Original Article

Optimizing geological design of J-shaped deviation oil & gas well by deepening kickoff point

Lei Huang[1] ©

Abstract

In the geological design of 2-D J-shaped deviated oil and gas wells, once the coordinates of wellhead and production layer target are determined (restricted by specific ground conditions and underground understanding, respectively), the position of the kickoff point (KOP) becomes very sensitive. By deepening the kickoff point (KOP) based on the current conventional fixed upper position and the dog leg severity (DLS) remaining unchanged within the penetrated range, a smaller drill axis and an angle between the production layer and axis can be obtained at the same designated target point to extend the section of penetrated oil-bearing layers, expand the oil drainage area, increase proven reserves, and ultimately enhance the oil production and recovery during the contract period. In addition, after optimization, it is expected to save 1-2% of well drilling costs by reducing drilling time. With the help of drilling engineering and production engineering, drilling KOP can be achieved easily in deeper and harder rock formations, which is able to improve the efficiency of the electric submersible pump (ESP) and to avoid eccentric wear of the ESP, resulting in extension of the service life of the ESP. This optimized design also runs in parallel with various well stimulation programs and projects without any confliction of each other. This design can be either used for comparison of the parameters of the completed inclined wells with assumed ones of deepening KOP design to show how the deepening KOP can be used to differentiate the increased thickness of the penetrated target layers and the drainage area of target zones, or it can be utilized to compare any pair of parameters between inclined production wells within a range. In the same drilling field, any random increase of 1° inclination angle in a stable inclination section can lead to a corresponding increase in the thickness of the penetrated oil-bearing layer and production. Our research results quantitatively indicate that in the geological design of J-shaped deviation oil and gas wells, the KOP can be re-set from a shallower fixed position along the current conventional trajectory to a reasonable position as deep as possible, which shall be suitable for most situations of optimizing well performance, especially for some restricted complex surface conditions and energy-deficient reservoirs, which assign the KOP a new geological significance in line with the business strategy of rapid oil recovery.

Key words: J-shaped oil & gas well, deviation, inclination, deepening, kickoff point (KOP), penetrated thickness.

Affiliation Info: [1] China National Oil and Gas Exploration and Development Company Ltd., No.6-1 Fuchengmen North Street, Xicheng District, Beijing, China. Postal Code 100037
Article Info: Received: 2 August 2023 / Revised: 4 October 2023 / Accepted: 3 December 2023 / Published Online: 12 December 2023. www.naturalisscientias.com
Authors' Contact Info: Huang, L: Huanglei@cnpcint.com
Citation: Huang, L. 2024. Optimizing geological design of J-shaped deviation oil & gas well by deepening kickoff point. Naturalis Scientias, 1(1): 100-105. DOI: https://doi.org/10.62252/NSS.2024.1007.

Corresponding Author©: Huang, L, PhD; Email: Huanglei@cnpcint.com

1 Introduction

With the development and improvement of drilling engineering technology in the oil & gas field, a variety of well types have been developed to meet the needs of oil & gas field exploitation, for example, traditional vertical wells, inclined wells, directional wells, multi-branch wells and so on. Among which, the vertical wells have their axes of borehole trajectory generally vertical to target layers within a permissible deviation range, that is, the horizontal projection distance between wellhead and its bottom should be close enough (for example, less than 30m is a critical standard for completing drilling target). However, for other well types, with geological design, the horizontal projection distance between wellhead and its bottom has been obviously extended away[1 & 2].

In practice, it is more and more common to drill multiple directional wells within the same well site to achieve the purpose of a uniform underground well pattern design in order to reduce the surface land cost and meet the requirements of environmental protection simultaneously. Based on this situation, this paper only deals with one-dimensional (1D) and two-dimensional (2D) well trajectories widely used at present (mainly J-shaped deviation oil & gas wells), other than three-dimensional (3D) well trajectories that are more complex and also less utilized. The well trajectory of J- shaped deviation well mainly consists of three sections, namely from top to bottom: the straight well section, the increasing inclination section, and the stable inclination section. Among them, the starting (or outset) point of transition from the vertical well section to the increasing inclination section is called the kickoff point (KOP) in 2D J-shaped directional well trajectory[2 & 3].

From the perspective of oil and gas reservoir development engineering, the important difference between directional wells and traditional vertical wells is that the drilling thickness of the production layer, which can directly reflect the productivity, no longer depends solely on the vertical thickness of the production layer, but is closely related to the inclination angle of well topography in the reservoir section[4]. Once the coordinates both of wellhead and target layer center are determined (namely the target distance is confirmed), the depth position of the kickoff point (KOP) in pre-drilling geological design becomes very sensitive.

