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Research on Anti-collision Early-warning and Remote Centralized Monitoring Technology of Sagd Dual-horizontal Wellbore

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Abstract: According to the problem of SAGD dual-horizontal wellbore anti-collision, by studying the characteristics of SAGD dual-horizontal well drilling process, this paper uses multi-source information fusion technology to carry out data fusion on parameters of multiple hole trajectory, establishes a mathematical model of spatial geometry, forms a set of real-time dynamic monitoring and early-warning technology of SAGD dual-horizontal well trajectory by using the new well trajectory spacing calculation method and achieves dynamic tracking and dynamic adjustment of the SAGD dual-horizontal well trajectory, finally ensures the effective implementation of SAGD dual-horizontal well drilling. Meanwhile, by using the remote transmission technology based on GPRS/CDMA, this paper achieves remote monitoring of the information between the well site and command center.

Key words: SAGD, parallel horizontal well, anti-collision early-warning of wellbore, centralized monitoring technology

INTRODUCTION

With the increase in world energy demand, the oil industry has intensified the efforts on the exploitation of heavy oil. Practice has proved that the SAGD (Steam Assisted Gravity Drainage) parallel horizontal wells recovery technology has the greatest contribution to heavy oil recovery efficiency (Lin *et al*., 2009). The technology injects the high-temperature steam through the injection well to the reservoir target layer, so that to form a steam chamber to heat the heavy oil. As a result, with the increase in crude oil's temperature and the decrease in viscosity coefficient, crude oil is driven by gravity to the bottom of the reservoir production wells and then continuous extracted. According to the process characteristics of the SAGD dual-horizontal wells, well site and command center should master the real-time and dynamic well trajectory, timely analyze, predict and control the drilling direction of borehole trajectory, then to realize an information integration from well site to command center.

FEATURES OF SAGD DUAL-HORIZONTAL WELLS DRILLING CONTROL

To achieve the desired high recovery efficiency, the SAGD dual-horizontal wells have higher control requirements than single wellbore horizontal wells gas in injection wells and production wells horizontal section. First of all, the wellbore trajectories' horizontal sections of the two wells must be sure to pass through the target layer in a certain angle and direction. Secondly, the relative position relationship in the gravitational vertical and the horizontal direction between the trajectories of the two upper and lower horizontal segments should be strictly controlled and kept a certain distance (Lin *et al*., 2009). The two well trajectories' horizontal sections should be parallel to each other as much as possible. If the distance between the two well trajectories' horizontal sections is too close, it is prone to cause steam channeling, the formation of steam condensed water cone would block the production wells; and if the distance is too far away, the heating effect cannot achieve the desired effect and affect recovery efficiency. In view of the above control requirements, the multi-source information fusion technology is applied in the drilling process to realize a real-time centralized monitoring of a variety of well trajectory parameters of the gas injection wells. A reasonable and effective mathematical model is built for analysis and calculation, it can achieve accurate and real-time well trajectory spacing parameters and adjust injection well borehole trajectory parameters dynamically in accordance with the design of well trajectory spacing and drilling position, to maintain

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the real drilling track spacing within the allowed error in engineering design stability. GPRS/CDMA-based remote data transmission technology is used at the same time, to achieve the integration of centralized control in the well site and command center, thus to realize the well trajectory centralized monitoring and borehole anti-collision early-warning.

ESTABLISHMENT OF SAGD DUAL-HORIZONTAL WELL ANTO-COLLISION EARLY-WARNING MODEL AND ALGORITHM ANALISIS

In order to keep the trajectory horizontal sections of gas injection wells and production wells parallel to each other and to keep the spacing within the scope of the design, it is necessary to carry out real-time monitoring on injection well borehole trajectory and measuring its distance to the production wells to control the direction of drilling. As this distance is difficult to be measured directly according to the measurement principle (Chen *et al*., 2011; Diao *et al*., 2011) of the MGT (Magnetic Guidance System Tool) and the MWD (Measurement While Drilling), it is of great significance in finding an algorithm for calculating the distance.

In Fig. 1, the line BE represents production wells trajectory, the line AF represents steam injector designed trajectory. Based on the technological characteristics of the SAGD dual-horizontal wells, injection wells' real drilling trajectory AD is projected to the horizontal plane where the designed trajectory locates to obtain the trajectory projection line AC and the angle between AD and AC can be defined as hole deviation angle changes $\Delta\alpha$ of point G relative to point A, the angle between AC and AF can be defined as azimuth angle changes $\Delta\phi$ of point G relative to point A. The depth changes of point G relative to point A is ΔL.

