Crude Oil in Water Drilling Fluid Properties and Application in Horizontal Wellbore Drilling

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Abstract. Oil in water drilling fluid is a suitable water based drilling fluid for horizontal well, because of good lubricity, liquidity and borehole stability. Optimized and matching emulsifiers, in the2:8 ratio of oil to water, the emulsifiers OP-10+SP-80 ratio of 3:2 is the best effect of emulsion stability, the formation of oil in water drilling fluid system have low filter loss, strong stability, low lubricating coefficient properties , which can meet the needs of drilling horizontal well design. The crude oil in Water drilling fluid application in Xin Sha21-1H,Xin Sha23-1H and XinSha 21-3H well shows that, the oil in water drilling fluid system has good rheological properties and lubricating property. The average single well diameter expanding rate of 12.23%, lower than 16.75% with other well. Utilization drilling rate increased from 35.82% to 54.67%, which increase 52.6% significantly reduced the horizontal well drilling cycle.

Introduction

The development of horizontal drilling technology provide a new way for improve exploration, the technology has become the one of most important oil industry technology in now[1]. The current level of foreign drilling fluid system is mainly used in the drilling process are five: polymer drilling fluid, oil-based drilling fluid, clean brine drilling fluid, mixed metal layered hydroxides and foam or inflatable drilling fluid[2~3].

Oil in water drilling fluid system has both water-based drilling fluid characteristics and has oil-based drilling fluid lubrication advantages, mainly used to solve some of the horizontal well borehole instability, poor performance of the drilling fluid lubrication technical problems. This system performance is stability, has good liquidity, low fluid filter loss, wellbore stability strong capacity; performance easily monitor, control and adjustment. The system has low cost compared to pure oil-based drilling fluid, low environmental pollution, is one of the preferred chose for horizontal well drilling.

The establishing of oil in water drilling fluid emulsifier

According to theory, the HLB value (hydrophilic-lipophilic balance) in the range of 8-18, emulsifier can be used as emulsifier in oil in water drilling fluid. But in the actual application process, one emulsifier emulsifying effect is not ideal, usually several mutually emulsifier mixed use. Emulsifiers having an HLB value plus the corresponding proportion and nature. From raw material economy and practical point of view, the project choose crude oil as based oil, pH is adjusted to 10, evaluate the stability of the emulsion, optimization preferably suitable emulsifier. In this study, referring to the drilling fluid emulsion stability evaluation in "SY-T 6615-2005 drilling fluid emulsifier evaluation process", doing the evaluation about the commonly used emulsifier for emulsification. The evaluation show in table 1.

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Table1 2:8 Oil-water emulsion stability

No.	Emulsifier name	Stratification after 24h		
		Upper layer	Middle layer	Low layer
1	TW-85	34mL	No stratification	
2	OP-10	34mL	No stratification	
3	TW-80	38mL	No stratification	
4	ABS	14mL	No stratification	
5	TW-80:OP-10=1:1	21mL	8mL	Clear
6	TW-80:OP-10=2:1	19mL	12mL	Clear
7	TW-80:OP-10=3:2	18mL	10mL	Clear
8	TW-80:SP-80=1:1	5mL	9mL	Clear
9	TW-80:SP-80=2:1	6mL	12mL	Clear
10	TW-80:SP-80=3:2	4mL	8mL	Clear
11	TW-85:SP-80=1:1	15mL	18mL	Clear
12	TW-85:SP-80=2:1	17mL	17mL	Clear
13	TW-85:SP-80=3:2	14mL	16mL	Clear
14	OP-10:SP-80=1:1	4mL	12mL	Clear
15	OP-10:SP-80=2:1	3mL	14mL	Clear
16	OP-10:SP-80=3:2	2mL	9mL	Clear
17	ABS: SP-80=1:1	14mL	17mL	Transparent
18	ABS: SP-80=2:1	15mL	19mL	Transparent
19	ABS: SP-80=3:2	13mL	22mL	Transparent

Remark: The upper layer is not emulsified crude oil, the middle layer is breaking emulsions, the low layer is stable emulsions.

From the experimental date in Table 1, in the oil-water ration 2:8 cases, crude oil can’t be emulsified by a single emulsifier, and can’t form a stable oil-in-water emulsion system. The use of complex ways to emulsify the crude oil has more significant effect, In order to research the effect of the amount of emulsifier on the emulsion stability.Emulsifier dosage evaluate experimental data are shown in Table 2.

Table 2 Emulsifier dosage evaluation of experimental data

No	Emulsifier name	Ratio	Stratification after 24h		
			Upper layer	Middle layer	Low layer
1	TW-80:SP-80=3:2	4%	15mL	6mL	Clear
2		6%	7mL	12mL	Clear
3		10%	4mL	8mL	Clear
4		15%	5mL	9mL	Clear
5		20%	3mL	9mL	Clear
6	OP-10:SP-80=3:2	4%	14mL	16mL	Clear
7		6%	11mL	7mL	Clear
8		10%	2mL	9mL	Clear
9		15%	2.5mL	10mL	Clear
10		20%	2mL	8mL	Clear

Remark: The upper layer is not emulsified crude oil, the middle layer is breaking emulsions, the low layer is stable emulsions.