2 Feasibility

2.1 Reservoir development

In drilling trajectory design within 2D section for the J-shaped deviation oil & gas wells, KOP shall be shifted downwards from the current shallower conventional fixed position to a deeper position, with the dog-leg severity (DLS) remaining unchanged within permission scope. In this case, a gentler angle between axes of drilling bit and pay zone surface can be obtained to allow the well trajectory in the stable inclination section to enter the target layer with a larger inclination angle. So that while drilling the same assigned target point (namely control point - CP) with a greater angle, a thicker oil-bearing interval can be penetrated, which can effectively extend well drainage area, increase proved reserves, and resultantly enhance both well production and EOR within life of contract[5].

Furthermore, this optimizing design of drilling trajectory can run parallel with various well stimulations and programs, e.g., well location deployment, well pattern arrangement, well type design, separate subzone development, improvement of petrophysical property of reservoir[4-5], and so on without confliction.

2.2 Drilling engineering

In LFY oilfield, only if deeper than 2100m True vertical depth subSea (TVDSS) subject to stratigraphic compaction, the formation hardness can meet the threshold requirement of environmental parameter for KOP drilling. On this basis, the further deeper KOP position is designed. With the increase of formation depth and rock hardness, it will be easier and easier for KOP to operate, where drilling model shifts from rotary steering bottom hole assembly (BHA) to directional drilling BHA.

2.3 Production engineering

Theoretically, the electric submersible pump (ESP) is formally required to be set at the position where is exactly close to the top of perforation interval of production well adjacent to the injection well. Such a positioning is to avoid the adverse effects on the pump efficiency caused by the decline of formation pressure and the upward shift of the bubble point in the later stages of oil field production. However, in actual production, in order to protect the electric submersible pump, most of the current electric submersible pumps in LFY Oilfield are set above or near the KOP, where the DLS is nearly 0°.
After optimizing and deepening the KOP, it will be beneficial to move the electric submersible pump downward closer to the top of the perforation section in the actual oil field site, boost ESP efficiency, avoid eccentric wear, and extend the service life of the ESP[4 & 6].
Parameter comparison between already completed deviation oil & gas well and assumed case of deepening its KOP

2.4 Selection of analytical wells

In this study, 97 wells have been selected from 128 available deviation wells with E pay zone as target, which are almost uniformly distributed all over the I oil field, while others have been rejected either due to nearly vertical trajectories or nearly horizontal, both of which are unqualified as deepening KOP sample. The 97 selected wells account for 3/4 of the total numbers of the deviation wells, and thus can fully meet the needs of the study for E pay zone in the I oil field.
DLS selection in increasing inclination section for assumed case of deepening KOP
In this study, 4° has been chosen as DLS angle, which is believed to be within conservative index. However, if choosing an angle smaller than 4o as max DLS in any deviation wells, it is considered to be far beyond conservative index in terms of standard of drilling engineering industry.
Based on the definition, DLS is an angle variation of drill bit at per 30m along drilling trajectory in the three-dimensional space. When entering an increasing inclination section starting from KOP, drilling trajectory can be assumed to follow a circular arc with 430m radius, namely, 30*(360/4)/pi()/2=430m.
Following the circular arc with a radius of 430m in the increasing inclination section the drilling bit starts from the KOP and shifts to stable inclination section until it runs down to the key point where the tangent line, the extended line of the bit axis, and the assigned target point (CP) in E pay zone exactly intersect. In other words, the drilling bit follows the tangent line at the end point of the circular arc with the same inclination and azimuth, and penetrates the same CP. Indeed there is little deviation between the above calculation and actual drilling trajectory at well site, but this is so minor that can be negligible and tolerable in this research. Fig.1 shows parameter comparison between completed deviation oil & gas wells and assumed case of deepening its KOP (Fig. 1).

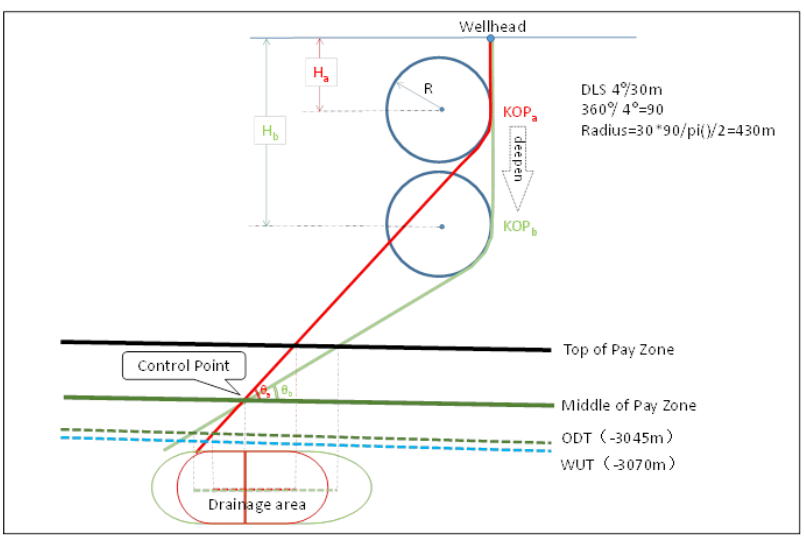

Figure 1. Parameter comparison between completed deviation oil & gas wells and assumed case of deepening its KOP
(A schematic diagram of an existing directional well and its hypothetical deeper formation inclination point)

The error between this theoretical analysis and the actual situation at the drilling site is small and considered to be acceptable.