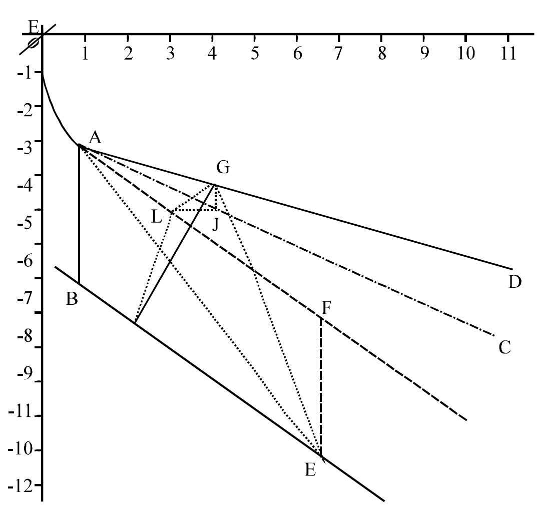

Fig. 1: Borehole anti-collision early-warning algorithm

As shown in Fig. 1, the point J, L, M represent respectively the projection points in the respective lines where the point G, J and L in. According to the space geometric, point G, J, L, M are in the same plane GL, GM is perpendicular to BE and point M is the foot of perpendicular. The length of GM is the distance from current measuring point to the production wellbore trajectory. The difference between the length of GM and the designed distance h can be obtained when GM is subtracted from h. In the right triangle Δ GLJ, right triangle Δ GJA and right triangle Δ ALJ:

$$|GJ| = |AG| \cdot \sin\Delta\alpha = \Delta L \cdot \sin\Delta\alpha \tag{1}$$

$$\begin{aligned} |LJ| &= |AJ| \cdot \sin\Delta\varphi \\ &= \Delta L \cdot \cos\Delta\alpha \cdot \sin\Delta\varphi \end{aligned} \tag{2}$$

As a result:

$$\begin{aligned} |GL|^2 &= |LJ|^2 + |GJ|^2 \\ &= (\Delta L \cdot \cos\Delta\alpha \cdot \sin\Delta\varphi)^2 \\ &\quad + (\Delta L \cdot \sin\Delta\alpha)^2 \end{aligned} \tag{3}$$

where, If $\angle GLJ = \theta$, $\angle GLM = 90°+\theta$, in the ΔGLM, by the cosine theorem:

$$\cos(90° + \theta) = \frac{|GL|^2 + |LM|^2 - |GM|^2}{2 \cdot |GL| \cdot |LM|} \tag{4}$$

where, in the right triangle Δ GJL $\sin\theta = \frac{|GJ|}{|GL|}$ and $\cos(90°+\theta) = -\sin\theta$, then:

$$\frac{|GL|^2 + |LM|^2 - |GM|^2}{2 \cdot |GL| \cdot |LM|} = -\frac{|GJ|}{|GL|} \tag{5}$$

The difference between the length of GM and the designed distance h can be obtained:

$$\begin{aligned} \Delta h &= |GM| - h \\ &= \sqrt{(\Delta L \cdot \sin\Delta\alpha + h)^2 + \Delta L^2 \cdot \cos^2\Delta\alpha \cdot \sin^2\Delta\varphi} - h \end{aligned} \tag{6}$$

In practical engineering, the circular flat with the center located at the measurement point which radius is designed distance consists of the designed distance, the measurement points and the projections of the measurement points in the production wells track, it is perpendicular to the direction of borehole trajectory, as shown in Fig. 2. According to (6), it can be seen that, whether the difference Δh is greater than zero or less than zero, both cases can directly determine the injection well borehole trajectory deviation from the designed trajectory and execute early-warning, for instance, the injection

