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Petroleum & Petrochemical Engineering Journal
ISSN: 2578-4846

The Research of Polymer Film-Forming Plugging Agent for Drilling Fluid

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Research Article

Volume 3 Issue 2

Received Date: April 22, 2019

Published Date: May 14, 2019

DOI: 10.23880/ppej-16000187

Abstract

In order to improve the film-blocking and anti-collapse of water-based drilling fluid, a polymer emulsion polymer film-forming plugging agent LWFD containing multiple adsorption groups was synthesized by emulsion polymerization. The effects of the agent on the rheological properties of polysulfonate and cationic drilling fluids, API fluid filter loss, lubricity, film-forming plugging properties, and their temperature and salt resistance are evaluated in the laboratory. The experimental results show that the agent has little effect on the rheological property and fluid filter loss of polysulfonate and cationic drilling fluids, and can improve lubricity by more than 30%. It has good film-forming and plugging property for sand discs with different permeability and its temperature resistance is 130 ° C, salt resistance is 10%. When the agent is combined with the inorganic nano-blocking agent NMFD, it can improve its film-forming and plugging property. Having been tested in an oil field in Fuling, Chongqing, the results show that the rheological property of the drilling fluid is basically unchanged after adding LWFD and NMFD in polymer drilling fluid during vertical well section, and API fluid loss and filter loss of the sand disc are significantly reduced. It shows that the film-forming blocking agent LWFD has good film-forming and plugging property.

Keywords: Film-forming plugging agent; Emulsion polymerization; Rheology; Lubrication coefficient; Sand filter loss

Introduction

The development and utilization of shale gas is a hot topic in the current oil industry in China and worldwide. The well wall is unstable due to extremely easy hydration expansion of mud shale. Therefore, oil-based drilling fluid is used in shale gas development widely. However, oil-based drilling fluids are highly polluting to the environment. It's difficult to treat cuttings subsequently. For these reasons, their application is limited. Especially after the implementation of the new environmental protection law, the research and application of new environmentally friendly water-based drilling fluids that can replace oil-based drilling fluids has become a top priority. Companies such as Halliburton and Baker Hughes have developed polymer film-forming plugging agents, inorganic nano-blocking agents and correspondingly high-performance water-based drilling fluid systems which have successful application in the United States, China, Canada and other countries during shale gas development [1,2]. The technology is to add one or several film-forming plugging agents to water-based drilling fluid, so that drilling fluid can form a dense semi-permeable or separator membrane on surface of mud shale, thereby effectively blocking pores and cracks of shale, preventing shale hydration expansion caused by collapse of well wall [3,4].

Film-forming blocking agents can be roughly classified into polymer film-forming blocking agents and inorganic nano-blocking agents. The inorganic nano-blocking agent has no deformability capability, and its formation adaptability is poor. It has a problem that its agglomeration becomes large in aqueous solution and loses its plugging capability to layer [5,6], thus limiting its use. The polymer film-forming plugging agent has excellent deformation and adsorption capability. It preferentially adsorbs pores and cracks on the surface of wellbore to form a polymer film. It has been reported both in the domestic and overseas [6-10]. The combination of nano-blocking agent and polymer film-forming plugging agent can effectively improve strength of plugging membrane and the size range of crack and pore. Polymer film-forming plugging agent is the most critical technology for high-performance drilling fluid. It is expensive and its cost is higher than oil-based drilling fluid. Thus, it is necessary to study this type of treatment in order to reduce the cost of high performance water-based drilling fluid systems. Based on some concepts of tunnel waterproofing, cement slurry water reduction and wall waterproofing technology, this paper selects adsorption chemical groups, rigid group and long carbon chain adsorption chemical group monomer to synthesize polymer film-forming plugging agent using emulsion polymerization method. To evaluate the effects of conventional water-based drilling fluid rheology, API fluid loss, high temperature and high pressure anti-expansion rate and lubricity, then assesses its film-forming plugging performance using drilling fluid plugging performance evaluation instrument (PPT). A high performance water-based drilling fluid is prepared by compounding a polymer film-forming plugging agent with an inorganic nano-blocking agent and put it on filed trial to investigate its promotion and application capability.

