Scientific Research Publishing

Open Journal of Yangtze Gas and Oil, 2022, 7, 203-212
https://www.scirp.org/journal/ojogas
ISSN Online: 2473-1900
ISSN Print: 2473-1889

Study on a Polyamine-Based Anti-Collapse Drilling Fluid System

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How to cite this paper: Zheng, W.W., Liu, F., Han, J., He, B.B., Zhang, S.Y., Cao, Q.C., Wang, X. and Li, X.T. (2022) Study on a Polyamine-Based Anti-Collapse Drilling Fluid System. *Open Journal of Yangtze Gas and Oil*, **7**, 203-212.
https://doi.org/10.4236/ojogas.2022.73011

Received: June 8, 2022
Accepted: July 26, 2022
Published: July 29, 2022

Abstract

In complex strata, oil-based drilling fluid is the preferred drilling fluid system, but its preparation cost is high, and there are hidden safety risks. Therefore, the new progress of high-performance anti-collapse water-based drilling fluid at home and abroad is analyzed. It is difficult to prevent and control the well collapse. Once the well wall instability problem occurs, it will often bring huge economic losses to the enterprises, and the underground safety accidents will occur. In order to ensure the stability of the well wall and improve the downhole safety, the key treatment agent of water-based collapse drilling fluid is selected, the anti-collapse drilling fluid system is formulated, the evaluation method of drilling fluid prevention performance is established, and a set of water-based drilling fluid system suitable for easy to collapse strata in China is selected to ensure the downhole safety. The development trend of high performance anti-collapse water-based drilling fluid is expected to provide a reference for the research of high performance anti-collapse water-based drilling fluid system and key treatment agent.

Keywords

Well Wall Stability, Anti-Collapse Water-Based Drilling Fluid, Evaluation Method, High Temperature Resistance, Salt Resistance

1. Introduction

In recent years, the various complex conditions and accidents caused by the instability of the well wall have not only caused great economic losses, but also seriously affected the production efficiency of production. Well wall collapse is not only a simple mechanical problem, but also the hydration of mud shale is also

the main factor causing well wall collapse [1]-[6]. Therefore, well wall stability is influenced not only by mechanical factors, but also by drilling fluid chemistry. The liquid column pressure of the drilling fluid in the drilling fluid is larger than the hole pressure in the formation, forming a pressure difference. When the drilling fluid enters the formation, the clay minerals in the formation become hydration, which causes the contraction of the well hole and the collapse of the well wall. The results showed that the formation, chemical, mechanical, physical and chemical factors had the greatest impact on the collapse. Through the analysis of formation collapse mechanism, the measures to strengthen plugging, restrain expansion and mechanical equilibrium are put forward to prevent formation collapse [7] [8] [9] [10] [11]. Therefore, we expect to find a low-cost, high-efficiency anti-collapse agent, and take it as the core, to formulate a set of anti-salt, calcium resistance, high-temperature anti-collapse drilling fluid system.

2. Experimental Instruments, Drugs and Methods

2.1. Laboratory Apparatus

The experimental instruments used are shown in Table 1.

2.2. Experimental Drugs

The main drugs used are shown in Table 2.

2.3. Empirical Method

2.3.1. Preparation of Bentonite-Based Slurry

Preparation: Take 10 liters of hot water (60˚C - 70˚C) and slowly add 400 g of bentonite while mixing. After the mud is evenly dispersed, slowly add 25 g of Na_2CO_3 and stir evenly for 2 hours, and place the matched moving soil slurry for 24 hours.

2.3.2. Selection of Drilling Fluid Additives

Under the condition of meeting the performance requirements, the principle of

Table 1. Laboratory apparatus.

Instrument name	Model	Manufacturer
Six-speed rotary viscosity meter	ZNN-D6A	Qingdao Xinruide Petroleum Co, Ltd
Medium pressure filter loss instrument	ZNS-2A	Qingdao Xinruide Petroleum Co, Ltd
Frequency conversion and high-speed mixer	GJS-B12K	Qingdao Xinruide Petroleum Co, Ltd
Force-enhancing electric mixer	JB50-D	Shanghai specimen model Factory manufacturing
Rolling furnace	GRL-1A	Qingdao Camera Factory special instrument branch factory
Electronic precision balance	EN0026	Shanghai Minqiao Precision Scientific Instrument Co., Ltd
Densimeter	GGS71-A1B	Qingdao Xinruide Petroleum Co, Ltd
Dial gauge	JB50-D	Qingdao Xinruide Petroleum Co, Ltd
Ageing can	LHG-2	Qingdao Xinruide Petroleum Co, Ltd

Table 2. Experimental drugs.

