Petroleum Science and Engineering
2017; 1(1): 10-16
http://www.sciencepublishinggroup.com/j/pse
doi: 10.11648/j.pse.20170101.13

Influence of Eccentrically Located Drilling String in the Well Bore Over Cleaning Capabilities of a Wellbore

Igor Chudyk*, Oleg Vytyaz, Volodymyr Hrymaniuk, Andrii Pastukh

Department of Drilling of Oil and Gas Wells, Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine

Email address:
chudoman@ukr.net (I. Chudyk), o.vytyaz@gmail.com (O. Vytyaz), tdcentre@nung.edu.ua (V. Hrymaniuk), drill@nug.edu.ua (A. Pastukh)
*Corresponding author

To cite this article:
Igor Chudyk, Oleg Vytyaz, Volodymyr Hrymaniuk, Andrii Pastukh. Influence of Eccentrically Located Drilling String in the Well Bore Over Cleaning Capabilities of a Wellbore. *Petroleum Science and Engineering.* Vol. 1, No. 1, 2017, pp. 10-16. doi: 10.11648/j.pse.20170101.13

Received: December 20, 2016; **Accepted**: January 10, 2017; **Published**: February 6, 2017

Abstract: It has been analyzed solution to the problem of definition eccentric location of the drill string in the hole using analytical studies and modern systems of mathematical computer modeling. Practical implementation of technological problem solution was represented as calculated parameters of the formation and changes in the area of stagnant zones in the cross section of the annular space hole in certain baseline characteristics of the process of washing. As a result, studies have found that at lower eccentric placement of both direct and deformed drill string in the well drilling mud flow looks like sickle core flow. The maximum speed of mud while inside the nucleus, and the minimum - in the contact zones flexible pipe and the borehole wall. This change dependencies hydraulic pressure loss pumping mud pump flow rate and distribution of nuclei along the axis of the drill string at its eccentric location in the borehole. It has been determined the conditions of dead mud zones formation in the annular space and offered solutions to solve this problem.

Keywords: Annular Space, Rinsing Well, Dead Mud Zone, Mud

1. Introduction

Energy consumption during drilling and formation of cylindrical excavation in rock is divided into interrelated processes of rotation and axial movement of the drill string in the hole, destruction of the rock face and washing out a well. In addition, the process of overcoming of the frictional forces between the drill string and the wall of the hole consumes about 10-15% of the energy rig. Another procedure of bottomhole destruction by drill bit consumes from 10 to 15% of energy, and to perform descent-lifting operations 5-10%. The greatest ammount of the energy that is consumed during the process of drilling (60-75%) goes to clean the well (clean face of drill out species, removal of cuttings to the surface, overcoming hydraulic resistance rubbing mud on the way to his movement, and others.) [1], [2], [3], [4], [5], [6]. Because of huge energy loses while drilling process for its washing out, there is a need to study the factors of their increase, how to manage them and reduce their amount.

The trend towards an increase in ultradeep drilling, deviated and horizontal wells in large proportion determines the increase in the share of unproductive loss of energy to overcome the resistance of the environment and its reduction in terms of fracture rock. This leads to the need of design approaches improvement, selection and implementation of efficient drilling technologies, tacking into account an important mining and geological, technical and technological factors and problems. These factors applies in particular problems of formation of dead mud zones in the annular space of horizontal wells through special sites (eccentric) location in its drill string, [7], [8], [9], [10]. This leads to the accumulation of sludge in the annular space of the well, the deterioration of axial displacement and rotation of the drill string during drilling, it differential sticking, reduces drilling speed and reduce energy transition to a bit [2], [4]. Dead mud zone is the are out of the drilling string where the movement of drilling mud is limited or absent.

2. Relevance of the Research Problem

Due to the multi-factor process of washing wells, difficulties related with establishing the degree of influence of the eccentric position of the column in the well and its impact on changing hydraulic resistance, the question that remains poorly understood. This article summarizes some of the results of earlier research in this area.

