Application of Drilling Oscillator During Drilling Directional Wells in the Field Conditions of Gubkinskoye Oil and Gas Field While Drilling No. 2156

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Abstract. The article describes the use of drilling oscillator when drilling directional wells in the field conditions of the Gubkinskoye oil and gas field while drilling No. 2156.

1. Introduction

The current state of the oil and gas industry in our country is based on the need to respond to a number of global challenges, in particular: increased global competition, new technological changes, the growth of energy efficiency technologies, ensuring global energy security, etc. In view of all this, there is an acute question about the profitability of oil production technologies. Among the most effective and economical drilling technologies is drilling directional wells with horizontal completion, which is especially important for fields with a complex geological structure of productive deposits, as well as at a late stage of their development.

Complete extraction of resources from our depths is the most important national economic task. But, unfortunately, in the development of deposits due to the imperfection of technics and technologies, in the depths there is a large number of resources. At the same time, oil and gas fields are characterized by the lowest recovery rate. It is known from world practice that the oil recovery of these fields does not exceed 30-40 %.

In the development of these fields, various methods of influencing the formation are used (marginal and in-boundary waterflooding of formations, thermal and physicochemical methods, hydraulic fracturing, etc.) and despite this, on average, more than half of the geological reserves of oil remain unexplored and are considered «buried».
Drilling of oil and gas fields in an oblique way and especially horizontal and branched-horizontal wells are effective methods of forming an optimal development system, as well as restoring the productivity of fields that are in a late stage of operation.

Opening the productive strata by horizontal and branched-horizontal wellbores increases the filtration area, eliminates the possibility of water entering during operation, and it is especially effective for low-permeable reservoirs, and well as reservoirs with vertical fracturing.

2. Actuality and scientific value

In recent years, new technologies based on horizontal drilling have made a real revolution in the practice and theory of oil production. As a result, the grids of wells were of discharged, depressions decreased, the time of waterless operation significantly increased, the categories of reserves that were previously considered to be non-recoverable, which can now be effectively extracted on an industrial scale, changed, the effectiveness of many old methods of operating on the reservoir during their implementation using horizontal wells increased. In many ways, impressive results have been achieved.

One of the important tasks in the construction of directional wells with horizontal completion are:

• the decrease in sticking danger of drill strings and its bottom layout, in particular, in the horizontal section;
• providing the ability to create the requirements for the destruction of rock load on the face during drilling, lowering the casing into the well with the overlap of the horizontal part of the barrel and the allowable load on the hook during the elimination of sticking.

Sticking is called an unpredictable process disturbance during well-drilling, which is characterized by loss of column mobility and cannot be eliminated under the application of permissible loads. This type of accident is the most time-consuming. It takes 35-45 % of the total time spent on the elimination of this accident. In this regard, it is necessary to reduce the possibility of sticking danger by a number of technological solutions, which will be discussed further.

3. Tasks

3.1. Sticking as the main problem when drilling directional wells with horizontal completion

Sticking of drills and casing strings – an unexpected loss of mobility of a pipe string due to:

• sticking under the action of pressure drop;
• jamming in grooves, places of constriction or foreign objects;
• As a result of a collapse, shedding of rocks from the walls of wells or sludge sedimentation due to a violation of the flushing mode;
• due to the formation of oil seals on the drill string.

Many factors affect the sticking of the drill string of pipes in the well, which by their nature are the result of physic-chemical, physic-mechanical and other types of interaction of the tool with the rock and drilling mud.

For an objective description of the existing points of view on the nature of sticking experts were interviewed, followed by statistical processing of the survey results.

