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Study on the recycling of fuzzy ball bionic drilling fluid

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ABSTRACT

A novel bionic drilling fluid imitating fuzzy bacteria's cell structure was introduced in the present paper, which was named fuzzy ball drilling fluid. The special structure of "one core, two layers, three membranes" makes fuzzy ball bionic drilling fluid have a automatic plugging ability and be able to resist high pressure. The composition of the fuzzy ball bionic drilling fluid can be adjusted according to different formation conditions. The main ingredient of the fuzzy ball bionic drilling fluid is vegetable gelatin and cellulose, so it is atoxic and environmentally safe. The fuzzy ball bionic drilling fluid has been applied successfully in more than 20 wells in China.

Three methods were proposed in this paper to recycle dumped fuzzy ball bionic drilling fluid, which are 1) separating by flocculation and produce low-density cement slurry; 2) separating by gel-breaking and discharge directly; 3)curing directly and produce solid cement. The lab experiments were conducted to study the feasibility of each method. The results show that 1) the cement slurry produced by flocculation separating liquid can satisfy the demand of shallow cementing of wells; 2) the separating liquid by gel-breaking satisfies the secondary standard of "GB8978-96 National Sewage Discharge Standard"; 3) the strength of solid cement produced by curing the dumped fuzzy ball bionic drilling fluid is high enough to be used for further well stimulation, and the leach liquid satisfies the secondary standard of "GB8978-96 National Sewage Discharge Standard". All the three recycling methods can be adopted according to different working conditions.

The research results improved the technical specification of the fuzzy ball bionic drilling fluid and proved a train of thought to recycling the dumped drilling fluid.

KEYWORDS

Fuzzy ball;
Bionic;
Dumped drilling fluid;
Recycling.

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INTRODUCTION

Drilling fluid is the circulatory mediator in the borehole when drilling a well. It can carry cuttings, cool the drilling bit, balance the formation pressure, transfer the hydraulic driving power and so on, due to its importance, it is also called "blood of drilling". However, drilling fluid is the main pollution source of petroleum engineering. The volume of dumped drilling fluid after drilling a 3000-4000m normal well add up to 300m^3 eventually. The investigation of petroleum pollution source by PetroChina in 2008 shows that more than 1.2×10^{10} kg of dumped drilling fluids were produced each year, and half of them were discharge to surrounding environment directly[3]. Nowadays, with the rapid increase of energy demand, many new kinds of drilling fluids come into service, and more toxic additives were emitted into environment. Innocent treatment of drilling fluid is a more and more concerned issue all over the world.

In this situation, imitating the micro structure of fuzzy bacteria, Zheng et al.[8] developed a novel working fluid by mixing Sodium carbonate, Sodium hydroxide, (Sodium Dodecyl Sulfate (SDS),Sodium Dodecyl Benzene Sulfonate (SDBS),hydroxyethyl starch (HES), MW 1.5 million polyacrylamide (PAM) in proper sequence. Because a lot of spherical materials with fuzzy spherical shells are found in the working liquid, it is named "fuzzy ball" working fluid. The fuzz will be broken by high shearing velocity making the viscosity of the working fluid very low, while the fuzz will expand at low shearing velocity and increase the apparent velocity and carrying ability, the leakage passages could be plugged automatically in this situation. Since the micro behavior of fuzzy balls is similar with fuzzy bacteria, the drilling fluid based on fuzzy ball working fluid is also called bionic drilling fluid[8]. The fuzzy ball bionic drilling fluid has proved to have a good performance in drilling and have been applied in more than 20 wells in China. However, up to now, there are still no relative studies about how to recycling fuzzy ball bionic drilling fluid economically and environment-friendly, and this is exactly the starting point of present research.

During the past 30 years, many methods such as emulsion-breaking treatment[4], biological treatment[4], dumping treatment[3], burning reclaims method[7], evaporation concentration method[1], curing treatment[2], salt cavern method[6] have been used to treat dumped drilling fluid. But, the costs of most of the treatments are too high for massive application. Moreover, which methods are suitable for recycling the dumped fuzzy ball bionic drilling fluid is still unknown. Some lab experiments are necessary to conduct to estimate the feasibility of each method.

