On the development of an experimental design and field test of an upper bit tool

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Abstract. The design of upper bit tools has been developed. Such tools provide crushing, sifting and removal of slurry from the bottom when drilling vertical, deviated and horizontal wells with a roller cone bit. The analysis of slurry samples from directional and horizontal wells was carried out to determine rational geometric dimensions of the working channels of the upper bit tool. The design requirements of upper bit tool, ensuring the stability of its operation, are presented.

1. Introduction

Bottoms of oil and gas wells during drilling, as a rule, become clogged with large drill cuttings, which leads to a deterioration in the process of rock destruction and a decrease in the performance of bits [3]. With increasing a drilling depth, an increasing amount of sediment, consisting mainly of large-sized sludge, remains in a bottom of well [1]. The removal of sludge is complicated when drilling deep vertical, deviated and horizontal wells, as well as when drilling shallow wells, i.e. when the circulation of the flushing fluid does not create sufficient upward flow for the removal of sludge. The most urgent problem is the cleaning of a horizontal wellbore from cuttings.

In the modern oil industry, horizontal drilling is the most effective way to develop oil and gas reserves. The task associated with the development of highly efficient equipment for cleaning the bottom of the well from sludge is relevant.

The eccentric location of the drill string in the borehole, the radial orientation of gravitational forces acting on the particles of the sludge determine the significant difference between the conditions for the removal of sludge by drilling fluid during drilling of horizontal wells from vertical ones [2, 4, 8].

Poor cleaning of wells from sludge leads to such complications as a decrease in the load on the bit, an unregulated change in the trajectory of the bore, difficulty in orienting the drilling tool, a change in the nature of the work of downhole assemblies, absorption of flushing fluid, and hydrodynamic sticking [3, 6].

In the narrowest part of annular space, the accumulation of sludge occurs, which causes complications when drilling horizontal wells [1, 5]. If the average value of transverse pulsations of the flow rate of washing liquid is less than the sedimentation rate of solid particles, the solid phase will begin to settle on the lower wall of the horizontal section of well, forming sediments. Calculations show that it is possible to transport particles of sludge of not more than 1-2 mm in suspended state [7].
To increase the efficiency of cleaning the bottom and the borehole from cuttings, various devices are used. These devices are built into the bit: ball vibrators, balancer, acoustic, jet pumps. Various upper bit devices are used to improve the cleaning of bottoms: a sub equipped with a screw, vibrators, jet pumps of various designs [11, 13]. These devices improve the cleaning of bottoms of well from a sludge to a certain extent, but do not provide the removal of large, solid sludge particles, allow re-crushing of sludge, the formation of sludge dunes when drilling horizontal wells [12].

2. Materials and methods

To increase the efficiency of cleaning wells from sludge, an upper bit device was developed, passing through which, large sludge particles are crushed to a size of 2 mm or less [7]. A schematic diagram of a upper bit sludge grinder is shown in Figure 1. The mesh screen 4 is mounted on the shaft 2 of the turbo-drill 1 and connected to the rotating shaft 2 by means of springs 5. The rotating shaft of the turbo-drill and drum connected by springs form an oscillating system. When the turbo-drill shaft rotates due to the presence of springs, torsional vibrations of the drum are created, which ensures grinding and sieving of the sludge.

![Figure 1. Schematic diagram of the drum drives near-bit slurry grinder: 1 – turbodrill; 2 – a shaft of a turbodrill; 3 – bit; 4 – drum; 5 – springs.](image1)

