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Mud cake simulation shale microcracks

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ABSTRACT

Exploration ultra-low permeability mud cake production conditions, using ultra-low permeability mud cake to simulate shale microcracks. Studied the dispersion conditions on permeability of the filter cake, such as bentonite, temperature, stirring speed, stirring time and drilling fluid additions, obtained the variation of the cake permeability, found the closest mud cake production conditions to shale permeability. As can be seen from the experimental data, the permeability of mud cake decreased with the increase of bentonite, stirring speed , stirring time. Effect of temperature on the permeability of the filter cake is reduced after the first increase, the critical temperature is 20 ℃. Join drilling fluid can significantly reduce the cake permeability. The results show that under the experimental conditions of mud cake permeability between 0.1986 × 10^{-6} μm^2 ~ 5.7904 × 10^{-6} μm^2, show mud cake permeability shale can reach nearly shale level.

Key words: Mud cake; Shale; Permeability; Microcracks

INTRODUCTION

In recent years, due to advances in horizontal drilling, hydraulic fracturing and other techniques,It is possible to obtain the low porosity and low permeability shale gas and other unconventional oil and gas resources that difficult to develop before [1-3]. In 2005, Al-Bazalithough capillary pressure formula calculate the average shale pore throat size distribution between 10~30nm,Katsube further analysis of shale pore distribution at different depths, with the increase of the depth of the formation, shale containing nano-pores more[4-5]. Thus, with the development ofshale gas, the use of nano-shale drilling fluid to block drilling has become an important technology[6-9]. However, there are no uniform standards and methods for evaluation plugging performance of nano drilling fluid. Currently, there are three main methods to evaluation the effect of micro-crack sealing effect: API fluid loss measurement experiment [10], HTHP static/dynamic filtration evaluation test and hypotonic artificial core block evaluation test [11]. Of these methods, the first one and the second one are used to simulate a particular paper formation fracture, but they can not reflect the micro-cracks and micro pores case. The third method that simulation artificial core also have many shortcomings, such as high costly,higher instrument, the experiment was difficult torepeated [12].

Usingmud cake simulation shale, better able to reflect shale microcracks and micropores, and also has good low cost, easy operation, as well as in theory technically feasible [13-14].

MATERIAL METHOD

Experimental equipment and materials

Experimental Materials: Calcium bentonite ,XinjiangXiazijie; anhydrous sodium carbonate (AR), Xindu District Magnolia Town Industrial Development Zone; Drilling fluid additives, HV-CMC, SMP-3, Chengdu Kelong Chemical Reagent.

Laboratory Instrument: 150mm vernier caliper, Shanghai tournament Extension Hardware Tools Co., Ltd.; 100℃ thermometer; SD3 mud water loss tester, Jinan Analysis Instrument Factory;

Ultra-low permeability mud cake making and measurement principles mud cake permeability measurement principle

In recent years, much work have been done about how to determination of mud cake permeability, wherein the static API water loss method is relatively mature. Using Darcy equation derived API water loss equation, it is suitable for computing mud cake permeability in laboratory condition.

Experiments at constant temperature and pressure conditions, assuming a linear relationship between the process fluid loss, that mud cake permeability constant. Darcy percolation equation (1), the solid and liquid phases of drilling volume formula (2), (3) and the solid phase content percentage formula (4) can be obtained equation (5), on behalf of Darcy's Law percolation equation (1), substituting the standard API static dehydration conditions can be obtained laboratory permeability calculation formula (6)

$$\frac{dV_f}{dt} = \frac{kPA}{h\mu} \quad (1)$$

$$Vm = V_f + Vc = Ah + V_f \quad (2)$$

$$V_c / V_f = R \quad (3)$$

$$V_s = hAC_c \quad (4)$$

$$h = \frac{V_f}{A\left(\frac{C_c}{C_m} - 1\right)} \quad (5)$$

$$k = 1.999\times10^{-5}\, m\, V_f V_c \quad (6)$$

V_f, filtration rate, cm^3; V_c, cake volume, cm^3; t, fluid loss time, s; k, mud cake permeability, mD; P, pressure fluid loss, kg/cm^2; m, filtrate viscosity, mPa.s; h, mud cake thickness, cm;

Ultra-low permeability mud cake making principles

According to the principle of rigid block,reduce the permeability of the mud cake by blocking internal microcrackswith different gradations of rigid particles.In the mud cake production process,

adjust the solid particles size distribution in the drilling fluidby changing the dosage of bentonite dispersion conditions and adding drilling fluid additives, so that the cake can be formed during the formation of closely packed, reducing mud cake permeability.

