UDC 622.24

Stimulation of the Drilling Process with the Top Driven Screw Downhole Motor

Sergey L. SIMONYANTS ✉, **Mostafa AL TAEE**
National University of Oil and Gas «Gubkin University», Moscow, Russia

Paper considers application of the top driven screw downhole motor during drilling of directional wells. The advantages and disadvantages of the rotation-sliding technology with implementation of top drive together with screw downhole motor are shown. It has been proven that the use of a screw downhole motor with simultaneous rotation of drilling pipes using the drilling rig's top drive allows increasing the bit rotation frequency without additional loading of the drilling string.

Field data for the work out of one-type PDC bits in identical geological and technical conditions with different types of drives during the construction of three directed wells at the Rumaila oil field of the Republic of Iraq were obtained. A regular increase in the mechanical penetration rate, which is explained by an increase in the bit rotation frequency, has been proved. According to the data obtained, a comparative analysis of the drilling indices was carried out, as a result of which the feasibility of joint use of top power drive with screw downhole motor at drilling oil and gas wells was proved.

***Key words*:** well drilling; top drive; screw downhole motor; Republic of Iraq oil fields; drilling mode forcing

How to cite this article: Simonyants S.L, Al Taee M. Stimulation of the Drilling Process with the Top Driven Screw Downhole Motor. Journal of Mining Institute. 2019. Vol. 238, p. 438-442. DOI: 10.31897/PMI.2019.4.438

Introduction. The specialists involved in the construction of oil and gas wells have no doubt that the use of the drilling rig top drive (TD) provides higher drilling speeds and a higher level of safety than the use of traditional rotary drilling equipment. The benefits of using a top drive system are:

• time saving on pipe buildup during drilling;

• reducing the likelihood of drilling tool sticking;

• possibility of expanding (developing) the wellbore not only during the descent, but also during the ascend of the tool;

• cleansing the wellbore at drilling string rotation;

• improving the accuracy of well construction during directional drilling.

Comparative analysis of drilling indicators, performed according to the results of the rotor drilling of two deep wells at one of the Republic of Iraq oil fields [1], showed the increase in the mechanical penetration rate of more than 20 %, obtained mainly by increasing the rotational speed of the drilling string using TD.

It is known that forcing the frequency of bit rotation leads to an increase in the speed indicators of drilling, but it is usually limited to the durability characteristics of the rotor and the drilling string, and application of TD does not always expand these possibilities. At the same time large potential of the rotary drilling method using TD can be realized by implementing hydraulic downhole motor (HDM) [10, 12, 13, 14], screw downhole motor (SDM) in particular, in a borehole bottom assembly of the drilling string [3, 4, 6, 8, 11]. The use of SDM with simultaneous rotation of the drilling pipes using TD allows increasing the bit rotation frequency (n_{bit}) without additional loading of the drilling string. At the same time, the bit rotation frequency becomes equal to the sum of the drilling string rotation frequencies using TD (n_{td}) and screw downhole motor (n_{sdm}):

$$n_{bit} = n_{td} + n_{sdm}. \quad (1)$$

The main objective of this study is to obtain quantitative indicators confirming the increase in the efficiency of the drilling process through the joint use of drilling rig TD and SDM.

DOI: 10.31897/PMI.2019.4.438

Methodology. The feasibility of applying the new technology, in which the investigated parameter is the type of a bit drive, can be determined as a result of a comparative analysis of technical and economic indicators of drilling in identical geological conditions, provided that other technical factors are equal. In order to do this, it is necessary to select wells drilled at one oil field approximately at the same depth using the same bit sizes and other drilling equipment. To compare the technical and economic indicators of drilling with TD and SDM, field data from three inclined wells at the Rumaila oil field located in the southern part of the Republic of Iraq were analyzed. The main method of drilling oil wells in Iraq is rotor with TD [1], which allows considering its performance as a representative base of comparison.

