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Selection of key additive materials for white oil – based drilling fluids

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ABSTRACT

The selection of key additive materials for a new type of oil-based drilling fluid was studied in this paper. The oil-based drilling fluid can strengthen well walls and ensure safety. It is suitable for high-temperature and high-pressure wells, deep wells and ultra-deep wells. A new type of high-temperature white oil-based drilling fluid was prepared by using 5# white oil as continuous phase, HIS as thickening agent, SDBS as emulsifier, and asphalt powder oxidized at 180°C as filtration agent. The results showed that the saturation concentration of sodium dodecyl benzene sulfonate (SDBS) was 4%, the saturation concentration of asphalt powder oxidized at 180°C was 4%, the saturation concentration of Tween-80 was 10%. The final resistance of high temperature and high pressure oil based drilling fluid formulation material is: No. 5 white oil + 4% SDBS + 5% modified bentonite + 4% asphalt powder oxidized at 180°C + 10% Tween-80 + 1.5% Barite + CaO. The performance evaluation of the new oil-based drilling fluid shows that shale expansion is 0.21mm, anti-temperature up to 220°C, and anti-pollution ability is good. The rheological properties, resistance of high-temperature high-pressure have been greatly improved. Therefore, the new white oil-based drilling fluid can resistance of high-temperature and also has low toxicity, which can meet the exploration and development of more complex wells.

Keywords: White oil-based drilling fluid; selection; formulation; high temperature resistance; rating of merit.

1. INTRODUCTION

Oil-based drilling fluids contain different types of oil, water and a variety of treatment additive materials. Compared with water-based drilling fluid, it has the advantages of strong hydration dispersion inhibition, better lubrication effect, reservoir protection performance, high temperature and pollution resistance. It has been widely used in the exploration and development of complicated wells such as high temperature and pressure wells, extended displacement horizontal wells and so on. Wenbo ZHANG *et al*. [1] developed an oil-based drilling fluid system and applied it in Xinjiang Oilfield, China. The field application shows that the oil-based drilling fluid can significantly reduce the expansion, improve the borehole stability of mud shale formation, and effectively avoid formation damage, which is conducive to reservoir protection. The field performance of oil-based mud also proves that the system has good stability and strong inhibition. TAUGBØL *et al*. [2] prepared a MBS (micro-barite) oil-based drilling fluid, its formula is: white oil + 1825Kg/m^3 micro-barite + 50Kg/m^3 emulsifier + 10Kg/m^3 organic soil + 20Kg/m^3 lime + 15Kg/m^3 calcium chloride solution + 12Kg/m^3 filtration reduction agent. When the temperature is 175°C and the pressure is 96.5mPa, the plastic viscosity is 36cp, the filtration volume is 3.8ml, and the circulating equivalent density is small, which can effectively meet the complex conditions of the underground hole. FOSSUM *et al*. [3] prepared a low solid phase oil-based drilling fluid (LSOBM) with the following formula: White oil + 30Kg/m^3 emulsifier + 10Kg/m^3 liquid resin organic matter filtration reduction agent + 10Kg/m^3 high-quality organic soil + 161Kg/m^3 water + 362Kg/m^3 calcium bromide brine + 10Kg/m^3 lime + 120Kg/m^3 dolomite + 20Kg/m^3 graphite. The drilling fluid used a high density calcium bromide saline solution and liquid resin organic matter instead of natural asphalt as a filtrate reduction agent. Laboratory tests have shown that LSOBM drilling fluids have better pluggeability and higher permeability recovery values than conventional oil-based drilling fluids.

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In today's world oil and gas drilling, due to the expansion of exploration fields and the development of deep layers, drilling high temperature and high pressure wells (predicted or measured bottom hole temperature greater than 150°C and bottom hole pressure greater than 68.9mPa or formation pore pressure greater than 1.80g/cm^3, known as high temperature and high pressure wells) has become one of the most prominent problems in drilling operations. Traditional drilling fluids are divided into water-based and oil-based drilling fluids. Oil-based drilling fluids are a growing trend. Although the cost of each well is relatively high, the cost is lower in the case of multiple wells because they can be reused. Water-based drilling fluid has low cost per unit, but it can not be reused and has certain pollution, so it is difficult to deal with it. Compared with water-based drilling fluid, oil-based drilling fluid has many advantages such as resistance to high temperature, resistance to salt and calcium invasion, good lubrication and less damage to oil and gas reservoirs.