Thus, for the first time in [2] considered the problem of investigations process flow of Newtonian fluid in a channel with full eccentric circular cross-section. The research found that in laminar fluid flow mode, the same pressure drop and peer-section of the channel flow of fluid in eccentric channel will always be greater than the concentric tube placement. The greater the value of the ratio of internal and external diameters of pipe, the flow is greater.

In studies [4] states that the actual wells contacting internal and external surfaces of the annular channel circulation drilling mud is not on the line, and some surface that leads to the formation of dead zones. This causes a decrease in cross-sectional area of flow of drilling mud.

One of the practical ways of dealing with the formation of dead mud zones in the hole now is a way to increase productivity mud pump, which has a number of significant drawbacks [2], [4], [10],:

- differential pressure increases at the bottomhole and hydraulic losses are hire in the annular space;
- enhanced erosion of the walls of the well to the formation of cavities and gutters;
- enhanced absorption of drilling mud, mud pump items, swivel threaded connections, drill string and the bit nozzles wear increase;
- increasing energy expenses for hydraulic applications flushing and drilling in general.

Due to the factors mentioned above, the negative impact on the process of drilling there is the need to find new and effective approaches to reduce the impact of stagnant drilling mud zone in the annular space to the drilling process, which is the actual problem that has to be solved.

3. The Purpose of the Study and Formulation of the Problem

In the wellbore of horizontal wells axial movement of the drill string is provided with longitudinal component of the weight located above its construction to overcome the friction forces between the pipe and wall of a well. Under the influence of the axial and transverse forces an elastic axis of the drill string becomes complex shape bend (figure 1) with an eccentric location in the borehole (value “e” on the figure 1).

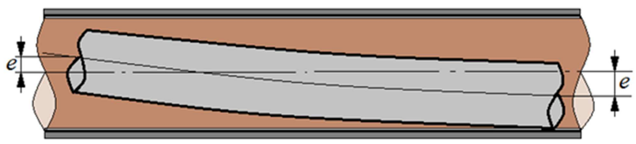
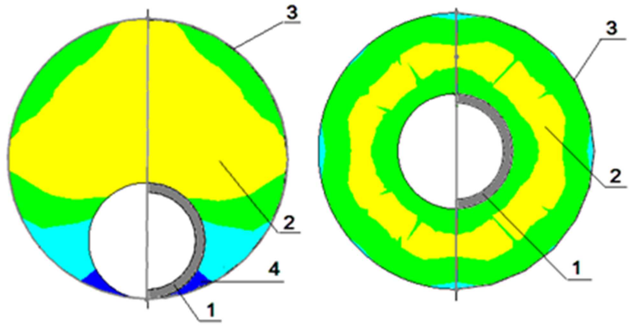


Figure 1. *Sample of drilling string eccentric location in a well.*

As a result of deformation of the drill string in the annular space borehole wells during washing changes the cross-sectional shape of the nucleus and its flow velocity distribution of motion, which is described by the following schemes, figure 2.



1 - drill string; 2 - core drilling fluid flow; 3 - hole wall; 4 - dead mud zone

Figure 2. *Scheme of targeting core drilling fluid flow and distribution of its velocity in the annular space of horizontal wells.*

Tacking into account this background, the aim of this study is to examine the impact of the eccentric location of the drill string in the wellbore of a horizontal well in the form of core drilling fluid flow in the annular space and its velocity distribution with diameters well with change and the drill string, drilling fluid parameters, energy characteristics of drilling pump and so on.

The study relates to computer modeling software environment SolidWorks Flow Simulation and mathematical modeling calculation method. The drill pipe is considering to be places into wellbore of horizontal wells with different boundary conditions in accordance with figure 2 and figure 3.

For investigation it has been accepted such parameters as the diameter of the hole; outer diameter and length of drill pipe; rate and pressure of a mud pump; roughness of the walls that are in a contact with drilling mud; density of the drilling mud, viscosity of the drilling mud due to one of rheological models.