Development of Film Forming Plugging Agent LWFD

Main Ingredient

Styrene (St), butadiene (Bd), acrylic acid (AA), unsaturated fatty acid, initiator (ammonium persulfate), emulsifier, co-emulsifier, all of the above reagents are of analytical grade.

Synthesis Method

St, AA, unsaturated fatty acid are dissolved in deionized water according to the formula ratio at room temperature, emulsifier and co-emulsifier are added, and fully stirred on the emulsion mixer to form a stable white emulsion. Then, transfer it into a three-necked flask equipped with a reflux condensing device, and nitrogen gas is supplied while stirring, and the water bath is heated to a predetermined temperature. The initiator is dissolved in deionized water to form an aqueous initiator solution, and the Bd monomer is added while adding the initiator aqueous solution, controlling the dropping rate and stirring rate of the Bd and the initiator aqueous solution. When the conversion rate reaches 10%-20%, the Bd monomer is added at one time, and the ivory-white liquid film-forming plugging agent LWFD is obtained after the initiator is added completely for 4 hours at constant temperature.

Physical Properties of the Sample

The film-forming agent LWFD has a ivory-white liquid with a density of 0.95-1.03g/cm^3, a pH between 8-9, and a viscosity of 45-48m Pa·s at 25°C.

Performance Evaluation of Film Forming Plugging Agent LWFD

Impact on Conventional Water-Based Drilling Fluid Performance

Add 2% LWFD separately to polymer drilling fluid and cationic water-based drilling fluid that are commonly used in the field, and roll at 120°C for 16h. Measure its rheology, API fluid loss (FLAPI), and lubrication coefficient (K_f) and calculating lubricity improvement rate K_f*. The experimental results are shown in Table 1.

Polymer drilling fluid formula: distilled water + 4% bentonite + 0.15% HV-CMC + 0.1% KPAM + 0.8% LV-CMC + 0.6% LV-PAC, ρ = 1.2g / cm^3.

Cation drilling fluid formula: distilled water + 4% sodium bentonite + 0.2% Na_2CO_3 + 0.2% NaOH + 0.5% cationic polymer + 0.5% LV-CMC + 0.8% modified non-ionic starch + 3% non-ionic lubricant + barite, ρ=1.2g/cm^3.

Drilling fluid	AV/mPa·s	PV/mPa·s	YP/Pa	FLAPI/ml	Kf	Kf*/%
4% Bentonite	8.5	6	2.5	21	0.452	
4%Bentonite+2%LWFD	8	6	2	20.8	0.178	60.6
polymer	31.5	23.5	8	5.1	0.132	
polymer+2%LWFD	30.5	21.5	9	4.9	0.09	31.8
cation	35.5	25	10.5	5.6	0.145	
cation +2%LWFD	34.5	25	9.5	5.3	0.1	31

Table 1: Effect of film-forming plugging agent LWFD on performance of conventional water-based drilling fluid.
Note: The experimental conditions of sand filter loss: 120 ° C, 3.5 MPa, 30 min. The same below.

As can be seen from Table 1: After adding 2% LWFD to the polymer and cationic water-based drilling fluid, the rheology and fluid loss of the drilling fluid decreased slightly, the lubrication coefficient decreased, and the lubricity increased by more than 30%. It indicates that LWFD has little effect on the rheology and fluid loss of drilling fluid, which can improve the lubricity of drilling fluid.

Plugging Performance

Add 2% polymer plugging agent LWFD to the polymer slurry to form a plugging polymer slurry, and roll it together with the polymer slurry at 120°C for 16 h. Select artificial sand discs with permeability of 400mD, 750mD and 2D and measure the filter loss of these two slurries at different times of the two pulps. The smaller the fluid filter loss, the better the film-forming plugging property. The experimental results are shown in Figure 1.

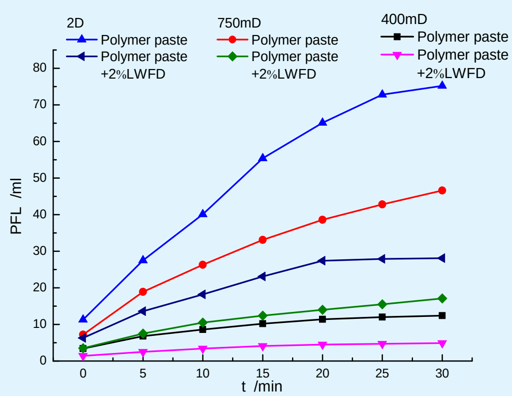

Figure 1: Blocking property of film-forming plugging agent LWFD for different permeability sand discs.