This questionnaire included 18 factors that significantly affect the occurrence of sticking:
1) the curvature of the wellbore;
2) the type of lubricant additive;
3) type of drilling mud;
4) compliance with technical rules and regulations;
5) the rigidity of the bottom of the drill string;
6) contact surface area;
7) the friction coefficient in the contact zone;
8) the time of contact of the tubing column at rest with the wall of the well;
9) the value of the pressure drop;
10) physical and mechanical properties of drilling mud;
11) the temperature in the sticking zone;
12) the absolute value of hydrostatic pressure;
13) rock permeability in the stuck zone;
14) type of formation fluid;
15) physical and mechanical properties of filtration crusts;
16) rock porosity;
17) the rate of upward flow of drilling mud;
18) the amount of lubricant in solution.
Measures that are rigorously executed, associated with the regulation of these factors virtually eliminates the problem of remove sticking.

4. Theoretical part

4.1. Modern methods of dealing with sticking
In turn, we would like to dwell on the following factors, on which the probability of sticking depends;
• borehole curvature;
• the type of lubricant additive and its amount in the drilling mud;
• the type and speed of the upward flow of drilling mud;
• the rigidity of the bottom of the drill string.
These measures for the prevention of sticking of columns, rigorously executed, virtually eliminate the problem associated with the elimination of sticking.

Further, using the example of a three-interval well, let us consider what types of loads the string undergoes when drilling a well consisting of 1 – a vertical section; 2 – sections of the zenith angle set; 3 – horizon section (Figure 1).

![Figure 1. Profiles of wells with horizontal (a) horizontally branched (b) the position of the trunks in the reservoir:](image)
1 – vertical section; 2 – an area of increasing zenith angle;
3 – horizontal or horizontally branched area in the reservoir.

From Figure 1 it can be seen that in the drilling process for the case of a three-interval well, axial loads on the bottom depending on the friction coefficient and for horizontal sections the frictional force can be significant and lead to sticking.

To combat sticking in the construction of directional wells with horizontal completion, it is proposed to introduce the following technical solutions to this problem in the well-construction wiring technology:

1. Chemical method. In order to reduce the frictional forces of the layout of the bottom of the drill string and the drill string in the curved sections on the borehole wall, I propose the insertion of lubricant additives into the drilling fluid.

2. Mechanical method. The inclusion in the layout of the bottom of the drill string of one of the following devices: oscillator, vibration dampers, vibrator, yass. Due to the fact that the cost of drilling
wells is high enough, it is proposed to use an oscillator-turbulator of domestic production as the main device.

The choice of methods of dealing with sticking danger in the construction of directional wells with horizontal completion based on field test conducted by the innovation department of PJSC Oil Company «RN-Drilling» on the Gubkinskoye field.

Furthermore, on the basis of the obtained data on the tests, we will conduct an analysis of each of the solutions for dealing with sticking.

5. Practical value and results

5.1. Technological solutions to combat sticking and puffing in the construction of directional wells with horizontal ending. Chemical method of dealing with puffs and sticking

One of the ways to reduce energy costs when performing tripping, preventing drags and sticking of drill strings and devices in wells is to increase the lubricating properties of drilling fluids. Experience shows that the use of flushing fluids with improved antifriction (anti-sticking) properties has a positive effect on the performance of rock cutting tools, therefore, affects the technical and economic indicators of drilling.

Oil is one of the most common additives in drilling mud to reduce the risk of seizure. It has been established that the input of 5-10 % (of the total mass of the drilling mud) into the untreated drilling fluid reduces the friction force between the metal surface and the mud pudding by 20-30 %, which leads to a decrease in the probability of differential sticking.

