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Satbayev University

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ИЗВЕСТИЯ
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НАУК РЕСПУБЛИКИ
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CHANGE OF HYDRODYNAMIC PRESSURES IN THE WELLBORE OF INCLINED-HORIZONTAL WELLS DURING DRILLING MUD CIRCULATION

Abstract. In recent years, as you know, the volume of drilling deviated and horizontal wells has increased dramatically.

When drilling these wells there are a number of problems: lack of technical means for drilling such wells, bringing the axial load on the drill bit, bringing strings to the bottom hole, problems with borehole cleaning from the drilled rock, etc.

The data collection and analysis of field data on drilling of deviated and horizontal wells (inclinograms mode parameters) in the Baku Archipelago areas showed the changes of hydrodynamic pressure in a well, when the mode parameters, axial load, bit rotational speed and fluid consumption were the same.

Further analysis of these data revealed that these changes occur as a result of changes in the spatial curvature of deviated and horizontal wells.

Analysis of the obtained data showed that the change occurred only in the case of changes in the spatial variation of inclined-horizontal wells.

To the end, the work presented studies to determine changes in hydrodynamic pressures in the borehole of deviated-horizontal wells.

On the basis of experimental, field, as well as computer simulation studies, data were obtained, which were processed by statistical methods. As a result, dependences for determination of hydrodynamic pressure in the wellbore of slanted horizontal wells were obtained.

The studies have shown that using the traditional method of calculating the hydrodynamic pressure in the wellbore of deviated horizontal wells differs from our calculations taking into account the zenith angles. This difference occurs in the direction of reducing these values.

Key words: deviated well, zenith angle, pumping capacity, horizontal well profile, pressure losses.

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БҰРҒЫЛАУ ЕРІТІНДІСІНІҢ АЙНАЛЫМЫ КЕЗІНДЕ КӨЛБЕУ-КӨЛДЕНЕҢ ҰҢҒЫМАЛАР ОҚПАНЫНДАҒЫ ГИДРОДИНАМИКАЛЫҚ ҚЫСЫМДАРДЫҢ ӨЗГЕРУІ

Аннотация. Соңғы жылдары, көлбеу және көлденең ұңғымаларды бұрғылау көлемі күрт өсті. Ұңғымаларды бұрғылау кезінде бірқатар проблемалар туындайды. Атап айтқанда: ұңғымаларды өткізуге арналған техникалық құралдардың болмауы, кескішке осьтік жүктемені жеткізу, бағандарды кенжарға жеткізу, бұрғыланған тау жыныстарынан тазарту проблемалары және т. б.

Баку архипелагының алаңдарында көлбеу және көлденең ұңғымаларды бұрғылау бойынша кәсіптік деректерді (инклинограммалардың режимдік параметрлері) жинау және талдау режимдік параметрлердің, осьтік жүктеменің тұрақтылығы, қашаудың айналу айналымының саны, сондай-ақ сұйықтық шығыны кезінде ұңғымадағы гидродинамикалық қысымдардың өзгеруі байқалғанын көрсетті.

Осы деректерді одан әрі талдау бұл өзгерістердің көлбеу және көлденең ұңғымалардың кеңістіктік қисықтығының өзгеруі нәтижесінде пайда болатындығын анықтады. Алынған деректерді талдау, өзгеріс көлбеу-көлденең ұңғымалардың кеңістіктік өзгеруі өзгерген жағдайда ғана болатындығын көрсетті.

Бұл жұмыста көлбеу-көлденең ұңғымалар оқпанындағы гидродинамикалық қысымдардың өзгеруін анықтау бойынша зерттеулер ұсынылды. Зерттеулерді эксперименттік, коммерциялық, сондай-ақ компьютерлік модельдеу негізінде статистикалық әдістермен өңделген мәліметтер алынды. Соның нәтижесінде көлденең ұңғымалардың оқпанындағы гидродинамикалық қысымды анықтау бойынша тәуелділіктер анықталды.

Зерттеулер көрсеткендей, гидродинамикалық есептеудің дәстүрлі

әдісін қолданған кезде көлбеу-көлденең ұңғымалардағы қысым зениттік бұрыштарды ескере отырып, біз ұсынған есептеулерден өзгеше болады. Бұл айырмашылық осы шамалардың азаюына байланысты.

Түйін сөздер: көлбеу ұңғыма, зениттік бұрыш, сорғылардың өнімділігі, көлденең ұңғымалардың профилі, қысымның жоғалуы.

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ИЗМЕНЕНИЕ ГИДРОДИНАМИЧЕСКИХ ДАВЛЕНИЙ В СТВОЛЕ НАКЛОННО-ГОРИЗОНТАЛЬНЫХ СКВАЖИН ПРИ ЦИРКУЛЯЦИИ БУРОВОГО РАСТВОРА

Аннотация. В последние годы, как известно, объем бурения наклонных и горизонтальных скважин резко увеличился.