It can be seen from Figure 1 that the smaller the permeability of the sand disc, the smaller the filter loss of sand disc; the filter loss of the film-forming plugging agent LWFD is much smaller than that of the unadded one. It shows that the polymer film-forming plugging agent has good film-forming and plugging property to sand disc, which can well prevent solid phase and liquid phase in drilling fluid from entering wellbore and prevent shale hydration expansion caused by filtrate and keep well wall stable.

Temperature Resistance

2% polymer plugging agent LWFD is added to polymer slurry to form a plugging polymer slurry, which is rolled together with the polymer slurry at different temperatures for 16 h, then measure 750mD sand disc filter loss using a drilling fluid permeability plugging tester (PPT). The smaller the fluid loss, the better the film-forming plugging property. The experimental results are shown in Figure 2.

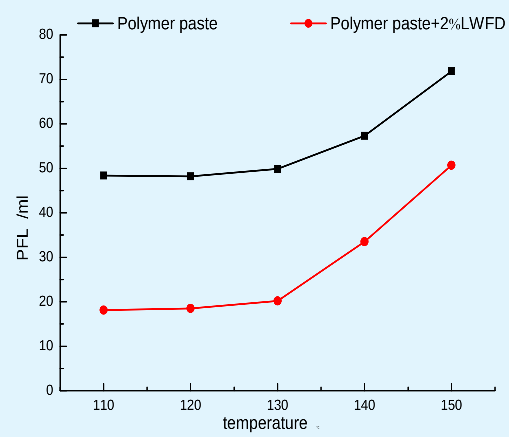

Figure 2: The effect of temperature on film sealing property of LWFD.

It can be seen from Figure 2 that as the temperature increases, the fluid loss of the polymer slurry and the polymer slurry disc with the film-forming plugging agent increases. When the temperature is lower than 130°C, the change is small, while when the temperature is higher than 130°C, the rise is more obvious. However, the fluid loss of the polymer slurry with the film-forming plugging agent is significantly lower than that of the polymer slurry, and the LWFD still has certain film-forming plugging properties. It indicates that the temperature resistance of LWFD is at least 130°C.

Salt Resistance

The polymer drilling fluid is prepared indoors, and 2% polymer plugging agent LWFD is added to form a plugging polymer slurry. NaCl solutions with different concentrations are added to the two slurries, and then rolled at 130°C for 16h to measure filter loss of the 750 mD disc. The experimental results are shown in Figure 3.

It can be seen from Figure 3 that as the amount of NaCl solution creases, the fluid filter loss of the polymer slurry and the polymer slurry disc with the film-forming plugging agent increases. When the amount of NaCl solution is less than 10%, the amount of fluid loss rises little, while when it is higher than 10%, the rise is more obvious. However, the filter loss of the polymer slurry with film-forming plugging agent is significantly lower than that of the uncoated polymer slurry. LWFD still shows a certain film-forming plugging capability. It is indicated that the salt resistance of LWFD is at least 10%.

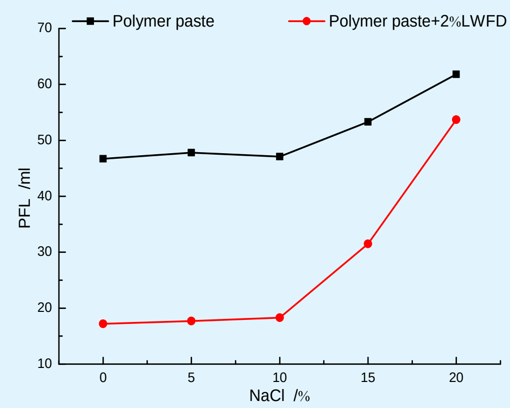

Figure 3: The effect of NaCl on film sealing property of LWFD.

Synergistic Effect with Inorganic Nano-Blocking Agent NMFD

Add 2% LWFD, 2% nano-inorganic plugging agent NMFD and 2% LWFD and 2% inorganic nano-blocking agent NMFD to the polymer slurry, and roll at 130°C for 16 h to measure rheology, fluid loss, lubrication coefficient and the sealing rate(P) of the 750mD sand disc . The experimental results are shown in Table 2.

