ISSN: 2664-9640

Research on Design Method of Low Friction Track for Deep Shale Gas

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Abstract

The deep purpose of shale gas horizontal well layer depth of 3500 m above, well depth is deeper, at the same time, at the same time open a long open hole section, causing more friction in the relatively shallow underground, for large offset three-dimensional horizontal friction problem is particularly prominent, therefore reduced the deep shale gas drag reduction is a priority for the horizontal well drilling safely and quickly. Low friction borehole trajectory design is one of the key measures of reducing friction all shaft, this paper USES the optimal trajectory design type, cant arc, paragraph five point six and 2 d three double track adaptability evaluation, analysis of their advantages and disadvantages from the workload, the friction torque, and optimize the low friction orbit parameters, thus the maximum frictional drag reduction, study, through the parameters and real drilling trajectory control can reduce friction, and the research of slope arc section 6 system design method, is advantageous to the deep shale gas well down the drag reduction.

Keywords

Deep shale gas, Bevel arc, Double two-dimensional, Friction reduction, Track control.

1. Common Orbital Design Methods

The trajectory of 3d horizontal Wells is built from the inclination point to target A, which is generally A combination of 2D well segments and 3D well segments, mainly in order to reduce the directional workload, smoothly enter the target and land, and realize the acceleration of drilling. Through literature research [1], the design methods of 3d horizontal Wells' borehole track at home and abroad are mainly used, such as bevel arc six-segment system, five-segment six-segment system and bi-dimensional track design [2].

1.1. Bevel Arc Five-Section Track

The conventional five-segment track is: Straight - - stability - toughening (torsion) - ping, the second increase oblique section (b.u. torsion bearing interval) designed to target, namely horizontal landing site, but the field applications generally there are two uncertainties, namely the reservoir geological vertical deep uncertainty and tools made slope uncertainty, which makes the actual drilling process inevitably to adjust well track the target, for ordinary two-dimensional horizontal Wells, the vertical depth adjustment only means the change of the deviation, power tool build-up rate only need to meet the deviation adjustment, for 3 d horizontal well, the trajectory of the adjustment is more complicated, Although in most cases it is only vertical depth adjustment, it means that the building slope and installation Angle have higher requirements. When vertical depth adjustment is too many, but the bearing has not been adjusted to the design direction, the building slope is easy to be insufficient, leading to the loss of borehole trajectory.

1.2. Five-six Track System

Five points are the starting point of the building slope, the starting point of the stable slope section, the starting point of the torsional azimuth, the full increase of the slope point, and the target. The five nodes divide the whole well into six sections, that is, the straight well section -- the first ramp section -- the stable Angle control section -- the torsional azimuth section -- the second ramp section -- the horizontal section, with clear division of labor and easy operation.

1.3. The Dual Two-Dimensional Orbits

The dual two-dimensional trajectory design designs the trajectory of three-dimensional horizontal wells in two intersecting vertical planes. In each vertical plane, there is only deviation change and no azimuth change. In theory, it can greatly reduce the difficulty of drilling operation, thus reducing the drilling cost of horizontal wells in shale gas wells and realizing the efficient development of shale gas reservoirs.

Different from three-dimensional horizontal well, the well trajectory of double two-dimensional horizontal well is designed in two intersecting vertical planes, and each vertical plane is a section of two-dimensional trajectory. Firstly, two intersecting vertical planes ABCD and bdef are established in the space rectangular coordinate system o-xyz, in which ABCD is called the first vertical plane and bdef is called the second vertical plane. In the figure1, O is the coordinate origin, X is the North coordinate, y is the East coordinate, Z is the vertical depth, Φ is the angle between the two planes, I is the wellhead, J and K are the entry and exit points respectively, and M is the intersection point of the drilling trajectory and the 1st and 2nd vertical planes [3].

