

Long Horizontal Section of Horizontal Well Section Optimization Design Research

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Abstract: The aim of this study is to optimize the long horizontal section of horizontal well section in extended-reach well. Extended-reach drilling technology has rapidly developed during the past three decades. It requires improved models and technology to extend to greater depth. Well profile design is one of the critical technologies for success in horizontal well because optimum well profile design is an effective means for reducing torque, drag and cost. This study presents long horizontal section of horizontal well section optimization design method based on the two buildup section well profile, and this method is analyzed in detail.

Keywords: Horizontal section, optimization, profile design

INTRODUCTION

Careful planning is the key to successful directional drilling. One of the first steps in planning the directional well should be the design of the wellbore trajectory (Gao, 2004). Wellbore trajectories can be categorized into three classes. The first type well is basically a "build and hold" trajectory where the wellbore is deflected from the vertical at some kickoff point and the angle built until a maximum angle is reached and then held until the target is intercepted by the wellbore. This type trajectory is appropriate for the condition that the build rate and target zone are all very accurate (Han, 2007). The second type well is a "build, hold, build" trajectory where the wellbore is deflected to some angle, the angle is held and then built in a manner such that the target is penetrated. In contrast to the first type, this trajectory adds a hold section between two buildup sections to adjust the trajectory deviation causing by the build error (Xiong, 2002). This type trajectory is appropriate for the condition that the target zone is accurate but build rate is not. The third type well is a "build, hold, build, hold and build" trajectory. This type trajectory is appropriate for the condition that the build rate and target zone are all not sure (Han, 1991). Along with the progress of the geological exploration technology, the accuracy of target zone is high (Luo, 2006). The objective of this

study is to optimize the long horizontal section of extended reach well, and research the method of optimization.

LONG HORIZONTAL SECTION HORIZONTAL WELL TRAJECTORY DESIGN METHOD

Long horizontal section of horizontal well trajectory design is one of the key technologies in the design of horizontal well. Generally long horizontal section of horizontal well use less vertical depth to get bigger displacement, the idea is used in the horizontal well trajectory design.

At present, long horizontal section of horizontal well trajectory uses constant curvature design and variable curvature design methods to design the well profile. Constant curvature is that in the directional drilling use "hold-build-hold-build-hold" well profile, and variable curvature design is the Britain's catenary profile design and Norwegian modified catenary profile design.

The catenary profile, neglect the drill string rigidity, consider that if the wellbore trajectory of the curve segment is catenary line, the drill string is in approximate impending state in the hole, friction force is reduced to the minimum between drill string and hole wall. Although this kind of ideal position does not exist in the actual drilling process, the some data show that

the profile design method has certain effect to reduce friction and torque. Due to the buildup rate of catenary profile increases too fast, in the basis of catenary profile design modified catenary profile design appeared.

There are many methods to modify the catenary profile, the main starting point is to use the modified method to modify the curvature of the catenary, reduce the curvature rate, make the hole become relatively flat, more suitable for the actual shape of drill string deformation, so this can improve the adaptability of assembly, at the same time reduce the length of catenary hole section. Modified catenary profile design has been applied in Norway North Sea oil field extended reach well design process of horizontal well. Quasi catenary profile design (also called constant variable curvature profile design) idea is in the curve well section, curve curvature change is constant. This profile has been applied in Britain WytchFarm oilfield, and has drilled a horizontal displacement above 10000 m large displacement horizontal well.

LONG HORIZONTAL SECTION HORIZONTAL WELLBORE TRAJECTORY DESIGN CRITERION

Long horizontal section of horizontal well track design, not only consider the rig and top drive device capability, friction/torque and the difficulty degree of construction, at the same time also must consider the strength of the drill string optimization design, casing wear and other factors. Long horizontal section of horizontal well track design, is not simple geometry curve calculation, but is a system engineering combining the drill string mechanics, drilling field. Different well trajectory design methods have their own advantages and disadvantages, but must follow the following three principles:

- **Well design must meet the requirements of the site construction conditions:** The main drilling operations are pulling out of hole, running and slide drilling, rotary drilling, reaming, back reaming, casing, etc. Under different working conditions, drill string stress is different, the change rules of friction/torque with wellbore trajectory about the string in the hole is also different. Which is the most difficult, and may be the main restricting factors of construction in the well design and we should consider this kind of condition.

When pulling out of the hole, the whole drill string bears the axial tension; the friction force will make the axial tension increase. If the friction force is too big, can start top drive to make drill string rotate, so that the friction changes direction reduces the axial friction force. So the pull out of the hole should not be the most difficult condition.

When running, the drill string can be run into the down hole relying on the drill string gravity to overcome the friction resistance. When the resistance is very big, the drill string gravity axial component can't overcome the resistance, at this time we also can start top drive, change the direction of friction resistance and reduce axial friction. So this condition also should not be the most difficult condition.

The drill string itself is rotating in the center of well when reaming, so the reaming is also not the most difficult condition.

There are two ways when drilling: rotary drilling and slide drilling. Rotary drilling is the same with the condition of starting the top drive, but because also give bit pressure, the upper drill string will be needed to provide more big axial pressure. Slide drilling is the same with the condition of not starting top drive when tripping condition, because of the drill string is not rotating, axial friction resistance is the largest, but also give bit pressure, this requires more axial pressure. In long horizontal section of horizontal well, the vertical interval is limited, the angle of "tangent section" is very big, drill string may provide the axial pressure is limited, so drilling condition, especially slide drilling condition, is the most difficult condition.

Research shows that the pull out of hole, sliding drilling and rotary drilling, these three kinds of conditions in long horizontal section of horizontal well in the construction of the typical have representative, so in long horizontal section of horizontal well track design, in order to make the design of wellbore trajectory satisfy the requirements of the various conditions.