Discussion. The operation of a screw downhole motor in the mode of constant rotation of the drilling string is a complex production process [9, 14]. Recently, this technology has been widely used for drilling inclined and horizontal wells with constant monitoring of curvature parameters using MWD downhole telemetry systems. It allows providing high-quality drilling of all sections of a directed well with the bottomhole reaching designed depth without lifting the SDM and the bit to the surface. It uses a short screw motor with a curved sub, having small skew angle of the axes. In the process of drilling the vertical or inclined-straight linear interval of the zenith angle stabilization, the drilling assembly is rotated slowly with a rotor or TD. If it becomes necessary to change the inclination angle of the well, the rotation of the assembly stops, the screw downhole motor is set in the desired azimuthal direction, and drilling continues with a non-rotating drilling string until the desired zenith angle is reached. This mode of well deepening is called sliding. If the following interval is a sloped-straight or vertical one, then the drilling string is rotated again. The whole process is carried out under the control of the operator with the help of a downhole telemetric system. The rotation-sliding technology allows not only high-quality drilling of an inclined well, but also ensuring a significant increase in technical and economic indicators of drilling by reducing the time of tripping operations.

The rotation of the drilling string with SDM in an inclined well has a number of technological advantages:

- reduced friction force of the drilling string in the wellbore;
- mechanical penetration rate increases;
- better wellbore cleaning from rock cuttings is provided.

However, as a result of the rotation, the loads on the screw downhole motor also increase [3, 7, 8, 14]. This can be critical when large skew angles are set on the SDM, especially in areas of excessive borehole curvature. Intensive rotation of the drilling string under adverse conditions can lead to rapid wear of the rotor and stator, excessive load and wear of the radial spindle bearings, heating of the SDM frame due to friction against the borehole wall, increased fatigue of the engine components due to the alternating load.

The catalogs of the SDM manufacturers provide special tables with technical characteristics of a downhole motor and limit values for the intensity of the well curving calculated on the basis of the skew angles, borehole diameter and stabilizers installed. When the operating mode of a downhole motor is close to these limit values, the rotational speed of the drilling string and the axial load on the bit must be appropriately limited to minimize the negative effects of SDM overloading.

At drilling string rotation with the simultaneous operation of the SDM, it is also necessary to consider the possibility of bit overloading, due to which the motor may stop. At the same time, drilling string can continue to rotate, but the blocked bit will cause braking of the downhole motor, accompanied by a sharp increase in pressure at the pump outlet, reaching significant values [2, 8].

Increased pressure at the outlet of the mud pump is a significant negative factor accompanying the use of any hydraulic downhole motor. However, with SDM application, it should be taken into account that the pressure of the pump will not only be higher than with the rotary method, but it will also increase as the axial load on the bit rises. At the moment of the SDM sudden stop, a hydraulic shock occurs in the circulation system, which is countered by means of a relief valve installed above the downhole motor and discharging the flow of drilling mud into the annulus. These factors should be considered in the joint use of TD and SDM.

Investigation results. The table shows comparative analysis results of technical and economic indicators of drilling using TD and SDM, obtained during the construction of three inclined wells at the Rumaila oil field.

Well drilling results

Indicators	Well		
	R-23	R-29	R-51
Drilling mode	Rotor	HDM	Rotor + HDM
Type of drilling bit drive	TD	SDM	TD + SDM
Drilling rig	ZB-924	DQ011	IDC 37
Mud pump	12T1600 PUMP-MUD	12T1600 PUMP-MUD	12T1600 PUMP-MUD
Designed depth, m	3370	3455	3459
Angle of the borehole curvature, deg	78º	70º	80º
Drilling interval, m	1835-3110	1961-3455	2161-3459
Bit diameter, mm	215.9	215.9	215.9
Bit type	PDC MMD55H/M323	PDC M1652R/M322	PDC M1652R/M322
SDM size	–	6.3/4 MOTOR 5/6	6.3/4 MOTOR 7/8
Model of the motor	–	MICON Drill	PowerPak
SDM manufacturer		MICON Drilling	Schlumberger
Drilling mud flow rate, l/s	33	29	30
Drilling mud density, kg/m^3	1260	1212	1200
Axial load on the bit, kN	90	80	100
TD rotation frequency, rpm	80	–	50
SDM rotation frequency, rpm	–	160	130
Bit rotation frequency, rpm	80	160	180
Total drilling depth, m	1276	1494	1298
Number of bits	2	3	2
Total time of drilling, h	590	420	282
Total advance per bit, m	638	498	649
Time of bit operation, h	295	140	141
Bit penetration rate, m/h	2.16	3.55	4.60
Drilling speed per run, m/h	2.09	3.32	4.29
Cost of penetration rate, USD/m	1034	759	586