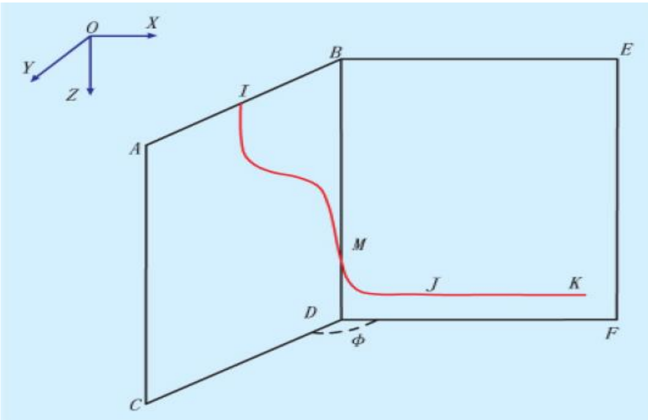

Figure 1. Schematic diagram of double two dimensional orbit

The first two-dimensional trajectory of the first section is designed in the first vertical plane, and the borehole profile of "straight increase stable drop stable" is adopted. In order to reduce the risk of adjacent well collision, after designing a vertical well section, the trajectory starts to increase the inclination in the first vertical plane towards the second vertical plane, and the deviation angle after the increase is not more than 25°. When the inclination is increased to the design angle, it starts to stabilize, and then it begins to descend after a certain length. The hole curvature of the down slope section is small, and the deviation angle is controlled within 5°. When the inclination is lowered to the designed well inclination angle, the stabilizing operation can be started until the intersection of the two vertical planes M, which is the starting point of the inclining section in the second vertical plane[4]. Because of the small inclination angle at point M, the azimuth angle can be ignored and can be directly designed as A two-dimensional horizontal well in the second vertical plane.

ISSN: 2664-9640

Compared with three-dimensional horizontal wells, the depth of deviation point in the first vertical plane of double two-dimensional horizontal wells is relatively shallow, generally 0-170m, thus increasing the distance between adjacent wells in the vertical section and reducing the risk of collision; in each vertical plane, the trajectory only changes the deviation, but almost no azimuth change, which greatly reduces the difficulty of borehole trajectory control; when entering the second vertical plane, the deviation angle of trajectory is very small, approximately In vertical wells, the azimuth can be adjusted directly to start deflecting[5], thus avoiding the large-scale azimuth twisting operation of conventional three-dimensional horizontal wells.

2. Adaptability Evaluation of Common Track Design Methods

2.1. Section Design Ideas

2.1.1. Inclined Arc Track

Design ideas: the deviation of the second spud in section is increased to 38.24° and part of the offset is consumed to drill to the middle completion depth; in the third spud, the mode of increasing the deviation while twisting the azimuth is adopted to increase the deviation to the target angle, and the azimuth is twisted to the line azimuth to complete the vector target.

Table 1. Inclined arc five segment track

Depth (m)	Deviation (deg)	Orientation (deg)	Vertical depth (m)	Closure distance (m)	Dogleg (deg/m)	tool face (deg)	section boss (m)	Note
0.00	0.00	148.92	0.00	0.00	0.00	0.00	0.00	
2100	0.00	148.92	2100.00	0.00	0.00	0.00	2100	Orientation point
2394.15	38.24	148.92	2372.80	94.57	0.13	0.00	294.15	Angle build
2492.45	38.24	148.92	2450.00	155.41	0.00	0.00	98.30	End of middle
2502.84	38.24	148.92	2458.16	161.84	0.00	0.00	10.39	Stable slope
3043.82	89.34	46.09	2746.77	467.01	0.18	259.46	540.98	Increasing inclination and twisting direction
3063.82	89.34	46.09	2747.00	479.12	0.00	0.00	20.00	Target A
4548.22	89.34	46.09	2764.00	1820.11	0.00	0.00	1484.40	Target B
4578.22	89.34	46.09	2763.95	1856.16	0.00	0.00	30.00	Pocket

2.1.2. Five Point Six System

Design ideas: firstly, the deviation is increased to 24.7° and the deviation is increased to 32.3° by using slight deviation drilling; secondly, the design azimuth is turned to the connecting direction of AB target with azimuth footage of 512M under the condition of 32.3° deviation; after the remaining azimuth is turned in the third opening, the angle is increased to land on target A.

