ISSN: 2664-9640

Optimization and application of drilling and completion technology for ultra-deep wells in Kuqa Piedmont area

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Abstract

In recent years, the deep and ultra-deep layers of the Tarim Basin are estimated to account for more than 80% of the proven reserves and resources. In order to cope with the problems of ultra-high pressure, ultra-high temperature, and complicated drilling in the Kuqa Piedmont block, a series of new drilling and completion technologies have been formed: ①The high-pressure forward injection and reverse extrusion cementing technology is used to achieve effective cementing; ②The pendulum speed-increasing technology has achieved at least 69.6% increase in ROP; ③The industry-leading logging while drilling technology is used to achieve effective prediction of special formations; ④The drilling fluid is optimized to achieve an initial shear force of only 2-3MPa, which reduces lost circulation occur.

Keywords

Ultra-deep well; drilling speed increase; drilling and completion technology; logging while drilling.

1. Status Quo of Exploration and Development in Kuqa Piedmont Area

Influenced by the strong compressional tectonic movement in the Himalayan period, the Kuqa Piedmont area has formed a series of complex thrust structural belts with various tectonic styles. The upper part of the Kelasu structural belt in the Kuqa Depression develops huge and thick gravel layers, which are mainly distributed in the Bozi, Dabei, Tubei areas and the north and south flanks of the Kelasu anticline, the average thickness of the gravel layer is 1000-3000m, and the maximum thickness is more than 5000m[1]. As the region continues to develop into ultra-deep and complex formations, a series of ultra-deep well drilling challenges have arisen:

(1) The Kuqa foreland basin has the characteristics of ultra-deep, ultra-high pressure, ultra-high temperature and complex formation, and has strict requirements on well structure, drilling tools and working fluid.

(2) The main reservoir is the Cretaceous Bashijiqike Formation. The commonly used three-opening and four-opening wellbore structure design may not meet the requirements of the must-sealing point, and the commonly used four-opening wellbore structure and matching need to be optimized.

(3) The gravel layer in the Kuqa Piedmont area has different composition, poor sorting, strong heterogeneity, poor drillability and low ROP. The damage to conventional drill bits is large, resulting in slow drilling speed and high drill bit consumption, which seriously affects the efficient development of oil and gas reservoirs in this area [1][2].

2. Cementing technology

The drilling and production environment of ultra-deep wells is very harsh. Under the action of high temperature and high pressure, many requirements are put forward for the application of cementing technology. Ultra-deep well cementing is difficult because the drilling environment is mostly high temperature and high pressure environment, the casing is difficult to run due to the small annular gap, the temperature difference between the wellhead and the bottom hole is large, and the mud performance requirements are high.

In order to cope with the above-mentioned complex problems in geology and construction, the forward injection and reverse extrusion cementing technology is adopted in the construction, which can implement large displacement forward injection to ensure the cementing quality of tube shoes, high pressure reverse extrusion cement injection, pressure holding and waiting to set, to ensure The cementing quality of the coincident section [3]. This process can achieve effective sealing of high-pressure saline aquifers through reasonable cementing displacement, optimized slurry performance, etc.

