Improvement and application of drilling fluid technology for gas exploration wells in Yanchi block

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Abtract. Currently, the exploration and development scope of Changqing oilfield has gradually developed to edge blocks and deep systems, typically of Yanchi block. However, in the construction process, there are some problems such as poor well wall stability, frequent well leakage and prominent collapse contradiction, which seriously restricts the increase of drilling speed. In this paper, the measures such as well structure optimization, system formulation optimization, separate management of collapse and leakage, refined performance control, and pressure-bearing leakage plugging were taken by a combination with the construction situation in 2021 so as to improve drilling speed and reduce the complexity of downhole failures.

Key words: Yanchi block; exploratory well; collapse prevention; leakage prevention; drilling fluid

1. Introduction

With the gradual development of exploration and development scope in Changqing oilfield to edge blocks and deep systems, the exploration and development intensity of Yanchi block has increased year by year in the past two years[1-4]. In 2020, the Fourth Project Department completed 7 gas exploration wells in the Yanchi block with poor production water quality and difficult drilling fluid performance maintenance. It is found that the stability of the strata near the thrust belt on the west margin is extremely poor[5-6]. Among them, reverse reaming is required for Li 56H well after three times. The double-rock layer of Li 47 well collapses seriously, and the pump is held back during the reaming process, so that the lifting and lowering are blocked. The collapse of the Anding, Zhiluo and double-rock layers is serious, and the drill resistance is serious. In addition, there are many leakage layers and frequent well leakage below the Yanchang stratum. The average single well plugging time exceeds 200 h, and the downhole failures are complex and time-efficient, showing a failure complexity rate as high as 13.56%. Moreover, the drilling fluids of Li 47 well, Li 69 well and Li 79 well constructed in 2020 have increased viscous shear force and increased filter loss, making it difficult to maintain and adjust performance on site[7-12].

Table. 1 Statistics of complicated conditions of construction wells in 2020

Well	Well depth (m)	Finish drilling layer position	Complex time (h)	Complex limitation (%)
Li 56H	5040	Shihezi	637	22.04
Li 47	4345	Krimori	986	26.27
Li 57-4	3936	Lashzhong	114	5.7

Table. 2 Exploration well leakage in the Yanchi block in 2020

Well	Well leakage		Measures			Leakage time (h)
	Leakage stratum	Leakage speed (m^3/h)	Static plugging	Squeeze plugging	Squeeze cement	
Li 57-4	Shihezi	30-35	3	0	1	104
Li 69	Krimori	20	1	2	1	136
Li 63	Liujiagou/Shiqianfeng/Shanxi	20	3		2	200
Li 64	Shanxi	30	2	2	1	210
Li 47	Yanchang/Liujiagou/ Shiqianfeng/Shihezi	15-60	3	8	7	417
Li 56H	Heshanggou/Liujiagou/ Shiqianfeng/Shihezi	5-25	16	4	2	323

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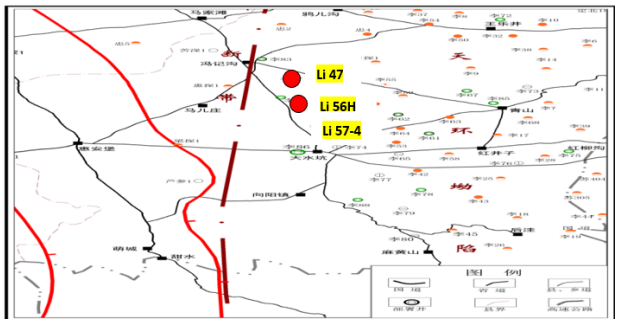

Fig. 1 Location of Li 47, Li 57-4 and Li 56H

2. Drilling fluid technology

2.1 Formula experiment with anti-salt treatment agent

Water-based drilling fluid was prepared from polymer protoslurry, 0.2% sodium hydroxide, 0.1% sodium carbonate, 0.15% PAC, 3% ZDS and 2% prehydrated clay. As shown in Table 3, it is found that the formulas of 5# and 6# meet the construction requirements, and the addition of potassium chloride improves the system inhibition, so that formula is determined as polymer protoslurry+0.2% sodium hydroxide+0.1% sodium carbonate+0.15% PAC+3% ZDS+2% prehydrated clay+3% SMP-2+3% SFT+2% SMC+5-7% KCl+0.05% K-PAM.

