Analysis and Application of Optimal and Fast Drilling Technology in Gaoshangpu Block of Jidong Oilfield

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Abstract. The Gaoshangpu block of Jidong Oilfield is a hot block for increasing production and storage in Jidong Oilfield. High-quality and efficient drilling and completion can shorten the operation time and have huge economic and social benefits. Aiming at the problems of large well depth, complex geological conditions, poor stratum drillability, low drilling machinery efficiency, and long drilling cycle in the Gaoshangpu block of Jidong Oilfield, this paper optimizes its drill bits, speed-up tools, drilling parameters, and drilling fluid performance. Through bit optimization, a PDC bit optimization template is formed. A single S1942 PDC and BTM159AR PDC bit can solve the problem of poor formation drillability, improve drilling efficiency, shorten completion time and optimize speed-up tools in the study area. For glutenite developed stratum (bottom of Guantao Formation), we use shock-absorbing thruster, and for gray mudstone (Shahejie Formation), we use shock-absorbing thruster + curved screw. 1% organic silicon polymer can be added to the three-open drilling fluid to improve the drilling fluid performance. The adding of the compound (PLH: KPAM: ammonium salt = 1: 1: 2) can inhibit mud making, and the 2% anti-collapse agent before drilling into basalt can solve the well wall collapse of Shahejie Formation and Guantao Formation. The liquid with density of 1.44-1.45 can prevent well overflow. The research results provide guidance for high-quality and efficient drilling in the Gaoshangpu block of Jidong Oilfield and ensure the safety of drilling operations.

1. Introduction
The main oil-producing layer in the Gaoshangpu block of Jidong Oilfield is the Shahejie Formation, with a buried depth of 3050~3720m. The physical properties of the reservoir are mainly mesoporous reservoirs with complex structural morphology, contradictory oil-water relations, and heterogeneous reservoirs. Five-segment well trajectory design is adopted for three openings[1]. The formation has poor stratum drillability, serious back pressure, low drilling efficiency, long drilling cycle, with average ROP of 10.19m/h and average drilling cycle of 58.20d, which is far lower than the rest of the surrounding blocks. The Gaoshangpu block has entered the mid-to-late development stage, with long-term water injection, and the formation pressure system has changed. For example, the basalt of the Guantao Formation are prone to well wall collapse, the Dongying Formation and the Sha 1st Member are prone to leakage accidents, and the Shahejie formation has poor drillability[2]. A number of drilling companies have carried out speed-up studies in this block. Among them, the drilling speed of...
Zhongyuan Drilling is 11.53m/h with the average drilling period of 34.85d, and the drilling speed of Bohai Drilling is 8.49m/h with the average drilling period of 46.56d.

Ren Guihe (2009) used the "screw + top drive" combination drilling for Well G17-30, with an average ROP of 11.5m/h, which improved the drilling rate and efficiency[3]. Xisheng Lu (2009) optimized Zhengyi round cutters for Well G17-19 and the wing PDC bit has an average ROP of 15.08m/h. Zhao Guoxi et al. (2015) used a rigid drilling tool structure for the complex conditions of the Gaoshangbao block to ensure the performance of the drilling fluid and increase the ROP[4]. In response to the above problems, the Gaoshangpu block needs to carry out research on PDC bit selection, well quality control, basalt formation collapse prevention, etc., to formulate appropriate drilling parameters, ensure drilling safety, improve drilling efficiency, and provide reference for the next step of optimal and fast drilling[5].

2. Methods and materials

Experimental materials: shock-absorbing thruster (Kunshan Belkin Shock Absorbing Equipment Manufacturing Co., Ltd.), silicone polymer (Inner Mongolia Hengxing Chemical Co., Ltd.), asphalt resin anti-collapse agent (Karamay Boao Industry and Trade Co., Ltd.), sulfonated asphalt (Henan King Fudun Petroleum Technology Co., Ltd.), S1942 model PDC drill bit (Beijing Ruishi Drill Bit Co., Ltd.), BTM159AR model PDC drill bit (Beijing Ruishi Drill Bit Co., Ltd.).

