

Research and Evaluation of High-Temperature and High-Pressure Drilling Fluid Measuring System

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Abstract. In recent years, the oil based drilling fluid measuring system has been widely used because of its good reservoir protective performance, lubricating performance and high-temperature and high-pressure resistant performance. This paper optimizes the main components of the oil based drilling fluid: base oil, organic soil, emulsifier, wetting agent, filtrate loss reducer, etc., and evaluates the optimized formulation of the oil based drilling fluid, thus developing high-temperature and high-pressure resistant oil based drilling fluid with good sedimentation stability, good lubricity and with little pollution to the reservoir and the environment.

1. Introduction

Nowadays, with the continuous exploitation of the oil and gas, the geological conditions of the newly mined formation becomes more and more complex so that the requirement for the drilling fluid is getting higher and higher. Compared with the previous drilling fluids, the full oil based drilling fluid has better anti-pollution capacity, good lubricity and thermal stability as well as strong inhibition. It greatly reduces the probability of the occurrence of wellbore collapse, shrinkage and other complex situations, and it can be well applied to the drilling of anti high-temperature high-density deep well, ultra deep well, directional well, large displacement well and other wells with special technique, and it can effectively prevent wellbore instability. This paper has independently worked out new oil based drilling liquid system by optimizing the base oil, emulsifier, wetting agent, filtrate loss reducer and developing bentonite.

2. The optimization of base oil

The base oil of the oil based drilling fluid shall meet the following requirements:

- (1) The viscosity of base oil should not be too high, and the rheological property of the system should be easy to control;
- (2) For the sake of safety, both of the flash point and ignition point of the base oil should be very high;

The performance of several base oils is shown as in the following table:



Table 1. The performance index of the base oil

Index Items	50°C Kinematic viscosity /mm ² /s	Pour point/°C	Flash point/°C	Ignition point/°C
3# White oil	4.0	< -5°C	85	110
5# White oil	5.0	< -5°C	120	145
7# White oil	6.0	< -5°C	130	150

3. The preparation of organic soil

The organic soil is prepared through ion exchange process between sodium based bentonite and organic modifier. Another preparation method is to cause the occurrence of cationic exchange between quaternary ammonium salt and sodium based bentonite of different structures.

The organic soil of the new oil based drilling fluid in this paper is prepared by adopting quaternary ammonium salt as organic modifier. The steps of the preparation are as follows: firstly, directly mix the pre-made organic modified liquid and the optimized sodium based bentonite under a certain temperature, and then use a heating mixer to stir and mix it until it is even; secondly, after the organic modified liquid and the sodium based bentonite are mixed for a certain time, add organic reinforcing agent, then allow the three to have mixed reaction for a certain time; lastly, after grinding, crushing and packing the mixture, the organic soil GW-GEL of the oil based drilling liquid is obtained.

4. The optimization of emulsifier

The emulsifier, which applies to the oil based drilling liquid, shall comply with the following principles:

- ① It shall have a strong affinity with base oil;
- ② It can greatly reduce the interfacial tension;
- ③ As for the salt or soap emulsifier, high valence metal salt should be chosen.

Selecting compound emulsifier for the oil based drilling liquid can improve the performance of the drilling liquid; therefore, we selected and compounded two emulsifiers SDMUL1 and SDMUL2 with good performance and evaluated their emulsifying effect.

Table 2. The evaluation on the emulsifying effect of the compound emulsifier

Emulsifier	Adding amount	Emulsion breaking voltage
SDMUL1+SDMUL2	3%(2:1)	1200
SDMUL1+SDMUL2	3%(1:2)	670
SDMUL1+SDMUL2	3%(1:1)	1250
SDMUL1+SDMUL2	3%(3:1)	1050

From the above table, we can know the effect is best when the proportion of the compound emulsifier SDMUL1+SDMUL2 with 3% adding amount is 1:1. The emulsion breaking voltage can reach 1250 V and the HLB value of the compound emulsifier is about 3, forming a composite film with high strength at the oil water interface.

5. The optimization of wetting agent

The wetting agent is a kind of surface-active agent with an amphiphilic structure. Due to the wetting reversal mechanism of the wetting agent, the addition of it makes the drilling liquid have a good suspended capacity. The experiment selected WETA-1 wetting agent and evaluated the performance of it.

Table 3. WETA-1 Suspended barite volume of wetting agent

Ti LI/%	60min	120min	180min	240min	300min	360min	420min	480min
0.5	96	93	91	87	81	73	68	63
1	95.5	92	89	87.5	84	78	72	70
2	95	94	90	88	86	80	76.5	75
3	96.5	95	91.5	89	87	82	77	74.5

Adding 0.5% wetting agent can improve the rheological property of the drilling liquid. Therefore, we select 0.5% WETA-1 as the wetting agent.

6. The optimization of filtrate loss reducer

Henan FB-MOFAC, SDFL1 and SDFL2 were respectively added in the oil based drilling liquid system for the evaluation of their filtrate loss reducing effect. HTHP temperature condition is 150°C. The experimental result is as shown in the following table.

Table 4. The optimization experiment of filtrate loss agent

Index		AV/ mPa·s	PV/mPa·s	YP/Pa	API/ml	HTHP/ml
Henan FB-MOFAC	Before aging	12.5	13	0.5	5.0	26
	After aging	41.0	30	11	5.6	
SDFL1	Before aging	12	13	1	6.7	42
	After aging	17.5	16	3	15.0	
SDFL2	Before aging	12	10	0.5	0	20
	After aging	31	25	4.0	2.6	

From the above table, we can know that among three kinds of filtrate loss reducers, SDFL2 not only have small API and HTHP filtrate loss amount and good capacity of anti high temperature after aging, but also have good rheological property. Therefore, we select SDFL2 as the filtrate loss agent of the oil based drilling liquid.

