Optimization Selection of Bit and Application Research on PDC + Motor Combination Drilling Technique in the Desert Oilfield

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Abstract: The drilling speed has a lot to do with whether the selected bit type and formation type is matched. Choosing a reasonable drill bit type can achieve the goal of high speed and low cost drilling by improving drilling rate and reducing the occurrence of down hole trouble. On the basis of performance analysis of PDC bits, the linear relationship between rate of penetration and drilling footage is obtained. By means of the optimization of motor and parameters, the drilling parameters, such as weight on bit, torque, type of mud motor and operating temperature, are optimized by application in desert oilfield. It provides an effective reference for the rapid development of the same type of oilfield.

1. Optimization of Bit Based on the Performance of Used Bits

The drilling speed has a lot to do with whether the selected bit type and formation type is matched. Choose a reasonable drill bit type can achieve the goal of high speed and low cost drilling by improving drilling rate and reducing the occurrence of down hole trouble. Bit is optimized for various wellbore and formation according to the practical using situation of bit used in drilled well.

Optimization Principle: the bit in the same wellbore and formation which has the best adaptability is priority

Optimization Parameter: bit adaptability

Bit adaptability=(average penetration rate of the same bit type in the same wellbore and formation)×(footage of the same bit type in the same wellbore and formation)

(1) Using situation and optimum analysis of 374.6 mm bit

Two types of cone bit with model GA114 and W111 are used in 374.6mm wellbore, both of which are used in surface well section, and their average footage is 612.39 m, and average penetration rate is 26.58 m/h.

It can be seen from the Fig 1 that the average penetration rate of bit W111 is little higher than that of bit GA114 in Recent formation in 374.6mm wellbore, and the gap is not big. The average penetration rate of bit W111 is 28.18m/h, and that of bit GA114 is 26.58m/h, so the optimizing bit for the 374.6mm surface well bore are W111 and GA114, and the Optimization results shown in the table:
Table 1. Optimization of bit for 374.6mm wellbore (Recent).

| Wellbore (mm) | Formation | Type of bit | Average Footage (m) | Average Penetration Rate (m/h) |
|---------------|-----------|-------------|---------------------|-------------------------------|
| 374.6         | Recent    | W111        | 597.88              | 28.18                         |
|               | Recent    | GA114       | 623.09              | 25.56                         |

Figure 1. Comparison table for average penetration rate of different bit in the wellbore of 374.6 mm.

(2) Using situation and optimum analysis of bit 250.8 mm

Table 2. Optimization of bit for the 250.8 mm wellbore (Recent).

| Wellbore (mm) | Formation                      | Type of bit | Average Footage (m) | Average Penetration Rate (m/h) |
|---------------|--------------------------------|-------------|---------------------|-------------------------------|
| 250.8         | Recent, Sokor, LVS, SS Recent  | DS752A B    | 982.43              | 12.23                         |
|               |                                | HA117G      | 689.99              | 13.57                         |

Figure 2. Comparison distribution of PDC and cone bit in 250.8 mm wellbore.
Figure 3. Analysis graphics of bit adaptability in 250.8 mm wellbore.

(3) Usage situation and optimal selection analysis of 215.9mm bit

Table 3. Optimal bit selection for 374.6 mm wellbore (Recent).

| Wellbore (mm) | Formation       | Type of bit | Average Footage (m) | Average Penetration Rate (m/h) |
|---------------|-----------------|-------------|---------------------|-------------------------------|
| 215.9         | Recent, Sokor, LVS, SS Recent | SP605       | 1038.00             | 10.53                         |
|               |                  | HA117G      | 724.5               | 14.00                         |
|               |                  | SP1675      | 900                 | 10.53                         |
|               |                  | KM1652G     | 643.08              | 13.83                         |

Figure 4. Comparison distribution of PDC and rock bit in 215.9 mm wellbore.
Figure 5. Analysis graphics of bit adaptability in 215.9 mm wellbore.

(4) The results of bit optimization
Surface casing hole section: Cone bit is optimized to be used; Production casing hole section: PDC bit is mainly used, and cooperate with using high efficient cone bit, and these measures can improve penetration rate and reduce the drilling cost.