At present,with the improvement of drilling technology and material science, the advantages of oil-based drilling fluid has become increasingly prominent. Back in the middle of the last century, Europe and the United States are very concerned about this field so that various oil - based drilling fluids have been developed and successfully applied in practice. Now, oil-based drilling fluid has been used in Texas oilfield in the United States and Alberta oilfield in Canada, achieving a good result, which, hereafter, also has been promoted successfully in West Africa, in Mexican ports, in China, Adriatic oilfield in Italy and other regions [4–6]. But the oil-based drilling fluid used in large-scale has high toxicity, easy to cause serious pollution so that experts have done more the research on white oil-based drilling fluid which is environment-friendly, efficient and non-toxic [7–9]. ZHOU *et al*. [10] fabricated a white oil-based drilling fluid system with an 80:20 oil/water ratio whose maximum working temperature was 120°C. Qiang LAN *et al*. [11] prepared a clay-free whole-oil drilling fluid with strong resistance to water, soil and salt pollution with good performance of shale inhibition and stabilization of the wall. Guiyou HUA *et al*. [5] prepared a kind of drilling fluid system based on No.5 white oil and aqueous solution of 25% calcium nitride which can resistant to 120°C high temperature. Wen ZHAO *et al*. [12] selected oligomer surfactants 3#MOEMUL and 4#MOEMUL to conduct a control experiment, and 3#MOEMUL was selected as emulsifier of the oil-based drilling fluid of high temperature resistant and high density in the final experiment.The high density oil-based drilling fluid system with high temperature resistance can withstand up to 170°C. Ruiyong TU and LIU [13] prepared an oil-based drilling fluid with a maximum operating temperature of 165°C and good settlement stability, and carried out field tests to meet the operational requirements of the field. Xiaowei SONG *et al*. [14] evaluated the main emulsifier, auxiliary emulsifier, and filtration loss reduction agent selected in the laboratory through comprehensive indexes such as emulsification efficiency and rheology, and evaluated the high-temperature resistant organic soil selected in the laboratory through rheology parameters, and constructed an oil-based drilling fluid system that could withstand the drilling operation requirements of 200°C.

From the above we can see, the temperature resistance of these white oil-based drilling fluids is less than 200°C, so that its use in the oil field is limited. The gelling rate and the viscosification with the existing organic bentonite are low. Therefore, in this paper, according to the special conditions encountered in the modern drilling process, a new type of bentonite material which is suitable for white oil drilling fluid is prepared. Through the selection of various additives, a new white oil based drilling fluid system is established. A new type of high temperature resistant white oil-based drilling fluid was prepared by using 5# white oil as continuous phase, HIS as thickening agent, SDBS as emulsifier, and asphalt powder oxidized at 180°C as filtration agent. In view of the characteristics of the drilling fluid formula, the oil-based drilling fluid with resistance to 220°C is preferably prepared for additive material types and dosages of the white oil-based drilling fluid. The preparation of the drilling fluid provides new ideas for the development of new, high temperature resistance and ecologically friendly oil-based drilling fluids.

2. EXPERIMENTAL

2.1. Materials and equipment

The following materials were used for the experiments: 5# white oil was provided by Panjin Xinanyuan Chemical Industry Co, Ltd. Bentonite of Panjin was offered by Shenyang Taiouke Chemical Co. Ltd. (Liaoning, China). Sodium bentonite,bentonite under the Oil Companies Material Association standard (OCMA), bentonite under the American Petroleum Institute standard (API) were provided by Shandong Huayi Bentionite Co, Ltd (Shandong, China). Calcium oxide, dodecyl trimethyl amine bromide (DTAB), sodium dodecyl benzene sulfonate (SDBS), sorbitan monooleate (SP-80),sorbitol anhydride fatty acid ester (SP-85), polyethylene glycol sorbitan monolaurate (Tween-20) and polyoxyethylene sorbitol mono ester (Tween-80) were supplied by Sinopharm Group Chemical Reagent Co, Ltd (Beijing, China). Asphalt powder is produced by oxidation at 150°C and 180°C was supplied by Hengshui Zehao Rubber Chemical Co, Ltd. Lignite resin was furnished by Renqiu Chemical Co. Ltd. Carboxymethylcellulose sodium (CMC) was provided by Foshan Special Chemical Co, Ltd.

