

Correcting Wellpath Design for Magnetic Guidance Drilling of Twin Parallel Horizontal Wells

Binbin Diao, Deli Gao, Zeliang Tong

Key Laboratory for Petroleum Engineering of the Ministry of Education, China University of Petroleum, Beijing 102249, China

ABSTRACT: The scientific planning of correcting wellpath has important practical significance for controlling well trajectory and reducing drilling time in magnetic guidance drilling of twin parallel horizontal wells. Connecting with external detection calculation of well trajectory, the calculation method of the injection well downhole parameters was obtained by fitting the measurements of magnetic guidance tool. And connecting with the calculation of the adjacent well distances between injection well and production well, the calculation formulas of correction target point parameters in inclined section and horizontal section were obtained. And then, the correcting wellpath design method in magnetic guidance drilling of twin parallel horizontal wells was proposed based on the three-dimensional wellpath design method for conventional directional well with drilling. The method can provide scientific basis for decisions of injection well trajectory control. And the adjacent well distance control objective can be achieved better.

1 INTRODUCTION

As borne out by domestic and overseas practice, SAGD (Steam Assisted Gravity Drainage) twin parallel horizontal wells can help develop heavy and super heavy oil resources. At present, in China, such wells are required to have 5m~8m between the horizontal sections of two wells, among which the vertical error should be no more than $\pm 0.5\text{m} \sim \pm 0.75\text{m}$ and horizontal error no more than $\pm 1\text{m}$ [1,2]. Due to the magnetic interference of such ferromagnetic materials as the casing or sieve tubes of the production well and the accumulative error of the well trajectory, it is hardly satisfactory to solely depend on the traditional survey tools to guide the SAGD twin parallel horizontal wells drilling. To exercise precise control over the distance from the adjacent wells of the SAGD twin parallel horizontal wells, A. F. Kuckes and others have developed MGT (Magnetic Guidance Tool) and RMRS (Rotating Magnet Ranging System)[3,4]. In foreign countries, over 95% of SAGD twin parallel horizontal wells combine the traditional survey tools with MGT to achieve such precise measurement and control of the distance between two adjacent wells.

To reduce the overall cost of SAGD twin parallel horizontal wells drilling and facilitate the further development of the drilling technologies in China, China University of Petroleum (Beijing)

independently developed DD-MGS. It was applied in the drilling project of Fengcheng Oil field in Xinjiang Autonomous Region and was proved to be effective[5-8]. The system can not only guide horizontal drilling along the horizontal section of the injection well, but also calculate the exact distance from the adjacent well in the build-up section of the SAGD twin parallel horizontal wells. However, because of the special requirements of SAGD twin parallel horizontal wells and the application of the magnetic probing system, the trajectory control of the injection well is different from the traditional directional wells. The target wellpath of the injection well is not the designed wellpath, but a wellpath that is parallel to and with a certain distance from the production well trajectory. When SAGD twin parallel horizontal wells magnetic guidance system is working, the vertical distance and the deviation on the left or right between the drilling bit and the production well can be measured, but the inclination angle and the azimuth angle cannot be directly measured. Therefore, the design method for the correction wellpath of the injection well is also different from that used in the traditional directional well.

This paper aims to introduce the design method for the correction wellpath of the injection well based on the calculation results of SAGD twin parallel horizontal wells magnetic guidance system.

2 CALCULATION OF THE TRAJECTORY PARAMETERS OF THE INJECTION WELL

After the vertical distance and deviation on the left or right between the injection well and production well are measured by the DD-MGS, they are fitted respectively with the magnetic subs' measurement depth, which helps determine more exact positions of the injection and production well. When the polynomial is fitted, the first and foremost problem is to determine the order of the polynomial fitting, which is closely correlated with the number and distribution of the fitting data. In this sense, an appropriate number of fitting data should be selected to achieve more precise fitting results. When there is too much fitting data and there are several extreme values on the trend line, the order of the fitting polynomial will increase. In this case, even the high order fitting polynomial cannot finish the fitting of the whole data series, which can cause big deviation with the fitting in the last measurement point. As a matter of fact, when the data size is relatively large, the position and direction of the injection well, mainly depends on whether the fitting of the measured data at the depth of the well is precise. Under such circumstances, if the measured data of the positions that are far from the well bottom is neglected to pay closer attention to the fitting of the measured data near the depth of the target well, the fitting order can be decreased and the fitting precision can be improved. After an appropriate number of the fitting data is decided, the fitting order should be altered to determine a more proper one.

