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Development of High Efficient Anti-sloughing Drilling Fluid and Its Application in Chunhua Block

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Abstract
Chunhua Block of Shengli Oilfield is one block where shale caving formation, borehole instability, well click, trip sticking, drill pipe blocking and sticking during completion logging and other downhole complex issues were encountered during the drilling process. The paper was based on slow down pressure transmission, filtrate invasion and strong inhibition of cooperation anti-sloughing basic principle. Through optimization and compatibility of the major additives, a new-type drilling fluid is characterized by good rheological properties, filtration loss, lubricity, stability and strong inhibition. The new drilling fluid has been applied in 5 wells for block test. The result showed that all wells gained a satisfactory anti-sloughing effect. The enlargement ratio of well bore diameter was reduced efficiently. The drilling time was saved. And the ratio of successful logging by one time was 100%.

Key words: Drilling fluid; Borehole stability; Shale strata; Cooperation anti-sloughing; Chunhua Block

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INTRODUCTION
The formation of Chunhua Block is complex. Wells drilled in this block have encountered several kinds of downhole problems such as borehole collapse and caving, drag and pipe sticking during trip, logging obstructing, sticking, bad cementing quality. There exist easily have hydrating swelling and dispersive red shale layers in Kongdian Formation in Chun-26 Block. During drilling process, the filtrate in drilling fluid soaking will form a soft -shale borehole around the bore hole. Cables and electrical measuring instruments are prone to sticking under the pressure effect in logging process[1~2]. Meanwhile there exist a certain salt-gypsum containing, after entering the segment, salt-gypsum pollution caused by excessive drilling fluid viscosity, bigger dehydration, difficult to control rheology, virtual thick mud cake often formed in the borehole, causing lageniform hole characterized by tight hole and hole washout coexistence, tripping sluggish, logging obstructing, sticking and other complex problems[3~4]. According to incomplete statistics, 90% of the construction wells which use conventional anti-sloughing drilling fluid system, collapsed severely in Shahejie Three, Shahejie Four Formation, the enlargement ratio of bore hole diameter was over 30%, and electrical logging obstructing and sticking in per well waste 96 hours time, which seriously affects the drilling process, consumes lots of manpower and resources, brings huge economic losses. Therefore, developing a high efficient anti-sloughing drilling fluid which adapted to the formation is urgent.

1. LABORATORY ON HIGH EFFICIENT ANTI-SLOUGHING DRILLING FLUID SYSTEM

1.1 Technology Roadmap
Through the analysis of technical data of well construction of Chunhua Oilfield, based on the formation characteristics of the oilfield, the author considers that

during drilling with the new drilling fluid system, the following conditions must be met.

(1) During the secondary drilling from Minghua to Dongying formation, due to serious mud problem, continue to use water circulation drilling fluid technology which commonly used in Shengli oilfield, appropriately make a large upper bore hole drilling into the open one.

(2) Drilling to the bottom of Dongying formation, begin to make proper transformation of drilling fluid, reduce the filtration loss, make drilling fluid moving freely.

(3) Because amine polymeric alcohol has a strong inhibitory ability[5~6], after entering the Shahejie formation, it is added to drilling fluid for improving the inhibition of the drilling fluid, reducing shale hydrating dispersion and erosion.

(4) Because the strong inhibition polysulphonate anti-sloughing drilling fluid system is weak dispersion system[7~8], particle size distribution of clay particles in system is coarser, need to add some inert rigid particles, fill with clay particles and additives, form dense filter cake, reduce the amount of drilling fluid filtration.

(5) Aluminum flexible polymer and polyalcohol anti-collapse agent are selected to give full play to their chemical solid wall, improve the bearing capacity of the formation, to a certain extent, prevent borehole collapse and lost circulation[9-10].

(6) In order to improve the high temperature capability of the drilling fluid, additives of temperature resistance above 150 ℃ were used in all wells, avoid using pyrolysis additives easily.

1.2 Encapsulation Inhibitor Optimization

In order to select the encapsulation inhibitor which is suitable for the formation, the red shale in Chun-26 block is used to evaluate several additives. The results are shown in Table 1.