Table 1: Preparation of bentonite.

PREPARATION CONDITION			STEPS OF PREPARATION		
SODIUM BENTONITE (G)	DISTILLED WATER (ML)	WATER BATH CONDITION (°C)	The unmodified solution was obtained by stirring	Then 100% DTAB was added	The modified bentonite was obtained and named HIS
100	1000	65			

Table 2: Formulation optimization.

INVESTIGATE THE ADDED DOSE				MEASURE OF PROPERTIES
HIS	SDBS	asphalt powder oxidized at 180°C	Tween-80	Demulsification voltage
3%	1%	1%	0%	Plastic viscosity (PV)
4%	2%	2%	5%	Apparent viscosity (AV)
5%	3%	3%	10%	Yield point (YP)
6%	4%	4%	15%	Filtration loss
7%	5%	5%		

Note: Yield point: The yield point is a point on stress-strain curve which indicates the limit of elastic behavior and the beginning of plastic behavior.
Yield strength: The yield strength is the material property defined as the stress at which a material begins to deform plastically whereas yield point is the point where nonlinear.

The barite was provided by Lingshou Hengyang Mineral Processing Factory. (Hebei, China). BT838 bentonite (The content of montmorillonite is greater than 90%, Apparent Viscosity (AV) is 20 mPa·s, The pH value is 6) supplied by Zhejiang Tianlong Organic Bentonite Co, Ltd (Zhejiang, China).

The following equipments were used for the experiments: GZX-9023 digital blower drying box (Shanghai Boxun Petroleum Machinery Manufacturing Co, Ltd), GTD-B12K variable frequency high speed mixer and GGS-42 high temperature and high pressure filter (Qingdao Hongxiang Petroleum Machinery Manufacturing Co, Ltd), DK-98-IIA electric constant temperature water bath pot (Tianjin Taisite Co, Ltd), TG16-WS table top speed centrifuge (Hunan Xiangyi Experimental Instrument Development Co, Ltd), ZNN-D6 rotational viscometer (Qingdao Senxin Mechanical and Electrical Equipment Co, Ltd) following materials were used for the experiments.

2.2. Method

Preparation of bentonite (Table 1). The 100g sodium bentonite was put into 1000ml distilled water and then was stirred up to make an unmodified solution under the water bath condition of 65°C. Then 100% DTAB was added into bentonite solution in order to modify bentonite well. The modified bentonite was named HIS.

Formulation optimization (Table 2). In this paper, the experiments were carried out in the HIS concentration range of 3%, 4%, 5%, 6%, 7%, the concentration of SDBS range of 1%, 2%, 3%, 4%, 5%, the concentration of asphalt powder oxidized at 180°C range of 1%, 2%, 3%, 4%, 5%, and the concentration of Tween-80 range of 0%, 5%, 10%, 15%. The following properties were measured: demulsification voltage, Plastic Viscosity (PV), Apparent Viscosity (AV), Yield Point (YP), and filtration loss in order to get the best formula of drilling fluid.

2.3. Experimental setup and operating conditions

(1) Demulsification measurement. The test solution was stirred in the high-speed mixer at 10,000 rpm/min for 10 minutes, heated to 50°C ± 0.2°C [15]. Then the drilling fluid was putted into cup. The drilling fluid was stirred for 30 seconds then stewed for 1minute. The experiment was repeated for three times, taking the calculation of the average number of ways to calculate.

(2) Rheology measurement. The speed of the six speed rotary viscometer was adjusted to 600 rpm/min, after the digital display window is stable, the data was recorded named Φ600 (Φ:Yield Strength).When the speed was 300 rpm/min, the data was named Φ300 [16].

$$AV = \frac{1}{2}\phi_{600}$$
$$PV = \phi_{600} - \phi_{300}$$
$$YP = \phi_{300} - \frac{1}{2}\phi_{600}$$

(3) High Temperature and High Pressure (HTHP) loss measurement. The drilling fluid was putted in the cup. The pressure was adjusted to 3.5Mpa and the temperature was raised to 220°C. The out of switch under the instrument was opened to accept the filtrate. The data was recorded.