ISSN: 2664-9640

Table 2. Track design of Five point six section system

Depth (m)	Deviation (deg)	Orientation (deg)	Vertical depth (m)	Closure distance (m)	Dogleg (deg/m)	tool face (deg)	section boss (m)	Note
1000.00	0.00	180.00	1000.00	0.00	0.00	0.00	1000.00	
1500.00	0.00	180.00	1500.00	0.00	0.00	0.00	500.00	Orientation point
1690.00	24.70	180.00	1684.17	40.32	0.13	0.00	190.00	Angle build
2070.00	32.30	180.00	2017.88	221.51	0.02	0.00	380.00	Hold angle
2582.00	32.30	55.44	2450.65	380.29	0.13	270.00	512.00	Twisting direction end
2602.00	32.30	55.44	2467.55	379.82	0.00	0.00	20.00	
2629.50	32.30	46.17	2490.80	378.48	0.18	270.00	27.50	Twisting direction
2817.50	41.70	46.17	2640.77	378.13	0.05	0.00	188.00	Hold angle
3082.50	89.40	46.17	2747.32	473.11	0.18	0.00	265.00	Angle build
3088.50	89.40	46.17	2747.38	476.80	0.00	0.00	6.00	Target A
4573.50	89.40	46.17	2762.93	1819.45	0.00	0.00	1485.00	Target B
4603.50	89.40	46.17	2763.24	1848.82	0.00	0.00	30.00	Pocket

2.1.3. Double Two Dimensional Section Design

Design ideas: the deviation is increased to 25.5° and most of the offset is consumed in the stable deviation drilling; then the deviation is reduced to about 5° and the remaining offset is consumed; when the well deviation is 5°, the design azimuth is twisted to the connecting direction of AB target, and the azimuth footage is 57.5 m; finally, the deviation is increased to land target a. As shown in Figure 2.

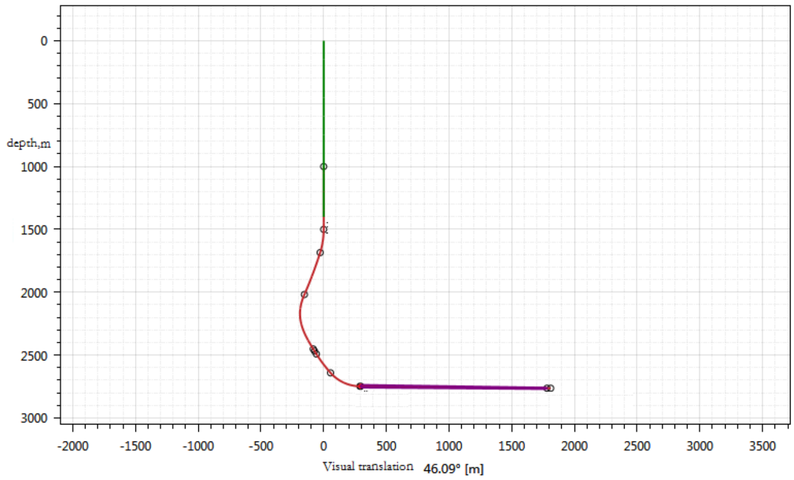

Figure 2. Comparison of three section projections

2.2. Workload Analysis of Three Kinds of Profile Orientation

Table 3. Comparison of directional footage of three profiles

	Second opening increase oblique footage, m	Two twist azimuth footage, m	Three twist azimuth footage, m	Increase of inclined footage in the third opening, m	Total directional footage, m	Completion depth, m
Five-six track system	190	512m	27.5	265	994.5	4603.5
Circular arc slope	294.15	0	540.98		835.13	4578.22
dual two-dimensional	170	57.5	0	442	669.5	4546.2

ISSN: 2664-9640

From the distribution of directional footage of the three profiles, the five point six section section section has the most workload in the second spud section. The 57.5m footage is used for the double two-dimensional section to twist all the orientations, and the inclined plane arc places the azimuth twisting workload in the third spud. In the aspect of three opening orientation, the five point six segment system is the least, the double two-dimensional system is the second, and the inclined plane arc is the most. Considering the workload analysis of the second and third opening orientation, the double two-dimensional profile should be the optimal track design method.

