 13). Abu Dhabi, United Arab Emirates: SPE. https://doi.org/10.2118/183381-ms

[2] Jardinez, A., Guzman, G., Karrer, C., Murillo, R., Verano, F., Araujo, J.C., & Lopez, J.R. (2014). Advanced FEA modeling produces first directional tandem reamer BHA: eliminates trip on deepwater exploration well. In *IADC/SPE Drilling Conference and Exhibition* (p. 14). Austin, Texas, United States: SPE. https://doi.org/10.2118/167925-ms

[3] Da Silva, L.P., Paixao, D., Kishi, A.R.K., & Silva, A.R. (2010). Hole enlargement in Brazilian. *SPE Latin American and Caribbean Petroleum Engineering Conference* (p. 10). Lima, Peru: SPE. https://doi.org/10.2118/139300-ms

[4] Raziyev, M., Liang, Q.J., Syaifullah, N., Tang, K.H., Lee, S.L., & Willis, S. (2011). Dual eccentric reamer BHA solves hole opening challenges and conductor sharing pass through constraints. In *SPE Asia Pacific Oil and Gas Conference and Exhibition* (p. 10). Jakarta, Indonesia: SPE. https://doi.org/10.2118/145864-ms

[5] Burimov, J., Kopylov, A., & Orlov, A. (1975). *Burenie verchnich intervalov glubokich skvazhin bol'shogo diametra*. Moskva, Rossiya: Nedra.

[6] Mason, C., Wenande, B., & Chen, D.C.-K. (2007). Supersize hole creates drilling opportunity. *SPE Annual Technical Conference and Exhibition* (p. 13). California, United States: SPE. https://doi.org/10.2118/108427-ms

[7] Rasheed, W., & Zhou, S. (2009). Uncertainty and costs in drilling and completion: innovative underreamer verifies wellbore diameter in real-time. In *Middle East Oil & Gas Show and Conference* (p. 10). Manama, Bahrain: SPE.

[8] Raykhert, L., & Fryz, I. (1985). Napravlenoe burenie skvazhin v anizotropnykh porodakh rotornym sposobom stupenchatymi KNBK. *Trudy VNIIBT*, (61).

[9] Voyevidko, I., Oleksiuk, M., & Tokaruk, V. (2018). Spetsyfika burinnia sverdlovyn velykoho diametra z vykorystanniam dvokh porodoruinivnykh instrumentiv. *Naftohazova Haluz Ukrainy*, (1), 1-10.

[10] Voyevidko, I., & Tokaruk, V. (2018). Proektuvannia komponovok nyzu burylnoi kolony z dvoma porodoruinivnymy instrumentamy dlia burinnia sverdlovyn v zadanomu napriamku. *Rozvidka ta Rozrobka Naftovykh i Hazovykh Rodovyshch*, (2), 8-13.

[11] Voyevidko, I., & Tokaruk, V. (2018). Razrabotka KNBK s dvumya porodorazrushayushchimi elementami dlya bureniya uslovno vertikal'nykh skvazhin diametrom 660 mm. *Vestnik Belorussko-Rossiyskogo Universiteta*, (1), 9-15.

[12] Voyevidko, I., & Tokaruk, V. (2019). Rozrakhunok KNBK z dvoma porodoruinuiuchymy instrumentamy dlia burinnia sverdlovyn ø555 mm z naborom zenitnoho kuta. *Naftohazova Haluz Ukrainy*, (6), 9-15.

[13] Hrechyn, E. (2006). *Raschety neorientiruemykh komponovok dlya bureniya naklonnykh i horizontalnykh skvazhin*. Tyumen, Rossiya: Neftehazovyy unyversytet.

[14] Meyer-Heye, B., Reckmann, H., & Ostermeyer, G.-P. (2010). Weight distribution in reaming while drilling BHAs. *IADC/SPE Drilling Conference and Exhibition* (p. 10). New Orleans, United States: IADC/SPE. https://doi.org/10.2118/127094-ms

[15] Voyevidko, I. (2007). *Rozrobka naukovo-metodychnykh osnov ta tekhnichnykh zasobiv dlia pidvyshchennia tochnosti provedennia naftohazovykh sverdlovyn v zadanomu napriami*. Ivano-Frankivsk, Ukraina: IFNTUNG.

[16] Chudyk, I., & Kozlov, A. (2006). Vplyv kryvyzny stovbura sverdlovyny na statychni formy rivnovahy neoriientovanykh KNBK. *Naukovyi Visnyk IFNTUNH*, (1), 5-10.

[17] Yanturyn, R. (2005). *Sovershenstvovanie metodov raschetov parametrov komponovok niza burilnoy kolonny i ikh elementov dlya bezorientirovannoho bureniya*. Ph.D. Ufa, Rossiya.

[18] Shreyner, L. (1950). *Fizicheskie osnovy mekhaniki gornykh porod*. Moskva, Rossiya: Gostoptekhizdat.

[19] Grigulets'kiy, V. (1988). *Optimal'noe upravlenie pri burenii skvazhin*. Moskva, Rossiya: Nedra.