Drug name	Rank	Manufacturer
xy-27	Technical Grade	Xuecheng Company
FA-367	Technical Grade	Binzhou, Shandong
SMP	Technical Grade	Jianghan Oilfield Salt Chemical Plant
PSC	Technical Grade	Hubei Province Salt Industry Company
K-PAM	Technical Grade	Xuecheng Company
KCl	Technical Grade	Xuecheng Company
YL-102	Technical Grade	Nanjing Haoxuan New Materials Co., Ltd
YL-103	Technical Grade	Nanjing Haoxuan New Materials Co., Ltd
YL-301	Technical Grade	Nanjing Haoxuan New Materials Co., Ltd
YL-201	Technical Grade	Nanjing Haoxuan New Materials Co., Ltd
YL-FT3	Technical Grade	Nanjing Haoxuan New Materials Co., Ltd
XZ-301	Technical Grade	Xuecheng Company
SMC	Technical Grade	Xuecheng Company
SMK	Technical Grade	Xuecheng Company

preparing anti-collapse water-based drilling fluid is the simpler the better, and use single-function products as far as possible. The components of stable high-temperature anti-collapse foundation drilling and completion fluid system usually include: aggravating material for density adjustment; filter loss reducing agent for filter loss control; viscosity lowering agent for mobility control; appropriate high-temperature stabilizer; appropriate lubricant and plugging agent; appropriate inhibitor.

2.3.3. The Inhibitory Test

1) Accurately weigh 1.5 g of earth, 0.8 g, 60 purpose river sand, fully mix and stir well.

2) Pour the evenly mixed soil and river sand into the mold sleeve of the shale sheet press, shake the pressure rod up and down, so that the pressure gauge reads to 2 MPa, and press the sheet for 5 minutes.

3) Take out the shale chip press mold set, put a plastic with a small groove in it, make its lower contact shale pressing, groove facing, then after high speed mixing, has added the reagent drilling fluid into the right amount of surface plate, cover the filter paper, and has put into the plastic shale pressing mold on the surface of the filter paper. Fix the dial table so that the bottom end just touches the groove of the plastic sheet, adjust the dial dial position so that the reading is 0 and start timing. As you can see, with the expansion of shale ballast water, the reading of the micrometer increases significantly.

4) Record a thousandth meter reading every hour. There are 4 groups in total.

2.3.4. Test of Heat Recovery Rate

In turn, the matched drilling fluid into the aging tank, called 30 g debris, respectively into the aging tank, temperature control in 180˚C, hot roll 16 h, oven cooling, pour out the aging tank drilling fluid and debris, with 40 standard sieve sieve in the drilling debris, and rinse with clean water, and then put the screened debris in the electric blast drying box, about 2 h, then weigh the debris X_1, calculate a recovery rate. Add 350 mL of tap water into the aging tank respectively, and pour the weighed 1 recovery debris into the human aging tank respectively, Put the high temperature roller furnace heating rolling, temperature controlled at 180˚C, hot rolling for 2 h, out of the oven cooling. Take the debris in the aging tank with a 40-mesh standard sieve, dry it in the human electric blast drying box, and then weigh X_2 with an electronic balance to calculate two recovery rates.

3. Analysis of Experimental Results

3.1. Performance Evaluation of Zwitterionic Polymer Drilling Fluid

The system parameters of 9 groups of drilling fluid added with additives according to the anti-collapse reagent formula listed above are as follows, and the results are shown in Table 3. The formula is based on SPNH(sulfonated lignite resin) and PSC (sulfonated lignite), supplemented by high temperature stabilizer SMP (sulfonated phenolic resin), the high temperature stabilizer can maintain the original mobility and filtration loss under the condition of increasing drilling fluid temperature, add the aggravating material barite regulating density to adapt to the formation pressure of high temperature deep well, and add the inhibitor KCl to improve the inhibitory heat roll recovery of drilling fluid system. In the experiment and species, the following formula 4% soil slurry + xy-27 + FA-367 + 2% SPNH + 2% PSC + 2% SMP + 4% KCl + 0.2% K-PAM + barite was obtained.