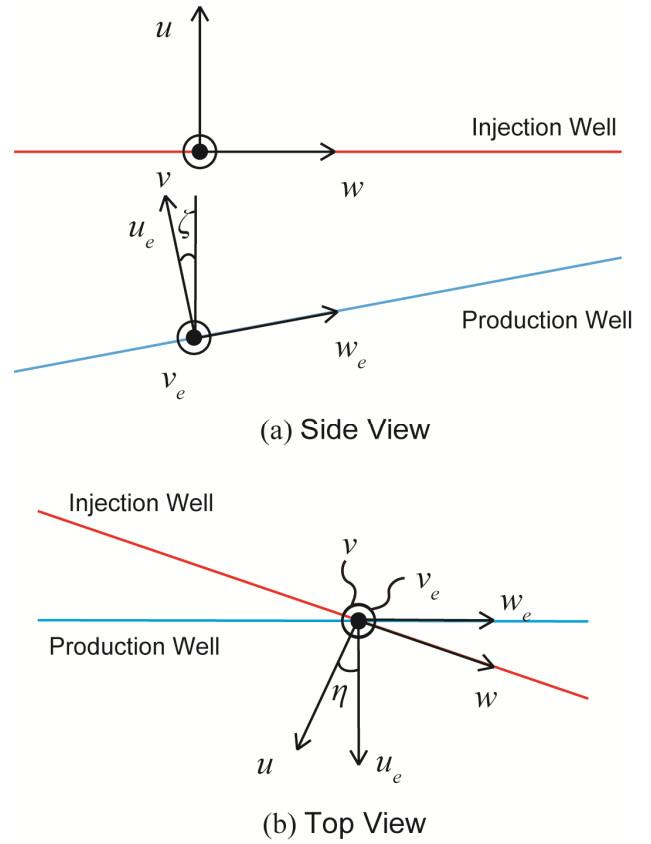


Figure 1. Side view and top view of the twin parallel horizontal wells.

As shown in Fig. 1, put the last set of calculation results of DD-MGS into the fitting polynomial, take the derivative with respect to the measured depths of the magnetic sub, then the convergence angle ζ and the non-coplanar η of the production well with regard to the injection well [6]. Therefore, the formula for calculating the inclination angle α_m , azimuth angle ϕ_m , North coordinates N_m , East coordinates E_m and the vertical depth V_m at the measuring point is:

$$\alpha_m = \alpha_p - \zeta \quad (1)$$

$$\phi_m = \phi_p - \eta \quad (2)$$

$$N_m = N_p + \Delta S \cos \eta \quad (3)$$

$$E_m = E_p - \Delta S \sin \eta \quad (4)$$

$$V_m = V_p - \Delta V \quad (5)$$

Where, α_p , ϕ_p , N_p , E_p and V_p stand for respectively the inclination angle, azimuth angle, North coordinates, East coordinates and vertical depth of the last measurement point. β is the non-coplanar angle; ΔV and ΔS represent respectively the calculation vertical distance and left/right deviation of DD-MGS.

According to the range method of DD-MGS, the distance between the measurement point and the well bottom is l , which can be provided by the system operators. Therefore, the formula for

calculating the inclination angle α_b , azimuth angle ϕ_b , North coordinates N_b , East coordinates E_b and vertical depth V_b of the well bottom can be obtained based on the extrapolation of the well trajectory calculation.