Drilling Fluid	AV/mPa·s	YP/Pa	FLAPI/ml	Kf	Kf*/%	PFL/ml	P/%
Polymer paste +2%LWFD	27.5	7	4.7	0.125		46.7	
Polymer paste +2%NMFD	31.5	9	4.6	0.081	35.2	17.2	63.2
Polymer paste+2%LWFD+2%NMFD	34.5	10.5	4.6	0.128	-2.4	26.2	43.9
	33.5	9	3.9	0.09	28	11.5	75.4

Table 2: Synergistic effect of film-forming blocking agent LWFD and inorganic nano-blocking agent NMFD.

It can be seen from Table 2 that when the inorganic nano-blocking agent NMFD is added to the polymer base slurry, the apparent viscosity and the dynamic shear force increase rates are higher than that of the LWFD, and the fluid filter loss does not change much. When LWFD and NMFD are applied in combination, the drilling fluid is slightly thickened, the API fluid loss is obviously reduced, and the sealing rate of 750mD sand disc is higher than 75%. This indicates that the combination of the polymer film-forming plugging agent and the inorganic nano-blocking agent can better improve the plugging and anti-collapse capability of the drilling fluid.

Field Application

The polymer film-former LWFD is tested in an oil field in Fuling, Chongqing in July 2018. The test well is a shale gas well with a designed well depth of 3163.5m, a horizontal length of 1001.5m, and a trial well section of 2162~3163.5m. The horizon is the Da'ansai section of the self-sustaining group. The rock composition is gray mud shale and siltstone, stratum and the maximum temperature is 103°C. The drilling fluid in the vertical well section is a conventional polymer system, and the glue formed by adding the polymer film-forming plugging agent LWFD, inorganic nano-blocking agent before entering the inclined section, then convert drilling fluid into a high performance drilling fluid system.

Horizontal section high performance drilling fluid formula: 1.0~1.2% bentonite+ 0.4~0.6% soda ash+ 0.6~0.8% composite multifunctional polymer+ 0.6~0.8% viscosity reducer+ 1.5~2.0%LWFD+ 2.0~3.0%NMFD+ 2.0~3.0% composite plugging agent + 1.5~2.0% polyamine inhibitor + 2.0~3.0% polymeric alcohol+ 2.0~3.0% lubricant+ barite; ρ=1.37g/cm^3.

When LWFD and inorganic nano-blocking agent NMFD are just added to drilling fluid, the drilling fluid became slightly thicker. After 4 hours of circulation, the rheology of drilling fluid returns to normal, and the API fluid loss decreases. The high temperature and high pressure filtration loss and the filter loss of the sand disc also decreases significantly, and there is no block phenomenon during drilling process. It shows that the film-forming plugging effect is good and has further popularization and application value. The performance before and after conversion of drilling fluid is shown in Table 3.

Drilling fluid	FV/s	AV/mPa·s	YP/Pa	PV/mPa·s	FLAPI/ml	FLHTHP/ml	K_f	PFL/ml
Straight well section (before conversion)	65	45.5	11.5	58	3.6	7.6	0.115	31.8
Horizontal well segment (after conversion)	67	46.5	12.5	59	1.1	1.9	0.085	8.5

Table 3: Performance comparison of drilling fluid system before and after conversion in field trial.
Note: High temperature and high pressure fluid filter loss experimental conditions: 110°C, 3.5 MPa, 30 min.

Conclusion

Using a variety of monomers with adsorbing groups, the film-forming plugging agent LWFD was synthesized by emulsion polymerization. The agent basically has no effect on the rheological property and API fluid loss of conventional polymer drilling fluid and cationic drilling fluid, while it can improve the lubricity of drilling fluid by more than 30%. It has good film-forming and plugging property for different permeability sand discs. And the temperature resistance is 130°C, the salt resistance is 10%.

When the film-forming plugging agent LWFD is combined with the inorganic nano-blocking agent NMFD, it can further improve the film-forming plugging property of drilling fluid. The field test results show that the rheological properties change little after adding LWFD and NMFD to conventional drilling fluid. While API fluid loss, high temperature and high pressure fluid filter loss and sand filter loss dropped significantly. There is no falling block during the drilling process, showing good film-forming plugging performance.

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