High Efficiency Drilling Control Technology for Shale Oil in Jiyang Depression

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Abstract. According to the geological characteristics of shale oil in Jiyang depression, the formation mechanics test was carried out to study the influence of well deviation orientation on wellbore stability, thus the high-efficiency drilling control method was put forward. The above research results were applied in the test wells, and the purpose of high-efficiency drilling was realized.

Keywords: Shale oil; Mechanical testing; Well deviation and wellbore stability.

1. Triaxial Test of Rock Mechanics
1) Triaxial test of rock mechanics
Samples were taken and tested. The basic information of rock sample is shown in Table 1, and the test results are shown in Table 2.

| Well name | Horizon | Depth m | lithology | Core diameter mm | Height mm | Density g/cm³ |
|-----------|---------|---------|-----------|------------------|-----------|--------------|
| J*1       | Es_3    | 3489.02 | Grey shale| 24.74            | 41.41     | 2.53         |
| J*1       | Es_3    | 3489.02 | Grey shale| 24.77            | 19.36     | 2.52         |
| J*1       | Es_3    | 3491.02 | Grey shale| 24.78            | 47.58     | 2.59         |
| J*1       | Es_3    | 3491.02 | Grey shale| 24.77            | 44.44     | 2.56         |
| J*1       | Es_3    | 3499.80 | Grey shale| 24.78            | 39.85     | 2.53         |
| J*1       | Es_3    | 3499.80 | Grey shale| 24.63            | 23.95     | 2.52         |

2) Dynamic and static relation model
The mechanical parameters of rock under confining pressure are tested by triaxial rock mechanics equipment, as shown in Table 2 below.
Table 2. Static mechanical parameters

| Well name | Depth m  | lithology    | Effective confining pressure, MPa | Elastic modulus, MPa | Poisson's ratio |
|-----------|---------|--------------|-----------------------------------|----------------------|-----------------|
| J*1       | 3489.02 | Grey shale   | 26.01                             | 28513.31             | 0.207           |
| J*1       | 3491.02 | Grey shale   | 29.82                             | 39902.52             | 0.302           |
| J*1       | 3499.8  | Grey shale   | 23.1                              | 18369.01             | 0.192           |
| J*1       | 3569.3  | Grey shale   | 29.85                             | 40639.73             | 0.335           |
| J*1       | 3571.3  | Grey shale   | 24.18                             | 24052.35             | 0.21            |
| J*1       | 3586.4  | Grey shale   | 21.32                             | 16917.43             | 0.109           |
| J*1       | 3589.4  | Grey shale   | 23.21                             | 13589.85             | 0.12            |

The acoustic parameters obtained from logging data are shown in Table 3, and the calculated mechanical parameters are called dynamic mechanical parameters, as shown in Table 4 below.

Table 3. Acoustic parameters of logging data

| Well name | Depth m  | P-wave time difference us/m | Shear wave time difference us/m | Longitudinal wave velocity m/s | Shear wave velocity m/s |
|-----------|---------|-----------------------------|--------------------------------|--------------------------------|-------------------------|
| J*1       | 3489.02 | 353.98                      | 594.20                          | 2883.74                        | 1631.80                 |
| J*1       | 3491.02 | 333.57                      | 555.72                          | 3061.07                        | 1719.49                 |
| J*1       | 3499.8  | 292.61                      | 506.58                          | 3479.44                        | 2000.11                 |
| J*1       | 3569.3  | 255.79                      | 434.98                          | 3860.72                        | 2204.60                 |
| J*1       | 3571.3  | 256.77                      | 438.94                          | 3939.88                        | 2345.71                 |
| J*1       | 3586.4  | 290.35                      | 501.25                          | 3441.58                        | 2007.22                 |
| J*1       | 3589.4  | 331.14                      | 581.65                          | 3002.16                        | 1801.97                 |

