Multiple Synergistic Drilling Fluid System Application in Aihu Oilfield

Yingbiao Liu¹, Zongyu Lu¹, Wenhui Dang¹, and Zhongxi Zhu^{2,a}

¹Engineering and Technology Research Institute of Xinjiang Oil Field Co, Karamay 834000, China

²National Engineering Laboratory of Petroleum Drilling Technology, Leak Resistance & Sealing Technology Research Department, Yangtze University, Wuhan 430100, China

Abstract. The unstable layer of Aihu oilfield is characterized by strong hydration dispersion and weak expansion. The theory of multiple synergistic wall stabilization was applied to improve synergistic efficiency of the drilling fluid. The recipe of multiple synergistic drilling fluid is worked out. The multiple synergistic drilling fluid was evaluated by analysing the rheology, filtration, wall building, inhibition for the borehole & the weak layers. The inhibition and rheology of the tested drilling fluid system is as good as anti-temperature performance. The ternary-inhibitive drilling fluid system is superior to the binary-inhibitive drilling fluid system. The ternary-inhibitive contained in the multiple synergistic drilling fluid system enhances the ability of water dispersion inhibition. The application of Aihu oilfield shows that the multiple synergistic drilling fluid has satisfied the requirements of low filtration and slight wall expansion.

1 Introduction

It is necessary to study the physicochemical properties and the mineral composition of the collapsible formation. The results offer the drilling engineers to solve the instability of the borehole wall and to improve the speed of drilling operation effectively. X ray diffraction technique is applied to determine the mineral composition and physicochemical properties of the rock samples from the groups of Sgh, Bjt, Krmy, Bkq and Urho in Aihu oilfield[1-4].

The collapsible strata of Aihu oilfield contains weak swelling clay minerals which are water sensitive dispersive minerals. Although it is difficult to expand, it is very easy to disperse[5].

Comprehensive experimental evaluation of the instable layers in Aihu oilfield shows that the clay minerals have the characteristics of weak swelling and strong water sensitive disperse. The clay minerals have the low activity and the little linear swelling rate. So the drilling fluid should be mainly aimed to avoiding the cuttings dispersion and preventing rock from expansion[6-8].

2 Optimization of drilling fluid inhibitor

2.1 Evaluation of inhibitive ability of inhibitors

The hot roll experiment and recovery experiment were done on the mudstone. The inhibitive ability of various inhibitors on hydration dispersion and swelling of mudstone was evaluated under the condition of inhibitors

interaction[9-11]. The single agent of inorganic salts (KCl, NaCl, or CaCl₂) were optimized the dosage range of the inhibitors. And the single agent of organic salts (Weigh2, Weigh3, OS-80, or OS-100), organic polymer (SIAT), silicone series (LYG, FMS-1, or MFG) were optimized the dosage range.

Figure 1. Hot rolling recovery of mudstone under the action of various inhibitors

As shown in figure 1, the inhibitive capacity of the optimum dosage of inhibitor on the dispersity of mudstone is, followed the order of large to small, 2% MFG > 2% JLX-B > 2% SIAT > 30% Weigh2 (OS-80) > 7% KCl > 30% NaCl > 15% Weigh3 (OS-100) > 0.5% CaCl₂.

The results show that organic inhibitors with the certain molecular weight have some advantages in inhibiting the dispersion of shale.

^a Corresponding author: zhuzhongxi@yangtzeu.edu.cn

Figure 2. Linear expansion rates of mudstone under the action of various inhibitors

As shown in figure 2, the inhibitive capacity of the optimum dosage of inhibitor on the swelling of the shale is, followed the order of large to small, 7% KCl > 2% SIAT > 30% NaCl > 30% Weigh2 (OS-80) > 0.5% CaCl₂ > 15% Weigh3 (OS-100) > 2% MFG > 2% JLX-B.

Therefore, the results of experiments shows that one drilling fluid inhibitor is difficult to meet two aspects of inhibiting clay requirements: hydration expansion and hydration dispersity. So the dominated contradiction should be selected according to the actual needs of the formation. If the need to suppress dispersion of the clay is dominated, organic inhibitors with a certain molecular weight should be selected. Conversely, if the need to inhibit the expansion of the clay is dominated, inorganic salt should be chosen as the main inhibitor.

2.2 Optimization of inhibitors

Laboratory test of 7% KCl, 0.5% CaCl₂, 30% weigh2, 15% weigh3, 2% SIAT, 2% JLX-B and 2% MFG for the instable formation in Aihu oilfield are given the order of inhibitory. The inhibitive ability of drilling fluid is related to the type of drilling fluids. That is to say, the oil base drilling fluids or the water base drilling fluids are sensitive to the inhibitory. Many drilling fluid researchers have already explicitly noted that inorganic salts, organic acids, salts and polymer inhibitors have different inhibitory effects on the hydration expansion and hydration dispersity of clay. Organic inhibitors with a certain molecular weight such as silicones (MFG); polymers (JLX-B) and polyamines (SIAT), have very high inhibition of the hydration dispersing ability to the shale formation. However, the ability of restraining the swelling of the shale formation is ordinary for the inorganic salts of KCl or the organic polyamine of SIAT.