The study of the field geological profile showed that the lithological composition and mechanical properties of the rocks in the considered wells are identical. This made it possible to conduct a comparative analysis of drilling performance in the range of the same drilling bits type. In the R-23 well, a rotary method of drilling with TD was used, in the R-29 well a downhole motor was applied, and in the R-51 well SDM was used with simultaneous rotation of the drilling string with TD. All drilling rigs used the same type of drilling pumps, weighted and drilling pipes, as well as PDC bits manufactured by a Chinese company.

Screw downhole motor MICON Drill of the German company MICON Drilling with a diameter of 172 mm (6¾″), lobes of 6/7 at a drilling mud flow rate of 29 l/s had a rotation speed of 170 rpm in idle mode. With an axial load of 80 kN, the operating speed was estimated at approximately 160 rpm. The screw downhole motor PowerPak of the American company Schlumberger with a diameter of 172 mm (6¾″), lobes of 7/8 with a drilling mud flow rate of 30 l/s had an idle speed of 140 rpm. With an axial load of 100 kN, the operating speed was estimated at approximately 130 rpm. The rotation of the drilling string using TD with a frequency of 50 rpm in the R-51 well allowed drilling with a total bit rotation frequency of about 180 rpm. Evaluation of the rotational speed in the operating mode of the SDM was carried out by calculation according to the method [5, 14, 15].

Thus, the performance of three PDC bits of the same type was analyzed in approximately equal geological and technical conditions: well depth, drilling interval, flow rate and density of drilling mud, axial load on the bit at different rotational frequencies: 80, 160 and 180 rpm. As a result, it was found that the average mechanical penetration rate was 2.16, 3.55 and 4.60 m/h, respectively. The increase in mechanical speed is logical and is explained by the increase in the frequency of bit rotation.

The main technical and economic indicator of well construction – the cost of penetration rate in the considered drilling intervals – was also evaluated. The calculation was carried out according to the formula [5]:

$$C_m = \frac{B + R(T_d + T_{tr}) + R_{sdm} T_d}{H}, \tag{2}$$

where H – drilling interval length, m; T_d – total time of interval drilling, h; T_{tr} – total time of tripping and auxiliary operations, h; B – total cost of all bits, USD; R – cost of drilling rig operation hour, USD; R_{sdm} – cost of SDM lease, USD/h.

The numerical values of the costs in the formula (2) were taken approximately, on the basis of unofficial information about the technical and commercial results of drilling in the considered region: one PDC bit = 50000 USD; hour of drilling rig operation R = 2000 USD; SDM lease R_{sdm} = 200 USD/h; average time of TO and AO T_{tr} = 10 h.

Analysis of the obtained data shows that the use of a screw downhole motor as part of the BHA, aimed for increasing the bit rotation frequency, provides an increase in the mechanical penetration rate and the drilling speed per run while reducing the cost of the penetration rate.

Conclusion. The use of a hydraulic downhole motor, SDM in particular, to stimulate the rotary drilling process with the help of TD is a very efficient way to increase technical, economic and speed indicators of drilling performance and can be recommended at forcing drilling modes.

REFERENCES

1. Al Taee M., Simonyants S.L. Application of top drive at well drilling on the oil fields of the Republic of Iraq. *Vestnik Assotsiatsii burovykh podryadchikov*. 2017. N 3, p. 44-48 (in Russian).