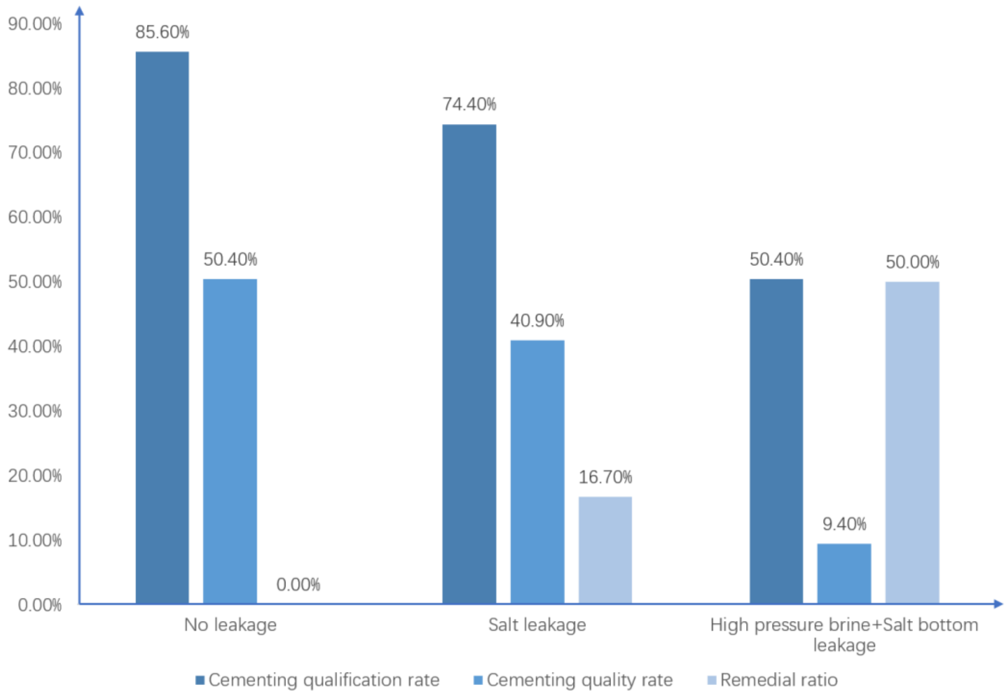

Fig. 1 Cementing quality of salt layer under different well conditions

Aiming at the problems of cementing in ultra-deep wells and improving the quality of the wellbore, the pressure stabilization and net replacement of the large-size casing cementing process are used as the core [4] to solve the problem of upper pressure. In the target layer, by strengthening the long-term integrity of the cement sheath, auxiliary sealing tools (top seal hanger, external packer) + self-healing cement slurry are used to reduce the annular pressure. The exploration and development cementing requirements of this block are quite fulfilled.

3. Drilling speed up

The salt stratum in the Tarim Piedmont area has a high and steep structure with a maximum stratum dip angle of 80°. ROP is low [5].

In view of the above problems, a screw drilling tool with equal wall thickness and high torque based on high-efficiency rock-breaking theory and continuous and stable transmission of rock-breaking energy is preferred. Compared with conventional screw drilling tools, the drilling tool combination has higher torque and longer life. The advantages of this method are to improve the output torque of the screw drilling tool to provide the drill bit with continuous and stable rock-breaking energy and output torque [6][7]. In view of the characteristics of strong abrasiveness, high hardness, poor drillability, and large vibration of the Cambrian dolomite section, the application of the double-pendulum speed-up tool has a good speed-up effect. The double pendulum speed-up technology utilizes the precession and self-stability characteristics of the gyroscope to actively suppress the lateral and longitudinal vibration of the drill bit cutting rocks. Compared with the single-pass drilling of the same hole size in the Ta dolomite stratum (select the best record of single-pass drilling), the average speed of the double-pendulum speed-increasing tool is increased by at least 69.6%.

Table 1 The speed-up effect of drilling tools in the 12 1/4″ wellbore in the dolomite formation of Tarim Oilfield

Hashtag	Construction time	Wellbore size	Drill tool assembly	Drill bit model	Construction well section	Footage	ROP	The newness of the drill bit
A	2019.12	121/4"	double pendulum+big pendulum	XZ816	6318-6386	68	1.88	98%
B	2015.10	121/4"	big pendulum	MD637HY	6257-6320	63	1.07	40%
C	2017.11	121/4"	Optical drill collar	HF637	5369-5466	97	1.02	30%
D	2013.11	121/4"	Optical drill collar	ST316TR	5973-6072	99	1.12	50%

4. Logging while drilling technology

Due to the deformation caused by tectonic compression, the development of faults and the complex existence of faults in the Kuqa Piedmont area, the location, depth and thickness of the strata vary greatly. The complex and changeable formation structure, the increase of well depth, and the increase of bottom-hole temperature and pressure cause the failure of MWD tools due to various reasons [8]. By counting the failures of MWD tools, the root causes of tool failures can be divided into the following major causes. kind:

(1) The pulse generator is blocked; the root causes are mostly unclean mud, the size of the plugging agent exceeds the specifications of the instrument, and the concentration of the plugging agent exceeds the specifications of the instrument;

(2) The vibration of the downhole instrument exceeds the standard, which leads to high mechanical vibration of the electronic part of the probe tube, and the circuit connection fails; because most MWD instruments are not equipped with shock sensors, it is difficult to monitor and prevent high-frequency vibrations during drilling. Adjust drilling parameters in time to reduce vibration [9];

(3) Failure of electronic components and circuit boards of the probe tube; this type of failure is often found in high-temperature well sections, and the temperature in the well reaches or exceeds the limit temperature of each instrument for a certain period of time, causing the instrument to fail.

In view of the failure of MWD instruments under high temperature and high pressure conditions, after the innovation of ultra-deep azimuthal resistivity technology technology, the depth of measurement before the drill bit (DoD) can reach a depth of tens of meters while meeting the temperature resistance of 180 °C. Deep Electro-Magnetic (EM) Look-Ahead goes beyond standard shallow and qualitative LWD resistivities to identify salt bottoms ahead of time. In addition, this technique can be effectively combined with other measurements, such as seismic and pore pressure detection, and provide more complex and comprehensive measurement information [10].