| Input lubricant additives from the volume of drilling mud, % | Reduction coefficient friction, % |
|-------------------------------------------------------------|-----------------------------------|
| Russian Graphite                                            | 0.02                              | 25                               |
| Oil                                                         | 10                                | 20-30                            |
| Surfactant                                                  | 0.01-0.03                         | 15                               |
| SMAD-1                                                      | 1-4                               | 50-60                            |
| T-66 and T-80                                               | 0.3-0.5                           | 30-50                            |
| Sprint                                                      | 2-3                               | 50-60                            |
| INHP-21, NIINP-360                                          | 0.5                               | 25-50                            |
| FFA (OSLC)                                                  | 0.5                               | 50                               |
| RHD                                                        | 0.3-1.0                           | 30-50                            |
| Emultal                                                    | 0.3-1.0                           | 25                               |
| LTM, SG                                                    | 0.5                               | 80                               |
| RAMBS, SEDB                                                | 0.5-1.0                           | 30-50                            |
| foreign K-lube                                              | 0.5                               | 30-50                            |
| Lube-167                                                    | 0.5-1.0                           | 30-50                            |
| Dreel free                                                  | 0.5                               | 40                               |
| EME-Sweet                                                   | 0.5                               | 30-40                            |
| EME-Salt                                                    | 0.5                               | 20-40                            |
| EBL                                                         | 0.5-1.0                           | 20-40                            |
The following Table 1 presents the experimental results obtained by classifying the methods of reducing the friction forces of a drill string against the walls of a well while drilling vertical, directional, and also wells with a horizontal end.

Based on the data obtained, it can be concluded that adding a lubricant additive such as LTM (light tall oil) or a mixture of tars of domestic production to the drilling fluid in an amount of 0.5% of the total drilling mud gives the result of reducing the friction coefficient by about 80%, thus showing the best performance among the considered types of lubricant additives.

However, the use of the above lubricant additives is limited due to environmental safety requirements. In this regard, the possibility of introducing lubricant additives into the drilling fluid must be coordinated with the subsoil user (Customer).

As foreign lubricant additives in the drilling fluid, reagent has found wide use LUBE-167 firm «MI Drilling Fluids» And with the use of LUBE-167 as an additive to drilling mud can reduce the risk of sticking to 40%. The main advantage of imported lubricant additives is the fact that they meet the requirements of well drilling technology, but due to the high cost, their use in the Russian Federation during the construction of wells is limited.

6. Mechanical method of dealing with puffs and sticking

In addition to the chemical method, I propose a mechanical method for dealing with puffs and stickings, by including the oscillator-turbulator in the bottom hole assembly to the barrel (BHA).

Oscillator-turbulator (Figure 2) – A device for oscillation of low-frequency oscillations of a washing liquid.

![Figure 2. Scheme of the oscillator-turbulator:](image)

1 – cover; 2 – case; 3 – upper diffuser; 4 – sleeve; 5 – valve; 6 – axis; 7 – lower diffuser; 8 – grooves (screw notches on the body); 9 – notches on the valve; A – through channel.

Oscillator-turbulator works as follows. Wash fluid is pumped from the surface by pumping units and passes through the string of drill pipes to the downhole oscillator. Through the passage channel, the jet of fluid enters the upper diffuser 3. The upper diffuser 3 performs the function of transferring fluid from around section to a square section on the sleeve 4. On the sleeve, the jet of fluid moves in a square section and enters the valve 5, which begins to perform oscillatory movements, bending one side and then the other to the flow channel. As a result of this, at certain points in time, the channel is blocked. The fluid after the transition from the valve 5 moves on the sleeve 4 and enters the lower diffuser 7, which has a circular cross-section. The valve 5 is held on the axis 6. The cover 1 serves to connect the oscillator-turbulator with a downhole motor.
The main element of the downhole oscillator-turbulator is a valve that oscillates in contact with the flushing fluid.

In accordance with the research conducted by researchers of PJSC Oil Company «RN-Drilling», the equation of the dynamics of the rotational motion of the valve of the downhole oscillator was determined to take into account the gravitational forces \(mg\) acting on it, the pushing out \(Ar\), and the pressure forces of the washing fluid \(P\):

\[
\frac{d^2\varphi}{dt^2} + \frac{3}{2} \left( \frac{g \cdot b \cdot m \cdot F_{fr} - Ar \cdot b \cdot F_{fr} + \rho \cdot c \cdot s \cdot Q \cdot P}{a^2 \cdot m \cdot F_{fr}} \right) = 0,
\]

where \(m\) is the valve mass, kg; \(\rho\) – density of the washing liquid, kg/m\(^3\); \(Q\) – flush flow rate, m\(^3\)/s; \(F_{fr}\) – friction force, N; \(a\) is the distance from the axis to the valve tip, m; \(b\) – the distance from the valve axis to the wall of the sleeve, m; \(P\) – the pressure force of the washing liquid, MPa.