- **Well trajectory design should meet the shortest path under various design conditions:** According to the geological to confirm target point, according to the different design methods to design trajectorys, their length is different. Obviously as far as possible to choose the short length track, reduce invalid footage, it can not only improve drilling economic benefits, but also can reduce the risk from the construction.
- **Drill string friction drag and torque of well trajectory design should be relative to the minimum:** The characteristics of long horizontal section of horizontal well are large horizontal displacement, big inclination, leading to big friction drag and torque of drill string and casing string in the hole, friction and the torque are the main limiting factor of the horizontal displacement of horizontal well. There are many ways to reduce friction and the torque, track optimization design is one of the ways. The well design should as far as possible to choose small friction and torque trajectory. Therefore, the friction resistance and

torque is one of the main factors to determine hole track.

WELL PROFILE DESIGN OF SOME OIL FIELD IN EAST OF CHINA (2000 METERS HORIZONTAL SECTION)

Basic data: The basic data to optimize the long horizontal section of horizontal well are shown in Table 1 and 2.

The results of well design (2000 m horizontal section): Use the two buildup sections profile design methods, the buildup rate of the first buildup section is $4.32^\circ/30\text{ m}$, and the buildup rate of the second buildup

section is $4.3^\circ/30\text{ m}$, the results of profile design are shown in Table 3.

From Table 3 we can see that the length of middle "tangent section" is only 8.36 m , though it can effectively reduce the friction torque, this lost the effect of "tangent section". It is suggested that in the design of 2000 m horizontal section, appropriate adjust the two buildup sections, give adjustment period to the "tangent section".

Well profile design (2000 m horizontal section) after adjustment: From Table 4 we can see that the new design results we can see that the length of the middle tangent section increases to 10.57 m . In this way, we can adjust the trajectory according to the first buildup section, and achieve the accurate target.

Table 1: Basic data of some oil field in east of China

Company: Some oil field in east of China	Project:	Site:	Well name	Well path
Trajectory	north reference: Grid North KB depth: 150 m	H(Z) reference: sea level Magnetic declination: 10.00°	Vertical reference : Rotary table	Date: 22,9,2012 Angle of convergence : 0.70°

Table 2: Information of target

Project	Abscissa	Ordinate	Elevation depth of target (m)	Vertical depth (m)	Effective thickness (m)
Ground well	21577211	4948406			
Landing point A of horizontal well	21577211	4948806	-3388.58	3553	15
The end of horizontal section B	21577211	4950806	-3409.58	3574	

Table 3: The results of profile design

Target	MD m	Incl deg	Azim deg	TVD m	NSm	EW M	DLS deg/30 m	Build deg/30 m	Turn deg/30 m	TFO deg
	0	0	0	0	0	0	0	0	0	0
	3170	0	0	3170	0	0	0	0	0	0
	3320	24	0	3315.65	30.96	0	4.8	4.8	0	0
	3716.98	81.16	0	3546.98	333.33	0	4.32	4.32	0	0
	3725.34	81.16	0	3548.27	341.6	0	0	0	0	0
Target point A	3783.99	89.57	0	3553	400	0	4.3	4.3	0	0
Target point B	5784.21	88.4	0	3574	2400	0	0	0	0	0

Table 4: The results of profile design

Target	MD m	Incl deg	Azim deg	TVD m	NS m	EW M	DLS deg/30 m	Build deg/30 m	Turn deg/30 m
	0	0	0	0	0	0	0	0	0
	3170	0	0	3170	0	0	0	0	0
	3320	24	0	3315.65	30.96	0	4.8	4.8	0
	3732.18	83.35	0	3549.03	348.40	0	4.32	4.32	0
	3742.75	83.35	0	3550.25	358.9	0	0	0	0
Target point A	3783.96	89	0	3553	400	0	4.11	4.11	0
Target point B	5784.09	88	0	3574	2400	0	0	0	0

Table 5: Profile design scheme contrast (2000 meters horizontal section)

Type	Well length m	Length of buildup section m	Hook load about sliding Kn	Hook load when pulling out of hole Kn	Hook load about rotating Kn	Rotary torque	Maximum hole curvature
Catenary	5791.014	539.5824	1080.354	1201.896	1193.097	19.3539	7.52
Modified catenary	5785.852	574.5151	1080.889	1195.365	1193.089	18.094	5.12
Parabola	5795.769	510.8443	1079.576	1205.876	1193.157	19.51352	10.473
Single buildup section ($4.3^\circ/30\text{ m}$)	5784.48	594.3691	1080.953	1195.134	1193.021	18.03	4.3
Two buildup section($4.32^\circ/30\text{ m}$ - $4.3^\circ/30\text{ m}$)	5784.21	606.63	1080.087	1195.615	1193.576	18.07852	4.32
Two buildup section ($4.32^\circ/30\text{ m}$ - $11^\circ/30\text{ m}$)	5784.09	603.39	1080.516	1195.164	1193.97	18.05573	4.32

The contrast of all kinds of well profiles: We have designed the well trajectory according to 3 profiles, these are catenary, modified catenary and parabola. And we have compared these profiles based on the well length, the length of buildup section, hook load about sliding, the hook load when pulling out of hole, hook load about rotating, rotary torque, maximum hole curvature, the detailed results are shown in Table 5.

From Table 5 we can see that the friction, torque, well length and the length of buildup section are the smallest when using the two buildup section profile ($4.32^\circ/30\text{ m}$ - $4.11^\circ/30\text{ m}$, so this profile can be used in the horizontal well (2000 meters horizontal section) in the oilfield of east China.

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