2.5 Availability of deepening KOP In vertical distance

Currently, KOP average depth position is conventionally fixed at 2150m TVDSS. Average vertical distance from KOP to CP is 866m (minimum 693m). Assuming the circular arc is 430m in radius, i.e., the maximum vertical distance in the increasing inclination section needed is no more than 430m when maximum drilling trajectory inclination angle reaches ~90°. However, in reality, statistics show that average vertical space of the increasing inclination segment is only 332m in this study. Therefore, there is large enough remaining vertical space surplus for deepening KOP in E pay zone of LFY oilfield[7].

2.6 Scenarios analysis

Scenario 1, deepening KOP 100m

When 100m of deepening KOP is assumed, the average thickness of the penetrated target zone is increased by 11m, equivalent to an increase of 6% comparing with that before deepening. Drainage area of the drilled target zone is increased by 0.4 km2 on average, compared with that before deepening, in which drainage radius is conservatively set at 250m only.

Scenario 2, deepening KOP 200m

When 200m of deepening KOP is assumed, an average increase in thickness of the penetrated target zone is 38m, which is 21% more than before deepening, while average increase of the drainage area of the drilled target zone is 1.5 km^2, compared with that before deepening, in which drainage radius is still conservatively set at 250m as shown in Fig.2.

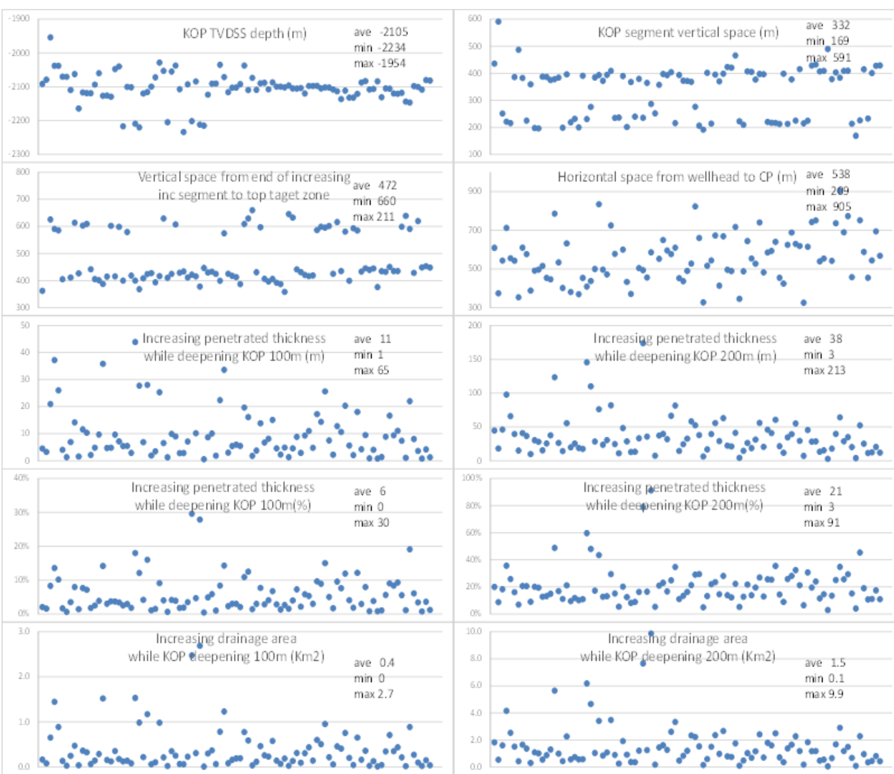

Figure 2. Two scenarios analysis

2.7 Parameter comparisons between any pair of current producing wells within the same drilling pads

Within the adjacent area in any specific well site, there are only relatively minor lateral geological changes in the target zone, in other words, almost remaining the same thickness of true oil-bearing zone. In the stable inclination sections, all selected wells in any selected pad are bearing different inclinations respectively. Furthermore any selected pad must be required to at least include one vertical well as a reference in this statistics process, so that the comparisons can become more meaningful and integrated.

