Set of measures to prevent liner sticking during directional drilling

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Abstract. The study considers the sticking problems of drilling. The study presents the classification and gives a general characteristic of liners. It is shown that the largest number of troubles occurs due to differential sticking. Differential sticking and methods of its elimination are considered in detail. The set of measures to prevent sticking, including the use of the Rhino XC Tool borehole expander, filters with plugs, dry lubrication, eccentric shoe, is developed and proposed.

1. Introduction
Sticking is the most common type of troubles that occur during directional drilling. Sticking can be divided into two categories: sticking due to mechanical interference, and differential sticking. The majority of sticking that occur during drilling (80%) is differential, the cause of the remaining 20% is mechanical interference or equipment failure. The sticking as a result of mechanical action is divided into two categories: sticking obtained as a result of accumulation of cuttings or due to rock slide in areas with complex wellbore geometry caused by column jamming [1, 2].

In most cases, sticking occurs when the tool is tripped out, and the most common reason for it is the presence of cuttings or rock slide, less often sticking occur during the running of tool into well. Poor borehole cleaning or poor wellbore stability may also cause sticking. Besides, long circulation loss of the washing fluid may cause sticking of a fixed drill string.

Cuttings or rock slide is the most dangerous, since the unfreezing of a column stuck by cuttings or rock slide is more labor-intensive compared to the unfreezing of a column stuck in areas with complex wellbore geometry or stuck by differential sticking. The elimination of such sticking is characterized by the loss of more equipment items and the more frequent need to drill a sidetrack [3].

The indentation of a fixed casing into the filter clay cake formed on the wellbore walls causes differential sticking that occur under the influence of pressure drop in a well and a permeable formation. At the same time the friction force generated between the casing string and the formation rock does not allow moving the drill string out of location. Most often, differential sticking is observed in wells that penetrate depleted productive formations. If the casing remains motionless for a long time, then it is almost impossible to avoid differential sticking [4].
The differential sticking is caused by the presence of permeable formations, repression, thick filter cake, column contact with a wellbore wall, column standstill, time, transverse load, negligence of a drilling crew. The above factors influence the force pressing the string to the wellbore wall with a filter cake and due to differential pressure [5].

Differential sticking occurs only in the permeable formation zone, for example, sand. There are several reasons for sticking (Figure 1):

1. Sticking of the column is possible in case of contact part of the column with the wellbore wall and its pressing to the filter cake. Hydrostatic pressure of the drilling mud column affects part of the column surface in contact with the filter cake.
2. The pressure gradient of the mud column and in the formation affects the column area in contact with the filter cake of the wellbore wall, and the resulting force holds the string.

Torque caused by differential pressure sticking is calculated as the product of differential pressure, contact area and friction factor [5].

![Figure 1. Differential sticking](image)

To successfully eliminate the sticking, it is necessary to determine its cause. Quick and proper actions play a huge role, since over time any situation only becomes more complicated. Statistics shows that within the first four hours after sticking, it is possible to release 50% of all stuck columns, and then this figure is reduced to 10%.

In the event of sticking with cuttings or rock slide, the pressure is released, which is caused by the resulting plug, and then a small pressure is created, since too much pressure can contribute to further movement of the casing into the plug. Low pressure restores the circulation of the washing fluid if the column can be moved out of location.

When trying to lift the casing, it can further advance into the plug. Therefore, it is necessary to move the casing and restore circulation, blur the plug and bring the plug material to the daylight surface. When the circulation is restored, the flow rate of the washing fluid is increased to the maximum value not resulting in absorption. Circulation must be continued until the well is cleaned.

2. Materials and methods

The analysis of experimental data and scientific literature, analytical research methods made it possible to obtain the results presented in the paper.

3. Method procedure and assessment of its efficiency

In the fields of Russia, which have been in operation for more than a year and are in the second and third stages of development, the problem of tailings is quite urgent.