Experimental method: The performance of the drill bit is evaluated by the Binneng method. The bit performance is proportional to the performance of the bit. The lower the bit performance, the higher the rock breaking efficiency and the better the performance of the bit.

\[ Sc = \frac{480NT_b}{\pi D^2} + \frac{4W}{\pi D^2} \]

Where: \( S_c \) is the Binneng index; \( T_b \) is the bit torque, kN·m; \( W \) is the weight on bit, kN; \( D \) is the bit diameter, mm.

3. Results and analysis

3.1. Drill bit optimization

The type and quality of deep-well drill bits are directly related to drilling efficiency and drilling cycle. A suitable type and high-quality drill bit can greatly increase the drilling rate, while an inappropriate type of drill bit reduces the drilling efficiency and increases the probability of downhole complications. At present, the drilling cost method, the drilling benefit method, and the Binneng method are commonly used for quantitative bit selection. There are many mudstone interlayers in the second member of Shahejie Formation in the Gaoshangbao block, so the drill bit needs to have good abrasiveness and impact resistance. Combining the use of the neighboring drill bit, the PDC bit is selected, which can greatly improve the drilling rate efficiency and reduce the overflow accident.

Through the analysis of the shape and wear resistance of the blade, the S1942 model PDC and the BTM159AR model PDC drill bit were selected. Combined with the regional geological background, the optimal template for the drill bit is obtained (Table 1). G23-52 well uses BTM159AR model PDC bit with an average ROP of 16.7m/h for the third section; G32-24 well uses S1942 model PDC with an average ROP of 14.35m/h, which is much higher than the block average ROP of 11.19 m/h.

| No. | Bit type       | Number | Depth (m)   |
|-----|----------------|--------|-------------|
| 1   | 444.5mmSKG124  | 0.2    | 0-203       |
| 2   | 311.1mmBTM115A9R | 1.0    | 203-1980    |
| 3   | 311.1mmHJT517G  | 1.0    | 1980-2103   |
| 4   | 215.9mmSKH517G  | 1.0    | 2103-2103   |
| 5-6 | 215.9mmES1925H  | 2      | 2103-4076   |
|     | BTM115A9R      |        |             |
3.2. Optimization of speed-up tools
The stratum of Shahejie Formation in Gaojiapu block develops glutenite, which is interlaced with mudstone. The bit wear is serious, which reduces the service life of the bit and is prone to sticking accidents. In the gray mudstone section (2600-3100m), the PDC bit slips seriously, which restricts the ROP. Combining the development of the strata in the study area, it is proposed to add a shock-absorbing thruster in the sandy conglomerate section to increase the ROP. The shock-absorbing thruster acts on the piston to generate weight on the piston by the pressure drop of the mud flowing through the drilling tool. In the gray mudstone section, measures of shock absorption thruster + curved screw are proposed to slow down the effect of slipping and increase the ROP.

It can be seen from Figure 1a that the ROP is 27.23m/h with the shock-absorbing thruster G23-49 and the ROP of G32-24 is 23.5m/h, which is much higher than that without the shock-absorbing thruster G23-54. The drilling speed is 12.47m/h, the drilling speed of G23-52 is 10.02m/h, and the drilling speed of G32-19 is 10.62m/h. It can be seen from Figure 1b that in the development of glutenite, the ROP of G23-49 is 4.31m/h, and that of G32-24 is 4.23m/h-4.4m/h, which is higher than that of G23-52. The drilling speed is 1.33m/h-2.85m/h, and the G32-19 mechanical drilling speed is 1.05m/h-1.62m/h. In summary, adding a shock-absorbing thruster in the sandy conglomerate section can increase the mechanical drilling speed.

![Figure 1. Comparison of ROP of the second member of Shahejie Formation in Gaojiapu block (a, ROP; b, bottom conglomerate of Guantao Formation).](image)