3 Mechanism of multiple synergistic drilling fluid

Because of the single inhibitor is limited to the inhibition of the target formation, it is necessary to study multiple synergistic inhibitor formulation according to the target formation characteristics. The aim is to improve the drilling fluid system's ability to control the unstable target formation. Based on the multiple synergistic theory, the

mechanism of multiple synergistic inhibitors was studied. The results provided a theoretical basis for the design of multiple synergistic inhibitors to Aihu oilfield[11].

3.1 Mechanism of synergistic inhibitors

The shale contains clay minerals and non-clay minerals. The basic reason for hydration dispersion and hydration expansion of shale is the clay minerals particles' dispersion and swelling. It is the key to inhibit the dispersion and expansion of shale.

The ways of inhibiting shale from hydrating include the following aspects:

Firstly, compress the clay minerals particles' thickness of double electric layers and reducing the clay minerals particles' repulsion of double electric layers.

Secondly, apply the insert layer Mosaic effect to increase electrostatic attraction.

Thirdly, utilize the adsorption package to maintain the integrity of the clay minerals particles.

Finally, reduce water activity and cutting down water entry.

Multiple synergistic inhibitors are based on the above considerations. The inhibitive mechanism of multiple synergistic inhibitors was verified through experiments. Multiple synergistic inhibitor formulations are further confirmed whether the inhibitors have the above-mentioned mechanisms of action.

3.2 Study on the formula of multiple synergistic inhibitor

According to inhibitor type and the lithologic character of stratum in Aihu oilfield, the experimental study on the optimization of multiple synergistic inhibitor formulations have been carried out. The evaluation and screening results are presented in the above text. Six inhibitors such as inorganic salts of KCl, organic salts of weigh2 (OS-80), organic salts of weigh3 (OS-100), organic silicon of MFG, Polymeric alcohol of JLX-B and organic amine of SIAT, were used in the experiments. According to the chemical action mechanism and the type of treatment agent, six inhibitors are divided into three categories: inorganic salt inhibitor, organic salts inhibitor and organic polymer inhibitor. It is shown in Table 1.

Table 1. List of experimental inhibitors

Category	Inhibitor
Inorganic salt inhibitors	KCl
Organic salts inhibitors	Weigh2 (OS-80) Weigh3 (OS-100)
Organic polymer inhibitors	Amines (SIAT) Organosilicon (MFG) Polymeric alcohol (JLX-B)

The experimental process is recommended to divide up into three kinds of combination way: inorganic Salt + organic salt, inorganic salt + organic polymer, organic salt + organic polymer. Three kinds form a binary synergistic inhibitor formula. Meanwhile, the

experimental process is recommended the way of inorganic salt + organic salt + organic polymer to form a ternary synergistic inhibitor formula.

During the evaluation experiment of inhibitor, two steps were carried out:

a) Using the above inhibitors and their optimum dosage, the formulation of "binary synergy" and "ternary synergy" were formed and evaluated the inhibiting ability.

b) Combined the formed inhibitor formulation with the base slurry of drilling fluid, the inhibiting ability of multiple synergistic inhibitor drilling fluid system was evaluated. The base slurry of drilling fluid formula is as follows: 4% basic mud + 0.3% FA367 + 2% SMP-2 + 2% SPNH + 0.8% Redu1 + 0.3% CaO + 0.3% KOH + 4% PHT + 1% graphite powder.

According to the experimental scheme, a series of experiments were conducted. The preliminary formula of multiple synergistic inhibitors was obtained to cater to the unstable formation of Aihu oilfield. The preliminary formula is shown in table 2.

Table 2. The preliminary formula

Formation	Preliminary formula of multiple synergistic inhibitors
Sgh	7%KCl+2%JLX-B(MFG)
Bjt	
Krmy	7%KCl+30%Weigh2+2%JLX-B(MFG)
Bkq	7%KCl+2%JLX-B(MFG)
Urho	

4 Optimization and evaluation of drilling fluid system

The inhibitor dosage was the best single agent contraposed the clay of the formation. The basic formula of multiple synergistic inhibitors for Aihu formation was required to further optimization for each inhibitor amount in the binary synergistic inhibitor or ternary synergistic inhibitor drilling fluid. The formula of multiple synergistic inhibition of drilling fluid system are evaluated to the corresponding drilling fluid system rheology, filtration, wall inhibition.

The best multiple synergistic inhibition of drilling fluid formula is 4% soil slurry + 0.3% FA367 + 2% SMP-2 + 2% SPNH + 1% Redu1 + 0.3% CaO + 0.3% KOH + multiple inhibitors + 4% PHT + 1% graphite powder + barite.

4.1 Optimization scheme

In the optimization experimental process, only one inhibitor's amount is adjusted, the other inhibitors are kept the amount unchanged. The amount of the selected inhibitor when the property of drilling fluid system changes abruptly is the perfect amount. Then the selected inhibitor maintains the perfect amount and adjusts the amount of other inhibitors, and so on. So it can form a

formula of the performance of the drilling fluid system. The perfect drilling fluid system.