Table 1
The Preferred Results of Encapsulation Inhibitor

Classification	Additives		Dosage %	Rate of recovery %
	Name	Code		
	Tap Water			20.98
Polymer	Polymethacrylate	PAM	0.2	91.94
	Complex metal lonsamphoteric polymers	PMHA-II		56
	Vinyl monomer copolymers	PAC-141		90.26
	Macromolecule Flocculant	LS-AOF		80.86
Lignite	Nonfluorescence filtration control agent	PA-1	2	24.82
	Brown coal resin	SPNH		12.90
	Sulfonated Lignite	SMC		13.8
	High temperature anti-sloughing viscosity and filtrate reducer	SD-201		28.28
	Anti-hightemperature viscosity and filtrate reducer	FTJN		18.24
	Silicone humic kalium	OSAM-K		28.18
Asphaltic	Sulfonated-asphalt	FT-1		14.30
	Emulsifled modified asphalt	RHFT-1		19.70
Polymeric alcohol	Polyalcohol Lubricants	JLX		46.76
	Polyalcohol Lubrication anti-sloughing agent	JHC-1		79.92
	Polyalcohol anti-sloughing shield agent	SD-302		28.30

From Table 1, we know that for red shale in Chun-26 block, PAM of polymer is the best, followed by the PAC-141, the dispersion effect of polymer encapsulation inhibitor is superior to other classified anti-sloughing agent; lignite products SD-201 places the highest recovery rate; emulsifled modified asphalt is better than FT-1 in asphalt products. In polyalcohol, JHC-1 has the highest recovery rate and the best inhibiting.

1.3 Development of High Efficient Anti-Sloughing Drilling Fluid System

There exist a certain of salt-gypsum, easily hydrating swelling and dispering in red shale layers of Kongdian formation Chun-26 block, after drilling the formation, drag and pipe sticking during trip, logging obstructing and sticking were encountered because of excessive drilling fluid viscosity, bigger dehydration, difficult to control rheology, but the Binzhou region Shahejie Formation is strong hydration, weak dispersion formation, collapse and caving are serious, the borehole diameter enlargement rate is larger, has seriously hindered the smooth implementation of drilling engineering. This requires that the drilling system not only has the appropriate rheology and filtration, but also has strong inhibition, good lubrication and stability (salt-resisted、calcium-resisted、anti-consolidated rock and good soil increased properties)[11-12]. Based on the above bore hole instability mechanism research, analysis and performance requirements for

drilling fluid, the formulations of a kind of high efficient anti-sloughing drilling fluid were indoor optimized, they are as follows:

4% bentonite + 0.2% PAC-141(or PAM) +0.4% SDKJ-1 + 0.4% MAN101 + 0.8% Si-Fl thinner + 3% SD-201 + 3% SD-101 + 2% RHFT-1 + 1% organic salt (Notes for a pulp).

After the system at room temperature and 150 ℃/16h aging properties as shown in Table 2, the experimental results known from the table, good conventional performance, low viscosity, water loss reduction effect is good, high temperature stability. The dispersion recovery rate reached 96.32% for red shale layers of Kongdian Formation of Chun-26 Block.

Table 2
Rheological Fluid Loss of High-Performance Collapse-Preventing Drilling Fluid System

Performance parameters	AV mPa·s	PV mPa·s	YP Pa	V_f ml	HTHP mL
Normal atmospheric temperature	31	23	8	6.0	
150℃/16h	25	19	6	3.0	11

Table 3
The Results of Test in Evaluating Drilling Cuttings Contaminate Resistance

Drilling fluid system			AV mPa·s	PV mPa·s	YP Pa	V_f ml
A	+5%consolidat-ed rock	Normal atmospheric temperature	44	32	12	4.8
	+10%consolid-ated rock	Normal atmospheric temperature	50	32	18	4.2
	+15%consolid-ated rock	Normal atmospheric temperature	53.25	34.5	18.75	4.0
		150℃/16h	39	29	10	6.4

1.4 The Performance Evaluation Test of High Efficient Anti-Sloughing Drilling Fluid System

1.4.1 Drilling Cuttings Contamination Test

The cuttings in red shale layers of Kongdian Formation Chun-26 Block were crushed and sieved. Taking 100 to 150 mesh powder shale for test, the results were shown in Table 3.

The test results showed that in high efficient anti-sloughing drilling fluid system, with the shale power dosage increases, the viscosity is almost no change, a slight decrease in the amount of filtration loss. If the additive shale was cleared timely, the drilling fluid viscosity declined, loss of water did not change significantly, anti-sloughing drilling system has strong debris contaminate resistance.