$$\alpha_b = \arccos(\cos \alpha_m \cos \gamma - \sin \alpha_m \sin \gamma \cos \omega) \quad (6)$$

$$\phi_b = \phi_m + \arctan \frac{\sin \gamma \sin \omega}{\sin \alpha_m \cos \gamma + \cos \alpha_m \sin \gamma \cos \omega} \quad (7)$$

$$N_b = N_m + \frac{l}{\gamma} (\sin \alpha_m \cos \phi_m + \sin \alpha_b \cos \phi_b) \tan \frac{\gamma}{2} \quad (8)$$

$$E_b = E_m + \frac{l}{\gamma} (\sin \alpha_m \sin \phi_m + \sin \alpha_b \sin \phi_b) \tan \frac{\gamma}{2} \quad (9)$$

$$V_b = V_m + \frac{l}{\gamma} (\cos \alpha_m + \cos \alpha_b) \tan \frac{\gamma}{2} \quad (10)$$

Where, γ is the dogleg angle between the measurement point and the well bottom; ω is the tool face angle in the section.

3 DETERMINATION OF THE CORRECTING TARGET POINTS

3.1 Correcting target points in the horizontal section

According to the design of the SAGD twin parallel horizontal wells, the horizontal section of the injection well is always on top of the production well and they are parallel to each other. Therefore, the formula for calculating the inclination angle α_{hb} , azimuth angle ϕ_{hb} , North coordinates N_{hb} , East coordinates E_{hb} and vertical depth V_{hb} of the correcting target points in the horizontal section of the injection well.

$$\alpha_{ht} = \alpha_p \quad (11)$$

$$\phi_{ht} = \phi_p \quad (12)$$

$$N_{ht} = N_p \quad (13)$$

$$E_{ht} = E_p \quad (14)$$

$$V_{ht} = V_p - D \quad (15)$$

Where, D is the designed distance between the horizontal sections of the SAGD twin parallel horizontal wells.

3.2 Correcting target points in the build-up section

Since the designed distance between the build-up sections of the SAGD twin parallel horizontal wells is not fixed and the positions of the injection and production well can be adjusted on the build-up section, correcting target points in the build-up

section are not as easy as that in the horizontal section. Then, the production well should be deemed as the reference well and the injection well as the comparison well, the normal plane scanning distance of the designed wellpath should be calculated[7-9]. After that, the target path of the injection well can be obtained based on the result of the normal plane scanning. Moreover, the correcting target points are on the path.

The inclination angle α_{ib} , azimuth angle ϕ_{ib} , North coordinates N_{ib} , East coordinates E_{ib} and vertical depth V_{ib} of the correcting target points in the build-up section are:

$$\alpha_{it} = \alpha_p - (\alpha_r - \alpha_c) \quad (16)$$

$$\phi_{it} = \phi_p - (\phi_r - \phi_c) \quad (17)$$

$$N_{it} = N_p + R \cos(\alpha_p) \cos(\theta + \theta_h) \quad (18)$$

$$E_{it} = E_p + R \cos(\alpha_p) \sin(\theta + \theta_h) \quad (19)$$

$$V_{it} = V_p - R \sin(\alpha_{it}) \quad (20)$$

Where, R is the scanning radius of the normal plane scanning distance; α_r and α_c are respectively the inclination angle of the reference point and the comparison point in the normal plane distance scanning; ϕ_r and ϕ_c are respectively the azimuth angle of the reference point and the comparison point in the normal plane distance scanning; θ is the scanning angle of the normal plane distance scanning; θ_h is the angle between the north direction and the high side direction on the reference point.

4 DESIGN FOR THE CORRECTING PATH OF THE INJECTION WELL

Given the coordinates of the correcting target points, the inclination angle and the azimuth angle, the dimension reduction method can be used in the design for correcting the directional well[10,11]. However, the design goal of the correcting path of the injection wells is to get the trajectory back to the target wellpath as quickly as possible, the relative position between the target wellpath and the production well trajectory had been designed. So the correcting target point cannot be obtained beforehand.