The drilling fluid after well completion can be separated and reused. For dumped fuzzy ball bionic drilling fluid, three methods are designed to treat it, which are 1) separating by flocculation and produce low-density cement slurry; 2) separating by gel-breaking and discharge directly; 3) curing directly and produce solid cement. Lab experiments are preformed to evaluate the feasibility of each method.

DETAILS ABOUT FUZZY BALL BIONIC DRILLING FLUID

The fuzzy ball drilling fluid is composed of fuzzy ball working fluid[3] and some other additives according to working conditions. As Figure 1 shows, observing under 1000 times microscope, "one core, two layers, threemembranes" structure similar with fuzzy bacteria is found in the liquid. The air core lies in the center of the fuzzy ball, because of the hydration of the surface active agent on both sides and the association effect of the water wet side, the compacted aqueous layer around the air core has a much higher viscosity than bulk solution. This layer is so-called "high-viscosity aqueous layer". The surfactant on the inner side of "high-viscosity aqueous layer" is lipophilic groups and tightly arranges inward to form a membrane, whose primary function of the film is to reduce the gas-liquid surface tension. So it is called "surface tension reducing membrane". The lipophilic groups are out of the "high-viscosity aqueous layer" which make up another membrane by tight arrangement named "the fixed membrane of the high-viscosity aqueous layer". The hydrophilic groups of surfactant arrange outward tightly and form the "water-soluble meliorative membrane" which can improve the solubility of the fuzzy balls. Outside the water- soluble meliorative membrane, an unstable thickness layer forms with the name: "concentration transition layer of polymer and surfactant"[3].

The fuzzy balls can exist steadily mainly because of

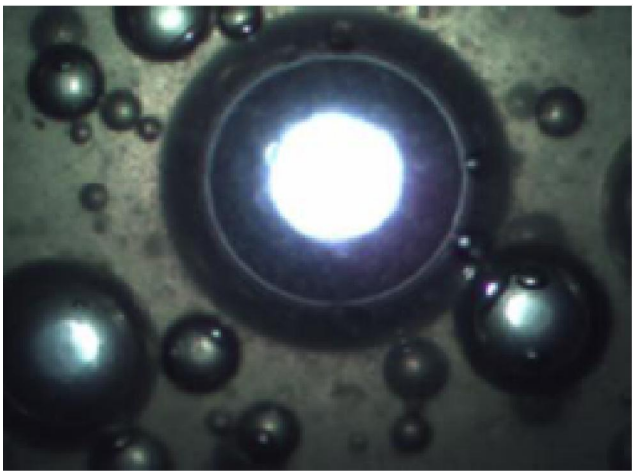

Figure 1: Microstructure of fuzzy ball working fluid under 1000 times microscope

cooperative effect of the surfactants, which make the critical micelle concentration (CMC) less than that of single agent. It can make the surface activity stronger. The steric clash of hydrophilic group of SDS differs from that of SDBS. Dense liquid membrane with remarkable viscoelasticity and long stabilization time will for by mixed usage. These two agents together with proprietary agents can enhance the dense degree of membrane. Hydration occurs between Hydroxyl and macromolecule chain of HES, which increases plastic viscosity of the working fluid, and makes high viscous water layer structure more stable, thus increases the stability of air pocket at low shear rate. Strong intermolecular forces of PAM generate Van der Waals' force between fuzzy ball transition layer and continuous phase, which ensures the existence of airbag in the working fluid by overcoming buoyancy[3].

The fuzzy ball drilling fluid can plug pores of different size with different mechanisms. It can plug leak passages without knowing whether the lost circulation will happen and how serious it is. The fuzzy ball drilling fluid has proved to have a high pressure capability up to more than 20MPa. The density, viscosity and stable time of the fuzzy ball drilling fluid can be adjusted by changing its composition. By now, the fuzzy ball drilling fluid has been applied in more than 20 wells in China.

