

The study of formulation and performance of formate drilling and completion fluid system

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ABSTRACT

Formate drilling and completion fluid system is a new type of clean organic salt brine system which has been developed from inorganic salt brine drilling fluid system. It is beneficial to protect and find hydrocarbon reservoir. Due to the solid free system, the damage of solid phase particles on reservoir, especially low permeability oil and gas layer, can be greatly eliminated, at the same time, drilling fluid and completion fluid have greater compatibility. It will avoid that precipitation which is not compatible with drilling and completion fluid and generates damages on reservoir. And because mud cake of the solid free system is thin and resilient, it is conducive to improve cementing quality greatly. Experiments show that the formate drilling and completion system has good rheological property, strong inhibition ability, good lubricating performance, good compatibility with reservoir rocks and formation water at high temperature.

Keywords: Formate; Drilling and Completion Fluid System; Solid Free System; Hydrocarbon Reservoir Protection

1. INTRODUCTION

Formate drilling and completion fluid is a new type of clean brine system which has been developed from inorganic salt brine drilling fluid system. Currently there are mainly three kinds of formate: sodium formate, potassium formate and cesium formate. Compared with conventional drilling fluid, formate drilling fluid is characterized by no bentonite slurry. It is the theoretical foun-

dition that formate drilling fluid can achieve strong inhibitory, and it is also the key to being better than conventional water base drilling fluid. Some scholars have studied this before, such as Liuyu has published a paper of "Researches and uses of solids-free high density formate and high temperature crosslinking water base systems as drill-in fluid" in 2005. Then he has applied the drilling fluid into Liaohe Oilfield and the petroleum-in-place has been increased. Wang Yongsheng has studied the application effect of the formate drilling fluid in Yingtai gas field in 2012. And this drilling fluid system has helped to protect the reservoir and save the exploration cost. Based on the previous research, this paper is studied for some new findings and applications [1].

2. THE BASIC NATURE OF FORMATE

Formate has the characteristics of high solubility, high density, high pH value, low crystallization point. With the increase of alkali metal atomic weight, saturation concentration, saturation density and pH value become higher, and crystallization point becomes lower.

Through indoor study, the following features of formate have been found:

1) There is the function of stabilizing shale. Shale is equivalent to the selective semi-permeable membrane in the non fractured low permeability shale formation ($K \leq 10 \times 10^{-3} \mu\text{m}^2$). In the high concentration brine, due to the low water activity, the osmotic pressure can promote the shale pore water reflux. This reflux will make formation stress and effective stress of near wellbore zone increase to stabilize borehole wall.

2) Formate has a good compatibility with the oilfield commonly used polymer, and can slow the speed of hydrolysis and oxidation degradation of many thickeners and filtrate reducers under high temperature and pressure.

3. DETERMINING THE FORMATE DRILLING FLUID FORMULATION

3.1. Optimization of Filtrate Reducer

The base slurry: 500 ml Water + 80% Sodium formate.

For the drilling and completion fluid system, filtration index of effective control system is crucial. We select TJ-1 for the filtrate reducer. And experiments that addition amount of TJ-1 is different are conducted. Results are shown in **Table 1**.

According to the experimental data in the table, when addition amount of TJ-1 is 3%, instantaneous water loss is small, and drilling preliminary requirements can be satisfied. Combining with the actual use situation, the TJ-1 that its addition amount is 3% is selected for the filtrate reducer.

3.2. Optimization of Oil Layer Protective Agent

In order to further improve the comprehensive ability of reduction in water loss of system and reduce the damage of oil and gas layer, we select the optimum oil layer protective agent in the laboratory. Experimental results are shown in **Table 2**.

According to the data in the table, by optimizing, TJ-1 plus JYW-3 can reduce water loss greatly after 150°C high temperature hot rolling. So JYW-3 that its addition amount is 3% is selected for the oil layer protective agent.

3.3. Optimization of Tackifier

Because the viscosity of formate fluid can not meet needs of drilling fluid viscosity in practical application, proper tackifier must be added in drilling fluid. We had carried on the contrast experiment to select tackifier. The results are shown in **Table 3**.