4. Numerical Example

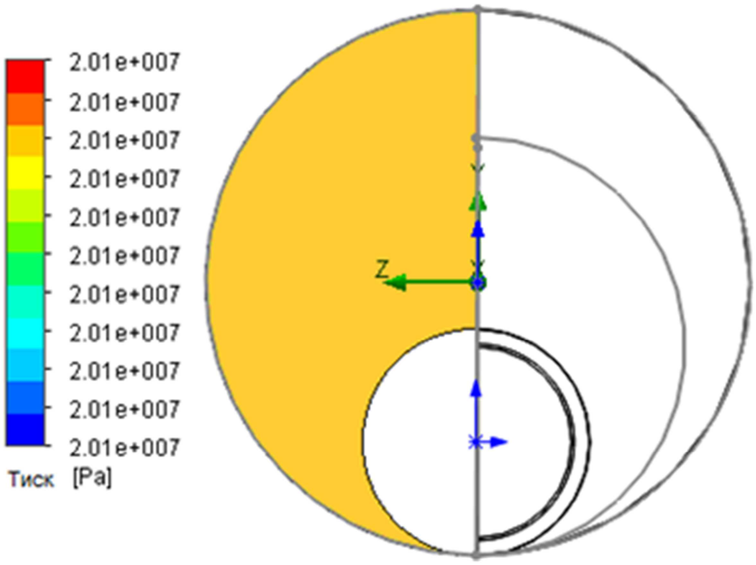
To determine the effect of eccentricity location of the drill string in a horizontal borehole by mathematical modeling (without simplifications and assumptions) a number interdependences of the velocity of the drilling fluid in the annular channel sickle space and pressure loss where obtained while using these initial data table 1.

Table 1. *Input parameters.*

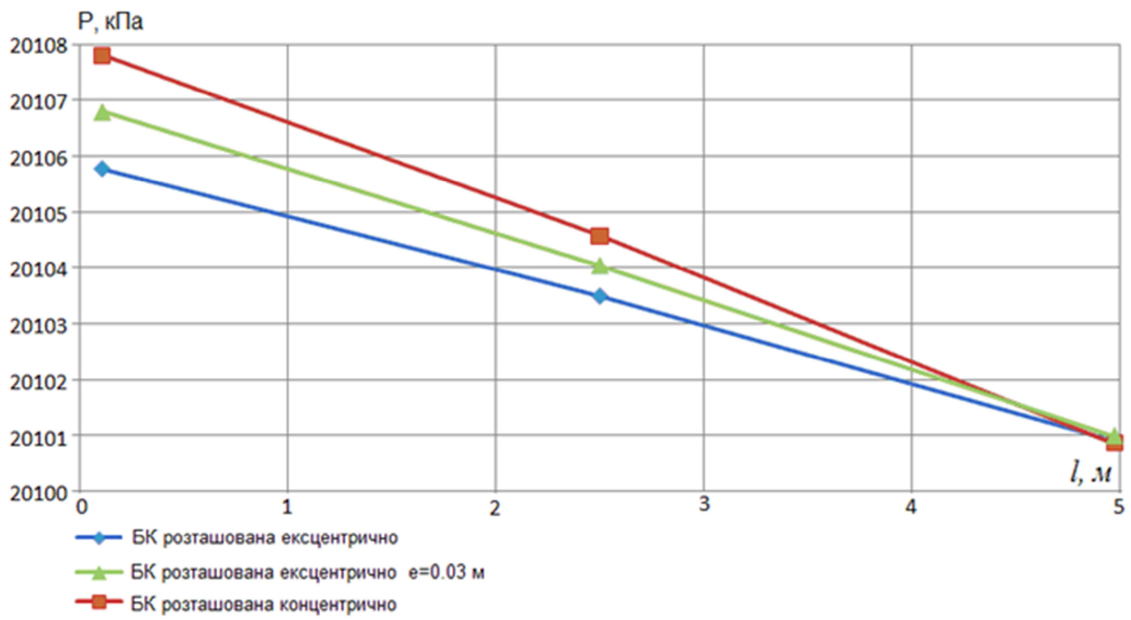
Number p/n	Parameter	Value	
		value	dimension
(1)	The diameter of the hole	0,136	m
(2)	The outer diameter of flexible pipes	0,06	m

