

Application of Autotrak Rotary Steering System in Marine Altra Deep and Highly Deviated Wells

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Abstract

The LeiKouPo reservoir in western Sichuan Basin has several drilling difficulties such as complex formation pressures, extra well deviation in upper strata, poor drill ability of Xujiahe-Xiaotangzi strata, and broken strata of LeiKouPo etc. Based on the three-pressure profiles and wellbore stability characteristics, the setting positions were optimized to propose the three spud casing program design. The bottom hole assembly were designed by pre-bending dynamics theory to keep borehole vertical, and high efficiency drill bits were designed and selected based on rock drillability. The researchers developed the downhole motor slide-steering trajectory control technology for directional well section. Those techniques were applied to well PZ3-5D which has the total depth of 7339m, average penetration rate of 4.28m/h and drilling operation time of 238.4d. The field application shows that the key drilling technology of ultra-deep highly deviated well can effectively ensure drilling safety, improve penetration rate, and provide important technical supports for subsequent highly deviated wells.

Keywords

ultra-deep; highly deviated well; three spud system; drilling technology; LeiKouPo formation.

1. Preface

LeiKouPo Formation gas reservoir in Western Sichuan gas field is located in Longmenshan structural belt of Western Sichuan depression. In 2014, the fourth member of LeiKouPo Formation in PengZhou 1 well was tested, and the daily gas production was $121 \times 10^4 \text{m}^3 / \text{D}$ under the oil pressure of 26Mpa. Thus, the LeiKouPo Formation gas reservoir in Western Sichuan gas field was discovered. The subsequent deployment of YaShen 1 well and YangShen 1 well have successively obtained industrial gas flow. As of 2018, the controlled reserves of $2166 \times 108 \text{m}^3$ have been submitted, which proves that the LeiKouPo Formation gas reservoir has broad exploration and development prospects, and is the "Tenth" national gas reservoir. An important position for increasing natural gas storage and production during the fourth five year plan period. In order to increase the crossing length of reservoir section and further increase the production of single well, cluster high angle well model is adopted. In PengZhou 4-2d well, the high temperature resistant rotary steering tool was applied for the first time in the ultra deep slim hole section of well PengZhou 4-2d, which realized the accurate control of trajectory and accurate target, and ensured the successful realization of geological target.

2. Engineering Geological Characteristics of LeiKouPo Formation Gas Reservoir

The buried depth of LeiKouPo Formation gas reservoir is 5700-6200m, which belongs to ultra deep gas reservoir; the formation pressure is 63.47-67.81mpa, and the ground pressure coefficient is 1.10-1.20, which is atmospheric formation; the fracture pressure coefficient is

2.40-2.99, the collapse pressure is generally lower than the formation pore pressure, and the local interval is close to or slightly higher than the formation pressure. The minimum level of LeiKouPo Formation should be 1.44-2.06mpa/100m, with an average of 1.77 MPA / 100M; the maximum level should be 1.73-3.55 MPA / 100M, with an average of 2.82 MPA / 100M. The direction of in-situ stress is relatively consistent, the maximum principal stress direction is near east-west direction, and the azimuth angle is 74-84° with an average of about 80° and the minimum principal stress direction is nearly north-south with an average azimuth of about 170° and the risk of borehole instability along the direction of minimum principal stress is the greatest. PengZhou 4-2d well is deployed in yazihe structure of Longmen Mountain Piedmont structural belt in Western Sichuan depression. Taking the fourth member of LeiKouPo Formation as the main target layer, the designed well depth is 6545m / vertical depth 5889m, and the maximum well deviation is 79.91°. According to the design trajectory and collapse pressure distribution map, the inclination angle of the fourth section of LeiKouPo Formation is 58-79° and the azimuth is 139° and the maximum formation collapse pressure coefficient is about 1.34, as shown in Fig.1.

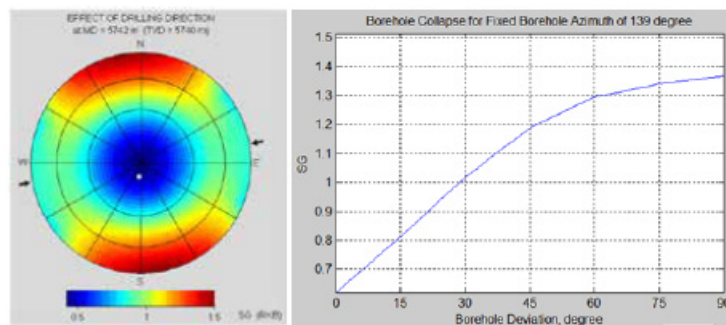


Fig. 1 Collapse Pressure Changes with Well Deviation Angle at 312 ° in LeiSi Member

