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Ladder Horizontal Well Trajectory Control and Completion Technique in Ultra-Thin Reservoir

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Abstract
Daqing peripheral oilfield in the shallow layer is low abundance and low permeability thin interbed reservoir, which has the characteristics of multiple layers, low permeability, and small interlayer thickness. The reservoir development is not balanced. According to this characteristic, in order to be effective and economically develop this kind of reservoir, the research adopts stepped horizontal well development technology. And with the application of dynamics and kinematics theory, establishing a three-dimensional track ladder design of horizontal wells, horizontal section of casing string lifting limit and the mathematics model to calculate stress. The establishment of the analysis of drilling technology can accurately judge the position of bit and reservoir development, and timely adjust track.

Key words: Thin layer; Stepped horizontal well; Optimization design; Trajectory control of; Cementing quality

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1. LADDER HORIZONTAL WELL DESIGN OPTIMIZATION TECHNOLOGY

1.1 Wellbore Structure Design Optimization

Three layer casing structure with the kickoff point below the technical casing guarantee the high ROP and shorten the well construction period in Φ 311.2 mm borehole.

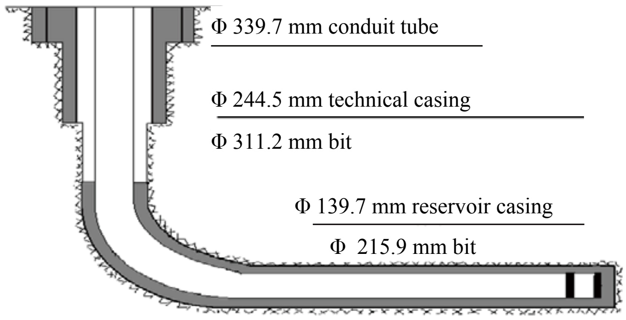

Figure 1
Ladder Horizontal Well Construction

1.2 Wellbore Trajectory Design Optimization

The ladder horizontal well in Daqing oil field are all medium curvature and constructed with seven sections which are first kick off-adjust-second kick off-oil detection-landing-horizontal section. The detection angle is 82° - 86°, which could insure the shortest wellbore length and accurate landing after the detection. The ladder horizontal well section is designed which have horizontal-drop off-hold on-build up-horizontal sections. This design structure could land twice in a well[1].

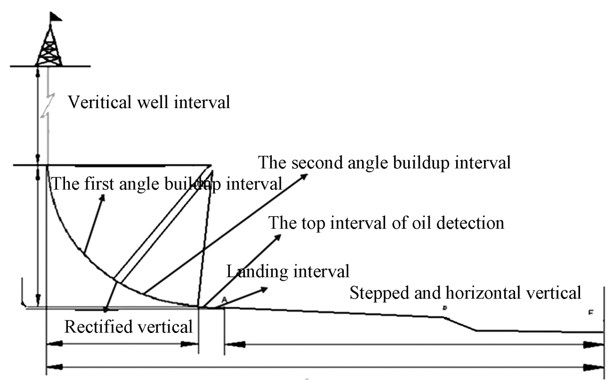

Figure 2
Ladder Horizontal Well Trajectory

2. THE WELL TRAJECTORY CONTROL TECHNIQUE OF LADDER HORIZONTAL WELL

2.1 Technical Measures

(a) According to the geometric information, the trajectory design could be optimized with the software computation of limitation. With the different characteristic of the formations, the drilling assembling and parameter could be achieved to reduce the drilling time.

(b) If the well trajectory needs to be adjusted due to complex formation, there is a need to recalculate the throughput capacity of drill string.

(c) With the analysis to the formation resistance, Gamma curve and the logging information of the neighbor well, the geometric property could be made sure and the drilling parameter and the drilling mode could be adjusted.

(d) Increase the refining and lubrication of the borehole to reduce the drag and torque.

(e) Drilling in combined ways could reduce the sliding drilling, improve the drilling speed and good at bringing the bricks.

(f) According to the calculation result of the rotary speed, the fatigue life of drilling tool could be calculated. The fatigue of drilling tool could be avoided by changing the drilling tools.