Combining trial computation method, the correcting path of the injection well can be achieved based on the method of reducing dimensions. First, the several correcting target points of the injection well can be obtained based on the method as described earlier in this paper. Then, set one point that is closest to the bottom of the injection well as the starting correcting target point and use the

method of reducing dimensions to create a correction design. Sometimes, the design results can be meaningless, which means the actual trajectory cannot reach the target point with the given build-up rate. In this case, the next point should be set as the correcting target point to continue with the correction design. When meaningful design results are produced, the corrected wellpath is usually composed of two circular sections with a holding section in between. Then, the difference between the length of the holding section and the predetermined length can be obtained. If the difference is within the given error range, then the result can serve as the final design; if the difference is without the given error range and the calculated length is less than the predetermined length, then the next point should be set as the correcting target point to continue with the design; if the difference is without the given error range and the calculated length is more than the predetermined length, apply the interpolation with a certain step length between the current correcting point and the former one, then search along the direction from the current target point towards the former target point to find the next correcting point and continue with the design. Such iterative is going on till the difference is within the given error range. Meanwhile, the result is the final design result.

5 APPLICATION

In 2008, the first SAGD test site was established in Fengcheng Heavy Oil Field in Xinjiang autonomous region. Currently, SAGD twin parallel horizontal wells have been used to develop heavy oil in Fengcheng, notable economic benefit is achieved. X-IP well group is one among them. Set the designed path of X-P well (production well) as the reference well and the designed track of X-I well (injection well) as the comparison well, the normal plane scanning distances can be obtained (Fig. 2). As shown in the Fig. 2, the designed distance between the mouths of the two wells is 20.54m. The two wells get close to each other in the build-up sections. The designed distance between the horizontal sections of the two wells is 5m, and the horizontal section of the injection well is over the production well.

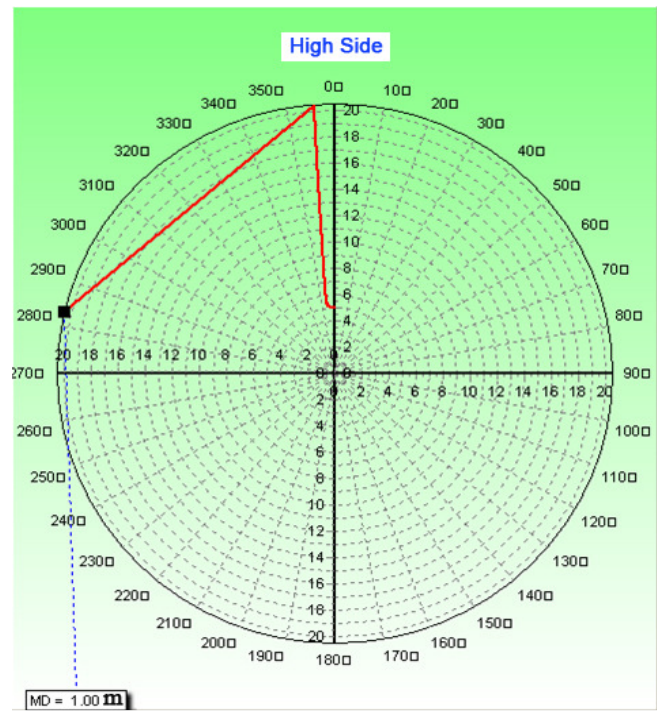


Figure 3. Normal plane scanning diagram of X-IP well group.

According to the design requirement of X-IP well group, DD-MGS is used in the drilling of the horizontal section of X-I well. As shown in Table 1, when the measurement depth of the horizontal section of X-I well is from 404.5m to 513.5m, the measured results of DD-MGS are:

Table 1. The measurements of DD-MGS.

Measurement depth of the probe (m)	Left/right deviation (m)	Vertical distance (m)
409.5	0.28	4.93
419.5	0.37	5.03
439.5	0.14	5.03
449.5	-0.17	4.96
459.5	-0.22	4.67
469.5	-0.60	4.40
479	-0.57	4.49
489	-0.61	4.52
499	-0.45	5.00
508.5	0.07	5.20