2. Baldenko D.F., Baldenko F.D., Gnoevykh A.N. Single rotor hydraulic machines: v 2 t. Moscow: OOO «IRTs Gazprom». 2007. *Vintovye zaboinye dvigateli*. Vol. 2, p. 470 (in Russian).

3. Baldenko D.F., Vervekin A.V., Plotnikov V.M. Ways to further improve the technology of drilling with the use of screw downhole motors. *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Geologiya. Neftegazovoe i gornoe delo*. 2016. Vol. 15. N 19, p. 165-174 (in Russian).

4. Dvoinikov M.V., Blinov P.A., Morozov V.A. Optimization of drilling parameters for stabilization of zenith angle. *Izvestiya vysshikh uchebnykh zavedenii. Neft' i gaz*. 2016. N 6, p. 65-71. DOI: 10.31660/0445-0108-2016-6-65-71 (in Russian).

5. Leonov E.G., Simonyants S.L. Improving the well deepening process. Moscow: Izd. tsentr RGU nefti i gaza im. I.M.Gubkina. 2014, p. 184 (in Russian).

6. Litvinenko V.S., Dvoinikov M.V. Justification of the choice on the parameters of the drilling mode by rotary controlled systems. *Zapiski Gornogo instituta*. 2019. Vol. 235, p. 24-29. DOI:10.31897/PMI.2019.1.24 (in Russian).

7. Molodilo V.I., Gusman A.M. Influence of drilling modes on the wear of the working bodies of screw downhole motors. *Vestnik Assotsiatsii burovykh podryadchikov*. 2016. N 2, p. 46-48 (in Russian).

8. Molodilo V.I., Korotaev S.N., D'yakonov G.A. Features of the screw downhole motors operation. *Vestnik Assotsiatsii burovykh podryadchikov*. 2013. N 3, p. 28-33 (in Russian).

9. Morozov V.A., Dvoinikov M.V., Blinov P.A. Investigation of the stable operation optimal range of the “bit-screw downhole motor-drilling string” system. *Neftegazovoe delo*. 2018. Vol. 16. N 2, p. 35-43 (in Russian).

10. Morozov V.A., Dvoinikov M.V. Justification of the choice on the parameters of the directional drilling mode with screw downhole motors. *Stroitel'stvo neftyanykh i gazovykh skvazhin na sushe i na more*. 2019. N 2, p. 15-18. DOI: 10.30713/0130-3872-2019-2-15-18 (in Russian).

11. Simonyants S.L., Dvoinikov M.V. Hydraulic downhole motors. Tekhnologiya bureniya neftyanykh i gazovykh skvazhin. Tyumen': Tyumenskii industrial'nyi universitet. 2017. Vol. 1, p. 448-522 (in Russian).

12. Simonyants S.L. Problems of turbine drilling modernization. Tyumen': Vektor Buk. 2003, p. 136 (in Russian).

13. Simonyants S.L. Turbodrill and screw downhole motor: the dialectic of development. Turbodrill and Screw Motor: Development Dialectics. SPE Russian Petroleum Technology Conference and Exhibition. 2016. Moscow. 26 October. SPE 182147 RU (in Russian).

14. Simonyants S.L. Well drilling with hydraulic downhole motors. Moscow: Rossiiskii gosudarstvennyi universitet nefti i gaza (NIU) imeni I.M.Gubkina. 2018, p. 208 (in Russian).

15. Simonyants S.L., Al Taee M., Gurinovich A.V. Determination of the operating parameters of a screw downhole motor. *Stroitel'stvo neftyanykh i gazovykh skvazhin na sushe i na more*. 2018. N 11, p. 5-7 (in Russian).

***Authors*: Sergey L. Simonyants,** *Doctor of Engineering Sciences*, *Professor*, *ssturbo@mail.ru* (*National University of Oil and Gas «Gubkin University», Moscow, Russia*), **Mostafa Al Taee,** *Postgraduate Student*, *mustafa.altaee@mail.ru* (*National University of Oil and Gas «Gubkin University», Moscow, Russia*).

The paper was received on 22 February, 2019.

The paper was accepted for publication on 21 May, 2019.