При бурении этих скважин возникают ряд проблем: отсутствие технических средств для проводки таких скважин, доведения осевой нагрузки на долото, доведение колонн до забоя, проблемы с очисткой стволов от выбуренных пород и т.д. Проведенный сбор и анализ промысловых данных по бурению наклонных и горизонтальных скважин (режимные параметры инклинограмм) на площадях Бакинского Архипелага показало, что при постоянстве режимных параметров, осевой нагрузки, числа оборотов вращения долота, а также расхода жидкости наблюдалось изменение гидродинамических давлений в скважине.

Дальнейшим анализом этих данных было установлено, что эти изменения происходят в результате изменения пространственного искривления наклонных и горизонтальных скважин. Анализ полученных данных показал, что изменение происходило только в случае изменения пространственного изменения наклонно-горизонтальных скважин.

С этой целью в работе были представлены исследования по определению изменений гидродинамических давлений в стволе наклонно-горизонтальных скважин. На основе экспериментальных, промысловых, а также компьютерного моделирования исследований были получены данные, которые были обработаны статистическими методами. В результате чего были получены зависимости по определению гидродинамических давление в стволе наклоны горизонтальных скважин. Исследования показали, что при использовании традиционного метода

расчёта гидродинамических давление в стволе наклонно-горизонтальных скважин отличается от предлагаемых нами расчётов с учётом зенитных углов. Это отличие происходит в сторону уменьшения этих величин.

Ключевые слова: наклонная скважина, зенитный угол, производительность насосов, профиль горизонтальные скважины, потери давления.

Introduction. Currently, due to the increase in the volume of drilling of inclined wells with large (>35°) zenith angles and deviations, as well as when drilling horizontal wells, it becomes necessary to investigate the movement of solid particles in the trunk of inclined horizontal wells.

As studies (Abughaban, et al, 2016) show, with an increase in the zenith angle, an increasing number of particles settle on the lower wall of the well, and in the case of a horizontal well, almost 60-70% of the drilled rock settles on the lower wall. When a solid particle settles on the lower wall, a so-called slurry layer is formed. The thickness of this layer increases as the well is flushed. This can lead, on the one hand, to the seizure of tools at the moment of lifting, and on the other hand, at certain values and the zenith angle (35 - 60°), the sludge can slide (like an avalanche) at the bottom of the well, which will lead to a decrease in the mechanical rate of penetration.

To reduce the slurry layer, it is necessary to reduce the mechanical speed of flushing the penetration or to choose such a minimum consumption of drilling mud that to ensure the removal of these settled particles to the daytime surface. In this regard, there is a need to study the movement of solid particles deposited on the lower wall of the borehole, which will determine the minimum consumption of drilling mud, ensuring the removal of these particles to the day surface.

Research materials and methods. The movement of solid particles to the lower walls of the well occurs in the form of sliding and rolling. Sliding or rolling of particles occurs, as a rule, due to hydrodynamic forces arising in the upward flow (Agayev, et al, 2001).

The case of particle motion is considered when the lower walls of the well do not roll and slide. The solution is considered as quite general, and can be used to study and calculate the motion of solid particles regardless of the type of motion.

These studies have shown how the parameters of the curvature of an inclined well affect the formation of a slurry cushion (Albaraa, et al, 2018).

Another important factor that occurs during the drilling of inclined-horizontal wells is the change in hydrodynamic pressure during its flushing. hydrodynamic pressures are all pressures in the well, which differ from the hydrostatic pressure of the liquid column both positively and negatively

(Axundova, et al, 2021; Bulatov, et al, 1984; Cardwell 1953). As a rule, they arise due to fluid motion in the circulation system of the well. Pressure fluctuations in the well may also be of another nature, in particular due to changes in circulating fluid density, separation (segregation) of phases, setting and hardening of cement slurry, infiltration of formation fluids into the well, osmotic phenomena. However, these phenomena will not be considered here. Excess pressures in the borehole can be caused by:

1) friction of fluids pumped into the circulation system of the well;
2) local resistances in the circulation system of the well;
3) movement in the well of the pipe string;
4) local resistances in the circulation system of the well when moving the pipe string;
5) inertia of the fluid column in the well;
6) pressure fluctuations arising from abrupt start or stop of pumps, lifting or abrupt braking of the drill string or casing.
7) overcoming the gel strength of thixotropic viscoplastic fluids when starting pumps or at the moment of starting drill string or casing string movement in the well;
8) rotation of drill string or casing string;
9) the effect of compression or rarefaction in fluid when the drill string is moving around (especially if there is a gland on the bit).