Number p/n	Parameter	Value	
		value	dimension
(3)	Mud pump rate	0,0015	m^3/c
(4)	Pressure pumping mud pump	20	MPa
(5)	The roughness of the walls, which contact solution	300	microns
(6)	The density of the drilling fluid (model Herschel-Balkli)	1100	kg/m^3
(7)	The length of the investigated area of the annular space	5	m

As a result of the study using computer modeling of the drilling fluid flow in the annular space due to the model "borehole, the drill string" it was established a number of features. First, the eccentric location of the drill string in the hole does not change the pressure pumping mud pump in cross-section, figure 3, a). Second, the eccentric location in the drill string hole reduces the gradient of the hydraulic resistance. So for a concentric arrangement of pipes in the well it is about 1.36 kPa/m, and for eccentric - 30% less, or 0.96 kPa/m, figure 3, b). This difference has a significant impact on reducing the hydraulic resistance, and with it the energy consumption for irrigation wells, but adversely affects the formation of dead mud zones, slime formation packs and other [2], [4].



a)



b)

Figure 3. *Distribution of mud pump pressure into eccentrically located hole out of the drill string a) - in the longitudinal section of the wellbore; b) - in the cross-section of hole.*

According to the result of charting changes in flow rate of drilling fluid in the annular space of the model "borehole, the drill string" it was established that dead mud zone forms when increasing eccentricity between the axes of the hole and the drill string, figure 4. In the concentric arrangement of the drill string in the hole (to set initial data) (figure 4, b), without a dead mud zone drilling fluid in the annular space. In extreme eccentric position of the drill string in the hole in the center of the core flow observed flow rate of drilling mud (figure 4, a) is clearly visible in the stagnant zone. Most attention is given for intermediate eccentric position of the drill string, in which there is no signs of congestive zone at the core flow of drilling mud. This justifies centering the drill string in the wellbore of horizontal wells for maximum flow rate of core drilling fluid flow in the annular space in the absence of its stagnant zone.