Table 3. Effects of different doses of treatment agents on the mobility and filter loss of drilling slurry.

Number	Drilling fluid	AV/MPa·s	PV/MPa·s	YP/Pa	FL/ml	Filter loss rate/%	Density g/cm^3
0#	Base pulp	11.0	6.5	4.6	26.0	—	1.03
1#	0.1%xy-27 + 0.1%FA-367 Base pulp	13.0	9.0	4.0	20.1	22.1	1.04
2#	0.1%xy-27 + 0.2%FA-367 Base pulp	17.0	13.5	3.5	16.3	36.7	1.04
3#	0.1%xy-27 + 0.3%FA-367 Base pulp	21.8	15.0	6.8	15.3	40.5	1.04
4#	0.2%xy-27 + 0.1%FA-367 Base pulp	13.8	11.0	2.7	17.9	30.5	1.04
5#	0.2%xy-27 + 0.2%FA-367 Base pulp	15.0	11.0	4.0	15.9	39.2	1.04
6#	0.2%xy-27 + 0.3%FA-367 Base pulp	20.0	14.0	6.3	13.5	47.5	1.05
7#	0.3%xy-27 + 0.1%FA-367 Base pulp	12.0	11.0	1.2	21.4	17.1	1.05
8#	0.3%xy-27 + 0.2%FA-367 Base pulp	15.0	13.0	2.1	19.9	22.8	1.05
9#	0.3%xy-27 + 0.3%FA-367 Base pulp	19.0	13.5	5.5	18.5	28.3	1.06

According to the data in Table 3, after different amounts of anti-collapse reagent are added to the base slurry, the formed drilling fluid system has changed in terms of viscosity and filter loss compared with the original base slurry. The viscosity showed a trend to increase, while the filter loss showed a trend to decrease. By comparing the viscosity, filtration loss and other parameters of each group of drilling fluid system, the best anti-collapse drilling fluid system formula determined in the test is as follows: 4% Moving slurry + 0.2%xy-27 + 0.1%FA-367 + 2% SPNH + 2% PSC + 2% SMP + 4% KCl + 0.2% K-PAM + barite.

As can be seen from Figure 1, Figure 2 and Table 4, Table 5, after the mobility of the drilling fluid system after 180˚C hot roll, the filter loss of the zwitterionic polymer drilling fluid increased greatly, and the expansion volume increased

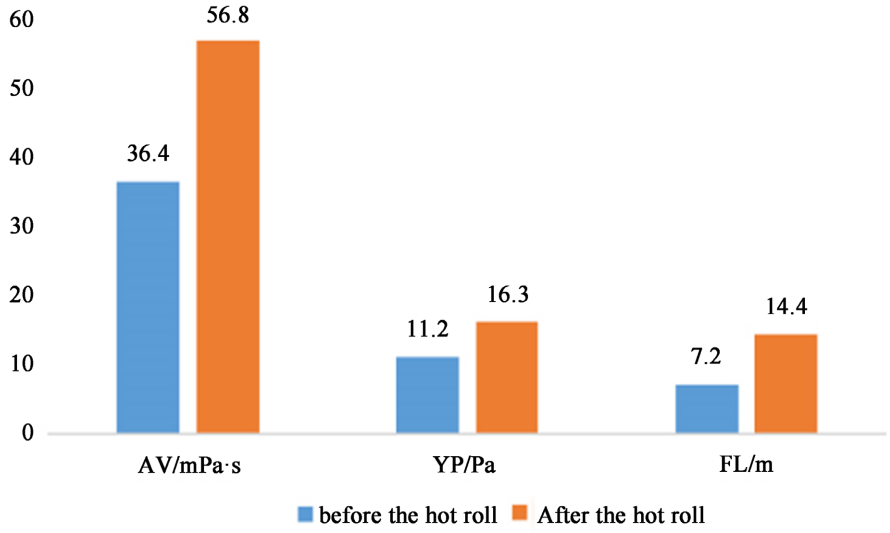

Figure 1. Comparison of AV, YP and filter loss changes before and after hot roll of drilling fluid system.