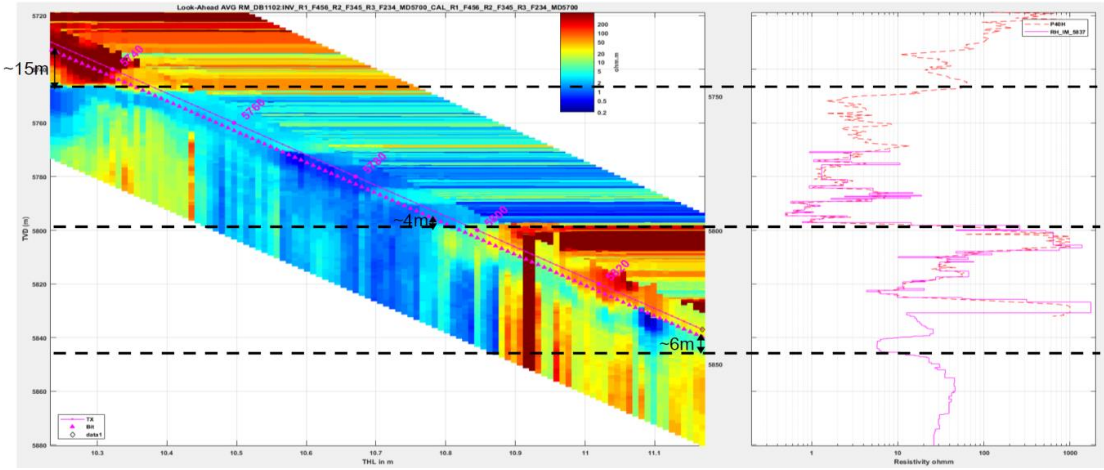

Fig. 2 The ahead of bit detection were clearly delineated along the section

5. Drilling fluid selection

Due to the high temperature, high pressure and large salt-gypsum formation in the Kuqa Mountains, the overflow rate has been high, and the large-scale use of oil-based drilling fluids also has certain problems. One of them is that once the brine overflow occurs during the drilling process, the performance of the drilling fluid will deteriorate and there is a risk of sticking [11]. The advantages of near oil-based drilling fluids are lubricity equivalent to drilling fluids, good rheological characteristics, super stability, oil formation, environmental friendliness, and overcoming the defects of oil-based drilling fluids.

In practical applications, the near oil base has a relatively regular well diameter, and its well diameter expansion is basically the same as that of the oil base. The performance of the drilling fluid basically meets the drilling needs, the density is relatively reasonable, the rheological properties meet the wellbore stability, the rock is carried back to the sand, the filtration loss is small, the lubricity is good, the well diameter is relatively regular, and there are only a small amount of blockage, mud and sand. Leakage is complicated. After adopting the modified drilling fluid system, the cost of oil-based drilling fluid at the same well depth is reduced by 46.5 million yuan, and the cost is greatly reduced [12][13].

Table 2 Drilling fluid performance in the fifth section of Well KS-C1

Properties	Relative density / （$g\cdot cm^{-3}$）	Funnel viscosity /s	API missing /mL	HTHP fluid loss/mL	PV/ mPa·s	YP/Pa	AV/mPa·s
Performance parameters	1.7	120	1.8	6.4	94	117	2~6/5~10

Compared with the adjacent well, the KS-C1 well has a relatively regular well diameter similar to that of the oil-based system, while the polysulfonic system has a significantly larger well diameter expansion. 76.48%, 19.23% smaller than organic salt. In Well KS-8-5, the five-opening

ISSN: 2664-9640

section is 6803.5~7006m, the footage is 202.5m, the drilling time is 22 days, and the drilling time is 36 days (the deadline is February 18), only a few times of leakage, and a total of 93.7m3 of drilling fluid was lost.

6. Conclusions and Recommendations

As the exploration and development of oil and gas reservoirs gradually develops towards the direction of ultra-deep wells, the drilling and completion technology in the Kuqa Piedmont area has also continued to make breakthroughs. New developments have been made in the optimized design of the wellbore structure, the optimized selection of drilling fluids, the innovative design of drill bits, the continuous innovation of logging while drilling, and the forward injection and reverse extrusion cementing technology. The development and exploitation of oil and gas reservoirs has a huge reference value and is of great significance to the development of oil and gas reservoirs in my country.

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