![Figure 2. Schematic diagram of an upper bit sludge grinder during turbine drilling: 1 – bit; 2 – case; 3 – auger; 4 – inlet openings; 5 – drum; 6 – drum holes; 7 – chipper; 8 – rotor; 9 – output channel; 10 – a shaft of a turbodrill; 11 – turbodrill; 12 – ribbed surface of the drum; 13 – torsion spring.](image2)
Figure 2 shows a schematic diagram of the operation of an upper bit slurry grinder during turbine drilling. The main device parts are the housing 2, which is equipped with a screw 3 and rotor 8, and the drum 5. The screw and rotor are installed inside the drum, which has input and output channels 4, 9, openings 6, bump 7. In the upper part, the drum is equipped with a ribbed surface 12, which mates with the end face of the rotor. The device is equipped with a screw, which sucks the sludge and directs it to the rotor, which in turn discards the sludge to the drum chipper 7. In this case, sludge is crushed, small particles of sludge are sifted through the drum, large particles are re-crushed by the end face of the rotor.

To determine the dimensions of working channels and holes of the upper bit sludge grinder drum, we analyzed the sludge samples from the following directional and horizontal wells [9, 10].

3. Results

Production horizontal wells No. 138Γ, No. 140Γ No. 141Γ, Shakshinskaya area. The layout of the drilling tool: the 123.8 SL62P bit, the screw downhole motor DR-106, telesystem CTT, SBT-73. The drilling was carried out by a clayless polymer-salt solution with a flow rate of 0.010 m$^3$/s. The axial load on the bit is 6 tons. Sludge samples were taken during drilling of the horizontal part of the trunk (Figure 3), depth 2100–2250 m, Tournaisian layer, hard rocks.

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Production directional wells No. 106 and No. 107, area – Yubileinaya. The layout of the drilling tool: the 215.9 TD61AXLK bit, the screw downhole motor D5-195, the weighted drill pipe UBTS-178 100 m long, SBT-127. The drilling was carried out by a clayless polysaccharide hydrophobizing low-carbonate solution with a flow rate of 0.028 m$^3$/s. The axial load on the bit is 15 tons. Sludge samples (Figure 4) were taken from a depth of 1208–1210 m, Kizel-Cherepetskiy horizon, hard rocks.

Production well No. 486, area – Belebeyevskaya. Drilling cutting 347 m to a depth of 2015 m. The geological section is composed of hard rock. The layout of the drilling tool: the 215.9 HP62ALK bit, UBTS-178 100 m long. The drilling was carried out by a polyglycol inhibited drilling fluid with the flow rate of 0.027 m$^3$/s, using a downhole screw motor D5-195 with a rotation speed of 90 rpm. Sludge samples (Figure 5) were taken from a depth of 2050–2052 m (Mullinsky horizon).
Production well No. 3114, area – Leonidovskaya. Drilling cutting 455 m to a depth of 1555 m. The geological section is composed of hard rock. The layout of the drilling tool: the 215.9 TZ-GAU R590 bit, UBTS-178 100 m long. The drilling was carried out by clayless polysaccharide hydrophobizing low-carbonate solution with the flow rate of 0.03 m$^3$/s, using the downhole screw motor D5-195 with the rotation speed of 90 rpm. Samples (Figure 6) of sludge were taken from a depth of 1546–1548 m (Nizhne-Famensky horizon).

Also, the sludge removal was investigated when drilling horizontal sections of wells No. 452 and No. 331 on Tuimazinskaya Square. The layout of the drilling tool: the ENP 142.9 KS bit, UBT-108 8 m long, SBT-73. The load on the bit was 30–50 kN, the pressure on the riser was 7 MPa and 10 MPa for wells No. 452 and No. 331, respectively. Drilling was carried out with a mud with a flow rate of 0.010–0.013 m$^3$/s, using a rotor with a rotation speed of 72 rpm. The geological section is composed of hard and hard rocks. Sludge samples (Figure 7) were taken from a depth of 1730 m from well No. 331 and 1178 m from well No. 452.

4. Conclusion
According to the study results, the largest particle size of sludge was 25 mm. With a margin, we select the diameter of input channels of the upper bit device equal to 30 mm. The diameter of output channels (holes in the drum) is 2.5 mm. The geometric dimensions of elements of slurry grinder were determined using the results of bench tests of the model and the results of theoretical studies of the upper bit system of slurry grinder.