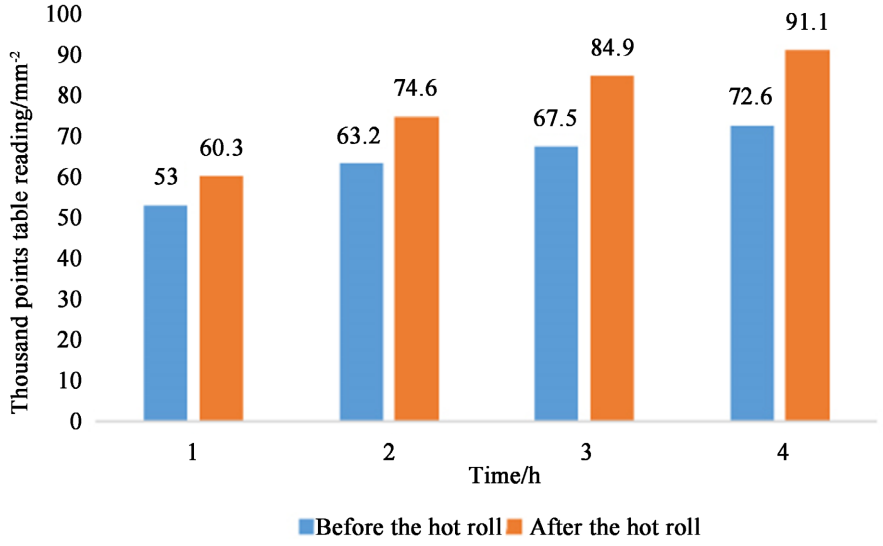

Figure 2. Inhibitory comparison before and after thermal roll of the best drilling fluid system.

Table 4. Effects of high temperature on drilling fluid mobility and filter loss of zwitterionic polymers.

Number	Drilling fluid	AV/ mPa·s	PV/ mPa·s	YP/ Pa	FL/ ml	Densityg/ cm^3
0#	Before hot rolling of zwitterionic polymer drilling fluid	36.4	21.3	11.2	7.2	1.93
1#	After hot rolling of zwitterionic polymer drilling fluid	56.8	43.5	16.3	14.4	1.93

Table 5. Effects of high temperature on the inhibition of zwitterionic polymer drilling fluid.

Number	Time/h	Table reading before hot roll/10^{-2} mm	Table reading after hot roll/10^{-2} mm
0#	1	53.0	60.3
1#	2	63.2	74.6
2#	3	67.5	84.9
3#	4	72.6	91.1

to a certain extent.

3.2. Performance Evaluation of Amine-Based Polymer Drilling Fluid System

The system parameters of 9 groups of drilling fluid added according to the anti-collapse reagent formula listed above, and the results are shown in Table 6. Based on the blocking agent YL-301 and the filter reduction loss agent YL-201, the blocking anti-collapse agent YL-FT3 increased the anti-temperature and anti-collapse performance, and the amine-based polymer inhibitor XZ-301 was added to increase the suppression performance and thermal roll recovery.

It can be seen from Table 6: after different amounts of anti-collapse reagent are added to the base slurry, the formed drilling fluid system has changed in terms of viscosity and filter loss compared with the original base slurry.The viscosity showed a trend to increase, while the filter loss showed a trend to decrease. By comparing the comprehensive analysis of the viscosity and filter loss parameters of each group of drilling fluid system, the best anti-collapse drilling fluid system formula makes the following formula by adding the optimal amount and type in the experiment:4% Moving soil slurry + 0.3%YL-102 + 2%YL-103 + 3%YL-201 + 2%YL-301 + 3%YL-FT3 + 2%XZ-301 + barite.

As can be seen from Figure 3, Figure 4 and Table 7, Table 8, the filtration loss of the drilling fluid in the drilling fluid system increased slightly after 180˚C thermal roll.

Through the above performance evaluation and comparison, it is not difficult to find that the amine-based drilling fluid system has good high temperature resistance, inhibitory properties and outstanding water loss, so we can further

Table 6. Effects of different additives on the mobility and filter loss of drilling slurry.