Table. 3 Formulation experiment

Number	Formula	FL (mL, 7.5min)	AV (mPa·s)	PV (mPa·s)	YP (Pa)	YP/PV (Pa/mPa·s)
1#	Black	10.4	25	20	5	0.25
2#	Black+2%SMP-2+ 1%SFT-1+1%SMC	7.6	22	18	4	0.22
3#	Black+3%SMP-2+ 2%SFT+2%SMC	6.2	23	18	5	0.28
4#	Black+3%SMP-2+ 3%SFT+2%SMC	5.2	23	17	6	0.35
5#	Black+3%SMP-2+3% SFT+2%SMC+ 5%KCl+0.05% K-PAM	5.2	22	16	6	0.38
6#	Black+3%SMP-2+3% SFT+2%SMC+ 7%KCl+0.05% K-PAM	5.0	25	18	7	0.38

2.2 Optimizing system transformation points

The well transformation point completed in 2020 was Zhifang-Heshanggou group. It is found that the lower part of the Yanchang collapses seriously as displayed by electrical measurement and the drilling encounters resistance. Therefore, the transformation point is optimized to enter 400 m into the Yanchang so as to control filter loss, enhance inhibition, and prevent the collapse of the Yanchang in advance.

Table. 4 Statistics of exploration well transfer system of Yanchi block in 2021

Well	Transformation point	Post-transformation performance
Li 81	2960 m (Yanchang)	1.04/36/5.8/9
Li 76	1970 m (Yan'an)	1.04/40/5.4/9
Li 77	2670 m (Yanchang)	1.06/41/5.0/9
Li 88	2750 m (Yanchang)	1.04/39/4.4/9
Li 96	2760 m (Yanchang)	1.05/40/5.2/9
Li 97	2650 m (Yanchang)	1.08/40/5.4/9
Li 87	2600 m (Yanchang)	1.06/41/4.8/9

2.3 Standardizing the performance of each stratum and strengthening the daily performance monitoring.

During the system transformation, it is the first time that KCl was added by 5%, and the content was gradually increased according to the field drilling fluid in the Yanchang group and Zhifang group. Subsequently, the drilling fluid performance of each stratum was standardized (seeing in Table 5). After entering Shiqianfeng group, the system enhances the plugging, the content of prehydrated clay reaches more than 3%, the content of SFT reaches 5%, filter loss (FL) is less than or equal to 5 mL, filter loss under high temperature and high pressure (HTHP-FL) is less than 16 mL. The strong system plugging is used to reduce the stratum collapse pressure.

Table. 5 Performance requirements of exploration Wells in the Yanchi block

Performance	Technical requirement
Density	After transformation: 1.10 g/cm^3; Yanchang: 1.15g/cm^3; Liujiagou: 1.17-1.18 g/cm^3; Shiqianfeng: ≥1.18g/cm^3; Before taking the core: ≥1.22 g/cm^3; Finishing drilling: 1.23-1.26 g/cm^3
FL	Yanchang-Liujiagou: ≤6 mL; Shiqianfeng-Shihezi: ≤5 mL; Shanxi-finish drill: ⩽4mL
HTHP-FL	Yanchang-Shihezi: ≤20 mL; Shanxi-finish drill: ⩽15 mL
Bentonite content	Yanchang-Shihezi: 20-30 g/L; Shanxi-finish drill: 30-40 g/L

2.4 Transforming joint management of collapse and leakage into separate management of collapse and leakage

After the system transformation, the plugging agent was blocked with the drill, select particles, sheets and fibers, and different types to gradually improve the pressure capacity of the stratum, and add the drill plugging agent by 1-2%. Preequipped 30 m^3 plugging slurry (8-10%), it was timely pumped into the well for plugging leakage. When plugging effect is not good, cement is used to plug the leakage. For the leakage layer that appears during the drilling period, it must be completely blocked and then continue to drill, to avoid the recurrence of the leakage layer. After drilling through Liujiagou group, the pressure plugging was carried on, and the drilling fluid density should be greater than 1.20 g/cm^3. If the requirements are not met, no drilling will be conducted, and the light drill rod is started for plugging.