The optimization result is shown in table:

| Bit Size mm | Bit Type | Average Penetration Rate m/h | Average Footage m |
|-------------|----------|------------------------------|-------------------|
| 444.5       | W111     | 22.54                        | 668.30            |
| 374.7       | GA114    | 26.72                        | 456.66            |
| 311.1       | SP605    | 16.46                        | 2271.00           |
| 250.8       | DS752AB  | 12.23                        | 982.43            |
|             | HA117G   | 13.57                        | 689.99            |
|             | SP1675   | 10.53                        | 1038.00           |
|             | KM1652GAR| 13.83                        | 643.08            |

2. Optimizing Selection of Bit Type According to The Formation Characteristics
The profile of rock drillability and abrasive property is established using the logging data[6], and the model takes example by the research results of the rock drillability in DG Oilfield:

\[ K_{yl} = 18.866e^{-0.0142AC} \]
\[ K_{PDC} = 52.325e^{-0.0359AC} \]
\[ P_y = 18515e^{-0.047AC} \]
\[ \text{Fang} = \sin(-1((V_p-1000)/(V_p+1000))) \]

Kyl, KPDC are respectively to the extreme value of corresponding rock drilling ability of cone bit and PDC bit; Py: hardness of rock; Fang: internal friction angle; AC: time difference of acoustic logging, us/ft; Vp: acoustic velocity, m/s

It is analyzed from the comprehensive of rock drillability and abrasiveness that the formation in X oilfield is soft, medium-soft formation with high-drillability and low-medium abrasiveness. So cone bit with IADC codes 117/127 and PDC bit with IADC codes 117/127 are chosen.

3. The Optimization of Motor and Drilling Parameters

3.1. General principles of the motor optimization
Different types of motors will be chosen for different work conditions, which can give full output to the effective power and improve the operation timelines.

The chosen of Motor should be on the basis of the working condition and the parameter, generally contains the following aspects.

3.1.1. The highest formation temperature
(1) The stator with temperature resistant ≤120 °C, its rated working temperature is 95 °C, and the highest working temperature is 120 °C
(2) The stator with temperature resistant ≤135 °C, its rated working temperature is 120°C, and the highest working temperature is 135°C
(3) The stator with temperature resistant ≤165 °C, its rated working temperature is 150 °C, and the highest working temperature is 165°C

Attention: please choose the appropriate level of heat-resistant, if the motor applicable temperature is higher than the actual temperature, motor will be short of power; The opposite situation may cause the motor stator expansion by thermal and early lead rubber to run out ahead of schedule.

3.1.2. Formation lithology
In general, high speed- low torque motor could usually be chosen in soft formation and high torque- low speed of the motor is used in medium, hard formation. In additional, it will be coped with high wear-resistant to extend the service life of motor drilling tools if the abrasiveness of the formation is rather high that will cause serious engine to motor drill tool and its centralizer.

3.1.3. Range of working flow rate
The appropriate motor will be chosen according to the actual work flow rate, the value of which is half of the motor delivery is suitable. If there is requirement on rotating speed, it should be considered whether the selected motor speed under work condition can satisfy the need.

3.1.4. Drilling fluid type
If the Cl- concentration in drilling fluid is higher than 30000 ppm, motor drill tool with resistant to salt water should be chosen. Ordinary rubber stator in oil-based mud would cause obvious swelling, which will have a big impact on motor, motor drill tool with oil resistance should be chosen when the oil-based mud is using. If using crude oil, diesel and waste engine oil for lubrication, enough of emulsifying agent should be added into drilling fluid.

3.1.5. Build-up rate
Generally speaking, motor build up parameter should be chosen in accordance with the build-up rate of designed wellbore trajectory, combined with formation features.

3.2. The optimization of motor in Desert X Oilfield

3.2.1. Formation temperature
According to the statistics of testing formation temperature, it is supposed that land surface temperature is 0°C, and the temperature gradient of formation SS and its upper formation is 5°C/100m, and Yogou is 4°C/100m. According to the formation depth analysis of the development plan, the depth of formation D fault block is deepest, in which formation SS vertical depth is about 2900m, so the highest formation temperature is 145°C, meanwhile, the deepest Yogou formation is 3200m, and the highest formation temperature is 128°C. The circulating temperature in actual drilling process is below to 120°C, so there is not special requirements of thermal stability to motor.
3.2.2. Formation characteristics
From drillability analysis of optimization formation according to bit type, it can be found that SS and the upper formation is soft-medium to soft formation and its abrasive property is not high. Then motor with high speed-low torque should be chosen in theory. But in view of the question of large friction drag and instability of WOB in drilling engineering, torque values of the motor should be appropriately increased, which can improve the motor's ability to fight against the damage caused by suddenly increase of drilling pressure. Moreover, to cope with directional drilling operation in Yogou formation, the motor torque should also be appropriate to improved, and drilling speed can be improved by adjusting displacement and speed of rotation.

3.2.3. The range of work flow rate
To satisfy the condition that the annular velocity should be larger than 1 m/s, the flow rate is required to each to 35-40 L/s in 250.8mm wellbore, annulus velocity should be in 28-32 L/s in 215.9 mm wellbore.