1.4.2 NaCl Contamination Test

The test results were shown in Table 4. It was concluded that the high efficient anti-sloughing drilling fluid could fulfill the demand of field application.

Table 4
The Test Results of NaCl Contaminate Resistance

Drilling fluid system	AV mPa·s	PV mPa·s	YP Pa	V_f mL
A	31	23	8	6.0
+1%NaCl	31.5	24	8.5	6.0
+3%NaCl	33	24.5	9	6.6
+5%NaCl	34.5	26	10	7.0
+7%NaCl	56	36	17	12.0

1.4.3 $CaSO_4$ -Contamination Test

The test results are shown in Table 5. It shows that when $CaSO_4$ contaminate resistance reached 1.5% (Due to the limited solubility of $CaSO_4$, 1.5% is already saturated, so do not need a large dosage test), it has strong abilities.

Table 5
The Test Results of $CaSO_4$ Contaminate Resistance

Drilling fluid system		AV mPa·s	PV mPa·s	YP Pa	V_f ml
A Slurry	Normal atmospheric temperature	31	23	8	6.0
+0.5%$CaSO_4$	Normal atmospheric temperature	41	31	10	5.2
+1%$CaSO_4$	Normal atmospheric temperature	44	33	11	4.8
+1.5%$CaSO_4$	Normal atmospheric temperature	45	33	12	5.2
	150℃/16h	28	16	12	6

1.4.4 Weighting Capacity

As shown in Table 6, the results show that Weighting Capacity of anti-sloughing drilling fluid is excellent, it can weight to ρ = 1.8 g/cm^3, enough to meet the needs of the field application.

Table 6
The Test Results of Weighting Capacity

Drilling fluid system		AV mPa·s	PV mPa·s	YP Pa	V_f ml
A Slurry	Normal atmospheric temperature	31	23	8	6.0
Weight to ρ = 1.6 g/cm^3	Normal atmospheric temperature	72	63	11	3.2
Weight to ρ = 1.8 g/cm^3	Normal atmospheric temperature	81	68	13	3.4
	150℃/16h	48.5	42	6.5	3

1.4.5 Reservoir Protection Capacity

For further evaluation and optimization reservoir protection of drilling fluid system, add in temporary plugging agent QS-2, evaluation of reservoir protection performance, the results shown in Table 7.

Table 7
The Core Flow Test Results

Before contamination		After contamination		Temporary slugging rate,%	Return permeability,%
K_W, μm^2	K_O, μm^2	K'_W, μm^2	K'_O, μm^2		
¥	0.1625	0	0.1333	100	82.0

From Table 7, drilling fluid is optimized with good reservoir protection capacity, the return permeability is above 80% after flow-back-broken down.

2. FIELD APPLICATION

There exists shale, gypsum and salt rock in the deep complex layers. The shale with hydrating, dispersing and swelling characteristics, it is bound to affect the rheology of drilling fluids. Salt gypsum layer dissolved will produce sodium、calcium and magnesium ions, and high concentration of sodium, calcium, magnesium and other ions compressed electric double layer of colloidal particles, so that thin film hydration, resulting in colloidal particles tend to coalesce, destructing stability of the drilling fluid, filtration soared, mud cake thickness, flow variation and even loss. Damage to property of drilling fluid. Salt gypsum layer on the dissolution properties of drilling fluid damage is irreversible, this is bound to increase the performance of drilling fluid and the difficulty of maintenance.

In addition, Shahejie shale formation broken, water sensitivity is weak, bedding is developed and interbeded sandstones and mudstones with different permeability, drilling fluid filtrate easily along the interface into the deep formation, collapse is mainly due to the drilling fluid and filtrate into the internal formation, shale surface hydration, thereby causing brittle shale collapse. While the less compacted shale crushed, high pressure, drilling pressure is released, also easy to cause the borehole collapse.

The new drilling fluid has applied in 5 wells for block test. During the drilling process does not appear any apparent collapse, caving, drilling fluid thickening, sticking and logging obstructing phenomenon. Compared with the adjacent well's logging curve, the well diameter rules, no "jagged" curve, no "lageniform hole", hole enlargement rate was significantly lower and achieved good results.