Formula 1: The base slurry + 3% TJ-1 + 0.5% TXZ-1 + 3% JYW-3;

Table 1. Optimization experiment of filtrate reducer.

Formula	$\phi 600$	$\phi 300$	$\phi 6$	$\phi 3$	Gel pa/pa	API ml
The base slurry + 1% TJ-1	25	13	0	0	0/0.5	-
The base slurry + 2% TJ-1	32	18	1	1	0.5/0.5	18 (18)
The base slurry + 3% TJ-1	42	24	0	0	0/0	18 (10)

Table 2. Optimization experiment of oil layer protective agent.

Formula	$\phi 600$	$\phi 300$	$\phi 6$	$\phi 3$	Gel pa/pa	YP Pa	API ml
Formula 1	113	64	8	6	2/2.5	7.5	23.5
Formula 2	187	117	6	4	2/2.5	23.5	6.5
Formula 3	141	81	3	2	0.5/1	10.5	2.6

Note: Test conditions of 150°C, hot rolling for 16 h.

Table 3. Optimization experiment of tackifier.

Formula	$\phi 600$	$\phi 300$	$\phi 6$	$\phi 3$	Gel pa/pa	API ml
Formula 1	29	15	0	0	0/0	16.5
Formula 2	99	74	17	12	1.5/2.5	8
Formula 3	32	17	0	0	0/0	14

Note: Test conditions of 180°C, hot rolling for 16 h.

Formula 2: The base slurry + 3% TJ-1 + 0.5% TXZ-2 + 3% JYW-3;

Formula 3: The base slurry + 3% TJ-1 + 0.5% 80A51 + 3% JYW-3.

By experimental contrast, we know that TXZ-2 has good viscosifying action and resistance to high temperature. So TXZ-2 that its addition amount is 0.5% is selected for the tackifier [2].

Through the above research, finally, the overall formula of the formate clay free drilling and completion fluid system was determined for: water + 80% sodium formate + 3% TJ-1 + 0.5% TXZ-2 + 3% JYW-3.

4. PERFORMANCE EVALUATION OF FORMATE DRILLING FLUID SYSTEM

4.1. Rheological Properties Evaluation

Drilling fluid rheological property is usually described with rheological curve, plastic viscosity (PV), yield point (YP), gel strength (Gel), apparent viscosity (AV) and other rheological parameters of drilling fluid.

According to the experimental data in **Table 4**, when the aging temperature is below 150°C, rheological property and building capacity of drilling fluid are stable, the change is not big. When the aging temperature is higher than 150°C, filtration of system increases by much, and rheological property and building capacity of system become bad. So temperature resistance capacity of formate drilling fluid system can reach 150°C.

4.2. Pollution Resistance Experiment

In drilling process, soluble salt and clay which are the main pollution sources can affect the rheological property and filtration property of drilling fluid system. In view of this, the capacity of soil penetration resistance and soluble salt pollution resistance of the formate drilling fluid system was evaluated. The results are shown in **Table 5**.

According to **Table 5**, after formate drilling fluid was 16 h under high temperature 150°C, in the drilling fluid system which added soil powder, its plastic viscosity, yield point and API filtration quantity increased. And after being polluted with soluble salt, its plastic viscosity reduced, yield point and API filtration quantity increased. Changes are within the acceptable range [3].

Table 4. Rheological properties of formate drilling fluid under high temperature.

Conditions	Rheological parameters			API FL ml	PH
	PV (mPa·s)	YP (Pa)	Gel pa/pa		
Before the high temperature	32	7.0	1/2	0.8	9
120°C/16 h	31	7.0	1/2	1.1	9
150°C/16 h	29	6.5	1/2	1.6	9
180°C/16 h	25	3.5	1.5/2.5	8	9

Table 5. Anti pollution experimental results under high temperature.

Formula	PV mPa·s	YP Pa	API FI ml
1#: The base slurry + 3% TJ-1 + 0.5% TXZ-1 + 3% JYW-3	29	6.5	1.6
2#: 1# + 5% bentonite	44	16	3.5
3#: 1# + 6% CaCl ₂	23	7	3.4

Note: Test conditions of 150°C, hot rolling for 16 h.