All these phenomena may occur simultaneously in the well, and their influence cannot always be evaluated separately.

Excessive pressures that occur when fluid is injected into the well circulation system have been considered in the literature (George, et al, 2011; Juan, et al, 2002).

As is known, the pressure created by drilling pumps during the circulation of the solution is equal to the sum of losses in the entire circulation system of the well and is determined by the following relationship:

$$P_B = P_p + P_{C.S.} + P_{wdp} + P_1 + P_b + P_{rb} + P_{turb}$$

where, P_p – pressure loss in drill pipes, MPa
$P_{C.S.}$ – pressure loss in the column space, MPa.
P_{wdp} – pressure loss in weighted drill pipes, MPa
P_1 – pressure loss in locks, MPa.
P_b – pressure loss in the bit, MPa.
P_{rb} – pressure loss in the rig binding, MPa.
P_{turb} – pressure loss in the turbobur, MPa.

The magnitude of these losses depends on many factors (pump performance, rheology, drilling fluid density, length and diameter of drill and casing pipes, local resistances, etc.).

When considering these dependencies, according to which these hydrodynamic losses are determined, it is clear that they lack the influence of factors such as zenith and azimuth angles.

Although in the authors propose (Maurer, 1971; Movsumov, 1976, 1967; Makovey, 1986) a dependence that allows determining additional pressure losses resulting from changes in azimuthal angles.

However, as you know, in recent years, the volume of drilling of inclined and horizontal wells has increased. When drilling such wells, the zenith angles reach large values (70°-90°). At the same time, a number of problems arise, one of which is the change in hydrodynamic pressures.

Based on the above, from a practical (experimental) point of view, the question of the influence of zenith angles on hydraulic losses during drilling of inclined-horizontal wells is interesting (Hemphill, 2010).

The fact of the influence of zenith angles on hydraulic losses during the movement of drilling mud was established experimentally and by field studies conducted by us on the areas of the Baku Archipelag.

Based on these studies, a summary table (1) was compiled and graphs (fig.1) are presented, which reflects the effect of pump performance and zenith angles with constant structural dimensions of the well (length, diameter) and rheology of the solution on pressure losses at zenith angles α = 0 and α = 90°.

Table 1

№	Q 10^{-3} m^3/s	Vertical well P_v (α=0°), Pa	Horizontal well P_h (α=90°),Pa
1	0,5	17	13
2	1	27	17
3	1,5	35	20
4	2	45	25
5	2,5	55	30
6	3	65	35
7	3,5	75	40
8	4	85	45

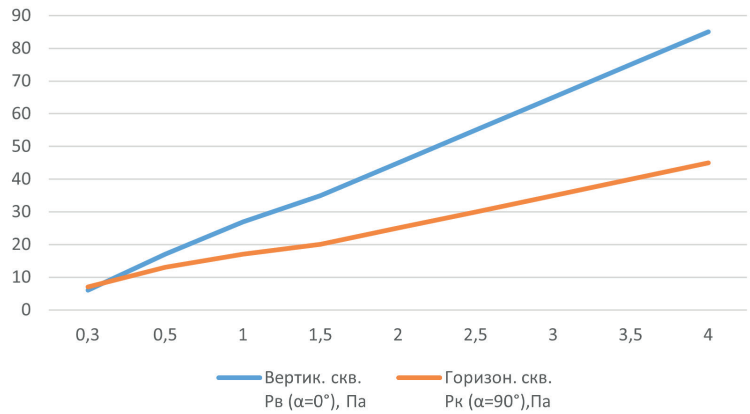

Fig.1. Dependence of pressure loss on pump performance

However, as is known, for practical calculations of pressure losses in the trunk of inclined-horizontal wells, it was necessary to have a dependence of the change in hydrodynamic losses on zenith angles.

For this purpose, the data obtained experimentally and commercially were processed.

Results. As a result of mathematical processing of these data (Qudilin, et al, 2007; Yemelyanov, et al, 1988), the dependence of the change in hydraulic losses on the zenith angles was obtained with the constancy of the technical and rheological parameters of the solution.

$$\Delta P_{i.h}^{2} = \frac{\Delta P_{v}^{1}}{1 + \mathrm{Sin}\alpha_{cp}}$$

where, ΔP_{v}^{1} – pressure losses in a vertical well when the depth of the well and the length of the inclined horizontal part of the well are equal, MPa.

$\Delta P_{i.h}^{2}$ - pressure losses in an inclined-horizontal well, taking into account the average value of zenith angles, MPa.

α_{av} – the average angle of the zenith angles, degrees.