(4) Performance evaluation. In order to test the performance of the drilling fluid, the following properties were measured: plastic viscosity, yield point, dynamic ratio, API filtration loss and HTHP filtration loss.

3. RESULTS AND DISCUSSION

3.1. Effect of the bentonite concentration

With the comparison of AV, PV, YP, Φ6 / Φ3 performance on HIS, OCMA, API, BT838, and organic soil, the conclusion should be drawn that the gelling rate was less than 85% and the demulsification voltage of the drilling fluid decreased to below 1600V when the OCMA, BT838, API or organic soil were added into drilling fluid. But when the HIS was added into the white oil-based drilling fluid, it can keep the demulsification voltage more than 1900V, even it can also keep above 2000V after aging. Therefore, HIS was selected as bentonite of the oil-based drilling fluid. The rheology, filtration loss and demulification voltage under the condition of different concentrations of HIS (3%,4%,5%,6% and 7%) were investigated for the purpose of getting the best concentration of HIS. The results were shown in Table 3, Figure 1 and Figure 2.

Table 3: Effect of HIS concentration on rheology of drilling fluid.

CONCENTRATION OF HIS		AV (mPa·s)	PV (mPa·s)	YP (Pa)	Φ_6 / Φ_3
3%	Before aging	30.35	13.4	16.95	0
	After aging	50.65	27.3	23.35	0
4%	Before aging	37.7	18.4	19.3	2
	After aging	59.75	29.6	30.15	5
5%	Before aging	53.8	28.9	24.9	5
	After aging	77.3	45.8	31.5	8
6%	Before aging	57.65	31.7	25.95	5
	After aging	82.55	50.6	31.95	8
7%	Before aging	60.55	32.3	28.25	5
	After aging	81.75	50.9	30.85	8

Note: #5 white oil + HIS; aging at 220°C for 24h.
(The speed of the six speed rotary viscometer was adjusted to 6 rpm/min, after the digital display window is stable, the data was recorded named Φ6.When the speed was 3 rpm/min, and the data was named Φ3.)

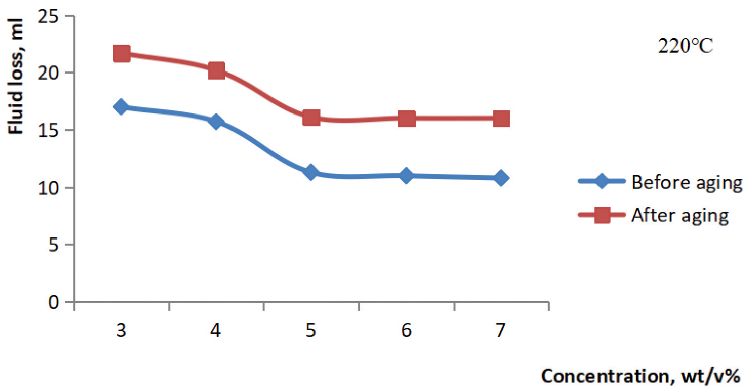

Figure 1: Effect of HIS concentration on filtration loss of drilling fluid.

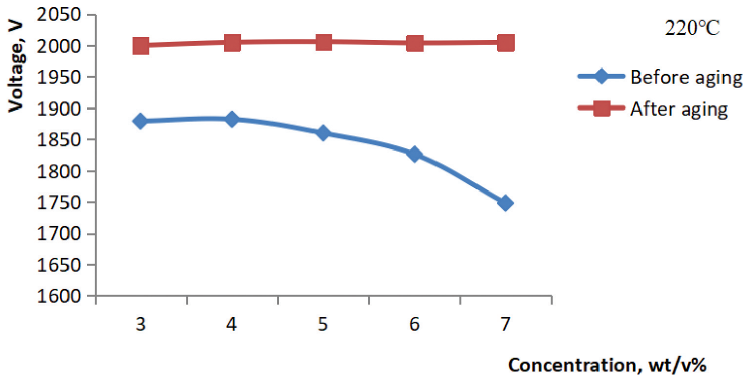

Figure 2: Effect of HIS concentration on demulsification voltage of drilling fluid.