Number	Drilling fluid	AV/mPa·s	PV/mPa·s	YP/Pa	FL/ml	Filter loss rate/%	Density g/cm^3
0#	Base pulp	11.0	6.5	4.6	26.0	—	1.03
1#	0.3%YL-102 + 1%YL-103Base pulp	12.8	11.5	4.0	21.7	16.5	1.04
2#	0.3%YL-102 + 2%YL-103Base pulp	13.1	12.0	3.5	16.8	35.4	1.05
3#	0.3%xy-27 + 0.3%FA-367Base pulp	22.3	15.0	6.8	15.7	39.6	1.06
4#	0.4%YL-102 + 1%YL-103Base pulp	16.8	11.5	2.7	16.2	37.7	1.06
5#	0.4%YL-102 + 2%YL-103Base pulp	13.9	12.5	4.0	15.6	40.0	1.06
6#	0.4%YL-102 + 3%YL-103Base pulp	15.2	13.0	6.3	17.4	33.1	1.06
7#	0.5%YL-102 + 1%YL-103Base pulp	14.4	13.5	1.2	18.9	27.3	1.06
8#	0.5%YL-102 + 2%YL-103Base pulp	15.0	12.0	2.1	17.8	31.5	1.06
9#	0.5%YL-102 + 3%YL-103Base pulp	16.2	12.5	5.5	22.6	13.1	1.06

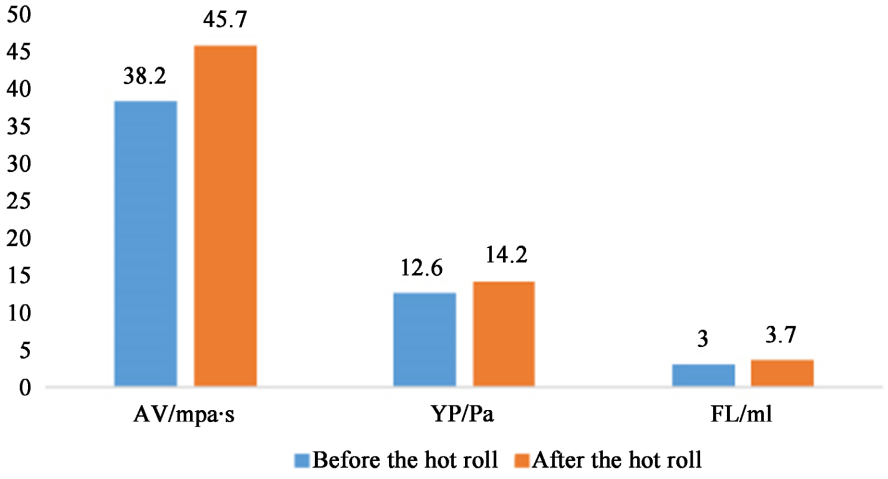

Figure 3. Comparison of AV, YP and filter loss changes before and after hot roll of drilling fluid system.

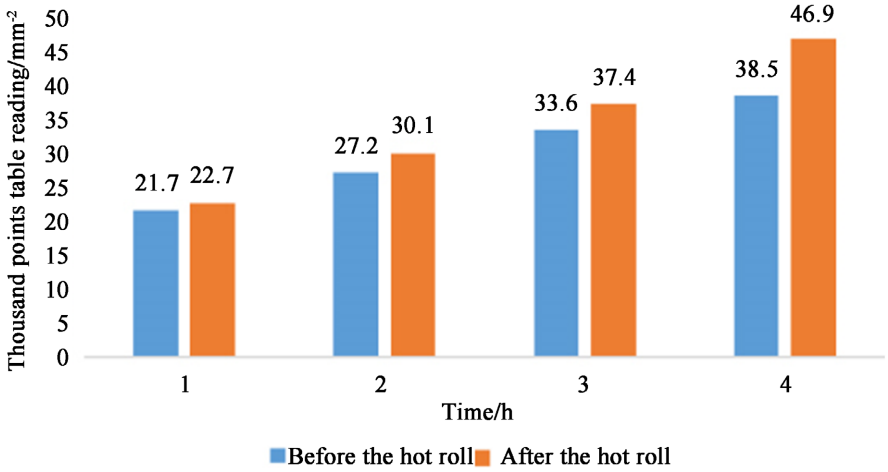

Figure 4. The inhibitory comparison before and after thermal rolling of the best drilling fluid system.

determine the performance evaluation of the amine-based polymer drilling fluid system.

As can be seen from Table 9, Table 10, with the increasing amount of NaCl, the rheology, filter vector and inhibition of the drilling fluid system show a small increase trend. Drilling fluid system has good salt resistance.

As can be seen from Table 11, Table 12, with the increasing mobility of the drilling fluid system, the filter vector and inhibition show a trend of small increase. Drilling fluid system has good calcium resistance.