According to the studies, at the deposits of the Krasnoyarsk Territory, the average formation pressure of the Nx-3-4 formation is 160 atm. At the same time, its accepted value is 270 atm. Thus, the coefficient of anomaly of the formation pressure amounts to 0.58. Therefore, the risks of emergency during the construction and reconstruction of wells using side-tracking, the occurrence of differential sticking, sloughing of unstable clays, etc. are obvious.
Considering the need to reduce the idle well stock, using the experience of sidetracking in conditions of low formation pressures of the productive formation Nx 3-4 (up to 60% of hydrostatic pressure), the following set of technical and technological measures are proposed for successful borehole drilling and accident-free running of a tail pipe:

1. Use of the Rhino XC Tool hydraulic expander with the ability to expand the borehole during drilling from 155.6 to 165 mm to the T2 point.

2. Use of a filter with plugs to allow the well to be flushed through the liner bottom, including pumping (if necessary) of calmatation packs of drilling fluid after passing the bottom of the layout through the supercollector interval.

3. Use of STIK LESS dry lubricant. Before running the “liner”, a pack with a material that reduces the friction coefficient is installed in the zone of high wellbore intensity to better bring the weight to the liner shoe during running.

4. Use of guide rotating liner shoe.

The Rhino XC Tool developed by Shlumberger is designed to increase the borehole, and its operation is based on the hydraulic activation of additional mills. The expander, passing through the borehole, increases its diameter to 165 mm, which is an advantage of this technology. The ability to activate and deactivate the expander at any stage of well drilling is also a positive factor. The use of this technology reduces the area of liner filter contact with the rock.

The first well in Russia using the Rhino XC expander was drilled in 2017 at the Vankorskoe field. Drilling with an expander was carried out to the target horizon, then the expander was deactivated.

Other companies also have positive experience using the extender. The SOCAR oil company, owned by the Republic of Azerbaijan, used the Rhino XC expander with hydraulic drive in the construction of a well at the Karadagskoe field, the use of the expander allowed drilling and expanding 989 meters of the upper section from 444.5 to 504 mm per run. As a result of using Rhino XC, a well of nominal diameter was drilled with high quality, which made it possible to facilitate the running of the casing as much as possible. The drilling process was accompanied by activation and deactivation of the expander (eight times). SOCAR management plans to expand the experience of using a well-proven expander to drill other wells [6].

Besides, STIK LESS dry lubricant, representing colorless microspheres measuring from 500 to 800 microns, was used to prevent sticking at Russian fields. This technology has several advantages. The addition of microspheres into the drilling fluid significantly improves the lubricity of aqueous, petroleum and synthetic based solutions. Laboratory and practical studies of dry lubrication have proved that its use significantly reduces the shear moment in case of differential sticking. There is also a significant reduction in the likelihood of pipe sticking when pressure drops. In addition, microspheres do not clog the formation and are easily washed out of the well [7]. In May 2018 the liner was successfully lowered using the STIK LESS dry lubricant at the Vankorskoe field.

In 2017, the effect of dry lubricant Alpine drill beard on the drill string mobility was studied at the Vankorskoe field. The 20 kg/m³ Alpine Drill Beads drilling mud pack was installed in the open hole during the last wiper trip of side-tracking. To assess the efficiency of the Alpine Drill Beads, the weight when lifting the drilling tool before and after installing the pack, as well as the hook weight when running the liner were compared with the calculated parameters. When running the liner, a road map was created allowing clearly seeing a significant decrease in the actual weight of the pack when running the liner compared to the calculated value. As a result of the recalculation, taking into account the actual weight of the pack when running the liner, the friction coefficient made less than 0.3, while the calculated coefficient was 0.4-0.5.