Table. 6 Blocking situation of exploration well in the Yanchi block

Well	Leakage depth	Stratum	Lease speed	Prformance	Treatment measure
Li 81	4551	Shihezi	10-15	1.20/52/7.8/9	Plugging slurry
Li 76	3169	Yanchang	Lost back	1.09/49/5.6/9	Plugging slurry while drilling
	3731	Liujiagou	20	1.17/52/5.4/9	Plugging slurry while drilling Cemented once in Yanchang and Liujiagou
Li 77	3144	Yanchang	40-50	1.15/46/5.2/9	Cemented once under light drill rod
	4319	Shanxi	20	1.24/70/4.8/9	Cemented once in Shanxi and Liujiagou
Li 88	3478	Zhifang	80	1.16/43/5.6/9	Cemented once
Li 97	3370	Zhifang	Lost back	1.11/44/5.6/9	Cemented once under Light drill rod
	3541	Heshanggou	10	1.10/44/5.8/9	Cemented once under light drill rod

Table. 7 Pressure-bearing and leakage plugging of exploration wells in the Yanchi block

Well	Pressure-bearing situation
Li 76	At Shiqianfeng with plugging slurry for pressure bearing, failed to bear the pressure, cemented in Liujiagou, and the density is increased to 1.23 g/cm^3
Li 77	Leakage plugging under pressure at Liujiagou, and the density is increased to 1.22-1.23 g/cm^3 during drilling, and the consumption is 1.6-2.4 m^3/h
Li 81	Leakage plugging under pressure at Liujiagou, the density is 1.22 g/cm^3, and the density is 1.21 g/cm^3 before coring
Li 88	Leakage plugging under pressure at Liujiagou, and the density is 1.24 g/cm^3, the density is 1.23 g/cm^3 before coring, plugging while drilling
Li 87	Leakage plugging under pressure at Liujiagou, and the density is 1.23 g/cm^3, the density is 1.23 g/cm^3 before coring
Li 96	Leakage plugging under pressure at Liujiagou, and the density is 1.25 g/cm^3, the density is 1.23 g/cm^3 before coring
Li 97	Leakage plugging under pressure at Liujiagou, and the density is 1.24 g/cm^3, the density is 1.24 g/cm^3 before coring

2.5 Making full use of small experiments to understand the efficacy of each treatment agent, fine to adjust the performance

The need to adjust the performance of the original slurry was to first carry out indoor experiments, according to the targeted formula adjustment of the experimental results, to achieve fine maintenance. Li 76 well was drilled to 3300 m, and the block appeared in the Yanchang, and the performance of drilling fluid was 1.16/45/6.2/9. The adjustment idea is to reduce the filter loss first, then increase the density, carry out small experiments to optimize the formula, and select the treatment agent, and finally get better results.

Table. 8 Performance adjustment experiment of Li 76 well

Order number	Formula	FL (mL)	HTHP-FL (mL)
1	Black	6.2	21.6
2	Black+1%SMP-2+1%SFT	6.0	20.2
3	Black+1.5%SMP-2+1%SMC	5.8	19.6
4	Black+1%SMP-2+1%SFT+0.5%SMC+1% ZDS+1% prehydrated clay	4.8	15.6

3. Field application

By optimizing the system, the potassium polysulfonic acid system has relatively stable performance, good salt and calcium resistance, strong inhibition and good sealing performance, and meets the construction requirements of gas exploration wells in Yanchi block, and there is no sudden change in performance.