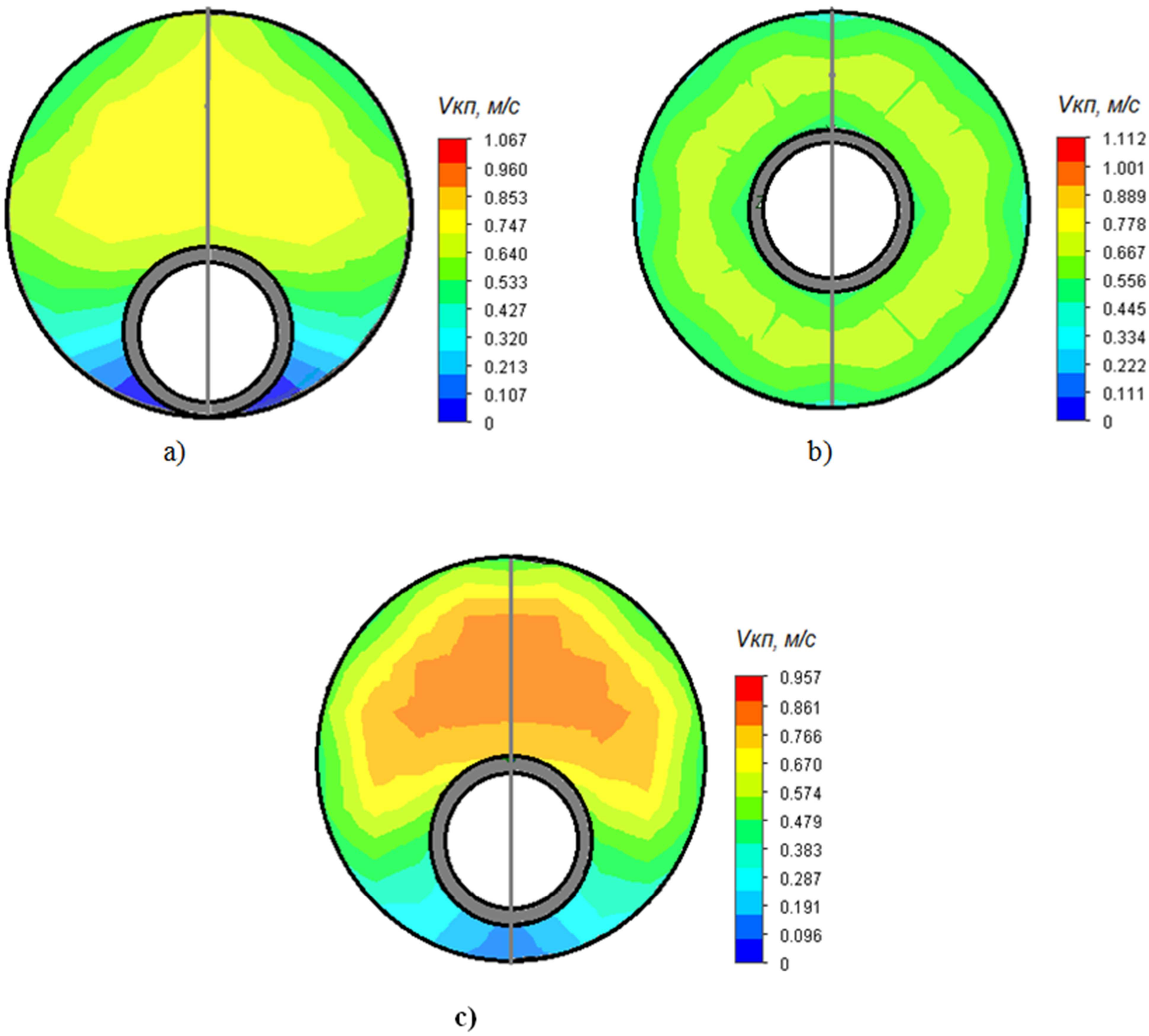


Figure 4. *Average flow rate of drilling fluid in the annular space of the borehole at different options for the location of the drill string in it.*

To study the effect of the eccentricity of the drill string in the wellbore of a horizontal well on the flow of drilling fluid parameters in the annular space it has been proposed scheme, shown in (figure 5), where R_2 - well radius, R_1 - the radius of the drill string, φ - value of half angle that covers area of congestive borehole wall drilling solution; ψ - value of half angle that covers drill string element congestive zone.

The ratio between the geometric dimensions of dead mud zone of drilling mud in the annular space at a mud pump pressure, expressed:

$$P \cdot A_t + \tau_0 \cdot A_1 = \tau_0 \cdot A_2, \tag{1}$$

where A_t - the cross-sectional area of stagnant zones mud;

P - mud pump pressure;

A_1 - the surface area of contact between the stagnant zone and moving mud;

A_2 - the surface area of contact with the pipe mud walls and wells in the area of movement;

τ_0 - the dynamic shear stress mud.

$$A_1 = 2\begin{pmatrix} R_2 \sin(\phi) - \\ -\sin\left[\arccos\left[\dfrac{R_2\cos(\phi)-e}{R_1}\right]\right] R_1 \end{pmatrix} l\,; \qquad (2)$$

$$A_t = \frac{1}{2}R_2^2\left(2\phi - \sin(2\phi)\right) - \\ -\frac{1}{2}R_1^2\begin{pmatrix} 2\arccos\left[\dfrac{R_2\cos(\phi)-e}{R_1}\right] - \\ -\sin\left(2\arccos\left[\dfrac{R_2\cos(\phi)-e}{R_1}\right]\right) \end{pmatrix}; \qquad (3)$$

$$A_2 = \frac{\pi}{180^0}\begin{bmatrix} \left(360^0-\phi\right)R_2 + \\ +\left(360^0 - \arccos\left[\dfrac{R_2\cos(\phi)-e}{R_1}\right]\right)R_1 \end{bmatrix} l\,, \qquad (4)$$