RECYCLING METHODS OF FUZZY BALL BIONIC DRILLING FLUID

Used fuzzy ball bionic drilling fluid is divided into drilling fluid after well completion and dumped drilling fluid. Fuzzy ball bionic drilling fluid after well completion can be separated by vibrating screen or desander, and be reused in another section or another well.

Dumped fuzzy ball drilling fluid has to be treated and discharge harmlessly or produce another useful material. Because the main ingredient of the fuzzy ball drilling fluid is vegetable gelatin and cellulose, the following three methods are designed to treat the dumped fuzzy ball bionic drilling fluid. The effect of each method is tested by lab experiment, and the feasibility of each method is evaluated in the end.

Separating by flocculation and produce low-density cement slurry

This method is adding flocculation agent into dumped fuzzy ball bionic drilling fluid, making the suspended particles flocculate and fall rapidly. The separated liquid can be used to produce low-density cement slurry, and the solid particles can be buried directly.

In order to evaluate the performance of the produced slurry, we prepare the 300ml of fuzzy ball bionic drilling fluid with the density of 0.8, 0.85, 0.9 and 0.95 g/cm^3 separately. Add 10ml of flocculation agent into each fuzzy ball bionic drilling fluid and leave it undisturbed for 12h. The liquid will separated from the mixture as Figure 2 shown. Then we add 500g of cement and 144ml of fuzzy ball bionic drilling fluid into the separated liquid, producing low-density cement slurry. The performance of the produced cement slurry is listed in TABLE 1.

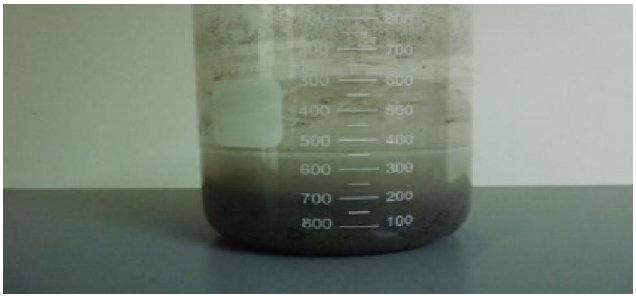

Figure 2 : Fuzzy ball bionic drilling fluid after flocculation

From TABLE 1, the produced low-density cement slurry can basically satisfy the demand of shallow well cementing.

Separating by gel-breaking and discharge directly

This method is breaking the stability of colloid by

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adding gel-breaking agent, making colloid granules assemble and deposit eventually. If the fuzzy ball bionic drilling fluid after gel-broken satisfy the environmental standard, this method is the most economical treating means.

TABLE 1: Performance of cement slurry produced by flocculation separated liquid

Drilling Fluid density (g/cm^3)	Cement slurry density (g/cm^3)	Liquid (%)	30min APIdehydration (mL)	Thickening time (h)	24hCompressive strength(MPa)
0.8	1.47	3.3	49	8.5	7.6
0.85	1.4	2.9	50	8	6.1
0.9	1.42	5	52	8.2	5.7
0.95	1.49	4.1	48	9	7.8

The fuzzy ball bionic drilling fluid with density of 0.85g/cm^3 was prepared for the experiment, 3% of gel-breaking agent was added into the fuzzy ball bionic drilling fluid, and leave it undisturbed for 12h after stirring (As Figure 3 shown). Analyzing the contaminants in the separated liquid, the results are listed in TABLE 2. The "maximum allowed content" means the maximum allowed contend by the secondary standard of "GB8978-96 National Sewage Discharge Standard".

We can see from TABLE 2, the separated liquid after gel-breaking can satisfy the secondary standard of "GB8978-96 National Sewage Discharge Standard", which can be discharged directly.