2.8 Inclination angle in stable inclination section versus penetrated measure thickness of oil-bearing zone

The analysis of 16 selected pair data shows that when the inclination angle increases any 1° in the stable inclination section, the penetrated measured thickness of oil-bearing zone gently increases 1.35m accordingly (horizontal wells are excluded from this quantitative statistics).

2.9 Inclination angle

Study of the inclination angle in the stable inclination section versus average daily production of first month data analysis based on 11 selected pair data out of 13 indicate that when the inclination angle increases any 1° in the stable inclination section, the daily production of first month gently increases by 16 barrels accordingly（horizontal wells are also excluded from the quantitative statistics）as shown in Table 1.

Table 1. Parameter comparison

Pad	Well name	Well type	Trajectory inclination at pay zone (°)	Penetrated thickness (oil zone + poor oil zone)	Increased penetrated thickness (%)	Perferating interval thichness	Choke size (/64")	Production style	First month of average oil production (stb/pd)	First month increasing prodution (%)
1	1	V	0	86	100%	43	40	Nature flow	828	100%
	1-D1	D	44	139	162%	54	40	Nature flow	1269	153%
2	2	V	0	36	100%	15	40	Nature flow	261	100%
	2-D2	D	29	113	314%	37	36-32	Nature flow	586	225%
	2-D1	D	35	128	356%	57	40-36	Nature flow	1451	556%
	2-D3	D	48	150	417%	70	40-36	Nature flow	430	165%
3	3	V	0	90	100%	37	22	ESP	448	100%
	3-D1	D	42	115	128%	38	36	Nature flow	929	207%
	3-D2	D	44	131	146%	57	40-36	Nature flow	1564	349%
	3-H1	H	90	784	871%	808	48	Nature flow	3111	694%
4	4	V	0	68	100%					
	4-D1	D	36	75	110%	Not yet been put into production				
	4-D2	D	36	75	110%					

3 Discussion

As discussed in section "Scenario 2", we can adjust 200m section below KOP to above KOP along the drilling trajectory, in other words, the 200m section drilling mode from directional drilling BHA is shifted upwards to rotary steering BHA, by which about 1 day drilling time can be saved because the upper vertical drilling mode is twice as fast as the lower sidetracking one. After the optimization, 1-2% drilling expenditure will be cut down by reducing the drilling time. In addition, the extension of ESP service life, increase in proven reserves and well production can bring additional remarkable potential economic benefits.

4 Conclusions

To summarize, in the geological design of two-dimensional J-shaped directional well drilling, if setting the KOP at a unified and fixed threshold depth that meets the deflection requirements of the drilling engineering and drilling engineering significance, then the KOP should be appropriately lowered to the proper depth according to the geological conditions, which would give KOP a brand new and more important geological connotation.

Especially, for some restricted complex surface conditions, e.g., if oil-bearing sections in the oilfield are paritially covered by local natural preservation zones and/or drilling is forbidden by severe local laws, then the geological optimazition along preservation zone's boundary with deepening KOP in oil & gas well will surely be a win-win recommended solution to effectively control both well pattern unbalance and reservoir development unbalance in the plane.

In addition, for some reservoirs with an inadequate natural energy supply, deepening KOP to meaningfully extend the well drainage area and to increase proved reserves are quite feasible and commendable remedy actions, which indeed meet the business strategy of rapid oil recovery during oil & gas field development.

Author contributions L Huang proposed and contributed to the whole research, interpretation, and writing of the paper. The author prepared and reviewed the manuscript and approved the final version of the manuscript.

Data availability statement The data that support the findings of this study is available from the author upon reasonable request.

Declarations The author declare that he has no conflict of interest.

5 References

1. Jia, CZ. 2004. *SEC Estimation Approach for Oil & Gas Reserves*. Beijing: Petroleum Industry Publishing House, pp28-65 (**in Chinese**).
2. Yuan, QF. 2014. *Practice and Understanding of Oilfield Development*. Beijing: Petroleum Industry Publishing House, pp7-82 (**in Chinese**).
3. Adnan, A.M; Jeremy, C; Goff, A.; Horbury, D. & Sadooni, N. 2010. The Petroleum Geology of Iraq. Baghdad：Scientific Press, pp28-84.
4. Mu, LX. 2021. Design strategy and methods of development plan at oversea oilfield. Beijing: Petroleum industry publishing house, pp63-89.
5. Liu, BH. 2009, *Encyclopedia of Petroleum Exploration and Development in China*. Beijing: Petroleum industry publishing house, pp444-449.
6. Chilingar, GV; Bissell, HJ; Fairbridge, RW. 1967. *Carbonate rocks*. Amsterdam, London, and New York: Elsevier Publishing Company, pp61-86.
7. Dake, LP. 1994. *The Practice of Reservoir Engineering*. Amsterdam: Elsevier Science Publisher, pp23-27.