Discussion. To compare the magnitude of the change in hydrodynamic losses during drilling of inclined-horizontal wells with pressure losses in a vertical well with the same technical and technological data, a standard three-interval horizontal profile (Fig.2) with a depth of H = 1200m, consisting of a vertical section with a length of the tool l = 1000m, an inclined section of 500m was calculated. and the horizontal section l_3 = 600m, with the following data, the diameter of the bit D_b=295.3mm, the diameter of the drill pipes D_{dp}= 140 mm, thickness δ=9mm, length WDP =100m, inclined length =500m, diameter WDP = 203mm, productivity Q=30dm^3/s, structural viscosity η =1·10-2 N * s/m^2, static shear stress t = 8.16 N/m^2.

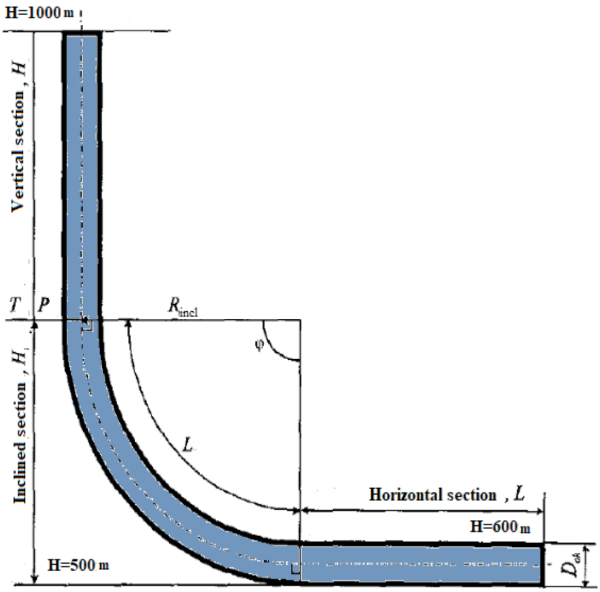

Fig. 2 Three-interval standard horizontal profile of the well.

Thus, when determining the exact value of hydraulic losses in inclined-horizontal wells, there is a need to calculate pressures at separate intervals according to the proposed method, i.e. vertical (α=0°-5°), inclined (α=5°-60°) and horizontal (α=60°-90°) sections, as well as the calculation of these pressures when drilling a vertical well with a depth of 2100 m.az, when determining the exact value of hydraulic losses in inclined-horizontal wells, there is a need to calculate pressures at separate intervals according to the proposed method, i.e. vertical (α=0°-5°), inclined (α=5°-60°) and horizontal (α=60°-90°) sections, as well as the calculation of these pressures when drilling a vertical well with a depth of 2100 m.

Numerical values of pressure losses in these areas obtained as a result of calculations for individual intervals are presented in table 2.

Table 2.

Interval,m	Average of zenith angle,°	$P_{p,}$ MPa	$P_{C.S.}$, MPa	P_{wp}, MPa	P_{1}, MPa	P_{b}, MPa	P_{rb} MPa	P_{turb}, MPa	Total losses at this interval α=0°, MPa	Total losses at this interval, taking into account zenith angles, MPa
Vertical length L_1,1000	0	0,702	0,32	0	0,228	0	0,132	0	1,3829	1,3829

Inclined length L_2,500	30	0,312	0,142	0	0,114	0	0	0	0,56865	0,3791
Length to horizontal. L_2,600	90	0,39	0,178	0,239	0,137	0,45	0	2,463	3,8571	1,92855
5,80865	3,69055									

As can be seen from the calculations obtained, the hydrodynamic losses in the trunk of inclined-horizontal wells are 2.0-3.0 MPa less than in vertical wells with the same tool lengths.

Conclusion. Reduction of hydrodynamic pressures in inclined-horizontal wells contributes to the fact that:

1) Based on the analysis of the collected and systematized field and design data on the drilling of inclined and horizontal wells on the shelf of the Caspian Sea, it was found that the hydrodynamic pressures during drilling in these wells, with other parameters constant, differed from the design values by 10 - 15%.

2. To identify the reasons for the change in hydrodynamic pressures in the wellbore of inclined and horizontal wells, computer simulation of this process was carried out, as a result of which the influence of the parameters of the well curvature (in particular, the zenith angle) on the change in this value was established.

3. Statistical processing of the data obtained as a result of computer simulation made it possible to obtain the dependence of hydrodynamic pressure losses on zenith angles.

4. The results of calculations of hydrodynamic pressures during flushing of inclined and horizontal wells according to the obtained dependence confirmed their decrease by 10–15% of the design data, with other parameters remaining constant.

5. The results obtained allow, on the one hand, to reduce the load on the mud pumps, and this, in turn, will increase its productivity while maintaining power, which will improve the quality of cleaning tables of wells.

6. The dependence obtained in the article can be recommended when drawing up hydraulic programs for drilling inclined and horizontal wells.

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