(1) Chun-52 well was drilled to TD 2470 m, completion layer is Kongdian with density 1.17 g/cm^3. Wells in the field were easy to paste the upper formation, to collapse and caving in the lower Shahejie formation, forming a "complex situation on the paste off". During drilling in Kongdian formation with long interval, it is prone to sticking and electrical obstructing; especially with a thin layer of gypsum in S4 section and the junction of Kongdian formation, when drilling through it that will make the drilling fluid loss of mobility, API dehydration spurt, causing downhole complex problems.

For sand-gypsum layer in S4 section and Kongdian formation interface, before drilling to the horizon about 50m, adding soda ash 200kg, compound salt filtration reducing agent (LL-JLS) 1.5-2% and organosilicon methyl collapse-preventing viscosity reducing agent (JS-3) 1.5-2.0%, improving the drilling fluid contaminate resistence. From the filtrate analysis shows, Ca^{2+} content increased 354.21 mg/L, Mg^{2+} content increased 200.01 mg/L, Cl content was also increased slightly by the analysis of well water and drilling fluid filtrate ion content, it was concluded that drilling gypsum layer, but the drilling fluid flow has been well maintained, apparent viscosity and API dehydration has no change and ensure the construction of the well smoothly.

By using the compound salt resistence drilling fluid system in the application of the well, water expansion,

tight hole and electric sticking in red layer Kongdian formation were controlled effectively, the well logging 3 times and the success rate is 100%.

(2) Chun-X103 well was drilled to TD 3291 m, drilling fluid density up to 1.30 g/cm^3. This well belongs to a STH of an old well, and the side tracking point is at 2380 m. The water sample analysis showed that Ca^{2+} contents up to 319.20 mg/L, Mg^{2+} contents up to 172.63 mg/L, and the content of Cl^- is 1650.31 mg/L, so the formation water salinity are on the high side, we still have adopted the compound salt resistence drilling fluid system, and all well construction smoothly, without complex problems.

(3) Chun95-X3 well was drilled to TD 2774 m, and drilling fluid density is 1.23 g/cm^3. When the well is drilled to 2000 m, it is gradually changed to compound salt resistence drilling fluid system. At 2180 m, a slight change of fluid loss, by the analysis of drilling fluid filtrate Ca^{2+} contents up to 378.82 mg/L, Mg^{2+} contents up to 274.30 mg/L, the Cl^- content is 2950.30 mg/L, but drilling fluid performance is stable, complex problems did not occur , the completion logging is successful one time.

(4) Liang20-30 well was drilled to TD 3230 m and drilling fluid density is 1.15 g/cm^3. When drilled to 2050 m tripping, before which API dehydration was 8 mL, going on drilling, API dehydration increased to 20 mL, after adding 1.5 tons of natural polymer drop water loss and 1 tons of polymer fluid loss agent, water loss is still in a high level (API dehydration was 16 mL), after add 1 ton LL-JLS, dehydration immediately dropped to 5.5 mL. Through the analysis of drilling fluid filtrate, Ca^{2+} contents up to 499.80 mg/L, Mg^{2+} contents up to 324.30 mg/L, the Cl^- content is 3950.30 mg/L, when drilled in salt water layer, the drilling fluid was converted to compound salt resistence drilling fluid system, well completion operation is smooth.

(5) Liang 20-X31 well was drilled to TD 3308 m, drilling fluid density is 1.15 g/cm^3 ; Liang 20-23 well drilled deep 3265 m, density is 1.15 g/cm^3. The two wells operation was based on the experience of the Liang 20-30 well, at 1900 m, the drilling fluid can be converted to compound salt resistence drilling fluid system, the result confirmed by drilling fluid filtrate analysis, there exist salt water layer in 2000 m or so, because the preparing work is enough, the drilling fluid performance is operated smoothly.

CONCLUSION AND ADVICE

(1) The new anti-sloughing drilling fluid has good rheological property, small amount of API filtration and lower solid content, its rheological properties can be adjusted by reinforced adhesion agent and flow pattern regulator.

(2) The new anti-sloughing drilling fluid has good temperature resistance, stability at 150 ℃; has strong resistance to salt, calcium, anti soil contamination ability; has good shale inhibition, can effectively prevent the borehole collapse and caving; the permeability recovery value and shale recovery rate is higher, reservoir protection effect is good.

(3) The new anti-sloughing drilling fluid meet the requirement of drilling operation in Chunhua Block. It can effectively prevent accidents and complex problems, and achieve considerable economic benefit.

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