The formulation of the new oil based drilling liquid is finally determined: base oil + organic soil + 3% 10g compound emulsifier (SDMUL1+SDMUL2) + 0.5% wetting agent (WETA-1) + filtrate loss reducer (SDFL2) + calcium oxide + barite.

7. The evaluation on the performance of the new oil based drilling liquid

7.1. The evaluation of the sedimentation stability

Age the drilling fluid with density of 1.60 g/cm³ for 20h under the temperature of 160°C, and then put it in the beaker; after being still for 24 hours, test the upper and lower density of the drilling liquid in the beaker to measure the stability.

Table 5. The comparison of the performance of the drilling liquid with density D=1.60 g/cm³ before and after being still in the high temperature

Experimental conditions	FL (mL)	FV (s)	Gels (Pa)	AV (mPa·s)	PV (mPa·s)	YP (Pa)	Φ6/Φ3	n	K
Before being still	9	50	7/9	47	39	9	11/9	0.78	164.24
After being still	11	56	19/21	82	54	29	41/39	0.58	329.81

From the above table, we can see that the drilling liquid has good suspension property while the viscosity and shearing force of the drilling fluid are increasing as the elapse of the static time.

7.2. The evaluation of anti high temperature performance

Table 6. Observe the performance of the drilling liquid with density of 1.20g/cm³ under the temperature of 20°C, 150°C, 200°C after aging

No.	Temperature °C	Aging situation (16 h)	AV (mPa.s)	PV (mPa.s)	YP (Pa)	G10"/10' (Pa)/ (Pa)	API FL (mL)	HTHP FL (mL)	pH value
1	20	Before hot rolling	22.1	17.9	3.0	2.1/4.4	3.2	10.3	9
2	150	After hot rolling	23.3	16.9	4.7	0.5/2.5	4.3	14.2	9
3	200	After hot rolling	24.1	17.0	5.9	1.3/7.1	3.8	16.6	9

From the above table, we can see that when the temperature reaching 200°C, the drilling fluid has good rheological property without gelation and thickening, which indicates that the drilling fluid has great performance of anti high temperature.

7.3. The evaluation of lubricity

Select GTL drilling liquid, diesel drilling liquid and oil base drilling liquid to compare their lubricity through mud cake adhesion coefficient and E-P extreme pressure value of these three drilling liquids.

Table 7. The evaluation on the lubricity of different drilling liquid systems

Drilling liquid system	Mud cake adhesion coefficient	E-P extreme pressure value
GTL drilling liquid	0	8~9
Diesel drilling liquid	0.056	12~13
New oil based drilling liquid	0	5~6

From table7, it is easy to see that the lubricity of the new oil based drilling liquid is obviously better than the other two drilling liquids.

7.4. The evaluation of inhibition

The inhibition performance of drilling fluid directly affects the wellbore stability, and the recovery rate is a measuring standard of the inhibition. Add 10% drilling cuttings that passed 6~10 meshes in clean water and drilling liquids with different formulations for 24-hour hot rolling, and measure the recovery rate of the drilling liquids under the same temperature.

Table 8. The experimental result of the inhibition performance of the drilling fluids

Formulation	Types	Hot rolling temperature (°C)	Recovery rate(%)
1	Clean water	200	7.52
2	Common drilling fluid	200	74.75
3	Oil based drilling fluid	200	95.73

From table 5, we can see that the well slurry recovery rate of No.3 new oil based drilling liquid is 95.73%, which can meet the relevant requirements.

7.5. The evaluation of reservoir protection

Select positively charged inhibitor drilling liquid, KCL/polymer drilling liquid, 5# white oil based drilling liquid, and use artificial cores to evaluate the reservoir protective performance of the drilling liquids.

Table 9. Permeability recovery value of the cores in different systems after pollution

Drilling liquid system	Core	Diameter (mm)	Length (mm)	Gas permeability (md)	K ₀ (md)	K ₁ (md)	K ₁ /K ₀ (%)
Positively charged inhibitor drilling liquid	1#	25.60	32.36	172.31	67.60	49.78	73.63
KCl/ polymer drilling liquid	2#	25.51	32.23	180.17	58.43	49.69	85.04
5# White oil	3#	25.35	32.27	140.59	50.21	49.23	98.04

From the above table, we can see that the permeability recovery rate of 5# white oil based drilling liquid is more than 90%, thus that system has great reservoir protective effect.

8. Conclusion

Through the optimization of base oil, organic soil, emulsifier, wetting agent, filtrate loss reducer, the basic formulation of oil based drilling liquid system is finally determined: base oil (5# white oil) + organic soil +3%10g compound emulsifier (SDMUL1+SDMUL2) +0.5% wetting agent (WETA-1) + filtrate loss reducer (SDFL2) + calcium oxide + barite.

The evaluation on the performance of the oil based drilling liquid indicates that the drilling liquid has great sedimentation stability and high-temperature resistant performance, good wettability, strong inhibition, strong anti pollution capacity, and it can effectively protect oil gas reservoir.

Acknowledgements

This work is supported by the National Natural Science Foundation of China (No.51774088).

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