From the experimental date in Table 2, in the oil-water ration 2:8 cases, the choice of emulsifier dosage is 10% of crude oil, it has been able to promote sufficiently emulsified crude oil, has good emulsion stability.

Oil-in-water drilling fluid system optimization

On the basis of the water-based drilling fluid formulations research emulsifier system OP-10: SP-80 = 3: 2 is introduced into the drilling fluid performance changes, investigate different oil-in-water drilling fluid rheology and lubricity. Show in Table 3.

Table 3 The influence of oil-water ratio to drilling fluid

Oil-water ratio	ρ g/cm^3	FV S	PV mPa·s	YP Pa	G_1/G_2 Pa	FL mL	K_f	EP	viscosity coefficient	Remark
1：9	1.60	59	23	15	5/18	2.3	/	/	/	Room temperature
	1.60	48	24	4.5	1.5/6	1.8	0.1183	0.2169	0.0542	After aging
2：8	1.60	49	21	13	6.5/20	1.8	/	/	/	Room temperature
	1.60	41	22	5.5	1.5/8	1.2	0.0930	0.1885	0.0262	After aging
3：7	1.60	73	38	18	9/23	1.3	/	/	/	Room temperature
	1.60	65	40	12	5/21	0.8	0.0835	0.1778	0.0262	After aging

From the experimental date in Table 3, using oil-water ratio 2: 8, Kf value is less than 0.1, can reach horizontal wells lubrication requirements, while medium pressure filter loss is also less than 1.5mL, thereby facilitating horizontal wells wall stability.

According to the basic composition of the oil-in-water drilling fluid system, Specific formula is as follows: 3~4%NV-1+0.5%~1%OP-10+13%~17%Crude oil +0.3%~0.8%SP-80 +0.05%~0.1%NaOH +2~4%SMP-1+2~4%SMC +0.2%~0.8%CaO+1%~3%anti-sloughing agent（FGH）+ BaSO4.

To evaluate the high temperature stability of the oil-in-water drilling fluid system, the preparation of a density of 1.60g / cm^3 oil-in-water drilling fluid temperature is 80℃, 90℃, 100℃ temperature stability experimental. Show in Table 4.

Table 4 High temperature stability test data

Aging condition	FV s	PV mPa.s	YP Pa	G_1/G_2 Pa	FL mL	HTHP/100℃		Remark
						FL/mL	K/mm	
80℃×16h	41	22	5.5	1.5/8	1.2	4.8	0.6	No demulsification stratification
90℃×16h	43	25	5	4/9.5	1.8	6.2	0.8	No demulsification stratification
90℃×32h	39	20	4.5	3/7.5	2.6	7.2	0.6	Trace demulsification stratification
100℃×16h	40	25	5.5	5.5/15.5	2.8	6.4	0.7	Trace demulsification stratification

From the experimental date in Table 4, oil-in-water drilling fluid system temperature resistance up to 100℃, the actual operation of the site may need to appropriate adjustments.

Application of oil-in-water drilling fluid in horizontal wells

Oil-in-water drilling fluid test wells drilled a total of three horizontal wells, respectively Xinsha 21-1H, Xinsha 23-1H and Xinsha 21-3H well, which aims layer are Shaximiao, The test results are shown in Table 5.

Table 5 Test well and no test well basic fact sheet

No	Well No.	Well type	Drilling	Drilled	The maximum	Remark
1	Xinsha21-1H	Horizontal well	Oil-in-wate	J2s	93.43°/2551.86m	Test well
2	Xinsha23-1H	Horizontal well	Oil-in-wate	J2s	92.4°/2697.05m	Test well
3	Xinsha21-3H	Horizontal well	Oil-in-wate	J2s	92.53°/2421.51m	Test well

Three wells in the deflecting and horizontal section adding 5% to 10% of crude oil, while adding emulsifier (SP-80, OP-10) to meet the requirements of drilling fluid lubricating properties, and according to the drilling speed, speed replenish footage various processing agents to keep its content in drilling fluid. Kf value is maintained at <0.12, dynamic plastic ratio controlled in 0.4 to 0.6, the performance of the oil-in-water drilling fluid as shown in Tables6 to 8.