where l - the length of the drill string

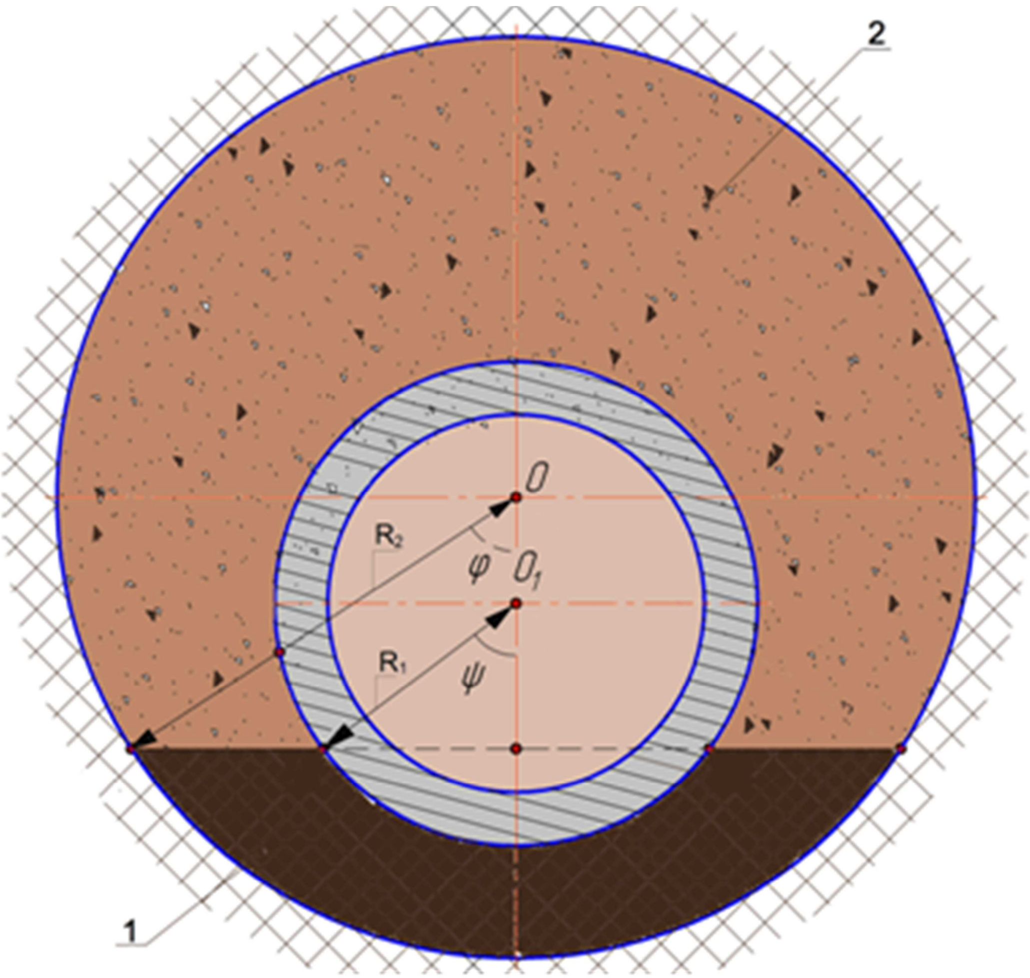


Figure 5. *Diagram formation of dead mud zones in the annular space of the eccentrically located drill string.*

To ensure effective hydraulic transportation of cuttings in the annular space of deviated or horizontal well drilling fluid flow is to provide the necessary speed and decrease its preconditions formation of dead mud zones.

For the design flow rate required value of drilling in the annular space mathematical model of a particle slurry spherical wall between the hole and the drill string set in the range of zenith angle, which is exposed to such forces (figure 6): gravity - F_1; buoyancy - F_2; centrifugal - F_3; centripetal - F_4; viscous resistance protection - F_5; friction - F_6 and lifting - F_7, [2].

This gravity and Archimedes, acting on a particle slurry in the circumstances defined:

$$F_1 = \rho_{ГП}\, g\, V_Ч\,, \qquad (5)$$

where $V_Ч$ - the maximum amount of sludge particles, which is made mud;

$\rho_{ГП}$ - density of rock.

$$F_2 = \rho_{БР}\, g\, V_Ч\,, \tag{6}$$

where $\rho_{БР}$ - density drilling mud.