3. Introduction to Autotrak Rotation Guidance

The third open hole size of PengZhou 4-2d well is Φ 165.1 mm, the bottom hole temperature is expected to be 140-150 °C , and the designed application well section is 5916-6545m. Considering the factors of borehole size, formation lithology and well temperature, Autotrak rotary steering system is selected. The tool outer diameter is Φ 121mm, the maximum outer diameter is Φ 134mm, the length of guide block is 620mm, the zero length of near bit deviation sensor is 1.2m, the maximum build-up slope is 10 ° / 30m, the suitable hole size is Φ 146 - Φ 171mm, and the maximum temperature resistance is 150 °C . With the use of ONTRAK measurement module, the sensor is designed as a whole, all components are built-in, with high reliability. Dual gamma / average gamma is imaged in eight sectors; using multi frequency resistivity technology, 2MHz and 400kHz, four transmitter and dual receiver structure, eight compensated resistances can be obtained, as shown in Fig. 2.



Fig 2. The Schematic Diagram of The Rotary Guide Tool

The strata encountered in the third spud in are mainly the fourth member of LeiKouPo Formation. The upper part of the upper sub member is dominated by algal sandstone limestone and micritic limestone, intercalated with gray micritic dolomite and calcareous dolomite. The upper part of the middle member is composed of gray gypsum dolomite and white dolomite,

and the lower part is algal bound dolomite and micro silty dolomite interbedding. The tensile strength is between 2.37 MPa and 11.90 MPa, with an average of 5.25 MPa. In terms of lithology, the tensile strength of limestone is greater than that of dolomite, indicating that limestone is more compact than dolomite. The results show that the uniaxial compressive strength is 59.3-163.2mpa, with an average of 102.0mpa; the elastic modulus is 603.7-27063.1mpa, with an average of 16112.7mpa; the Poisson's ratio is between 0.102-0.343, with an average of 0.254. The drillability is 4-6, which belongs to carbonate rock stratum with medium compressive strength and good drillability.

According to the characteristics of high compaction degree and poor eating ability of LeiKouPo Formation, the design idea of strong eating and attacking bit is adopted to improve the comprehensive drilling index of bit. T1356b PDC bit is optimized, and the 5 blade structure design of 3 main + 2 pairs is conducive to improving the attack and directional construction; 13mm teeth ensure the feeding ability of cutting teeth; cutting depth control technology reduces the vibration in all directions to make the bit work stably; strengthen the diameter protection design, improve the wear resistance of inclined shaft section, ensure the service life of the bit, and avoid early wear, as shown in Fig. 3.

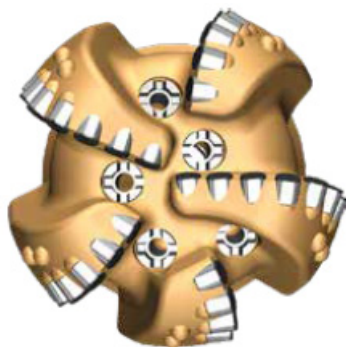


Fig. 3 The Schematic Diagram of T1365b Bit Selection

4. Drilling Risk Analysis and Technical Response

The risk of upper wellbore instability: the upper reservoir of the fourth member of LeiKouPo Formation may be broken, and it is difficult to stabilize the borehole wall in high angle (58-78.6 °). The risk of damage of high-temperature rotary instrument caused by abnormal ground temperature: the target layer temperature is high (expected to be 140 ° C), and the high temperature will lead to the normal operation of the rotary guide tool, even irreversible damage. In addition, there is also the risk of lost circulation. Fractures are developed in the fourth member of Lei formation to prevent lost circulation. High vibration may lead to the damage of rotary guide tools. The lithology of the upper part of lei-4 member is limestone and dolomite, and its drillability is poor. The vibration of rotary guide tool during drilling is large, which leads to premature damage of downhole instruments. In view of the possible wellbore collapse in the upper reservoir of the fourth member of Leizhou formation, the drilling fluid should be supplemented with lubricant and anti sloughing agent in time during the construction, so as to make the drilling fluid have strong inhibition and anti sloughing lubricity. Acid soluble materials should be used to strengthen the plugging performance of drilling fluid, and the anti sloughing and reservoir protection should be done at the same time. During drilling, the system of short trip lifting and tripping should be adhered to. Short trip tripping must be conducted once every 100m interval or 48h drilling, and short trip tripping should be intensified in complex well sections to ensure smooth tripping.