Table 6 The performance of oil-in-water drilling fluid in Xinsha21-1H

Well depth m	ρ g/cm3	FV s	FL ml	K mm	pH	YP Pa	PV mPa.s	G1/G2 Pa	Cs %	Vs %	Oil content%	Kf
2400	2.01	56	3	0.5	9	13	27	7/16	0.2	31	8	0.109
2450	1.98	44	3.6	0.5	9	12	24	5/13	0.2	32	8	0.108
2920	1.93	47	3.0	0.5	9	11.5	23	6.5/15	0.2	30	8	0.109

Table 7 The performance of oil-in-water drilling fluid in Xinsha23-1H

Well depth m	ρ g/cm3	FV s	FL ml	K mm	pH	YP Pa	PV mPa.s	G1/G2 Pa	Cs %	Vs %	Oil content %	Kf
2600	1.84	42	2.8	0.5	9	11	25	6/13	0.2	30	6	0.1001
2700	1.81	40	2.8	0.5	10	10.5	25	6/13.5	0.2	30	7	0.098
3240	1.89	44	2.6	0.5	9	11.5	24	6/14	0.2	30	8	0.083

Table 8 The performance of oil-in-water drilling fluid in Xinsha23-1H

Well depth m	ρ g/cm3	FV s	FL ml	K mm	pH	YP Pa	PV mPa.s	G1/G2 Pa	Cs %	Vs %	Oil content %	Kf
2008	1.89	40	3.8	0.5	9	10	23	5.5/13.5	0.2	31	5	0.1267
2433	1.90	41	3.0	0.5	9	15	23	11/16.5	0.2		9	0.1183
2722	1.90	42	2.6	0.5	9	14.5	25	8.5/18	0.2	33		0.1183
2942	1.93	42	2.4	0.5	9	14.5	26	9/18	0.2	34	10	0.1183

Since western Sichuan middle and low layer horizontal wells drilled in the multi-layer bit prone to collapse, and contains a large section of soft shale drilling test easily swelling necking or off the block, to the anti-drilling collapse has brought great difficulties, oil in water drilling fluid and zwitterionic polysulfonate drilling fluid in three wells enlargement rate with conventional comparison shown in Table 9.

Table 9 Table of test wells and non-test wells well bore stabilizing effect

No	Well number	Drilling fluid	Kickoff point m	well diameter enlargement ratio %	Remark
1	Xinsha 2H	Zwitterionic polysulfonate drilling fluid	2163	14.82	Non-test well
2	Xinsha311H	Zwitterionic polysulfonate drilling fluid	1951	14.55	Non-test well
3	Xinsha 21-1H	Oil-in-water drilling fluid	1810	14.50	Test well
4	Xinsha 23-1H	Oil-in-water drilling fluid	1980	11.10	Test well
5	Xinsha 21-3H	Oil-in-water drilling fluid	1730	11.09	Test well

Remark: The range of well diameter enlargement ratio is 100m range of kickoff point.

From the date in Table 9, before the apply of new drilling fluid system and borehole stability technology, the average single well hole enlargement ratio was 14.69%. After using the oil-in-water drilling fluid system average single well hole enlargement ratio was 12.23%, representing a decrease of 16.75%, indicating that the oil-in-water drilling fluid system has a strong inhibitory effect and efficient anti-collapse, well hole stability improved significantly.

After field application shows in Table 10, low density oil-in-water drilling fluid was optimized, prevention and treatment technology complexities of the construction process in shallow horizontal wells have strong adaptability, and achieved good results. The average net drilling utilization from

35.82% ↗54.67%, and increase of 52.6%, significantly shortening the period of the horizontal well drilling.

Table 10 Test wells and non-test wells complexities fact table

No	Well number	Well depth m	Pure drilling efficiency %	Drilling period d	Remark
1	Xinsha 2H	3232	38.40	110.49	Non-test well
2	Xinsha 311H	3010	33.24	139	Non-test well
3	Xinsha 21-1H	2940	52.15	75.42	Test well
4	Xinsha 23-1H	3240	57.02	91.02	Test well
5	Xinsha 21-3H	2942	54.74	53.81	Test well

Conclusions

Single emulsifier can't emulsified crude oil well, can't form stable oil-in-water emulsion system, while the use of complex ways to emulsify the effect of the original to be significantly more, including OP-10 + SP-80 ratio of 3: 2 complex was the best method.

The OP-10+SP-80 complex emulsifier system incorporated into conventional drilling fluid to form an oil-in-water drilling fluid has a good compatibility, it has high temperature stability, cake sticking coefficient was 0.0930 ~ 0.1014, extreme pressure lubrication coefficient was 0.1885 ~ 0.2255, viscosity coefficient was 0.0262 ~ 0.0437, below the horizontal drilling design requirements and can meet the needs of horizontal drilling wells.

Three wells test in field show, oil-in-water drilling fluid system has good rheological and lubricating properties, the average single well hole enlargement rate was 12.23%, representing a decrease was 16.75%, the average net drilling utilization from 35.82% up to 54.67%, an increase of 52.6%, shortening the period of the horizontal well drilling significantly.

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