Table 4: Effect of SDBS concentration on rheology of drilling fluid.

CONCENTRATION OF SDBS		AV (mPa·s)	PV (mPa·s)	YP (Pa)	Φ_6 / Φ_3
1%	Before aging	24.05	18.4	5.65	0
	After aging	37.15	29.6	7.55	0
2%	Before aging	27.7	19.6	8.1	0
	After aging	40.75	29.3	11.45	0
3%	Before aging	31.15	22.3	8.85	1
	After aging	44.4	31.1	13.3	1.25
4%	Before aging	46.95	35.5	11.45	1
	After aging	60.3	42.3	18	1.5
5%	Before aging	48.9	36.7	12.2	1
	After aging	63.35	45.3	18.05	1.5

Note: #5 white oil + 5% HIS + SDBS; aging at 220°C for 24h.

The results of rheology were shown in Table 3. Whether before aging or after aging, all above the apparent viscosity, plastic viscosity, yield point, there was all had a growing trend. Φ6 / Φ3 rose with the concentration of the bentonite increasing, but Φ6 / Φ3 remained unchanged when the bentonite was equal to or higher than 5%. It showed that 5%, 6%, and 7% could meet the demand of rheological dynamic shear stability.

It can be seen in Figure 1 that before aging, the filtration loss of the drilling fluid reduced obviously with the concentration of HIS increasing from 3% to 5%. Then with the increasing of the concentration of HIS, the filtration loss basically didn't changed; and after aging, the filtration loss decreased from 21.5ml to 17.5ml when the concentration of HIS increased from 3% to 5%, and it can keep above 17.5ml when the concentration of HIS was more than 5%. So 5% might be the best concentration.

The similar results can be seen in Figure 2. Before aging, the demulsification voltage of the drilling fluid gradually reduced but it can stay constant more than 1850V with the increasing of the concentration of HIS from 3% to 5%. It could be under 1850V when the dosage was more than 5%; but after aging, it basically remained unchanged and it can also stay constant 2000V. Therefore, 5% HIS was the best concentration.

3.2. Effect of the emulsifier concentration

In this paper, under normal temperature and pressure, the concentration of SP-80, SP-85, SDBS, Tween-80, and Tween-20 were optimized at a concentration of 2% as emulsifier through the investigation of demulsification voltage. The results showed that the demulsification voltage of them respectively were 410V, 390V, 800V, 350V, and 270V. It only SDBS can keep demulsification voltage above 800V. Therefore, SDBS was selected as the emulsifier of the drilling fluid. The rheological and demulsification voltage of different concentrations of SDBS (1%, 2%, 3%, 4%, 5%) were measured in order to get the best concentration of the emulsifier. The results were shown in Table 4. and Figure 3.

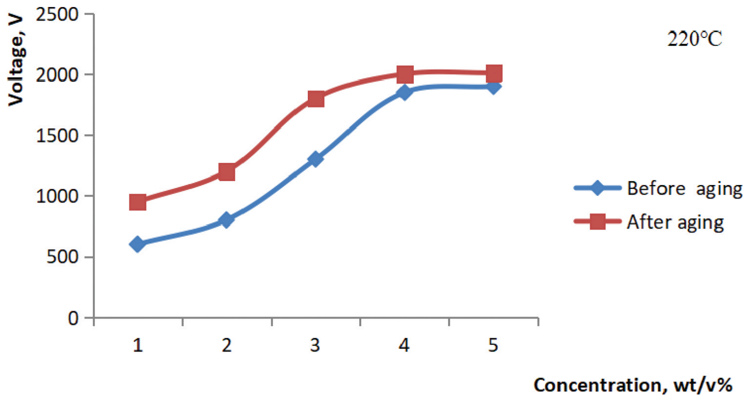

Figure 3: Effect of SDBS concentration on demulsification voltage of drilling fluid.

As shown in Table 4. whether before aging or after aging, with the increasing of the concentration of SDBS, all above apparent viscosity, plastic viscosity and yield point there was a downtrend. But Φ6 / Φ3 increased firstly then kept stable. Before aging, Φ6 / Φ3 remained unchanged when the concentration reached 3%. And after aging, Φ6 / Φ3 remained unchanged when the concentration reached 4%. So 3% and 4% met the temperature requirement.