4.3. Inhibitory Experiment

The linear expansion rate of shale in drilling fluid system is tested to obtain the ability of system to inhibit shale swelling. The experimental results are shown in **Tables 6** and **7**.

According to experimental data, we can see that formate clay free drilling and completion fluid is superior to the polymer drilling fluid and similar to oil-in-water drilling fluid in inhibiting clay hydration expansion ability. It has a good ability that hydration expansion of mineral composition such as the shale is prevented to avoid dispersion and migration of micro-sized particles.

Rolling recovery rate of the shale is used to describe inhibition dispersion capacity of drilling fluid system to shale [4].

Shale recovery experiment results show that optimal formate clay free drilling and completion fluid system is superior to the polymer drilling fluid and similar to oil-in-water drilling fluid in inhibiting clay dispersibility. It can effectively inhibit clay dispersion and has a good stability in shale.

4.4. Compatibility Experiment

350 ml drilling fluid mixed with 50 g reservoir rock debris, then hot rolled 16 h under 120°C. Rock debris recovery rate was 98.5%, the shape and size of rock debris were little changed. It shows that the drilling fluid has good compatibility with reservoir rocks.

Formate drilling and completion fluid filtrate mixed with the certain proportion simulation formation water. Then we used the method for the visual and flocculation to evaluate the compatibility of drilling fluid and formation water. It can be seen that chemical reaction and

Table 6. Swelling experiment results.

Type	Time			
	30 min	1 h	2 h	3 h
Oil-in-water drilling fluid	0	0.01	0.02	0.03
Formate drilling fluid	0.01	0.02	0.03	0.04
Polymer drilling fluid	0.07	0.09	0.11	0.11

Table 7. Rolling recovery experiment results.

Type	10 mesh	20 mesh	30 mesh
Oil-in-water drilling fluid	97.3%	99.3%	99.7%
Formate drilling fluid	97%	98.7%	99.3%
Polymer drilling fluid	70.7%	79.3%	80%

sediment were not generated between drilling fluid filtrate and simulation formation water. It shows that formate drilling and completion fluid has good compatibility with reservoir fluid.

4.5. Lubricity Experiment

Lubricity evaluation needs three main parameters, the drilling fluid lubrication coefficient K, the extreme pressure film strength P and mud cake friction coefficient K_f. Evaluation data and the results are shown in **Table 8**.

According to the above table, the lubrication performance of system is good. It provides a powerful guarantee in order to decrease the friction torque of drill tool. The drilling fluid can fully meet the needs of the deep drilling as long as strengthening solid phase control.

5. CONCLUSIONS

The formate drilling and completion fluid system has been applied to the deep well of Lungu area in Tarim. Through the field experimentation, some new and good performance of the formate drilling fluid can be found out. The formate drilling fluid is of good rejection capability and shale stability. In the conditions of low viscosity, the shear thinning and capability of bringing cuttings of the formate drilling fluid are also excellent. It can meet the drilling requirements. As the formate drilling fluid is of low density and no solid phase, it helps to find problems in time so as to protect reservoir. The formate drilling fluid system has removed the damage caused by the solid particles, which block the hydrocarbon reservoir. At the same time, the compatibility between the formate and common treating agents of oil field is fine. Therefore, the operating temperature of CMC and biopolymer can be enhanced to 140°C. According to the experimental results, it can be concluded as follows.

1) It uses single treatment agent optimization experiment such as the optimization of filtrate reducer, oil layer protective agent and tackifier in laboratory. Finally, the

Table 8. Unctuousity evaluation results.

System	K	K _f	P (pound/cun ²)
Formate system	0.15	0.0602	47,360
Formate system + 20% Drilling cuttings	0.19	0.0730	39,520

overall formula of the formate clay free drilling and completion fluid system was determined for: water + 80% sodium formate + 3% TJ-1 + 0.5% TXZ-2 + 3% JYW-3.

2) Indoor evaluation experiments show that the formate drilling and well completion fluid system has good rheological property, pollution resistance and reservoir protection performance in the heat. At the same time, filter loss is low, inhibition ability is strong, high temperature resistance reaches 150°C, lubrication performance is fine, and there is good compatibility with the reservoir rock and formation water.

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