(g) Master the rules of kicking off with different BHA could help to predict the borehole curvature, control the well trajectory and improve the reservoir meet ratio[2-3].

2.2 Well Trajectory Control Technology

2.2.1 Building up Section and Oil Detection Section

(a) The BHA should be simpler to reduce not only the drag and torque but also the downhole complexity. The motor should be selected with 20-30% safety range[4].

(b) The real building up ratio should be calculated in operation, with the change of curvature, the drilling parameter need to be changed in time. The actual borehole trajectory need to follow the design or higher than the design. The LWD and Gamma logging need to applied after 50 degree of the inclination angle. The neighbor well data should be analyzed to adjust the error and control the well trajectory.

(c) The oil detection should carry on 30 - 50 meters before the target. According to the building up ratio of the BHA, the inclination should be controlled in certain range to prepare for the leading or lagging of the oil reservoir.

2.2.2 Horizontal Section

(a) Build up the Geometric Model of Reservoir

With the 3D seismic data and the new well completion data, the reservoir structure and fracture could be clear. The formation and depositional model has be built up using LPM and JASON software. With the log interpretation information, the reservoir model has be built up to guide the horizontal well trajectory in practice.

(b) Logging Data Analysis

With the rock sample, the formation lithology could be clear. The different formations have different color, grain size, structure, binding material content and oil/gas content. The gas logging could change a lot in different formation.

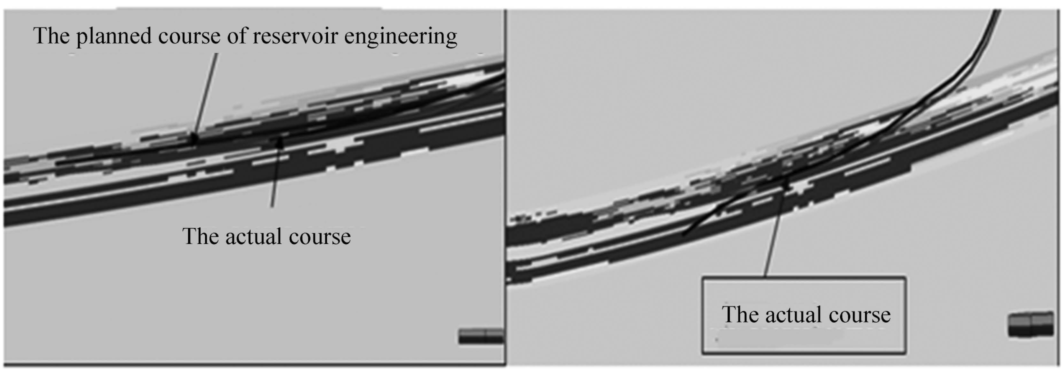

Figure 3
Geometric Model of Zhao 57-Ping 35

3. THE COMPLETION REPLACEMENT TECHNIQUE OF HORIZONTAL WELL

3.1 The Rules of Cementing Fluid Numerical Simulation for Horizontal Well

(a) According to the actual situation of casing string center, the need to have reasonable replace displacement can realize wide-brimmed and narrow edge of uniform propulsion, in order to improve the efficiency of fill.

(b) Turbulence replace not only improve efficiency, but also replace hydraulic fill. The inertial force viscous force is smaller, replace efficiency higher.

(c) Negative density difference replace will seriously influence replace efficiency increase, so in cementing operation as far as possible the positive density difference replace way should be used.

(d) Based on eccentric annulus wide-brimmed with narrow edge to the scale of equipped with reasonable replace parameters, hole enlargement ratio influence less on the parameters optimized[5].

(e) Larger the inclination angle means severer the interface, replace efficiency are relatively low, so fill parameters optimization of horizontal should consider mainly the horizontal section fill and take into account other interval.