Ultra-low permeability mud cake production methods

Amount of 600mL of water, adding a certain amount of bentonite, adding Na2CO3(4% of bentonite),modified calcium bentoniteto sodium bentonite, at the set speed stirring for a certain period of time, pour into the mud tank, conservation 24h at seal condition.Then usingthe prepared mud for API water loss test, the experiments pressure was 0.68MPa, filtration time was 30min, recording fluid loss. Rinse the cake, then use calipers to measure the thickness of the cake. Measured five times and averaged. Repeat the test under different conditions. Find the lowest permeability mud cake preparation conditions.

RESULTS AND DISCUSSION

Effect of bentonite dosage and mixing time

Take 600mL 20 ℃ tap water, adding different amounts of bentonite, adding Na_2CO_3(4% of bentonite),dispersed at 5000r / min stirring speed,after thatconservation the mud in the mud tank24h at the seal condition. Then remove the base paste, doing API static water loss experiment.

Table1: Different dosage of bentonite and stirring time on the mud cake thickness and fluid loss

T(℃)	Bentonite dosage（g）	Stirring time（min）	Stirring rate(r/min)	Mud Cake thickness（mm）	Fluid loss（mL）
20	24	10	5000	1.84	34.98
20	24	30	5000	1.96	20.14
20	24	50	5000	2.04	16.96
20	36	10	5000	1.98	22.36
20	36	30	5000	2.32	15.15
20	36	50	5000	2.48	10.56
20	48	10	5000	2.08	15.70
20	48	30	5000	2.36	12.14
20	48	50	5000	2.52	10.63

According to a calculation table cake permeability

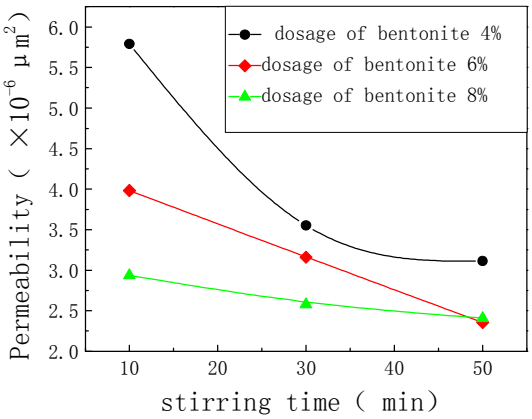

Figure 2-1. Bentonite dosage and mixing time on the permeability（20℃，5000r/min）

As can be seen from Figure 2-1, when the temperature is 20℃, stirring speed is 5000r / min, the mud cake permeability decreased with the bentoniteincrease, substantially between 1mD to 6mD, when bentonite dosage between 6% and 8%, stirring time reaches 50min, the permeability of the mud cake comes close gradually, the minimum can be achieved 2.36mD. And the longer mixing time, the lower permeability mud cake.

Analysis shows that, due to the increased content of bentonite, exacerbating the particles collidefriction and other effects with each other, these effects contribute to fracture bentonite particles become smaller. Increase the thickness of the cake formed under the same conditions, making the base mud in the process of percolation resistance increases, resulting in reduced fluid loss, so reducing the permeability of the formation of mud cake. At the same time, due to the increased mixing time, the more uniform shear dispersion of bentonite, smaller particle size, the formed mud cake denser, also making the mud cake permeability reduction.

Effect of temperature and stirring speed

Take 600mL of water at different temperatures, adding 48g of bentonite, then added 1.92g Na_2CO_3, dispersed in different drilling rate, after that conservation the mud in the mud tank 24h at the seal condition.Then remove the base paste, doing API static water loss experiment.