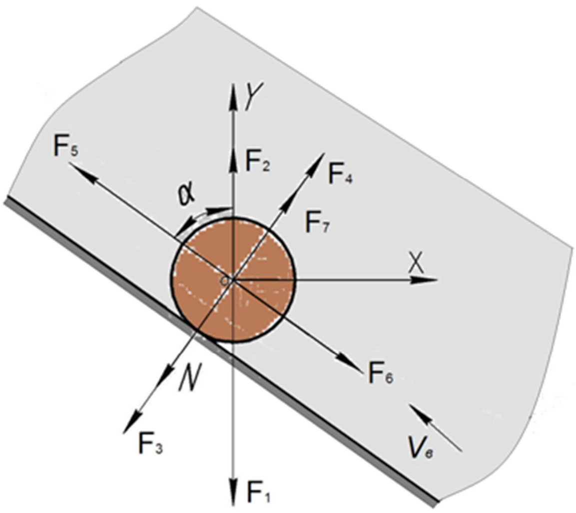


Figure 6. The scheme of distribution of forces acting on the particle slurry in drilling fluids into the annular space the of deviated well.

$$F_3 = 2\rho_{ГП}\, V_{КП}^2\, V_Ч\, \kappa \big/ \left(2+\kappa\, D_{CB}\right); \tag{7}$$

$$F_4 = 2\rho_{БР}\, V_{КП}^2\, V_Ч\, \kappa \big/ \left(2+\kappa\, D_{CB}\right), \tag{8}$$

where κ - curvature of the borehole;

D_{CB} - diameter of the hole.

Taking into account the fact that the formation of dead mud zones mud leads to a decrease in cross-sectional area of the annular space, this leads to an increase in the flow rate of mud, which is determined by:

$$V_{КП} = 4Q \Big/ \left[\pi\left(D_{CB}^2 - d_{БК}^2\right) - 4A_t\right], \tag{9}$$

where Q - mud pump performance.

$$F_5 = c\,\rho_{БР}\, S_{ГП}\, V_Ч\, {V_{КП}}^2 \big/ 2\,, \tag{10}$$

where $S_{ГП}$ - the maximum cross-sectional area of the particle slurry largest fractional composition formed on the bottom;

c - empirical coefficient:

$$c = \left[\left(36\,\mu \Big/ d_{ГП}^{1.5}\, \sqrt{3\, g\, \rho_{БР}\left(\rho_{ГП} - \rho_{БР}\right)}\right) + 0.67\right]^2, \tag{11}$$

where μ - the absolute viscosity of the mud;

$d_{ГП}$ - conditional diameter of sludge.

Friction sludge particles to the wall well considering sticking it to the cover of filtration:

$$F_6 = N\, f\,, \tag{12}$$

where f - coefficient of friction particle slurry to the drill string or the borehole wall;

N - normal component of the force pressing sludge particles to the wall of the hole:

$$N = V_Ч\left(\rho_{ГП} - \rho_{БР}\right)\left[\left(2\,\kappa V_{КП}^2 \big/ \left(2+\kappa\, D_{CB}\right)\right) + g\sin(\alpha)\right] - F_7\,, \tag{13}$$

where α - the zenith angle of the shaft.

During the drill string rotation with angular velocity $\omega = const$ on particle slurry that enters the zone of turbulence mud, a force:

$$F_7 = \rho_{ГП}\, V_Ч\, \omega^2\, d_{БТ} / 12\,, \tag{14}$$

where $d_{БТ}$ - the diameter of the drill pipe.

According to (figure 6) we obtain the equation of equilibrium of forces acting on the particle slurry during its movement in drilling fluids:

- force projection on the axis OX:

$$(F_5 - F_6)\,cos(\alpha) + F_2 - F_1 + (F_7 + F_4 - N - F_3)\sin(\alpha) = 0\,; \tag{15}$$

- force projection on the axis OY:

$$(F_7 + F_4 - N - F_3)\cos(\alpha) - (F_5 + F_6)\sin(\alpha) = 0\,. \tag{16}$$

Combining (1)-(16) in equations and having the appropriate calculations and obtain the values given F_i and $V_{КП}$ in technical and technological parameters of the process and condition $A_t \to 0$.