3.3. Drilling fluid performance optimization
The special lithology of black-gray basalt is developed in the Gaoshangpu block. The clay minerals in the shale of the third member of Shahejie Formation are mainly brittle minerals such as chlorite and illite/Montmorillonite. At the same time, the pressure coefficient of the area is 1.22-1.39, and the pressure distribution is complex. The performance of drilling fluids needs to not only prevent the occurrence of complex accidents such as well wall collapse and lost circulation, but also protect oil and gas reservoirs. The silicone polymer system has the characteristics of strong resistance to high temperature (up to 200℃), strong anti-collapse and easy maintenance. The addition of 1% silicone polymer to the original drilling fluid system of the third section can improve the performance of the drilling fluid.
The formation mudstone of Minghua Town and Shahejie Formation has strong mud-making ability, it is necessary to increase the inhibitor to maintain the good performance of the drilling fluid. The compound shale inhibitor (PLH: KPAM: ammonium salt = 1: 1: 2) has good rheology. Drilling into basalt formations is prone to well wall collapse and adding 2% anti-collapse agent in advance can effectively avoid this problem. The anti-collapse agent is composed of asphalt resin anti-collapse agent + sulfonated asphalt. Asphalt resin can reduce water loss at high temperature and high pressure. Sulfonated asphalt can seal the pores of the formation, reduce the penetration rate of drilling fluid, and extend the period of formation collapse. The formation pressure coefficient in the Gaoshangpu block ranges from 1.22 to 1.39, and the drilling fluid density remains at 1.44 to 1.45 (Figure 2).

3.4. Research on complex accident prevention

The Gaoshangpu block has a long development cycle, and the formation pressure coefficient of long-term water injection development has changed. Currently, it is mainly facing complicated accidents of overflow and well collapse. The essence of overflow is that the pressure in the wellbore is lower than the pressure of the formation fluid, which causes a large amount of formation fluid to enter the wellbore. Excessive suction pressure and abnormal formation pressure will cause overflow. The occurrence of overflow is often accompanied by multiple displays: such as the increase in the flow rate of the exit pipe during drilling, the increase in the return volume, the rise of the drilling fluid level, the increase in the size of the cuttings, the decrease of the Dc index, the increase of the suspended weight of the drill and the decrease of the pump pressure drops. The pump speed increases all indicate overflow, and the well needs to be shut down in advance to avoid property losses.

3.5. Case analysis

Well G23-52 is located on the G5 fault block, and the target horizon is below the S3. The layers drilled by the first opening are the Pingyuan Formation and the Minghuazhen Formation, which are mainly faced with sticking and mud making accidents. Inhibitors (PLH: KPAM: ammonium salt = 1:1:2) are added to inhibit mud making. The drilling horizons of Minghua Town and Guantao Formation are mainly faced with mud making, anti-collapse, and leakage prevention. While adding inhibitors, a
shock-absorbing thruster is added to the sandy conglomerate of the Guantao Formation. The third-opening target layer is Shahejie Formation. The drilling fluid density is maintained at 1.44-1.45. For the mudstone section, a shock absorber + curved screw is placed to control the tripping speed to prevent the well overflow. At the same time, we need to pay attention to the drilling fluid flow rate, cuttings content, and pump parameters during the drilling process such as pressure, pump speed, to prevent well overflow.

4. Conclusion
(1) The Gaoshangpu block of Jidong Oilfield has large well depths, complex geological conditions, poor stratum drillability, low efficiency of drilling machinery, and long drilling cycle. Through bit optimization, a PDC bit optimization template is formed. A single S1942 PDC and BTM159AR PDC bit can solve the problem of poor formation drillability, increase drilling speed, and shorten well construction period. We optimize speed-up tools in the study area for the development of sandy conglomerate. For the stratum, shock-absorbing thruster is used, and for gray mudstone, shock-absorbing thruster + curved screw is used.

(2) Adding 1% organosilicon polymer to the drilling fluid for the third section can improve the performance of the drilling fluid. The compound (PLH: KPAM: ammonium salt=1: 1: 2) can inhibit the mud making. Adding 2% anti-collapse agent can solve the well wall collapse of Shahejie Formation and Guantao Formation. The drilling fluid density of 1.44-1.45 can prevent well overflow. During the drilling process, we need to pay attention to the drilling fluid flow rate, cuttings content, pump pressure, pump speed and other parameters to prevent the emergence of complex accidents. The research results are tested in the G5 block. The ROP increases from 7.94m/h to 13.81m/h, with an increase of 41.3%. The well construction period is shortened from 59.84d to 42.17d with a reduction of 35.2%. The accident complexity rate is 2.2% with a reduction of more than 55%. The average drilling and completion cycle speed has exceeded the previous target wells, which is better than the expected target.

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