3.2 The Development and Application of Efficient Lead Liquid

3.2.1 Efficient Lead Liquid Annulus Flow

Table 1
Different Density Efficient Pre-Filter of Liquid Annulus Rheological Calculation

Intensity(g/cm^3)	Return speed(m/s)	Displacement of threshold(L/s)
1.20	1.06	24.50
1.30	0.93	23.17
1.35	0.94	23.50
1.40	0.81	20.17
1.50	0.73	18.34
1.60	0.74	18.50
1.70	0.83	20.84

In Daqing oilfield common oil layer annulus casing, for example, casing size Φ 139.7 mm, use Φ 215.9 mm of drill bit. The hole enlargement rate 5%, the relevant data generation into type may be calculated turbulent critical backflow speed V_k and critical displacement Q_c.

$$V_K = \frac{Re_k'\left[\eta_p{}^2 + \sqrt{\frac{\rho\tau_0(D-d)^2}{2Re'_k}} + \eta_p{}^2\right]}{2\rho(D-d)}$$

$$Q_c = 60\frac{\pi}{4}(D^2 - d^2)V_K$$

In the formula：Re'_k—turbulence critical Reynolds number Re'_k= 3,000;

η_p—Bin han fluid plastic viscosity, mPa·s;

ρ—Fluid density, g/cm^3;

τ_0—Bin han fluid limit dynamic force, Pa;

D—Well diameter, mm;

d—Casing diameter, mm;

V_k—Turbulent critical backflow speed, m/s.

Different density preparation of critical backflow liquid high speed and critical displacement calculation result see Table 1.

From Table 1, which can be seen this efficient preparation of critical turbulent liquid highest fill emissions in 24.5 L/s, and the replace displacement mostly in 25 L/s above, explains efficient lead liquid in the actual cementing note for process can be fully realized turbulent instead.

3.2.2 Rinse Performance Evaluation

Using DCX-1 type flush makes man-made sandstone core at formulating the differential pressure and temperature formed under the mud cake, then according to the site cementing operation hydraulic parameters set rinses annulus return rate, simulation rinses in cementing annulus flow state, flush adhesion in sandstone core of mud cake, determination of a certain time washing efficiency (Table 2).

Table 2
Efficient Lead Liquid Washing Efficiency Evaluation Results of the Experiment

Serial number	Flush fluid type	Flush time (min)	Flush efficiency(%)
1	Water	5	80
2	DWG flush isolation fluid	2	100

Note. Drilling fluid: Silicon-based cationic drilling fluid, simulate circular temperature 45 ℃; Analog loop empty return speed 1.2 m/s, mud cake thickness 3 - 4 mm.

From Table 2, we can see DWG silicon-based cationic drilling fluid efficient flushing action, in a relatively short period of time, rinse efficiency contact 100%[6].

3.3 Zero Tomographic Water, Low Dehydrate Slurry System Development

3.3.1 Slurry Evaluation Test

3.3.1.1 Free Fluid Evaluation Test

Different water cement ratio of slurry system is in different temperature, pressure condition, garnish prefabricated 250 mL Liangtong, within its in different gradient thermostatic placed 2 h, determination of free fluid rate. The results are presented in Table 3. From the comparative data in Table 3, we can see:

(a) The DL slurry system for free liquid has strong shuffle in water-cement ratio less than 0.55 situations in different Angle, which can be controlled conditions of slurry water chromatography. Thereby it can be zero in horizontal section.

(b) When the water cement ratio is less than 0.6 later, DL slurry system precipitation of free fluid increases slightly, while if confecting low density of slurry, can join the amount of drift beads, micro silicon, fly ash, and solid-phase additives, free fluid can also be zero.

(c) In the same Angle, under the situation of DL slurry system of free less affected by temperature liquid rate that has certain of temperature-to-resistance ability.

Table 3
Different Slurry System in Different Conditions Free Fluid Rate

Temperature ℃	Inclination °	Slurry %			DL slurry system %			
		w/c = 0.38	w/c = 0.44	w/c = 0.50	w/c = 0.38	w/c = 0.44	w/c = 0.55	w/c = 0.60
38 ℃①	0	2.1	2.62	2.94	0	0	0	0.08
	45	2.82	3.18	3.06	0	0	0	0.12
	75	2.84	3.46	3.90	0	0	0	0.12
	90	3.26	3.62	4.06	0	0	0	0.16
93 ℃②	0	3.2	3.64	3.92	0	0	0	0.16
	45	5.28	5.76	6.00	0	0	0	0.16
	75	6.4	6.76	7.08	0	0	0	0.16
	90	6.92	7.32	7.76	0	0	0	0.20

Note. ① Test active cement Harbin grade A cement; ② Tests for the Dalian active cement of class G cement.