5. Conclusions

1. Consideration of the study of eccentrically located drill string in the hole makes significant changes in quality cleaning of the hole and requires clarification of existing methods for the design and selection of optimum drilling pump rate that has considerable practical interest.

2. To determine the quantitative and qualitative impact of eccentrically located drill string in the wellbore it has been offered the hydrodynamic system of washing out wells in the application modules of Flow Simulation program SOLID WORKS and conducted appropriate studies. It was used nonlinear visco-plastic rheological model mud Herschel-Balkli and accounted pressure mud pump performance and roughness of the walls of the well.

3. To design mud pump rate and support the process of cuttings washing out of the well to ensure the flow of drilling fluid into the annular space it has been offered an improved mathematical model. At the same time, it takes into account a number of technical and technological parameters and factors that prevent the formation of dead zones mud in the annular space obliquely-directed hole of arbitrary curvature.

4. Tacking into account the conditions of ecantrically located drilling string, well profile parameters and geometrical shape of cuttings while calculating mud pump rate will enhance the quality of wellbore cleaning and prevent formation of the dead

mud zones into the annular space. This provides management of energy consumption for the washing out of a well.

5. Using of the current method enables to project effective washing out program for every individual well if low flow rate is required tacking into account friction of cutting with wells of the well and with mudcake on them, longevity and build up rate of a wellbore, bit and drilling string diameter, type of drilling bit washing system, rheological parameters of drilling mud and rock density, data of thickness and shear adhesion strength of mud cake.

References

[1] Kovalev A. V., Ryabchikov S. Y. (2015) *Prolemy gidrodinamicheskikh sposobov byreniya skvazhin I osnovnye napravleniya* [Problems of hydrodynamic methods of well drilling and basic directions of their solution] Tomsk polytechnical university, 3: 6-12.

[2] Chudyk I. I., Kovbasyuk, Yatsenko T. V. (2012) *Problemy I shlyakhy efektyvnoi modernizacii procesu promyvannya sverdlovyny* [Problems and ways of energy efficient modernization of washing out process of a well] National University of Oil and Gas, 2: 46-53.

[3] Rukavitsyn Y. V., Zhuravlev A. G. (2013) *Sovershenstvovanie tekhnologii bezopasnogo stroitelstva glubokikh skvazhin na osnove optimizatsii zaboinykh parametrov byreniya* [Improvement of safety deep well construction technology on a basis of optimization bottomhole drilling parameters], Oil and gas wells construction, 3: 4-7.

[4] Vytyaz O. Y. Chudyk I. I. (2015) Study of the effects of drilling string eccentricity in the borehole on the quality of its cleaning. Theoretical and practical solutions of mineral resources mining, 3: 472–477.

[5] Kravchuk M. V. (2015) *Analiz rezervov pri realizacii gidromonitornoy promyvki* [Analyse of reserves while performance of jet washing out of a well], Oil and gas wells construction, 2: 15-18.

[6] Vyshegorodtseva G. I. (2015) *Puti povysheniya efektivnosti ochistki zaboya pri burenii sharoshechnymi dolotami* [Methods of bottomhole wasing out improvement while drilling whith a help of cone bits], Oil and gas wells construction, 6: 12-17.

[7] Dobyk Y. A. (2016) *K voprosy technologicheskogo obespecheniya ochistki stvola gorizontalnoy skvazhiny ot shlama v procese byreniya* [Regarding technological support of bottomhole washing out of horizontal well while drillling], Oil and gas wells construction, 5: 12-16.

[8] Dobyk U. A. (2017) *Sovremennye metody kontrolya kachestva ochistki stvola skvazhiny* [Modern methods of well washing out quality control], Oil and gas wells construction, 1: 16-20.

[9] Korchagin P. N., Korchagin D. N. (2012) Optimizaciya gidravliki bureniya glubokikh ckvazhin pri byrenii dolotami PDC [Optimization of well drilling hydraulic while using PDC bits], Drilling and Oil, 3: 45-48.

[10] Alexandrov S. S., Lugumanov M. G. (2013) *Regulirovanie rezhima ochstki skvazhiny v procese byreniya* [Management of wellbore washing out process while well drilling], Drilling and Oil, 2: 32-35.