As can be seen from Table 13, after 180˚C thermal roll, the recovery rate of the polyurethane-based drilling fluid system is basically greater than 80%, which is obviously better than the comparative drilling fluid system and can meet the basic requirements of anti-collapse drilling fluid.

Table 7. Effects of high temperature on drilling fluid mobility and filter loss.

Number	Drilling fluid	AV/ mPa·s	PV/ mPa·s	YP/ Pa	FL/ ml	Density
0#	Before the hot roll of the amine-based polymer drilling fluid	38.2	26.3	12.6	3.0	1.94 g/cm^3
1#	After the hot rolling of the amine-based polymer drilling fluid	45.7	37.6	14.2	3.7	1.94 g/cm^3

Table 8. Effects of high temperature on the inhibition of amine-based polymer drilling fluid.

Number	Time/h	Table reading before hot roll/10^{-2} mm	Table reading after hot roll/10^{-2} mm
0#	1	21.7	22.7
1#	2	27.2	30.1
2#	3	33.6	37.4
3#	4	38.5	46.9

Table 9. Effects of different additional amounts of NaCl on the mobility and filter loss in the amine-based drilling fluid system.

Number	Drilling fluid	AV/ mPa·s	PV/ mPa·s	YP/ Pa	FL/ ml
0#	Amine-based polymer drilling fluid	38.2	26.3	12.6	3.0
1#	Amine-based polymer drilling fluid+4.0%NaCl	39.4	27.1	13.5	3.1
2#	Amine-based polymer drilling fluid+8.0%NaCl	40.7	28.8	13.6	3.4
3#	Amine-based polymer drilling fluid+12.0%NaCl	42.1	27.4	14.2	3.8
4#	Amine-based polymer drilling fluid+16.0%NaCl	43.4	28.7	15.1	4.1
5#	Amine-based polymer drilling fluid+20.0%NaCl	46.2	30.2	16.1	5.4
6#	Amine-based polymer drilling fluid+24.0%NaCl	48.3	32.5	17.6	5.1

Table 10. Effects of different additional amounts of NaCl on the inhibition of the amine-based drilling fluid system.

Number	Drilling fluid	1 h/mm^{-2}	2 h/mm^{-2}	3 h/mm^{-2}	4 h/mm^{-2}
0#	Amine-based polymer drilling fluid	21.7	27.2	33.6	38.5
1#	Amine-based polymer drilling fluid + 4.0%NaCl	22.8	28.1	34.7	39.1
2#	Amine-based polymer drilling fluid + 8.0%NaCl	23.5	29.4	36.4	43.2
3#	Amine-based polymer drilling fluid + 12.0%NaCl	25.2	31.8	38.8	44.5
4#	Amine-based polymer drilling fluid + 16.0%NaCl	26.4	33.3	40.1	46.7
5#	Amine-based polymer drilling fluid + 20.0%NaCl	27.3	35.5	43.8	50.6
6#	Amine-based polymer drilling fluid + 24.0%NaCl	30.6	38.3	47.1	53.2

Table 11. Effects of different additional amounts of $CaCl_2$ on the mobility and filter loss of the amine-based polymer drilling fluid system.

Number	Drilling fluid	AV/mPa·s	PV/mPa·s	YP/Pa	FL/ml
0#	Amine-based polymer drilling fluid	38.2	26.3	12.6	3.0
1#	Amine-based polymer drilling fluid + 0.2% $CaCl_2$	39.0	28.0	13.2	4.1
2#	Amine-based polymer drilling fluid + 0.5% $CaCl_2$	41.5	31.2	13.5	5.6
3#	Amine-based polymer drilling fluid + 0.8% $CaCl_2$	43.8	34.2	14.2	6.5
4#	Amine-based polymer drilling fluid + 1.0% $CaCl_2$	46.2	36.7	16.5	7.2

Table 12. Effects of different added amounts of $CaCl_2$ on the inhibition of amine-based drilling fluid system.