When the temperature reaches 125 °C, the top drive pump should be connected as much as possible to observe the temperature of the downhole rotary guide tool in real time. When the

formation temperature exceeds 150 °C, it is not allowed to run into the rotary guide tool. Reduce the time of column connection and avoid any non circulation. A certain amount of time should be reserved for cuttings returning before connecting a single pipe to avoid excessive cuttings deposition. After connecting the single pipe, the pump should be started with a small displacement, and then the drilling displacement can be used after it is normal. The drilling displacement should be smaller under the premise of sufficient annular return speed. Pay close attention to the vibration of downhole tools, and optimize and adjust the drilling parameters to control the downhole tools to complete the construction section safely and quickly.

5. Field Application of Autotrak Rotary Steering

In the third spud, the drilling depth was 5883m, PDC bit + 1.5 ° single bending screw sliding steering BHA was run in to verify the wellbore stability of Lei 4 section. The actual footage was 27m, and the friction torque was normal under the condition of drilling fluid density of 1.50g/cm³, and there was no block falling, indicating that the downhole condition was good and the running conditions of rotary steering tool were met. Since September 8, 2019, the well was put into the well with a depth of 5913m, which was used for 3 times. On September 27, the well was drilled to 6573.77m and the whole well was drilled.

On September 8, the first round of drilling was conducted at the wellhead. The rotary steering instrument worked normally. When it went down to about 5000m, it began to drill from the well depth of 5913m. When drilling to the depth of 5940.33m, it was found that the deviation near the bit did not increase, and 100% deviation increasing instruction was issued. The well deviation was still not increased after time control drilling to 5944m. Field analysis was related to the formation. The trip out was conducted on September 12. The drilling interval is 5913-5944m, footage is 31m, average ROP is 2.24m/h, well deviation is increased from 62.01 ° to 63.36 ° and average build-up rate is 4.35 ° / 100M.

In the second round of drilling, the wellhead test was conducted on September 12. After the rotary guide tools were in normal condition, normal drilling was started. When drilling to a depth of 6209.51m, it is found that without changing any parameters, the azimuth suddenly increases from 140.65 ° to 143.07 ° and sends instructions to lower the azimuth to drill steadily. According to the geological requirements, a command was issued to change the parameters at 6279.22m depth, with 96.77% of the resultant force increasing inclination, - 19.36% of the force drop direction, and 10-20min/m control time. The well depth was 6298.67m, and the deviation was reduced to 77.1 ° with azimuth of 145.65 ° and the deviation near the bit was 76.9 ° C. the deviation of the steering tool was increased with full force, and the circulation temperature was 140.7 °C. On September 19, the well was drilled to 6302m depth, with 30-40min/m control time, the slope was increased with all efforts, and the slope was still reduced to 6 ° / 100M. The drilling section is 5944-6302m, the footage is 358m and the average ROP is 4.61m/h.

In the third round of drilling, the wellhead test was conducted on September 20. The tool signals and data were normal, and normal drilling was started after running to the bottom. The well depth was 6387.35m, the downhole temperature was 157.2 °C and the well depth was 6403.39m. The temperature could not be measured after repeated measurements. Trip out to the casing, debug the rotary steering instrument and run in again. When drilling to 6462.57m, lost circulation occurred and trip out to 6060m to stop lost circulation. On September 27, the drilling was completed to 6573.77m. Drilling section 6302-6573.77m, footage 271.77m, average ROP 5.26m/h. As shown in Fig. 4, during the third spud drilling, the problems such as no increase of formation inclination, low decoding rate of instrument, easily broken Marine Formation and high downhole temperature were overcome, and the drilling was completed successfully to a depth of 6573.77m.



Fig. 4 Production of Rotary Steering Tool

6. Conclusion

In the process of actual drilling, the geological geophysical exploration engineering team cooperated closely, applied the rotary steering system to optimize and adjust the trajectory in real time, controlled the well deviation from 58° to 79.9° and then decreased to 70.5° and accurately controlled the drilling through the reservoir section. The drilling of high-quality reservoir 315m, the maximum total hydrocarbon reached 14.43%. The target points a and B met the requirements, and the well bore quality met the design requirements, realizing the first third opening of the West Sichuan gas field Successful completion of drilling in ultra deep and highly deviated wells. With the advantages of rotary drilling and near bit control, rotary steering drilling tool can realize fast drilling and precise trajectory control. Moreover, the borehole is smooth, reducing friction torque, increasing ROP, reducing drilling time and soaking time of drilling fluid on reservoir, which is beneficial to reservoir protection. The successful application of rotary steering tool in PengZhou 4-2d well 3 shows that the tool basically meets the requirements of trajectory control for ultra deep and highly deviated wells in Western Sichuan. With the acceleration of development progress of West Sichuan gas field, the rotary steering tool has broad application prospects in this area. In view of the high bottom hole temperature of marine ultra deep wells in Western Sichuan, which has adverse effects on the performance of directional instruments, it is suggested to strengthen the research and development of drilling fluid circulation cooling system to ensure the normal operation of directional instruments.

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