To ensure the best concentration of SDBS, demulsification voltage was measured. As shown in Figure 3, whether after aging or before aging, demulsification voltage increased rapidly when SDBS dosage increased from 1% to 4%, but it changed a little bit when the dosage increased from 4% to 5%, which indicated that the addition of 4% SDBS can maintain the electrical stability of the drilling fluid. Therefore, the saturation concentration of SDBS was 4%.

3.3. Effect of the filter loss agent concentration

Asphalt powder oxidized at 150°C, asphalt powder oxidized at 180°C, refikite, and CMC are filter loss agents of white oil-based drilling fluid selected in the experiment. The results showed that the filtration loss of the fluid can keep below 9ml with asphalt powder oxidized at 180°C and the others' were all above 11ml. So asphalt powder oxidized at 180°C was selected as the filter loss agent of the oil-based drilling fluid. The rheological and API filtration loss of different amounts of the asphalt powder oxidized at 180°C (1%, 2%, 3%, 4%, 5%) were measured in order to determine the amount of asphalt powder oxidized at 180°C. The results were shown in Table 5, Figure 4 and Figure 5.

It can be seen from Table 5 that apparent viscosity, plastic viscosity, and yield point had a growth trend before aging. And they had a downtrend after aging. Whether before aging or after aging, Φ6 / Φ3 increased

Table 5: Effect of asphalt powder oxidized at 180°C concentration on rheology of drilling fluid.

CONCENTRATION OF ASPHALT POWDER OXIDIZED AT 180°C		AV (mPa·s)	PV (mPa·s)	YP (Pa)	Φ_6 / Φ_3
1%	Before aging	56.25	34.9	21.35	1
	After aging	95.35	50.1	45.25	1.5
2%	Before aging	61.65	37.1	24.55	1.5
	After aging	93.25	49.5	43.75	2
3%	Before aging	63.35	37.2	26.15	1.7
	After aging	92.35	49.6	42.75	1
4%	Before aging	73.05	40.4	32.65	2
	After aging	87.75	50.4	37.35	2.2
5%	Before aging	76.45	41.1	35.35	2
	After aging	86.55	48.1	38.45	2.4

Note: #5 white oil +5% bentonite + 4% SDBS + asphalt powder oxidized at 180°C; aging at 220°C for 24h.

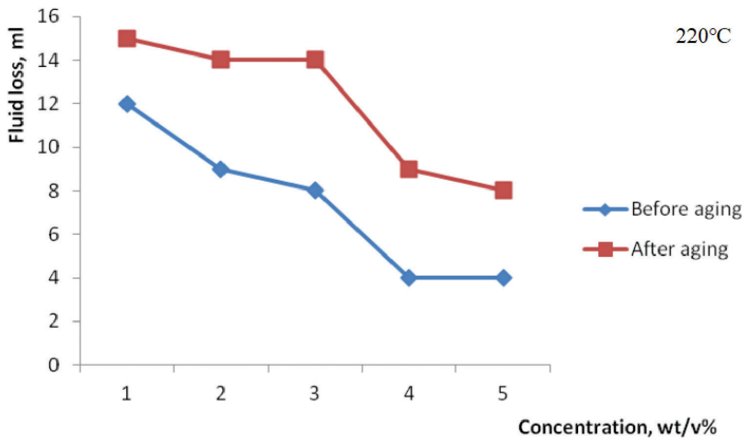

Figure 4: Effect of asphalt powder oxidized at 180°C concentration on API filtration loss of drilling fluid.