Table II Effect of different temperature and stirring speed on the cake thickness and fluid loss

T(℃)	Bentonite dosage（g）	Stirring time（min）	Stirring rate(r/min)	Mud Cake thickness（mm）	Fluid loss（mL）
5	48	50	500	1.93	27.00
5	48	50	5000	2.13	24.00
5	48	50	10000	2.06	17.00
20	48	50	500	2.62	12.50
20	48	50	5000	2.52	11.51
20	48	50	10000	2.32	10.27
40	48	50	500	2.25	19.94
40	48	50	5000	2.55	17.36
40	48	50	10000	2.43	16.13
60	48	50	500	2.19	17.84
60	48	50	5000	2.29	17.49
60	48	50	10000	1.84	17.48
80	48	50	500	2.44	18.18
80	48	50	5000	1.96	17.19
80	48	50	10000	1.98	15.47

Calculation cake permeability according to Table II

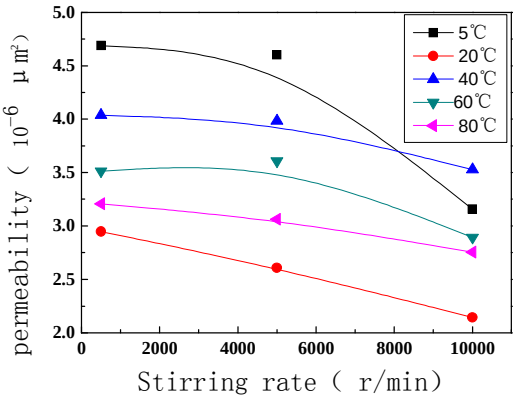

Figure 2-2. Bentonite amount of 8%, stirring time is 50min

At different speeds penetration rate of change with temperature

As can be seen from Figure 2-2, bentonite dosage is 8%, stirring time is 50min, with stirring rate increase,the cake permeability reduce, but the decrease is not obvious. Mud cake thickness thicker with the pulp temperature at 20℃, the lowest penetration rate. Analysis of the sample, with the increase rate of the stirring, the bentonit in solution was subjected shearing action increases, so that the bentonite particle size becomes smaller, more evenly dispersed, and the mud cake permeability decreases. At 20℃, bentonite dispersion strongest. The temperature is below 20 ℃, bentonite hydration weak, low dispersion capacity. The temperature is above 20 ℃, softening bentonite particles easily deformed. The mud cake has more porous and lower permeability.

Effect of drilling fluid additives

According to the above experiment, the amount of water taken 600mL20℃, bentonite was added 48g, added 0.2gNa_2CO_3. Then added different drilling fluid additives and stirred at 10000r/min dispersion 50min, after that conservation the mud in the mud tank 24h at the seal condition.Using base slurry was prepared API filtration test.

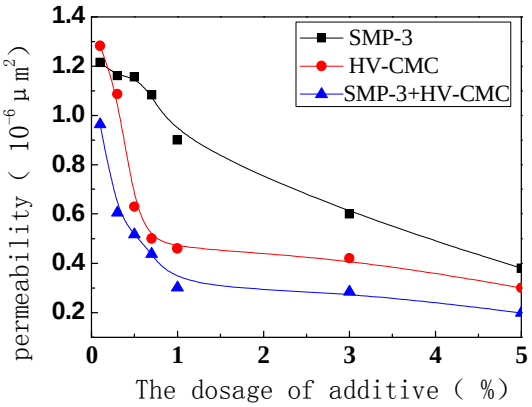

Figure 2-3 The relationship between permeability and additives

As can be seen from Figure 2-3, add SMP-3 alone or added separately HV-CMC can make the cake permeability decreases, while adding SMP-3 and HV-CMC mud cake permeability is reduced to the maximum amount, when the amount of SMP-3 and the HV-CMC from 0.1% to 5%, permeability can be reduced from 0.96×10^{-6} μm^{2}to 0.1986×10^{-6} μm^2. This is because the surface of bentonite particles positive and negative charges exist, adding drilling fluidaddtives, uniform coverage of the particle surface, forming the greater electrostatic repulsion and steric hindrance, so that the particle surface electric double layer is compressed, reducing the electrostatic repulsion, the cake formed denser and lower permeability.

CONCLUSION

1. Experimental conditions measured mud cake permeability between 0.1986×10^{-6} μm^2~5.7904×10^{-6} μm^2, and mud cake permeabilitydecreases withthe increase of the amount of bentonite, stirring time, and the stirring rate.The permeability of mud cakehave the lowest permeability at 20 ℃.
2. Fluid loss agent SMP-3 and HV-CMC can greatly reduce the permeability of the cake, and

with the increase of the amount,the effect is more obvious. When mixed dosage is 5%, the permeability can be reduced to 0.1986×10^{-6} μm^2.

3. Can use mud cake simulation shale microcracks, Ultra-low permeability mud cake can replace shale evaluation nano drilling fluidsealing performance.

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