Research on oil-based drilling fluid for protecting oil reservoir

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Abstract:

Adopt a set of diesel-base drilling fluid system. Laboratory experiment shows that the diesel-base drilling fluid is of good rheological property and high resistance of salt,calcium, water pollution , and is a good protector of the oil and gas reservoir, which can solve the problem of strong water sensitivity and easy to collapse.

Key words: ultra-deep complex wells, drilling fluid, protect of the oil and gas reservoir, performance assessment.

1. Introduction

Oil-based drilling fluid has many advantages: resistance to high temperature and calcium salt, good lubricity and excellent performance of reservoir protection, which is one of the important means of drilling complex wells. In recent years, the research on oil-based drilling fluids has made much progress, particularly in the performance of treating agent and optimization of added amount, improvement on the performance of reservoir protection.

But lost circulation and borehole collapse in some shale layer are still serious in field application, which will cause serious reservoir damage in near wellbore area[1]. J.M.Davison et al [2] evaluated the performance of an oil-based drilling fluid used for horizontal wells, which includes property of reservoir damage and the initial pressure of oil flowing through mud cake. Hassan Bahrami et al [3] proposed that oil-based filtrate will form an immiscible liquid mixture around the wellbore in tight formation. Mitchel Tsar et al [4] put forward that reservoir porosity and permeability decrease with the increase of oil-based mud invasion, the inlet capillary pressure and pore size distribution index change considerably, and oil phase trap gets great damage. Yan et al [5] discussed the mechanism of reservoir damage caused by the invasion of oil-based drilling fluid filtrate from experimental research and theoretical calculation. Research showed that reservoir damage caused by oil-based drilling fluid mainly relates with solid invasion, oil phase trap, alkali sensitivity and stress sensitivity [6]. But protection ability of oil-based drilling fluid for formation is still lack of analysis and evaluation systematically.

This paper carried out laboratory experiments according to the poor ability of reservoir protection of oil-based drilling fluid used by Silurian formation, and optimized a diesel oil-based drilling fluid system, whose performance of protecting reservoir is favorable.

2 Drilling fluid system optimization design

2.1 Optimization design principles

Research on the using problems of oil-based drilling fluid used in the field, oil-based drilling fluid needs to solve the problems from three aspects as follow: rheology adjustment, stability control, reservoir protection performance. According to these three aspects put forward the countermeasures, and establishment principle of the optimal drilling fluid system.

1. Rheology adjustment: optimizing treatment agent increment, reducing the use of emulsifiers and other treatment agents.

2. Stability control: Enhanced breaking voltage.

3. Reservoir protection performance: In both matrix and fracture protection principle, combined with multi-level bridge plugging accurate, reasonable choice graded lipophilic calcium carbonate and blocking fiber particles.

2.2 Rheology adjustment

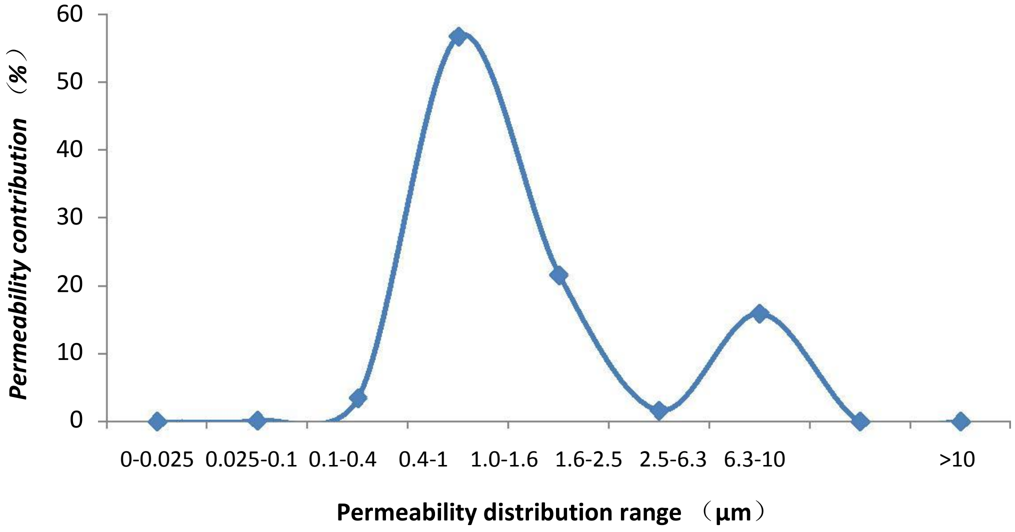
As can be seen from the active Drilling fluid evaluation measure rheological between different experiments there is a large system is to change, which indicates that the rheological properties of drilling fluids are used there is an adjustable space. Active Drilling fluid on the temperature resistance, shear thinning properties such poor performance by adding emulsified asphalt, flow regulator, etc., in addition to the treatment agent through optimal adjustment of increment is adjusted to achieve the rheological properties.