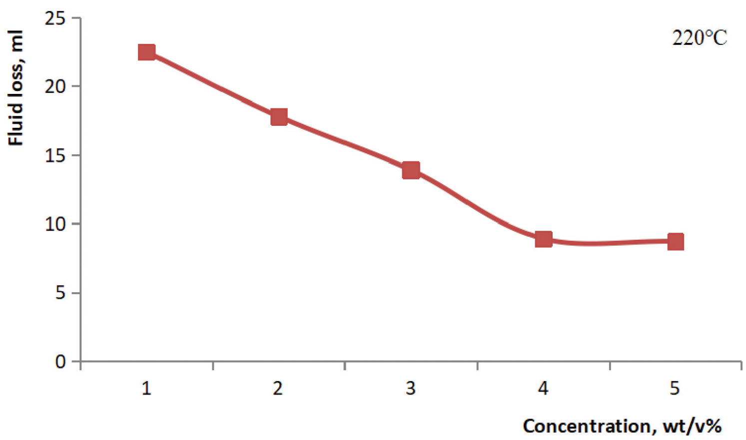

Figure 5: Effect of asphalt powder oxidized at 180°C concentration on HTHP filtration loss of drilling fluid.

obviously. But when the concentration was equal to or higher than 4% it remained unchanged. Therefore, 4% and 5% of asphalt powder oxidized at 180°C satisfied requirements of drilling fluid.

According to Figure 4 whether before aging or after aging, API filtration loss of drilling fluid decreased obviously when the concentration of asphalt powder oxidized at 180°C increased from 1% to 4%. But when the concentration was more than 4%, API filtration loss decreased smoothly. It showed that 4% was the saturation dosage.

In order to confirm the temperature resistance of the drilling fluid, HTHP filtration loss was measured. As Figure 5 showed that HTHP filtration loss decreased from 21.5ml to 9.5ml when the concentration increased from 1% to 4%. But it basically remained unchanged when the concentration was more than 4%. Therefore, the saturation concentration of the asphalt powder oxidized at 180°C was 4%.

3.4. Effect of the wetting agent concentration

Tween-80, PA-VERT (A mixture of cationic surfactants and betaine type surfactants as a wetting agent) and FB-MOWET (A mixture of anionic surfactants and betaine type surfactants as a wetting agent) were selected as wetting agents of white oil-based drilling fluid. The results showed that the suspensions of PA-VERT and FB-MOWET were fewer than 85%, only Tween-80 can keep the suspension above 85%. Therefore, Tween-80 was selected as the wetting agent of the white oil-based drilling fluid. In order to determine the optimum concentration of Tween-80, the rheology of the oil-based drilling fluid was measured. The results were shown in Table 6.

From the results in Table 6 whether before aging or after aging, when the concentration of Tween-80 increased from 0% to 10%, apparent viscosity, plastic viscosity, yield point and Φ6 / Φ3 decreased smoothly. But they decreased rapidly when the concentration increased from 10% to 15%. Therefore, we can conclude that the saturation concentration of Tween-80 was 10%.

Table 6: Effect of TWEEN-80 concentration on rheology of drilling fluid.

CONCENTRATION OF TWEEN-80		AV (mPa·s)	PV (mPa·s)	YP (Pa)	Φ_6 / Φ_3
0%	Before aging	73.05	40.4	32.65	2
	After aging	87.75	50.4	37.35	2.2
5%	Before aging	70.7	41.4	29.3	2
	After aging	86.25	49.6	36.45	2
10%	Before aging	65.35	40.3	25.15	1.7
	After aging	82.75	48.4	34.35	2
15%	Before aging	40.05	26.4	13.65	1
	After aging	51.35	33	17.65	1

Note: #5 white oil + 5% bentonite + 4% SDBS + 4% asphalt powder oxidized at 180°C + TWEEN-80; aging at 220°C for 24h.

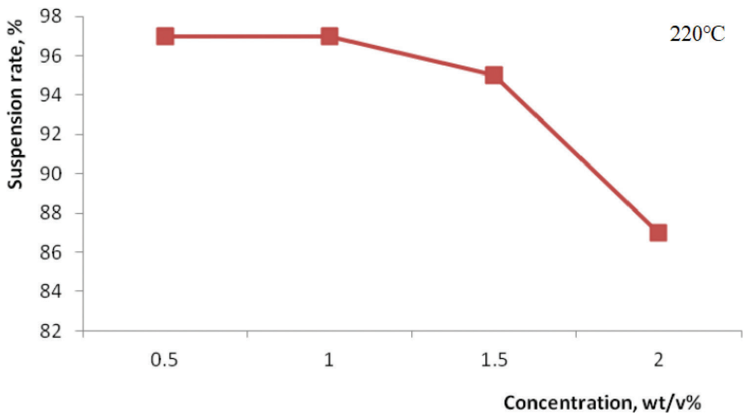

Figure 6: Effect of Tween-80 concentration on suspension of barite.