RN-Uvatneftegaz LLC introduced injection of a drilling fluid pack containing “dry lubricant” in the form of calibrated glass microspheres with a diameter of up to 800 µm before running the production casing in wells with vertical deviation of more than 3500 m. The pack was installed at the intervals of the open borehole, namely, in the area of the zenith angle fall in the S-shaped directional wells and in the interval of the zenith angle rise in the J-shaped tangent section of the horizontal well, in which the greatest friction coefficients were observed. Lubrication was used simultaneously with
semi-positive centralizer, which made it possible to reduce the friction coefficient when running casing strings in deep wells in a cased hole up to 0.20 and in an open hole up to 0.30. When using standard technologies and tooling the friction coefficients equal 0.25 and 0.40 [8].

Since October 2016, Gazpromneft-Khantos LLC has drilled 10 horizontal wells at the Yuzhno-Priobskoye field, in which drilling mud was used to drill a horizontal hole without the developed active solid phase with the addition of microspheres or “microballs”. The use of this technology made it possible to reduce the risk of complications with increased density of the solution caused by sticking [9].

During horizontal drilling, the fixing of the liner, which has a pre-perforated part and is cemented above the filter, may be accompanied by liner failure to reach the bottom without washing through the shoe, and poor-quality removal of clay solution and cuttings may also occur in the filter interval and the borehole annulus of the liner [10-13]. One way to reduce the risk of sticking when running the liner is to use filters with plugs FS114-6000x0.3-10x64-KC132. These filters are used in oil, gas and water wells of any design and operate in the medium of mineralized reservoir water, oil, natural gas, condensate and other well fluids. The filters are designed to prevent destruction of weakly cemented collectors and ingress of sand and other mechanical impurities into the well. The filter is installed at the bottom of the casing string through threading. After cementing and flushing the well, the sealing plugs are cut off the filter of FS114-6000x0.3-10x64-KC132 type with the device for removing the plugs with their tracking at well mouth. The proposed technology allows the following:
- running the tool with the liner to the measured depth with high-quality washing and without complications;
- pumping the colmatation packs.

Another way to reduce the risk of sticking is the use a column rotating shoe – BK-Vr 114. The rotating column shoe BK-Vr is designed for the bottom of the casing string to direct it along the well bore and pass complicated zones (cavities and tight spots) without landing, which is carried out by overcoming ledges and obstacles with the eccentric tip of the shoe. In a horizontal wellbore, the landing and subsequent stoppage of the casing are generally always associated with cuttings accumulated from the lower wellbore area. For better visibility, the movement of the casing can be compared to log skidding. Equipping the log with a rotating hemispherical eccentric head makes it possible to significantly improve its sliding along any uneven surface. A similar principle is implemented in the new design of the rotating shoe. The BK-Vr shoe has structural features: the guide plug of the shoe is made with a bevel of 20–30° and an eccentric displacement of the top of the rounded cone relative to the shoe axis. BK-Vr 114 is used in wells with casing columns which nominal diameter is 114 mm. The field of application of the device is vertical and directional horizontal wells. The assembly of the BK-Vr 114 column shoe includes an eccentric aluminum alloy nozzle with one central and four side flushing holes fixed in a coupling and having a sliding bearing.

In May 2018, the technologies proposed in the paper were used at the Vankorskoe field for the successful installation of the borehole and accident-free running of the liner. A lateral borehole with a horizontal end was successfully drilled, during the construction of the well, the experience of drilling boreholes in conditions of low formation pressures of the productive formation Nx 3-4 was used. The use of the Rhino XC expander allowed increasing the diameter of the wellbore, which is reflected in acoustic log data. STICK LESS 20 reagent was used to reduce the friction coefficient when running the liner casing. Besides, the liner arrangement included a guide rotating shoe together with filters with plugs.

4. Conclusion
The well is designed for long-term operation and is an expensive fundamental hydraulic structure. Therefore, the use of advanced modern technologies in well construction will reduce complications and accidents during construction and ensure their better operation. The analysis of the use of the described technologies in various fields suggests that the use of a set of measures to prevent sticking,
including the use of the Rhino XC Tool borehole expander, filters with plugs, a rotating shoe guide and a “dry lubricant” makes it possible to recommend these technical and technological measures.

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