3.2.4. Drilling fluid type
KCL polymer-silicate drilling fluid system is used currently, the Cl-contention of which is higher, so it is required that the motor rotor should take measures to resistant to corrosion of Cl-.

3.2.5. The ability of build-up
In ordinary design of drilling engineering, the build-up rate of the conventional directional well is 2.4-3.6°/30m, general motor bent angle about 1° can realize the requirement of built-up, and bent angle cannot be too big. In order to improve the PDC + motor compound drilling speed, motor turn cannot be bigger than 1.3°, while the biggest required is less than 1.5°. To cope with the future construction of horizontal, well can purchase some adjustable corner motor in order to meet 4 to 7°/30m build-up rate requirements.

3.2.6. The requirement of size specification, torque and rotate speed
Directional construction at present is mainly completed in 215.9 mm and 250.8 mm wellbore, motor with 165 mm and 172 mm outer diameter can be okay, considering that the bigger motor size have longer service life, therefore 172 mm motors is recommend to be chosen. Torque and speed are need to match the bit selection and working condition, according to the selection of bit type, M223 or M323 PDC bit is recommend, generally drilling the pressure and rotational speed correspond to the two PDC bit with ADC codes are: 250.8 mm drill bit, WOB 20-120 KN, 60-200 rpm speed; 215.9 mm drill bit, drill press 20-80 KN, 60-200 rpm speed, so in order to give play to the bit, the matching motor speed and pressure can exert drill pressure should be consistent with the drill bit. Therefore the recommend motor speed is between 60-200 rpm, and the displacement between 28 to 40 L/s, the maximum bit pressure should be greater than 80 KN, the output torque of the motor should be > 4000 N·m in 215.9 mm hole, that in 250.8 mm hole should be > 5000 N·m, but given the current drilling in the drilling pressure unstable problem, leaves the motor output torque margin, it is suggested that the output torque of the motor should be > 6000 N·m in 215.9 mm hole, that should be > 7000 N·m in 250.8 mm hole.

Presently the chosen motor model is 7LZ172-7s with recommend flow rate 20-40 L/s, the pressure drop 4 MPa, torque 7176 N·m, drill pressure 100 KN, rotation speed 84-168 rpm. The motor bent angle is 1.15°, and quotas is 7-8.

3.3. The operation parameters optimization
Due to the requirements of cluster-well design, the kick-off points are relatively shallow, and the formation is loose, in order to meet the requirements of the directional and control the quality of borehole, the flow rate is recommended to use the lower limit in shallow wellbore, and WOB could be increased properly with high torque and low rotation speed. On the premise of carrying cutting, reducing flushing for the borehole, stabilizing hole inclination at the bottom, it can be appropriate to reduce the weight on bit and improve the ROP to speed up.
In 215.9 mm wellbore, it is suggested that in shallow kick-off section, the recommend WOB is 2-4 KN, flow rate 28 L/s, and unstable slope section at the bottom, WOB is 4-6 KN, flow rate 32 L/s. In 250.8 mm wellbore in kick-off section it is suggested that the recommend WOB is 2 to 4 KN, and the flow rate is 35 L/s, in lower stable section recommend WOB is 5-7 KN, and the flow rate is 40 L/s in composite drilling with rotation speed of top drive system 30 to 50 rpm.

4. Conclusion
(1) In view of the drillability and abrasive of formation, the lithologic of SS and its upper formation is soft - soft to medium with low-medium abrasiveness, and totally showed as preferably drillability. In addition, the lithology of SS and its upper formation is sand-mudstone, while there is hardly any conglomerate or pebbly sandstone, which is suitable for PDC bit. PDC bit is superior to the cone bit in Desert X oilfield in the application practice effect of drilling bit, so it is recommended to increase the proportion of PDC bit, especially IADC code with M223 or M323. It is special required to strengthen the hydraulic characteristics of sticking balling of bit.

(2) In the progress of motor selection, the compatibility of motor and bit should be considered. The recommended motor speed is between 60-200 rpm, and its flow rate is between 28 and 40 L/s. The maximum allowable WOB should be greater than 80 KN, while the output torque of the motor should be >6000 N·m in 215.9 mm wellbore, and that should be > 7000 N·m in 250.8 mm wellbore.

(3) The operation parameters in drilling are optimized combined with formation characteristics. In 215.9 mm wellbore the recommend WOB is 2-4 KN, and the flow rate is 28 L/s in building-up section; the recommend WOB is 4-6 KN, and the flow rate is 32 L/s in lower steady section. In 250.8 mm wellbore the recommend WOB is 2-4 KN, and the flow rate is 35 L/s in building-up section, the recommend WOB is 5-7 KN, and flow rate is 40 L/s in lower steady section. The top drive rotation speed is 30-50 rpm in combination drilling.

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