As shown in Fig. 3 and Fig. 4, when the fitting order is set 5, the fitting of the left/right deviation and the vertical distance can produce the best results. Meanwhile, based on the methods introduced in this paper, the left/right deviation of the bottom of the injection well and the production is 0.06m, the vertical distance is 5.21m, the non-coplanar angle on different surfaces is 4.18° , the convergence angle is -0.74° . Then, as shown in Fig. 5, if the build-up rate in the given correction wellpath design is $13^\circ/30\text{m}$, the length of the holding section is 0, the correcting path of the injection well can be obtained based on the method proposed in this paper. The

design results show that when set the tool face angle as 84.85° and drill 21.09m into it, then set the tool face angle as 269.38° and drill 10m into it, the injection well can be brought back on the target path. In the process of correction, the largest error on the vertical direction is 0.2m, that on the horizontal direction is 0.79m, which meets the design requirement of X-IP well group.

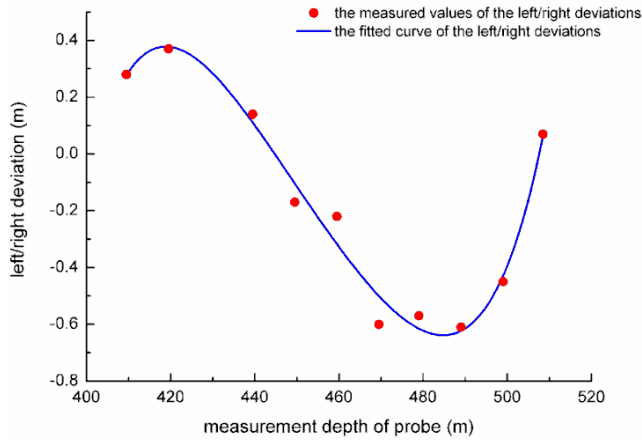


Figure 4. The fitting results of horizontal offset data.

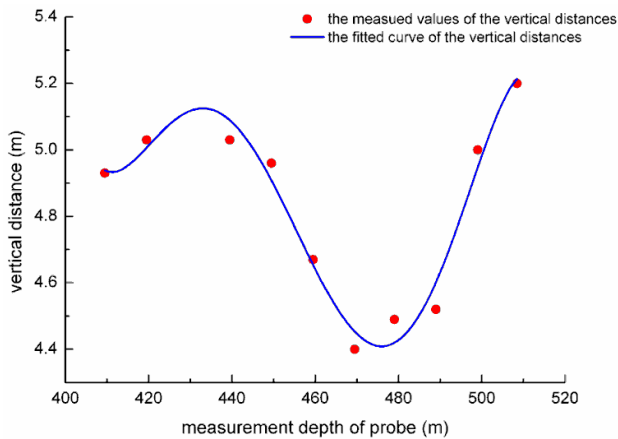


Figure 5. The fitting results of vertical interval data.

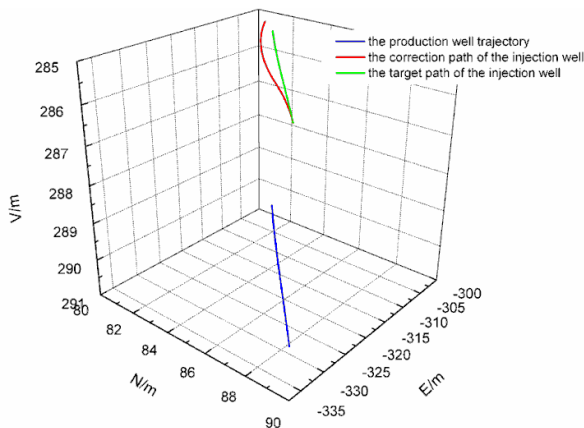


Figure 6. Three-dimensional diagram of correcting wellpath.

6. CONCLUSION

(1) The design method for the correction path of the injection well in the drilling engineering of SAGD twin horizontal wells is different from that used in the traditional directional well. The method introduced in this paper can help directional drilling engineers to control the trajectory of injection well preferably. So the method has important practical significance.

(2) The precision of the trajectory parameters of the injection well can be greatly improved by fitting the measured data of DD-MGS. Because the design method introduced in this paper is based on the dimension reduction method, it is easier to understand and accomplish in the programming.

7. ACKNOWLEDGEMENTS

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