2.3 Stability control

Check out the history of wells, high temperature stability of drilling fluid that drilling wells segments were poorer. By using anti-temperature, emulsifying ability of emulsifiers, emulsifier desorption temperature solve problems, to ensure the stability of oil-based Drilling fluid emulsion. Use structuring agents to improve oil-based drilling fluid shear, oil-based drilling fluids to solve the problem of high temperature suspension. By adding calcium oxide, oil-based drilling fluids to control the pH, the reasonable control of the drilling fluid than water.

2.4 Reservoir protection performance

Study area reservoirs are low porosity and permeability reservoirs which fractures and micro-fractures or more developed, mainly because of the study area in pores, cracks and micro cracks, supplemented by the use of multi-level bridge will be designed to accurately temporary blocking mainly to temporary blocking pores, cracks and micro cracks into account.



Figures 1 The permeability contribution rate of reservoir core pore throat interval curve

Figures 1 Statistics show that the greatest contribution rate for permeability pore throats mainly concentrated in the 0.4 ~ 1.0μm, 1.0 ~ 1.6μm and 2.5 ~ 6.3μm these three intervals. According to the principle of two-thirds of the bridge, corresponding to the section of these three bridging particle diameter of 0.5 ~ 1.33μm, 1.33 ~ 2.13μm, and 3.33 ~ 8.40μm. Considering the Silurian reservoirs there are some cracks and micro cracks, fractures / micro-cracks average permeability of $54.17\times10^{-3}\mu m^{2}$, add the appropriate short fiber particles in the recipe. According to the temporary blocking particle levels, based on existing products, we will use 1~ 3μm, 3 ~ 8μm these two different particle size of the particles and the amount of fiber, complex multi-level bridge a temporary blocking particle products. Therefore, temporary blocking particles design are: Lipophilic $CaCO_3$ (D_{in} = 1 ~ 3μm) + lipophilic $CaCO_3$ (D_{in} = 3 ~ 8μm) + deformable particles + fiber particles.

Research Block Silurian reservoirs are low porosity and permeability and a certain degree of special crack / micro-fractures, which the purpose layers is deeper but the thickness.So the total amount of bridging particles can be controlled between 1.5 to 2.0 percent, deformable particles may be appropriate to increment reduced to about 0.5%. According to the existing temporary blocking agent commonly used product size distribution, research block Silurian reservoir multilevel bridge temporary blocking precise formula is: 1~1.5% lipophilic $CaCO_3$ (D_{in} = 1 ~ 3μm) + 0.2 ~ 0.5% lipophilic $CaCO_3$ (D_{in} = 3 ~ 8μm)+ 0.2 ~ 0.5% of the deformed particles + 0.5 ~ 1 fiber particles.

3 System formula established

Evaluation the optimized drilling fluid including routine performance, ability to resist pollution, reservoir protection . The inhibition of drilling fluid performance is very good, this do not repeat.

3.1 Temperature resistance evaluation

The experiment results of optimized oil-based drilling fluid system resistance temperature are shown in table 1.

Table 1 The optimized oil-based drilling fluid temperature resistance evaluation

Experimental conditions	μ_a/ mPa·s	μ_p/ mPa·s	τ_d/ Pa	T初/ Pa	τ终/ Pa	FL_{API}/ mL	ρ/ g/cm3
Before heating rolling	43	39	1.8	10	11	2.6	1.39
After heating rolling	43	36	3.3	10	17	2.2	

Note: μ_a =Apparent viscosity; μ_p= Plastic viscosity; τ_d =Dynamic shear; τ初= Initial gel; τ终= Final gel strength FL_{API}=Drilling Fluid Filter Loss; The same below.

The table1 shows that drilling fluid viscosity basic no change before and after aging. Shear increases is advantageous to the drilling fluid solid phase particles in suspension. System overall performance has no change. It shows that the thermal stability of performance is strong, can meet the need of site construction.

3.2 Temperature resistance evaluation

The evaluation results of the optimized oil-based drilling fluid system resistance to salt are shown in table 2.

Table 2 The performance evaluation of the optimized oil-based drilling fluid system resistance to salt

Experimental conditions	μ_a/ mPa·s	μ_p/ mPa·s	τ_d/ Pa	τ初/ Pa	τ终/ Pa	FL_{API}/ mL
Before heating rolling	45	34	5.6	7	11	3.6
After heating rolling	50	34	8.4	8	17	1.0

Combining with the system temperature resistance evaluation.The table2 shows that after adding NaCl in drilling fluid, apparent viscosity and dynamic shear force has a certain degree of increase. But the comprehensive performance has no change. It show that the system has good salt resistance.

3.3 Calcium resistance evaluation

The evaluation results of the optimized oil-based drilling fluid system resistance to calcium are shown in table 3.

Table 3 The performance evaluation of the optimized oil-based drilling fluid resistance to calcium

Experimental conditions	μ_a/ mPa·s	μ_p/ mPa·s	τ_d/ Pa	τ初/ Pa	τ终/ Pa	FL_{API}/ mL
Before heating rolling	43	37	3.1	8	13	4.0
After heating rolling	48	41	3.6	7	16	1.0

The table3 shows that there is no change of the drilling fluid performance after joining $CaSO_4$ in drilling fluid. It shows that the drilling fluid calcium resistance is better.