3.5. Effect of the barite concentration

Barite, as the weighting agent in drilling fluid, has a great influence on the rheology and stability of drilling fluid. Therefore, the concentration of barite is selected to obtain the best concentration of barite. 0.5%, 1%, 1.5% and 2% of the barite was respectively added into the drilling fluid solution then full mixing and standing for 1h. The results were shown in Figure 6.

As shown in Figure 6, the suspension dropped gradually from 97% to 95% when the amount of barite increased from 0.5% to 1.5%. But the suspension decreased significantly to 87% when the amount of the barite was 2.0%. Therefore, 10% Tween-80 can maintain the stability of 1.5% barite.

4. PROPERTIES OF THE DRILLING FLUID

The drilling fluid was compounded after optimal the amount of additives. In this paper, the performances of the new white oil-based drilling fluid are compared with that of the traditional oil-water formulation (oil + 20~25Kg/m^3 PF-MOGEL (Modified organic soil) + 25~30Kg/m^3 PF-MOEMUL (Emulsifier, a mixture of two kinds of anionic surfactants) + 20~25Kg/m^3 PF-MOCOAT (Coemulsifier, anionic surfactant) + 20~30Kg/m^3 PF-MOWET (Wetting agent, nonionic surfactants) + 20~25Kg/m^3 PF-MOALK (Alkalinity regulator) + 20~30Kg/m^3 PF-MOTEX (Oxidation hard bitumen powder) + 2~5Kg/m^3 PF-MOHSV (Flow pattern regulator) + $CaCl_2$ [17]). The results showed as Table 7.

As shown in Table 7 that apparent viscosity of the new drilling fluid was increased by 17%, plastic viscosity increased by 22% and dynamic ratio increased by11% after aging at 220°C. It can be concluded that the rheology of the drilling fluid can be guaranteed. Whether before aging or after aging, the demulsification voltage of new type drilling fluid was more than 2000V, which showed that the new drilling fluid had good stability and various additives can not affect the voltage of the drilling fluid. After aging, the API filtration loss increased from 3ml to 6ml and HTHP filtration loss remained at 6ml, which indicated that the drilling fluid had good resistance to high temperature. It was found that the overall performances of the new drilling fluid were in accordance with the technical requirements of drilling fluid performances.

Table 7: Rheological parameters of different type of drilling fluid.

TYPE		PV (mPa)	AV (mPa·s)	YP (Pa)	DYNAMIC RATIO	API FILTRATION LOSS (ml)	HTHP FILTRATION LOSS (ml)	DEMULSIFICATION VOLTAGE (V)	PRICE
Oil-based drilling fluid	Before aging	36.3	80.4	44.1	2.25	3	6	>2000	186 rmb/m
	After aging	44.5	94.1	49.75	2.06	6	6	>2000	
Oil-water drilling fluid [17]	Before aging	25.6	60.2	69.3	1.01	3	6	>1400	232 rmb/m
	After aging	30.5	70.8	71.6	1.08	6	6	>1400	
Requirements [18]	Before aging	15–60	>20	≥PV	>0.36	<8	<20	>400	–
	After aging								

5. CONCLUSIONS

Through the selection of various additive materials, the new white oil-based drilling fluid system was established. 5# white oil was used as the continuous phase, HIS was used as thickener, SDBS was used as emulsifier, and asphalt powder oxidized at 180°C was used as filter loss agent in the new high-temperature white oil-based drilling fluid.

The optimal formulation of the new oil – based drilling fluid was developed by selection the design of SDBS, HIS and asphalt powder oxidized at 180°C. The final formula material of the oil-based drilling fluid studied in this paper is determined as: #5 white oil + 4% SDBS + 5% HIS + 4% asphalt powder oxidized at 180°C + 10% Tween-80 + 1.5% Barite + CaO.

Compared with the traditional water-in-oil drilling fluid formula, the oil-based drilling fluid has been significantly improved in rheology and high temperature resistance.

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