Table 4. Dynamic elastic parameters considering confining pressure

| Well name | Depth m  | Effective confining pressure MPa | Dynamic modulus of elasticity MPa | Dynamic Poisson ratio |
|-----------|---------|---------------------------------|----------------------------------|-----------------------|
| J*1       | 3489.02 | 26.01                            | 19941.22                         | 0.34                  |
| J*1       | 3491.02 | 29.82                            | 31954.92                         | 0.40                  |
| J*1       | 3499.8  | 23.1                             | 26370.46                         | 0.29                  |
| J*1       | 3569.3  | 29.85                            | 42381.02                         | 0.39                  |
| J*1       | 3571.3  | 24.18                            | 23884.70                         | 0.27                  |
| J*1       | 3586.4  | 21.32                            | 24680.88                         | 0.26                  |
| J*1       | 3589.4  | 23.21                            | 21322.12                         | 0.25                  |
2. The Influence of Deviation Direction on Wellbore Stability
On the basis of in-situ stress, the formation collapse pressure and fracture pressure under different well deviation and azimuth are simulated, and the influence of different well deviation and azimuth on wellbore stability is analyzed, as shown in Figure 1 and Figure 2 below. It can be seen from the analysis results that drilling straight wells in this block is conducive to wellbore stability. If horizontal wells are drilled in this area, the direction of minimum principal stress is the most favorable for drilling.

3. Research on Efficient Drilling Control Technology of one Trip Drilling
1) Bit optimization
Carry out rock drillability experiment, study the hardness and brittleness of rock, determine its drillability level, and determine the optimal bit type. The experimental equipment adopts a full-automatic rock drillability tester. It is found that the drillability level of shale is low, belonging to soft to medium soft formation, and it is plastic brittle formation, which meets the requirements of PDC bit for formation conditions, and PDC bit is suitable for use. Based on the analysis of the bit application in the early construction well, the indoor experiment of bit drillability and empirical bit selection are carried out, and the highest bit technical benefit index is selected.

The recommended bits are as follows:
① if the upper stratum is loose, choose the cone bit.
② In Dongying Formation, grey and dark grey mudstone and oil shale are mainly intercalated with sandstone, which are suitable for PDC bit drilling.
③ Pk5363s-311 mm bit, but in the actual drilling, the cone bit should be run in after drilling through the gravel layer. Pay attention to observe whether there is choking phenomenon in the drilling process. In case of skipping, low speed, light pressure and slow drilling are required. There are many interlayer in the directional section, so pk6257mjd-311 mm bit is selected.
④ In the horizontal section of shale, attention should be paid to the problem of mud pack prevention. Because of the high ash content in the formation, the service life of the bit should also be considered. Therefore, pk5336mj-215.9 mm and pk6257md-215.9 mm bits are selected.
2) Efficient trajectory control technology for shale horizontal wells
According to the friction torque level of different sections, combined with the drilling experience at home and abroad, different drilling methods are selected according to the trajectory control characteristics of different sections of shale oil horizontal wells to realize the efficient control of the trajectory.
In the process of directional drilling, the directional tool combination is based on the three-point circle method. The reducing diameter of the lower centralizer can enhance or weaken the tool deflecting ability. The use of reducing stabilizer can significantly improve the directional drilling efficiency and reduce the directional drilling time.

The key of variable diameter stabilizer is composed of variable diameter structure, variable diameter actuator, variable diameter control mechanism, spline sleeve control mechanism and sealing system, shown in Fig.3

![Figure 3. Structure diagram of variable diameter stabilizer](image)

3) Field application of technical achievements
Since 2018, Shengli Oilfield Company has started the second round of shale oil exploration and development. At present, two test wells have been deployed and constructed in Bonan and fanjiagang blocks. The test wells have applied the above research results to achieve the purpose of efficient drilling. The average ROP of the new experimental well is 9.69 M / h, and that of the third opening section is 5.85 M / h, which is 56.04% and 33.56% higher than that of the previous shale oil experimental well. The acceleration effect is obvious.

4. Conclusion
In the process of shale oil drilling and development, considering the influence of well deviation orientation and using one trip high-efficiency control technology, the application of new test wells has proved that the speed-up effect is obvious.

Reference
[1] Dutta N. C. Ray A.. Image of Geopressure Rocks Using Velocity and Acoustic Impedance Inversion of Seismic Data. Geophysics, 54(1):82-89
[2] Dutta N. C.. Deepwater Geohazard Prediction Using Prestack Inversion of Large Offset P-wave Data and Rock Model. Leading Edge Geophysics, 21(2):193-198
[3] Bowers G. L.. Pore Pressure Estimation from Velocity Data: Accounting for Overpressure Mechanisms Besides Undercompaction[J]. SPE Drilling and Completion, June, 1995.