[20] Hulyzade, M., & Mamedbekov, O. (1982). Raschet tempa prostranstvennoho iskrivleniya naklonnykh skvazhin pri burenii neorientirovannymi KNBK. *Teoriya i Praktika Bureniya Naklonnykh Skvazhin*, (1), 63-69.

Проектування компоновок низу бурильної колони з двома породоруйнуючими елементами для буріння стовбурів великого діаметра

В. Мойсишин, І. Воєвідко, В. Токарук

Мета. Розробка методики розрахунку компоновок низу бурильної колони (КНБК) з двома породоруйнівними інструментами для буріння свердловин великого діаметра з можливістю керування траєкторією.

Методика. Розроблено математичну модель розрахунку компоновок для буріння свердловин великого діаметра із використанням двох породоруйнівних інструментів – долота та розширювача. Змодельовані основні технічні й геологічні фактори, що мають вплив на елементи компоновки (напружено-деформований стан КНБК, відхиляючі сили, які виникають через вплив породи). Створено алгоритм для визначення розподілу осьового навантаження між долотом і розширювачем. Змодельовано формування ексцентричного зміщення розширювача відносно пілотного стовбура та зміну інтенсивності викривлення стовбура у процесі поглиблення. Далі наведено практичний розрахунок згідно розробленої методики.

Результати. Встановлено, що зростання коефіцієнта ресурсу озброєння (тобто збільшення сумарної кількості зубців на долоті, або їх зменшення на розширювачі) призводить до зменшення навантаження, що припадає на долото. Зі збільшенням коефіцієнта площ руйнування навантаження на долото зменшується. Виявлено, що при бурінні з компоновками значний вплив на напружено-деформований стан КНБК і на зміну відхиляючих сил, має ексцентриситет на розширювачі, при цьому змінюється інтенсивність викривлення свердловини. Доведено, що одна й та сама компоновка дозволяє проводити свердловину з різною інтенсивністю викривлення, яку можна регулювати за допомогою встановлення обмежувача під розширювачем.

Наукова новизна. Запропоновано новий комплексний підхід до розрахунку компоновок з двома породоруйнівними інструментами, який відрізняється тим, що дозволяє проводити ітераційний циклічний розрахунок з постійним уточненням основних параметрів і створенням масиву даних для побудови траєкторії свердловини.

Практична значимість. Розроблена методика розрахунку компоновок низу бурильної колони з двома породоруйнівними інструментами дозволяє визначити раціональну конструкцію КНБК для буріння свердловини в заданому напрямку за рахунок зміни конструктивних параметрів ОБТ, опорноцентрувальних елементів, долота, розширювача і обмежувача ексцентриситету.

Ключові слова: *свердловина, породоруйнівні інструменти, розширювач, буріння, пілотний стовбур, ексцентриситет*

Проектирование компоновок низа бурильной колонны с двумя породоразрушающими элементами для бурения стволов большого диаметра

В. Мойсишин, И. Воевидко, В. Токарук

Цель. Разработка методики расчета компоновок низа бурильной колонны (КНБК) с двумя породоразрушающими инструментами для бурения скважин большого диаметра с возможностью управления траекторией.

Методика. Разработана математическая модель расчета компоновок для бурения скважин большого диаметра с использованием двух породоразрушающих инструментов – долота и расширителя. Смоделированы основные технические и геологические факторы, влияющие на элементы компоновки (напряженно-деформированное состояние КНБК, отклоняющие силы, возникающие из-за влияния породы). Создан алгоритм для определения распределения осевой нагрузки между долотом и расширителем. Смоделировано формирование эксцентричного смещения расширителя относительно пилотного ствола и изменение интенсивности искривления ствола в процессе углубления. Далее приведен практический расчет согласно разработанной методики.

Результаты. Установлено, что рост коэффициента ресурса вооружения (то есть увеличение суммарного количества зубцов на долоте, или их уменьшение на расширителе) приводит к уменьшению нагрузки, приходящейся на долото. С увеличением коэффициента площадей разрушения нагрузка на долото уменьшается. Выявлено, что при бурении с компоновками значительное влияние на напряженно-деформированное состояние КНБК и на смену отклоняющих сил, имеет эксцентриситет на расширителе, при этом изменяется интенсивность искривления скважины. Доказано, что одна и та же компоновка позволяет проводить скважину с разной интенсивностью искривления, которую можно регулировать посредством установления ограничителя под расширителем.

Научная новизна. Предложен новый комплексный подход к расчету компоновок с двумя породоразрушающими инструментами, который отличается тем, что позволяет проводить итерационный циклический расчет с постоянным уточнением основных параметров и созданием массива данных для построения траектории скважины.

Практическая значимость. Разработана методика расчета компоновок низа бурильной колонны с двумя породоразрушающими инструментами, позволяющая определить рациональную конструкцию КНБК для бурения скважины в заданном направлении за счет изменения конструктивных параметров ОБТ, опорноцентрированных элементов, долота, расширителя и ограничителя эксцентриситета.

Ключевые слова: *скважина, породоразрушающие инструменты, расширитель, бурение, пилотный ствол, эксцентриситет*

Article info

Received: 15 April 2020
Accepted: 28 August 2020
Available online: 4 September 2020