4.2 Optimization of binary synergistic inhibitor amount

Through the above optimized schemes (shown in Table 3), the formula of binary synergy inhibitive water-based drilling fluid has been obtained: 4% basic mud + 0.3% FA367 + 2% SMP-2 + 2% SPNH + 1% Redu1 + 0.3% CaO + 0.3% KOH + 1% MFG + 3% KCl + 4% PHT + 1% graphite powder + barite.

Table 3. Optimization schedule of binary synergistic inhibitor

KCl (%)	MFG (%)
7	2
5	1.5
3	1

4.3 Optimization of adding amount of ternary synergistic inhibitor

The results of binary synergistic inhibitor optimization shows that compound inhibitors are more conducive to the performance of their respective advantages. So ternary synergistic inhibitor is employed according to the optimization result of binary synergistic inhibitor drilling fluid system. The optimization research of ternary synergistic inhibitor drilling fluid system was continued.

The different amounts of organic salt are screened out on the base of the optimized binary synergistic inhibitor formula. The compound inhibitors or ternary synergistic inhibitors are evaluated the rheological properties, filtration, wall forming and inhibition capacity. The schedule of organic salt OS-80 dosage experiments is shown in Table 4.

Table 4. Schedule of organic salt OS-80 dosage adding in the binary synergistic inhibitor

Dosage of OS-80	ρ g/cm ³	Φ 600	Φ 300	FI-API (mL)	Rate of recovery %	Rate of expansion %
10%	1.63	102	55	3.4	94.16	15.7
15%	1.63	86	44	3.6	92.4	15.55
20%	1.62	75	36	3.6	94.6	15.22

From Table 4, the binary synergistic inhibitor drilling fluid system is increased the inhibition by the organic salt OS- 80. The rheological properties of the corresponding system or ternary synergistic inhibitors system can be further improved with the increasing amount of organic salt OS-80. The recovery rate of shale has been improved by the he ternary synergistic inhibitors system compared with binary synergistic inhibitors drilling fluid system. The linear expansion rate also increases slightly. It indicates that the inhibitive ability of ternary synergistic inhibitors drilling fluid system has increased the inhibition of drilling fluid for Aihu oilfield. Considering

the performance and economic rationality of drilling fluid, the amount of OS-80 added to organic salt is 10%. Therefore, ternary synergistic inhibition water base drilling fluid system has been formed.

The optimized formula of binary and ternary synergistic inhibition water base drilling fluid has been obtained. Multiple synergistic inhibitor drilling fluid system has been carried out.

The plastic viscosity and dynamic shear force of the binary synergistic drilling fluid with density of 1.63g/cm³ before hot roll are 49Pa and 3.5Pa respectively. The plastic viscosity and dynamic shear force after hot roll are 52 and 4.5Pa respectively. The water loss of API is 3.6ml and the water loss of HTHP is 12ml before and after the hot roll. It shows that the binary synergistic drilling fluid system has good rheological and temperature resistance properties. The binary synergistic drilling fluid system can meet the requirements of filtration and wall forming performance. At the same time, the average cutting recovery rate of the binary synergistic drilling fluid system is about 85%, and the linear expansion rate of binary synergistic drilling fluid system is about 13.5%.

The plastic viscosity and dynamic shear force of the ternary synergistic drilling fluid with density of 1.63g/cm³ before hot roll are 47Pa and 4Pa respectively. The plastic viscosity and dynamic shear force after hot roll are 52 and 3Pa respectively. The water loss of API is 3.4ml, and the water loss of HTHP is 11.2ml before and after the hot roll. It shows that the ternary synergistic drilling fluid system also has good rheological and temperature resistance properties. The ternary synergistic drilling fluid system can also meet the requirements of filtration and wall forming performance like as the binary synergistic drilling fluid system. At the same time, the average cutting recovery rate of the ternary synergistic drilling fluid system is about 94%. It shows that the ternary synergistic drilling fluid system has the better ability of enhancing hydration and dispersing inhibition than binary synergistic drilling fluid system. The linear expansion rate of ternary synergistic drilling fluid system is about 15.7%. The improvement is not obvious because the formation of Aihu oilfield belongs to the strong dispersed and weakly swelling formation.

5 Conclusions

The drilling fluid of Aihu oilfield should mainly focus on improving the restraining ability and decreasing the expansion of formation. Using inorganic salt + organic salt, inorganic salt + organic polymer, or organic salt + organic polymer, the binary synergistic inhibitor formula is formed. The ternary synergistic inhibitor formula is formed by inorganic salt + organic salt + organic polymer way. The basic recipe of multiple synergistic inhibitor that suits to the target layer in Aihu oilfield can cater to the requirement of the sensitive formation. The dosage of different inhibitors that consist in the multiple synergistic inhibitor can further improve the inhibitor of the drilling fluid. The ideal multiple synergistic inhibitor using in Aihu formation are formed. According evaluating the rheology, filtration wall inhibition and inhibition ability

of multiple synergistic drilling fluid, the demand of the sensitive formation is met.

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