Table. 9 Statistics of core extraction and finished drilling performance in Yanchi block in 2021

Well	Core taking performance	Before taking the core HTHP-FL (mL)	Finish drilling performance	Finishing drilling HTHP-FL (mL)
Li 81	1.20/52/6.0/9	18.8	1.23/62/5.8/9	17.6
Li 76	1.22/62/4.8/9	14.2	1.23/81/4.4/9	12.8
Li 77	1.23/65/4.8/9	14.8	1.24/85/4.2/9	13.2
Li 88	1.24/65/5.0/9	15.6	1.25/83/4.6/9	14.2
Li 96	1.24/63/4.8/9	16.2	1.25/86/4.4/9	14.6
Li 97	1.23/68/4.8/9	15.8	1.25/88/4.6/9	14.4
Li 87	1.24/66/4.4/9	15.2	1.25/85/4.2/9	13.4

Through the transfer system in the middle of the Yanchang, the downhole collapse is greatly reduced, no serious jamming phenomenon occurs, and the phenomenon of drilling and tripping jamming is less.

From the completion of the well coring to the completion of the trip, the drilling is normal. Among them, 5 wells are opened for the second time to the completion of the trip without encountering obstacles, and the average well diameter after the electrical measurement does not exceed 10%.

Table. 10 Statistics of average well diameter in Yanchi block in 2021

Well	Finishing drilling depth (m)	Finishing drilling stratum	Average well diameter expansion rate (%)
Li 96	4435	Krimori	5.23
Li 81	4830	Krimori	3.63
Li 88	4690	Krimori	6.36
Li 76	4510	Krimori	5.22
Li 77	4560	Krimori	6.11
Li 97	4470	Krimori	4.98
Li 87	4260	Krimori	4.59

Through the measures of plugging while drilling in advance and dividing and controlling the collapse and leakage, there is no well collapse caused by well leakage, and the success rate of the plugging has been greatly improved. The average plugging time for a single well was shortened by 106.3 h compared with 2020, a decrease of 44.29%, and the success rate of one-time plugging was 100%.

Table. 11 Statistics of plugging of construction Wells in Yanchi block in 2021

Time	Well number	Number of leakage wells	Plugging time time (h)	Average plugging time in a single well (h)
2021	7	5	668.5	133.7
2020	6	6	1440	240
Comparison			-771.5	-106.3（-44.29%）

The overall speed-up effect is obvious. Compared with 2020, the average drilling cycle is shortened by 19.69 days, the well construction cycle is shortened by 21.83 days, the monthly speed of drilling rigs is increased by 50.15%, and the complexity rate is reduced by 54.8%.

Table. 12 Comparison of conventional gas exploration Wells in Yanchi block in 2021

Time	Finishing drilling numbe	Average well depth (m)	Average drilling cycle (d)	Average well building cycle (d)	Average monthly speed of drilling rig (m/ty)	Complex rate (%)
2021	7	4536	41.34	65.19	2494	5.79
2020	6	4299	61.03	87.02	1661	12.81
Comparison	+1	+237	-19.69	-21.83	+833	-7.02
%			-32.26	-25.09	50.15	-54.8

4. Conclusions

In this paper, the poly-sulfur system has good inhibition, blocking nature, strong salt and calcium resistance ability and stable performance, which meets the safe construction of gas exploration wells in Yanchi block. The advance transformation system can effectively prevent the collapse of the stratum above the Yanchang group and greatly reduce the complex downhole aging. Precise maintenance of drilling fluid performance and adjustment of performance according to the timely characteristics of the stratum can greatly reduce the complexity of downhole failures. By plugging leakage while drilling in advance, gradually increasing stratum pressure, dividing and controlling collapse and leakage, and plugging leakage under pressure in Liujiagou, the contradiction between collapse and leakage can be alleviated in essence, and the drilling speed can be accelerated. When adjusting the performance of the system, it is very necessary to carry out small-scale experiments to avoid blind operation, which will cause the performance to be unadjusted for a long time and cause downhole complexity.

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