Number	Drilling fluid	1 h/mm^{-2}	2 h/mm^{-2}	3 h/mm^{-2}	4 h/mm^{-2}
0#	Amine-based polymer drilling fluid	21.7	27.2	33.6	38.5
1#	Amine-based polymer drilling fluid+0.2% $CaCl_2$	23.8	29.1	35.7	42.3
2#	Amine-based polymer drilling fluid+0.5% $CaCl_2$	24.6	30.4	36.2	48.2
3#	Amine-based polymer drilling fluid+0.8% $CaCl_2$	25.3	31.3	39.8	50.3
4#	Amine-based polymer drilling fluid+1.0% $CaCl_2$	27.4	33.3	41.3	56.7

Table 13. Comparison results of debris recovery of amine-based polymer drilling fluid system.

Drilling fluid system	Initial rock mass X	Crash quality X_1	Crash quality X_2	Single heat roll recovery rate	Secondary heat roll recovery rate
Polyamine drilling fluid	30.12 g	26.93 g	22.58 g	89.41%	83.85%
Polysulphur drilling fluid	29.91 g	22.80 g	16.77 g	76.23%	73.56%
Three sulphur drilling fluid	30.04 g	20.07 g	12.98 g	66.83%	64.67%

4. Conclusions

1) The influence of the amount of different monomer on the performance of drilling fluid is known the best amine-based polymer anticollapse drilling fluid system formula is: 4% soil slurry + 0.3%YL-102 + 2%YL-103 + 3%YL-201 +

2%YL-301 + 3%YL-FT3 + 2%XZ-301 + barite.

2) At the high temperature of 180˚C, the mobility, filter loss and inhibition of the drilling fluid system are basically unchanged compared with that before the thermal roll, and its temperature resistance is good.

3) According to the experimental data of testing the amine-based polymer drilling fluid system, the best anti-collapse drilling fluid system selected in this experiment is mobility under the condition of 24.0% NaCl or 1.0% $CaCl_2$, and the filter loss and inhibition are not much affected, and the salt and calcium resistance is good.

4) Shale rolling recovery rate experiment shows that the first heat roll recovery rate and the second time are more than 80%, which basically meets the requirements of the site anti-collapse drilling fluid.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ma, C., Zhao, L. and Song, Y.S. (2014) Research and Application of Drilling Fluid. *Petroleum Drilling Technology*, 55-60.

[2] Chen, Z.H. (2015) Application of Drilling Fluids in Junggar Basin. *Western Exploration Project*, **27**, 45-47.

[3] Wang, X.Y., Zheng, J.H., Wang, R.X., *et al.* (2013) Application of Anti-Collapse Drilling Fluid in Sankai, Jinjing District. *China Petroleum and Chemical Standards and Quality*, 183-184.

[4] Zhang, W. and Liu, Z.D. (2008) Promotion and Recycling of Oil-Based Drilling Fluid. *Petroleum Drilling Technology*, **36**, 34-38.

[5] Wang, J., Shu, F.C., Wu, B., *et al.* (2007) Indoor Study of Strongly Inhibited Polyurethane Drilling Fluid System. *Oilfield Chemistry*, **24**, 296-300.

[6] Gao, L., Zhang, H., Jiang, G.C., *et al.* (2013) Stable Drilling Fluid in Ordos Basin. *Fault-Blcok Oil-Gas Field*, **20**, 508-512.

[7] Lin, Y.X. and Wang, J.G. (2014) Progress and Thinking of Sinopec Oil-based Drilling Fluquid Technology. *Petroleum Drilling Technology*, **42**, 7-13.

[8] Liu, Z.D. (2015) Analysis of the Problems in the Application of Oil-Based Drilling Fluids. *Oil and Gas Chemicals*, **44**, 84-88

[9] Yong, T.C., Chou, C.C. and Li, C.F. (2005) Antibacterial Activity of n-Alkylated Disaccharide Chitosan Derivatives. *International Journal of Food Microbiology*, **97**, 237-245. https://doi.org/10.1016/S0168-1605(03)00083-7

[10] Beppu, M.M., Vieira, R.S., Aimoli, C.G., *et al.* (2007) Crosslinking of Chitosanmembranes Using Glutaraldehyde: Effect on Ion Permeability and Water Absorption. *Journal of Membrane Science*, **301**, 126-130. https://doi.org/10.1016/j.memsci.2007.06.015

[11] Li, X., Chen, S., Zhang, B., *et al.* (2011) Biochemical Activities of N,O-Carboxymethyl Chitosan from Squid Cartilage. *Carbohydrate Polymers*, **85**, 832-837. https://doi.org/10.1016/j.carbpol.2011.04.007