2.3. Analysis of Friction and Torque of Three Rail Design Methods

Table 4. Comparison of friction and torque of three profiles

	Friction in second spud sliding drilling	Friction in third spud sliding drilling	Rotary drilling torque	Insertion friction / buckling or not	Friction / buckling of production casing
Five-six track system	12.66t	23.70t	25.34kN.m	14.07t/ No buckling	14.61t/ No buckling
Circular arc slope	7.06t	23.64t	22.40kN.m	3.77t/ No buckling	13.25/ No buckling
dual two-dimensional	14.09t	24.43t/ Sinusoidal buckling	25.37kN.m	17.56t/ No buckling	15.27t/ No buckling

Through the simulation calculation and analysis of friction of three profiles, the inclined arc profile occupies the largest advantage among the six indexes, followed by the five point six segment system. The double two-dimensional profile has greater friction resistance than other profiles due to the great change of trajectory. Even in the third spud sliding drilling (WOB 10t), there will be sinusoidal buckling, WOB can not be effectively transferred, and the risk of drilling tool breaking is high.

3. Research on Design Method of Low Friction Track

As mentioned above, low friction is the first principle in the design of deep shale gas horizontal well trajectory. Therefore, in terms of trajectory design method, the inclined plane arc trajectory design method with low friction resistance is preferred. In order to enhance its engineering operability and meet the requirements of engineering and geology, the method of inclined plane circular arc summation is improved to form a six segment inclined arc profile, i.e. direct increase- Stable increase (twist) - increase - flat.

The design method of inclined plane arc needs to be optimized due to the influence of landing, while the improved method only needs to modify the well trajectory structure properly. According to the research and analysis, the structure of borehole trajectory profile is changed to six segment system, i.e. "straight increase steady increase (torsion) - increase flat", and a t point is set before the target point By adjusting the azimuth to be consistent with that of the horizontal section, and designing the last increase slope section as a low build-up slope section, the difficulties in well trajectory control caused by the uncertainty of reservoir vertical depth and build-up rate can be overcome and the drilling success rate can be improved.

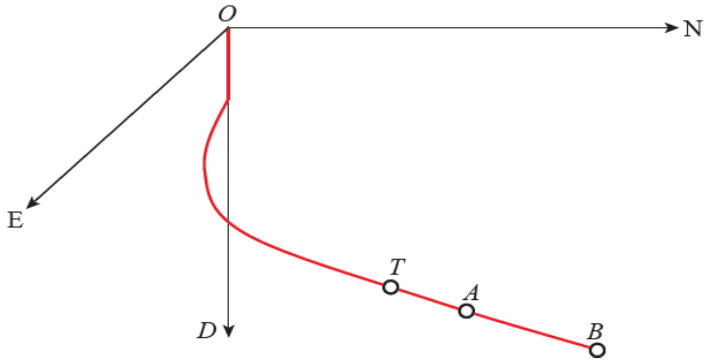

Figure 3. Schematic diagram of inclined arc optimized track

From the point of view of horizontal well landing control and geosteering, turning the azimuth to the right position in advance is conducive to the layer judgment, avoiding the landing failure resulting in high build-up slope layer pursuit and even sidetracking.

4. Optimization of Design Parameters for Low Friction Track

4.1. Selection of Depolarization Azimuth

Parameter setting: assuming that the target orientation of deep shale gas horizontal well is 0 ° and the target length is 1600m, the displacement before the target is 950 m and the offset distance is 630 M. Five angles of 55 °, 60 °, 65 °, 75 ° and 90 ° with the target azimuth are selected to eliminate the deviation. A three-dimensional soft rod model considering the viscous force of drilling fluid is used to establish the friction torque mechanical calculation method. Through the calculation of wellhead friction and torque, the appropriate offset direction is selected through comparative analysis.