Thus, having considered all the acting forces, the equation of rotational motion of the valve of the downhole oscillator-turbulator was obtained, which allows obtaining the dependence of the valve length on the acting forces, flow rate and density of the washing liquid.

During the study, it was found that the flow rate of the flushing fluid affects the amplitude of the fluid pulsation, and the valve length affects the pressure drop and frequency. Thus, with increasing valve length and flushing fluid flow, the pressure drop of the downhole pressure oscillator increases proportionally. Also, in the course of mathematical modeling, it was found that the optimal valve size is 0.125 m length, which is necessary for the efficient operation of the downhole oscillator. Next, we consider the composition of the bottom hole assembly BHA to the barrel with an enhanced dynamic load on the PDC bit (Figure 3), which will include an oscillator-turbulator and comparative data on the use of this bottom hole assembly to the barrel in the constructions of wells in the Gubkinskoye field.

The purpose of drilling with this bottom layout was to compare the results of drilling with previous wells in the field and to determine whether the oscillator-turbulator included in the BHA affects the mechanical drilling rate.

![Figure 3. BHA diagram with enhanced dynamic load on bit PDC.](image)

Table 2 shows the comparative data of well-construction using bottom hole assembly without an oscillator and with an oscillator.

| The presence of an oscillator | without oscillator | with oscillator |
|-------------------------------|--------------------|----------------|
| Well number                   | 2153               | 2154           |
| Drilling intervals, m         | 50-472             | 50-471         |
| Passage per flight, m         | 422                | 421            |
| Drilling time, h              | 30.21              | 30.61          |
| Mechanical speed, m/h         | 14.0               | 13.8           |
| Load, tons                    | 6-8                | 6-8            |
| Pressure, atm.                | 100                | 100            |
| Productivity, l/s             | 28-30              | 30             |
| Mode of drilling              |                     |                |

Table 2. Comparative data of well-construction using bottom hole assembly without an oscillator and with an oscillator.
Conducted field tests showed that the drilling rate increased on average by 1.5 times, and the drilling time, respectively, decreased by 1.5 times. After conducting field tests, the oscillator-turbulator and all its components were in working condition. The economic effect of the introduction of the downhole oscillator is about 300 thousand rubles per well.

7. Conclusions
In order to prevent sticking and puffs, two methods were proposed:

1. **Chemical method** by introducing into the drilling fluid lubricant additives such as LTM (light tall oil) or SG (a mixture of tar) of domestic production in the amount of 0.5% of the total amount of drilling mud, which gives the result of reducing the friction coefficient by about 80%. The best performance among the considered types of lubricant additives. The use of a foreign-made lubricant additive LUBE-167 from «M-I Drilling Fluids» was also proposed. The use of LUBE-167 reagent as an additive to drilling mud reduces the risk of sticking up to 40%. The cost of domestic lubricating additives is much lower in comparison with imported additives, however, there is a downside to the coin, imported additives are the most environmentally friendly in relation to domestic ones. From all this, it follows that the method is effective, but limited on the one hand by the low quality of the product, and on the other by the high cost.

2. **A mechanical method** by including into the bottom-hole assembly (BHA) of a domestic-made oscillator-turbulator, which increases the energy supplied to the rock-breaking tool as a result of reducing the friction coefficient of the drill string against the walls of the intermediate string or wellbore, by creating an additional longitudinal vibration of the column with an oscillator.

Entering an oscillator into the BHA gives an economic effect due to the fact that the well-construction time is reduced due to an increase in the drilling rate, which has been proven by experiment in the construction of well No. 2156 on the Gubkinskoye field.

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