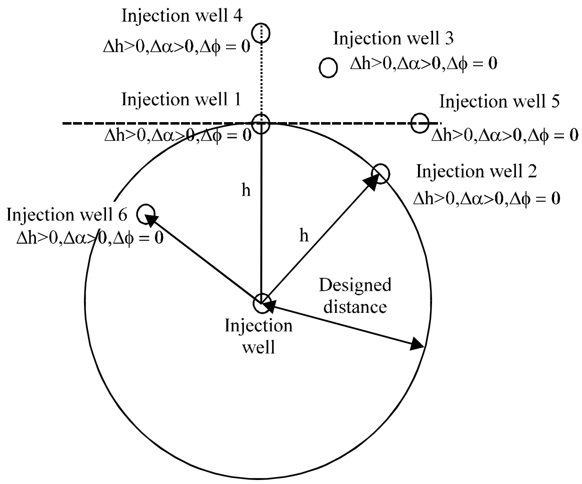

Fig. 2: Results of borehole anti-collision early-warning algorithm

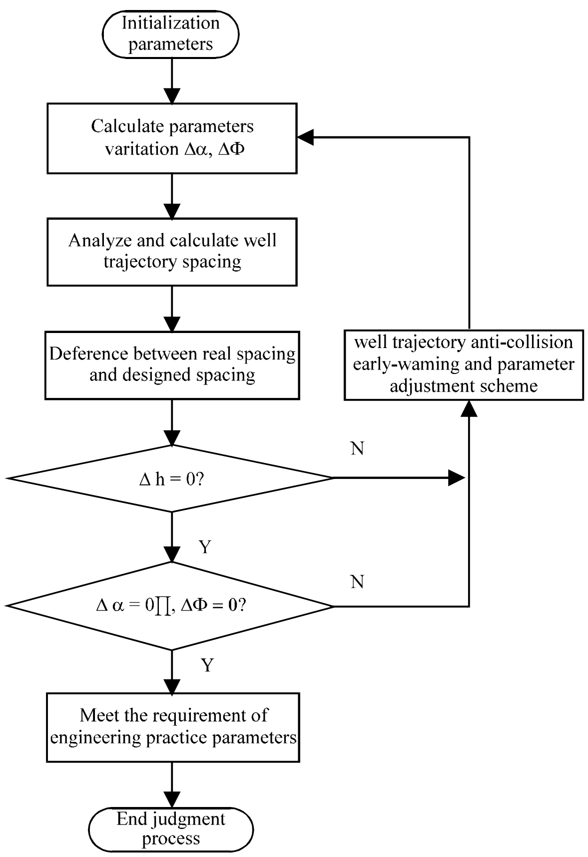

Fig. 3: Borehole anti-collision early-warning judgment process

well 3 to the injection well 6 in Fig. 2. When the difference Δh is equal to zero, it comes to a conclusion that the distance meets the requirements as well as the measurement point is located on the circle, as injection wells 1 and 2 shows in Fig. 2, which cannot determine the spacing of the two well trajectories meets the process requirements of the SAGD dual-horizontal well drilling(Zhang *et al*., 2011). Thus, the changes of the deviation angle and azimuth angle should be introduced to the judgment when the difference between the real distance and a designed distance is equal to zero. Borehole anti-collision early-warning judgment process is shown in Fig. 3.

According to the simulation results (Liu *et al*., 2011) of the temperature field during oil displacement process of the SAGD dual-horizontal wells and practical application experience, the borehole position of the injection well's horizontal section should be parallel to the production well as much as possible. The vertical displacement should zbe controlled at 1 to 2 meters, horizontal displacement should be less than 5 meters. Thus, the designed target surface in Fig. 2 is a square target surface which length and width are1 meter, i.e., the borehole trajectory position of injection well within this area are considered to meet the requirements, the early-warning system would not alarm. In this context, the actual drilling trajectory of injection well should be maintained a certain distance above the production well in vertical direction, in parallel.

DESIGN AND APPLICATION OF REMOTE ANTI-COLLISION CENTRALIZED CONTROL SYSTEM BASED ON MULTI-SOURCE INFORMATION FUSION TECHNOLOGY

Design of remote anti-collision centralized control system: The multi-source information fusion technology is applied in the drilling process to realize a real-time centralized monitoring of a variety of well trajectory parameters of the injection wells. A reasonable and effective mathematical model is built for analysis and calculation, it can achieve accurate and real-time well trajectory spacing parameters and adjust injection well borehole trajectory parameters dynamically in accordance with the design of well trajectory spacing and drilling position, to maintain the real drilling track spacing within the allowed error in engineering design stability. Meanwhile, GPRS/CDMA-based remote data transmission technology is used at the same time to achieve the integration of centralized control in the well site and command center, thus to realize the well trajectory centralized monitoring and borehole anti-collision early-warning. The block diagram of design is shown in Fig. 4.