Table 5. Friction and torque of wellhead in different azimuth

Depolarization orientation	Depolarization distance(m)	Lift up friction (KN)	Drop friction (KN)	Compound drilling torque (KN. m)	Empty drilling torque (KN. m)
55°	200	48.8	121.8	28.85	23.17
60°	240	31.8	55.1	21.8	16.08
65°	330	20.8	69.8	22.89	16.81
75°	350	21.6	60.1	22.1	16.48
90°	410	19.8	64.9	22.47	17.04

According to the calculation results, the larger the offset angle is, the more offset distance is eliminated, and the wellhead friction and torque are generally reduced. If the offset is eliminated at an angle close to the target azimuth, the offset can be eliminated quickly, but the subsequent torsion workload will be increased, and the torque will also increase. Considering the inconvenience of field construction, it is not recommended to eliminate the offset with a larger angle The best azimuth angle is ± (60 ° to 70 ° between the target and the azimuth).

4.2. Selection of Stable Angle of Inclination and Torsion

The selection of the azimuth angle of stable deviation and torsion should be determined according to the specific well conditions, and the selection basis is the residual offset distance.

Parameter setting: assuming that the target azimuth of deep shale gas horizontal well is 0 °, the target length is 1600m, the displacement before the target is 950 m, the offset is 630 m, the well deviation in the stable inclined section is 65 ° and the offset azimuth is 65 ° when the offset is changed, the subsequent full angle change rate and azimuth change are shown in Table 6 below.

Table 6. Change of track parameters with offset

Target offset distance(m)	Current offset(m)	Offset allowance(m)	Margin ratio (%)	Azimuth change (°)	Follow up full angle rate of change(°/100m)
630	300	330	52.38	65-39-42-0	12
630	346	284	45.08	65-39-42-0	12.6
630	392	238	37.78	65-39-42-0	15.68
630	438	192	30.47	65-39-42-0	19.72

According to the simulation results, when the residual migration distance is more than 50% of the total migration distance, the lower the follow-up full angle change rate is, but the torsion direction is too early, so it is easy to turn the azimuth; when the residual migration distance is less than 30% of the total migration distance, the azimuth is twisted, and the subsequent full angle change rate is higher, which brings difficulties to the three large wells. Comprehensive evaluation shows that 35% - 45% of the ratio of residual migration distance to total migration distance (residual ratio) is selected as the safety window of variable azimuth, and the time of azimuth twist is the most appropriate. The residual offset should be taken into account when selecting the torsion azimuth angle of the horizontal well in deep shale gas.

4.3. Building Slope Selection

With the decrease of build-up rate and build-up rate, the curve will be smoother, and the tension, torque and friction will be reduced. The build-up slope must be as small as possible and the stability of the build-up slope must be ensured.

Ensuring the designed build-up rate to meet the requirements is the key to well trajectory control. If it is difficult to meet the design requirements (lower than the design value) in the slope making section, the subsequent construction will be very passive in case of emergency. Therefore, screw drilling tools with a slightly larger theoretical build-up rate can be used in the deflecting section. Generally, the deflecting ability of the selected tools is 20-30% higher than the designed build-up rate.

After entering the horizontal section, it is usually not necessary to adjust the trajectory too much. The screw drilling tool with relatively small build-up rate can meet the requirements of horizontal section trajectory adjustment. On this basis, it can also ensure drilling safety and make the horizontal section drilling track more smooth.

5. Conclusion

(1) Under the condition of large offset and large displacement in front of target, the friction torque of deep shale gas horizontal well is further increased, which affects the drilling efficiency.

(2) For deep shale gas well trajectory control, open hole length, trajectory design parameters and actual drilling trajectory adjustment are the main factors affecting wellbore friction torque, among which trajectory design parameters and actual drilling trajectory adjustment are controllable factors.

(3) Among the commonly used profile design methods, the wellbore friction torque of inclined plane arc design is the minimum. Combined with the engineering and geological requirements, the design method of inclined plane arc six section profile is optimized, which is conducive to reducing friction and drag of deep shale gas wells.

ISSN: 2664-9640

Acknowledgements

Fund Projects: Major National Science and Technology Projects, "Petroleum Engineering Integration Technology of Shale Gas Demonstration Area in Fuling Area". Number:SG1305.

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