Figure 3 : Fuzzy ball bionic drilling fluid after gel-breaking

Curing directly and produce solid cement

This is a popular way to treat dumped drilling fluid all over the world, the idea of which is to add some additives into the dumped drilling fluid to produce solid cement. The advantage of this method is low transportation distance, rapid treatment period, high treatment quantity, low environmental damage and great economic benefits.

The fuzzy ball bionic drilling fluid with density of 0.85g/cm^3 was prepared for the experiment, some drilling cuttings and specific additives were added into the fuzzy ball bionic drilling fluid to make solid cement, the composition of each additive is shown in TABLE 3.

TABLE 3 : Curing compositions of solid cement produced by dumped fuzzy ball bionic drilling fluid

Compositions	Additives				
1#	fuzzy ball bionic drilling fluid 160mL	drilling cuttings 240mL	cement 15%	lime 10%	sodium silicate 4%
2#	fuzzy ball bionic drilling fluid 160mL	drilling cuttings 240mL	cement 20%	gypsum 10%	sodium silicate 6%
3#	fuzzy ball bionic drilling fluid 160mL	drilling cuttings 240mL	cement 20%	gypsum 10%	calcium oxid 2%
4#	fuzzy ball bionic drilling fluid 160mL	drilling cuttings 240mL	cement 10%	blast-furnace slag 10%	lime 10%

The performance of eachsolid cement was tested in the lab. The results are shown in TABLE 4, which indicate that the strength of all the 4 groups of solid cement are big enough to be used for further formation stimulation.

The leach liquid of the curing treatment is analyzed, and the results are listed in TABLE 5. From TABLE 5, the leach liquid of curing treatment on fuzzy ball bionic drilling fluid totally satisfies the secondary standard of "GB8978-96 National Sewage Discharge Standard" and can be discharged directly.

TABLE 4 : Measured strength of each solid cement

Compositions	Maintenance time (d)	Pressure (KN)	Strength (MPa)
1#	7	23.1	9
2#	7	4.7	1.8
3#	7	8.7	3.4
4#	7	3.6	1.4

TABLE 5 : Contaminants analysis results of leach liquid of each group of solid cement

Compositions	Contaminants	pH	Chroma	Suspended solid (mg/L)	BOD_5 (mg/L)	COD (mg/L)	Total chromium (mg/L)	six valence chromium (mg/L)
	Maximum allowed conetend	**6~9**	**80**	**300**	**60**	**150**	**1.5**	**0.5**
1#	Measured results	8	5	85	52.3	88.7	0.32	0.03
2#	Measured results	8	5	97	52.3	84.2	0.05	0.02
3#	Measured results	7	5	8	33	76.7	0.09	0.05
4#	Measured results	7	5	87	19.6	6	0.1	0.06

CONCLUSION

A novel drilling fluid imitating the microstructure of fuzzy bacteria is introduced in the present paper. The "one core, two layers, three membranes" structure of fuzzy ball bionic drilling fluid guarantees its dynamic self-matching plugging ability and high pressure capability. The density, viscosity and stable time can be adjusted by its composition according to different formation conditions. The fuzzy ball bionic drilling fluid has been applied in more than 20 wells in China.

This paper conducted a pioneer research on how to treat dumped fuzzy ball bionic drilling fluid environment-friendly and economically. Three methods including 1) Separating by flocculation and produce low-density cement slurry; 2) Separating by gel-breaking and discharge directly; 3) Curing directly and produce solid cement are proposed to treat the dumped fuzzy ball bionic drilling fluid. The experimental results show that 1) the cement slurry produced by flocculation separating liquid can satisfy the demand of shallow cementing of wells; 2) the separating liquid by gel-breaking satisfies the secondary standard of "GB8978-96 National Sewage Discharge Standard"; 3) the strength of solid cement produced by curing the dumped fuzzy ball bionic drilling fluid is high enough to be used for further well stimulation, and the leach liquid satisfies the secondary standard of "GB8978-96 National Sewage Discharge Standard". All the three recycling methods can be adopted according to different working conditions.

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