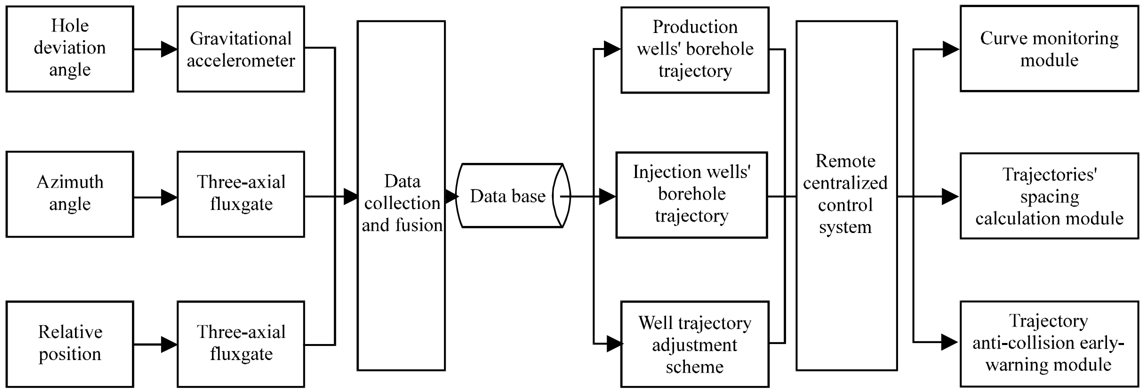

Fig. 4: The block diagram of remote anti-collision centralized control system

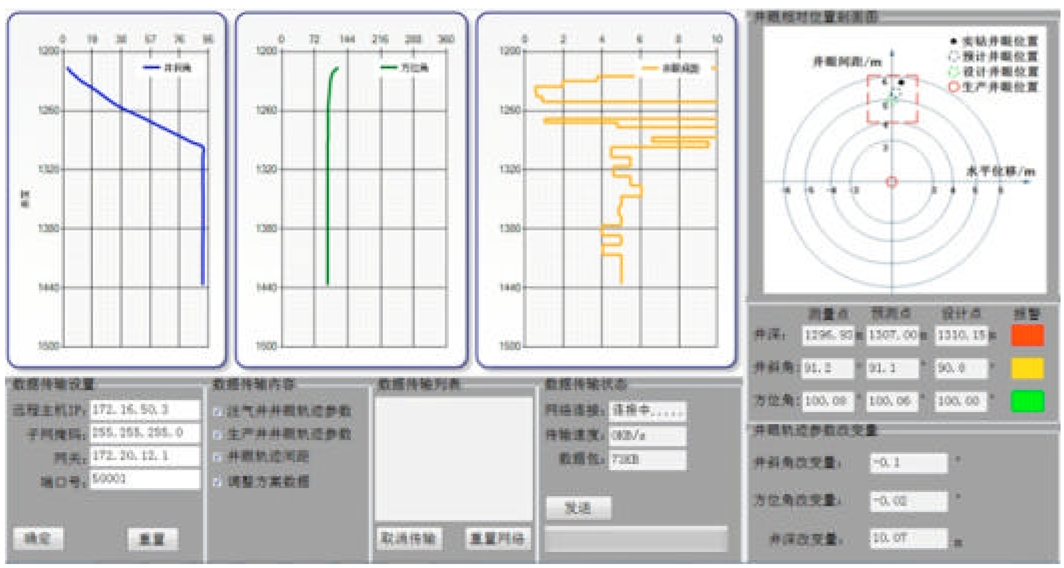

Fig. 5: Interface of borehole anti-collision early-warning and remote transmission system

Application of remote anti-collision centralized control system: The system collected borehole trajectory parameters from 1200 to 1500 m of a SAGD dual-horizontal wells' injection well such as depth, deviation angle and azimuth. By using multi-source information fusion technology, safter the analysis and calculation, it formed a real-time curve of centralized monitoring that borehole trajectory parameters are changing with the depth of the injection well. The real-time monitoring interface reflected the position of the well trajectory and achieved dynamic monitoring of the well trajectory. In addition, the system can realize data fusion of multiple parameters in collection and fusion mode and borehole anti-collision early-warning with mathematical models and algorithms previously mentioned. This system can monitor centrally the real drilling borehole and the relative position between designed borehole and projected borehole and adjust and control the well trajectory spacing dynamically. At the same time, the system used GPRS/CDMA -based remote transmission technology to transmit the collected parameter packets to the command center and realized an integration of centralized control and analysis from well site to command center. The interface of the centralized control system is shown in Fig. 5.

CONCLUSION

According to the application of the SAGD dual-horizontal wells borehole anti-collision early-warning system designed in this paper, we can draw the following conclusions:

- The system carries out a real-time acquisition of multiple parameters of injection wells wellbore trajectory, uses multi-source information fusion technology for data fusion analysis, forms dynamic monitoring curves that changes with the well depth, thus, realizes the centralized monitoring of multiple borehole trajectory parameters and the real-time control of real drilling trajectory
- According to process characteristics of the SAGD dual-horizontal wells, the system the space geometric mathematical model is established, it can achieve accurate calculation of the wellbore trajectory spacing between injection well and production well and judges that whether wellbore trajectory deviation, realizes anti-collision early-warning, then adjusts the wellbore trajectory dynamically to maintain the wellbore trajectory spacing within the range of allowable error in engineering design. Wellbore trajectory spacing is stabilized within the range of 4-6 m starting from 1300 m under the well
- The system used GPRS/CDMA -based remote transmission technology to transmit the collected parameter packets to the command center, forms information integrated control mode from the well site to command center, thus, the command center is able to carry on the analysis judgment and decision-making timely according to the collected data

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