3.3.1.2 Gel Strength Assessment Test

All sorts of slurry under different conditions gel strength development curve is shown in Figure 4.

From Figure 4 visible DL slurry system of gel strength initial slow to develop metaphase is accelerated, the same temperature, DL slurry τ k of smaller, post strength development quick to prevent moisture cluster of occur, and G level of larger, τ k consumptions. The transmitting pressure effect is poor, for hydrocarbon channeling provides opportunity.

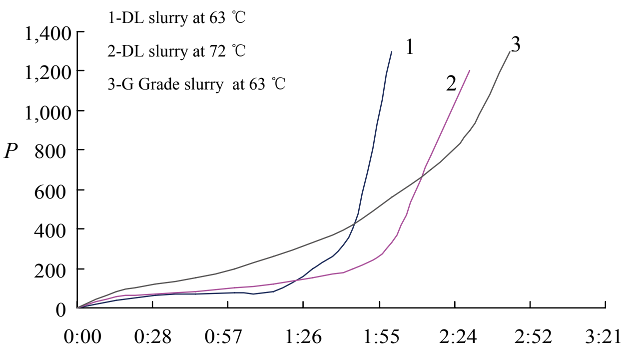

Figure 4
Gel Strength Development Curve

3.3.1.3 Permeability Evaluation Test

Slurry from liquid to solid state transition period, the change in the stratum high pressure gas easily penetrate causing steam breakthrough had cement ontology, the influence of horizontal well cementing quality.

From the data in Table 4, it is known that the permeability of DL cement paste to far below the cement paste. It is helpful for anti-gas channeling lightweight capability is improved.

3.3.1.4 Static Fluid Loss Evaluation Test

In pressure under the action of the slurry after horizontal section permeable formation will occur "infiltration". After slurry filtrate into the ground, firstly it will cause slurry volume loss, and lost water amount is larger, the volume of cement paste, the greater likelihood makes channeling flows. Secondly it can cause slurry liquidity becomes poor, can make the cementing operation failure seriously[7].

Table 4
The Experimental Permeability Comparison Between DL Cement Paste and Cement Paste

	Penetration rate of gas, 10^{-3} μm^2					Average valve
Slurry	0.563	0.284	0.526	0.422	0.204	0.400
DL Slurry①	0.018	0.015	0.026	0.025	0.011	0.019
Slurry②	0.526	0.263	0.418	0.358	0.229	0.359
DL Slurry	0.014	0.017	0.019	0.022	0.016	0.018
Slurry	0.481	0.162	0.425	0.324	0.103	0.299
DL Slurry③	0.012	0.014	0.016	0.022	0.013	0.015

Note. Slurry density is 1.90 g/cm^3; ①, ②, ③ The testing temperature is 38 ℃, the pressure is 20.7 Mpa, the curing time is 48 h.

CONCLUSIONS

(a) The low abundance reservoirs in peripheral Daqing use ladder horizontal technology development, can realize single-well multiple layers of mining, which could increase oil production and has significant economic benefits.

(b) According to horizontal geological and engineering technology requirements of ladder horizontal well, we establish the 3d wellbore trajectory and well body profile optimization design model and calculation methods of optimization design of horizontal ladder optimized the kick off point, build up ratio and multiple landing site.

(c) Geological data, cutting logging, LWD measuring parameters comprehensive analysis used in horizontal well trajectory control is the key of construction.

(d) Development of horizontal wells casing string down into, centered and fluid numerical simulation optimization software for horizontal well casing string structure design and replace efficiency provides a practical technical means.

(e) Developed new low viscosity and high cutting flush isolation liquid chromatography, low water dehydrate zero of slurry system can effectively increase the washing, replace efficiency and cementing quality in horizontal wells.

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