3.4 The performance evaluation of the resistance to water pollution

The evaluation results of optimized oil-based drilling fluid system resistance water pollution are shown in table 4.

Table 4 The optimized oil-based drilling fluid performance evaluation of the resistance to water pollution

Dosage (%)	Experimental Conditions	μ_a/ mPa·s	μ_p/ mPa·s	τ_d/ Pa	$\tau_{初}$/ Pa	$\tau_{终}$/ Pa	FL_{API}/ mL
5	Before heating rolling	43	42	0.3	6	9	0.9
	After heating rolling	47	39	4.1	6	12	1.3
10	Before heating rolling	43	41	1.0	7	10	0.8
	After heating rolling	47	38	4.9	6	14	1.2
15	Before heating rolling	46	43	1.5	9	15	1.1
	After heating rolling	42	40	1.0	6	12	2.0

The table4 shows that with the intrusion increment of water , The system viscosity and shear force changes are smaller. Filtration volume changes is also little. It shows that the drilling fluid system has good ability to resist water pollution.

3.5 The performance evaluation of the reservoir protection

Do reservoir protection experiment with the optimized oil-based drilling fluid. The experiment chooses two core of crack in the same layer. The experimental results are shown in table 5.

Table 5 The dynamic damage evaluation of the optimized oil-based drilling fluid

Formula	Core	Permeability before the damage $K_0(10^{-3}\mu m^2)$	Permeability afer the damage $K_d(10^{-3}\mu m^2)$	Restoration ratio（%）	The mean recovery rate（%）
The optimized diesel oil base drilling fluid	A3	22.45	21.23	94.57	93.83
	A4	26.78	24.93	93.09	

It can be drawn from the experimental results: After optimization of the diesel oil base drilling fluid permeability recovery rate increased by 39.46%, the recovery rate is as high as 93.83%.It shows that the drilling fluid reservoir protection performance is good.

4 Field application

Well Field Application test results showed that good rheological properties, fluid loss properties and blocking rejection of the drilling fluid system. To prevent and reduce the constriction or collapse because of water sensitive formation wells produce hydration, swelling and dispersion caused. Drilling fluid performance indicators to meet the needs of the construction site, the specific performance in Table 6. As can be seen from Table 6: (1) low the drilling fluid loss, API loss always 2mL or less, high temperature and pressure loss in 6mL following; (2)the rheological properties of the drilling fluid is easy to control, good shear thinning properties, can effectively carrying rocks; (3)the drilling fluid has a strong inhibition, to prevent and reduce the water sensitive formations produce hydration, swelling and dispersion caused by constriction or well collapse; (4)the drilling fluid system breaking voltages up to 1847v, have a good emulsion stability at high temperatures.

Table 6 The performance monitoring process of the test wells diesel oil-based drilling fluid

Depth (m)	Sp.gr. (gm/cc)	Viscosity(s)	Filtrate (ml)	pH	Gel strength 10''/10'(Pa)	PV (mPa·s)	YP (Pa)	VB (v)	V (Pas)
5692～6356.1	1.70~1.75	130-160	≤2	9.5	3-5/10-12	60-107	15-28	1847	0.05

5 Conclusions

(1) Targeted optimized for oil-based drilling fluid system used in the field. The optimization of the chaiyou-based has great drilling fluid salt, anti-calcium and strong anti-pollution properties, able to adapt to the study of blocks that has high water sensitivity, severe water reservoir lock layer characteristics;

(2) The chaiyou-based drilling fluid that prefered out has great rheological properties,which can effectively stabilize the wall, reservoir permeability recovery rate of over 90%, with good reservoir protection;

(3) Test well field tests show that the youji-based drilling fluid system really solved the Silurian Kepingtage clasping block problem, is to meet the drilling, borehole stability and protection of reservoir needed.

References

[1] Wang Zhonghua.Several Views on Accelerating the Development of Oil-based Drilling Fluid System in China[J]. Sino-Global Energy.2012,02:36-42.

[2] Davison J M, Jones M, Shuchart C E, et al. Oil-Based Muds for Reservoir Drilling: Their Performance and Cleanup Characteristics[J]. SPE Drilling & Completion, 2001, 16(2): 127-134.

[3] Bahrami H, Rezaee R, Saeedi A, et al. Phase trapping damage in use of water-based and oil-based drilling fluids in tight gas reservoirs[C]//SPE Asia Pacific Oil and Gas Conference and Exhibition. Society of Petroleum Engineers, 2012.

[4] Tsar M, Bahrami H, Rezaee R, et al. Effect of drilling fluid (water-based vs oil-based) on phase trap damage in tight sand gas reservoirs[C]//SPE Europec/EAGE Annual Conference. Society of Petroleum Engineers, 2012.

[5] Xiaolin B X P. Research and Application of Novel Oil-based Drilling and Completion Fluids Technology Abroad [J][J]. Advances in Fine Fetrochemicals, 2005, 12: 005.

[6] Kang Y, Yang B, You L, et al. Damage evaluation of oil-based drill-in fluids to shale reservoirs[J]. Natural Gas Industry, 2013, 33(12):99-104.