Applications upper-bit sludge grinder: for drilling deep vertical, deviated and horizontal wells. When drilling shallow wells – when the circulation of flushing fluid does not create a sufficient upward flow for the sludge removal.

Requirements for the construction of upper bit slurry grinder: 1) ensuring the reliability of work when performing all technological work on drilling wells; 2) providing a gap between the wall of well
and drum; 3) length not more than 600 mm; 4) the outer diameter is less than the diameter of turbodrill (layout of the bottom of drilling tool); 5) connecting threads must allow installation above the bit; 6) the drum is mounted on a shaft with an axial and radial clearance of 2 mm; 7) minimum manufacturing cost.

The technical characteristics of upper bit device developed are given in the table.

The study of the effect of upper bit sludge grinder on the mechanical speed and drill bit penetration during drilling was carried out at well No. 27B/180 of the Mellyaneft’ area drilled for technical water supply. In the process of drilling wells, the following parameters were monitored: flow rate of flushing fluid, standpipe pressure, mechanical drilling speed, penetration to the bit, dimensions of the slurry carried out by flushing fluid.

The well drilling was carried out by the drilling rig URB 3A3, the pump NB-40. The drilling was carried out with a clay solution (specific gravity 1.21 g/cm, viscosity 30 s) with a flow rate of 4 l/s, using the P-25 rotor with a rotation speed of 120 rpm. The chisel load is the weight of the tool. The depth of well is 102.5 meters. Drill tool layout (Figure 8):

- bit 215.9 MFG;
- near-bit slurry shredder;
- 147 mm weighted drill pipes 4.65 m long.

| Table 1. Technical characteristic of near-bit Sludge Grinder |
|-------------------------------------------------------------|
| Parameters of upper bit sludge grinder                       | For assembly with a chisel diameter 215.9 mm | For assembly with a chisel diameter 146 mm |
| Outer diameter mm                                            | 190                                           | 126                                           |
| Mesh outer diameter, mm                                       | 185                                           | 121                                           |
| Drum inner diameter, mm                                       | 168                                           | 109                                           |
| Outer diameter of the drum, mm                               | 123                                           | 70                                            |
| Internal shaft diameter, mm                                  | 85                                            | 48                                            |
| Overall length, mm                                           | 510                                           | 500                                           |
| Mesh length, mm                                               | 264                                           | 264                                           |
| Connecting thread, mm                                         | 3-117                                         | Z-86-upper, Z-88-lower                        |
| The diameter of the grid cell, mm                            | 2.5                                           | 2.5                                           |
| Screw diameter, mm                                           | 157                                           | 103                                           |

Figure 8. The bottom of the boring tool, equipped with a slurry grinder: 1 – chisel; 2 – case; 3 – drum; 4 – a nut; 5 – sub
The geological section of drilled interval: grayish-brown sandstone, sandstone interbedding with marl and clay, brownish-gray clay with marl and sandstone interlayers, strong brown-red sandstone with clay interlayers, red-brown sandstone strong clay, thick reddish-brown clay, interbedding sandstone with marl and clay, clay is brownish-brown, sandstone is brown of medium strength.

Using a slurry grinder, 93.5 m were drilled in the interval 9.0–102.5 m in 26 hours. The mechanical speed was 3.59 m/h. Sludge, crushed to 2.5 mm, was stably carried to the surface by a stream of washing liquid. Bit wear is negligible.

As a result of experimental drilling, it was established:
- upper bit sludge shredder is operational: during the drilling of the well there were no failures (breakdowns of parts);
- large particles of crushed sludge are 2.5 mm;
- the mechanical drilling speed due to the stable removal of crushed sludge by the flushing fluid increased by 18%;
- upper bit slurry shredder is recommended for widespread adoption to increase the efficiency of drilling vertical and horizontal wells.

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