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Pressure and Temperature Bearing Capacities of Fuzzy-Ball Fluid†

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Fuzzy-ball fluid with the microstructure of "one core, two layers, three membranes" is an ideal plugging material in drilling engineering because it can plug different-sized leak channels automatically and can be degraded within a certain time. However, pressure and temperature are both high in deep wells, while the bearing capacities of pressure and temperature for Fuzzy-ball fluid are still not known so far. In this study, experiments were conducted to evaluate the pressure and temperature bearing capacity of the Fuzzy-ball fluid. The results show that: (1) Fuzzy-ball fluid can plug the coal rock core under the driving pressure up to70 MPa; (2) Fuzzy-ball fluid can keep its rheological properties up to 150 ºC. Since Fuzzy-ball fluid can keep its excellent performance up to 70 MPa and 150 ºC, it could be used in the wells as deep as 5000 m or more.

Keywords: Fuzzy-ball fluid, Plug, Polymer, Pressure bearing capacity, Temperature bearing capacity.

INTRODUCTION

Fuzzy-ball fluid is a kind of steady polymer solution made from sodium carbonate, sodium hydroxide, sodium dodecyl sulphate (SDS), sodium dodecyl benzene sulfonate (SDBS), hydroxyethyl starch (HES), MW 1.5 million polyacrylamide (PAM) in proper sequence[1]. Observed under 1000 times microscope, many polymeric vesicles look like Fuzzy balls suspending in the liquid as shown in Fig. 1, so this polymer solution is called Fuzzy-ball fluid.

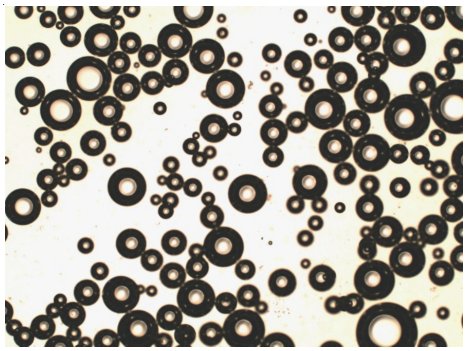

Fig. 1. Fuzzy-ball fluid under 1000 times microscope

The Fuzzy-ball vesicle has a "one core, two layers, three membranes" structure, as shown in Fig. 2. The gas core is wrapped by the high-strength polymer composed of the layers

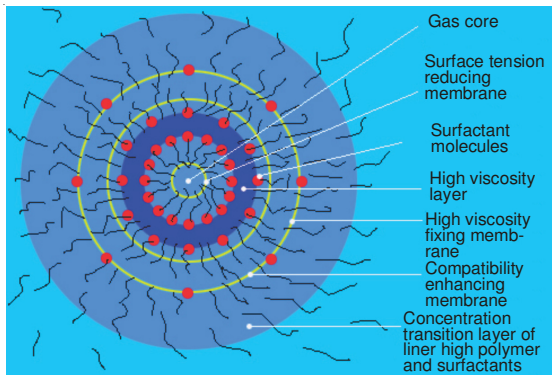

Fig. 2. Microstructure of Fuzzy-ball vesicle

and membranes.This ball-like vesicle can change its shape and volume with pressure and temperature guarantee in the Fuzzy-ball fluid can plug leak passages of different sizes dynamically. The outermost part of Fuzzy-ball vesicle is the dynamic adsorbing transition zone formed by the water soluble membrane with polymers and surfactants transition layer which mainly controls the rheological properties of the system. This peripheral part seems like animal furs, so it is called fuzz in the Fuzzy-ball fluid system[2].

All the agents used to form Fuzzy-ball fluid could be divided into four parts. The first part could be referred as Gas-core generating agent (GA) which is a mixture of anionic surfactant and non-ionic surfactant.The main function of

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this part is to generate gas core. The second part can be called membrane generating agent (MGA) which is a mixture of cationic and zwitterionic surfactant, the main function of which part is to enhance the strength of membrane. The third part is called layer generating agent (LGA),which is a mixture of two kinds of nature modified zwitterionic compounds whose molecular weight are about 200000 and 300000.The main function of this part is to generate the dense layer. The last part can be named as Fuzz generating agent (FGA) which is a nature modified nonionic polymer, whose molecular weight is about 500000 and the main function of this part is to generate the fuzz.

Because of the special structure, the Fuzzy-ball fluid has been proven to be able to plug leak channels of different sizes in normal conditions[3] and be recycled safely after usage[4]. However, if used in deep wells, the Fuzzy-ball fluid has to bear high pressure and temperature. In order to evaluate the performance of Fuzzy-ball fluid under high pressure and temperature, experiments were conducted in this paper to test the plugging ability up to 70 MPa and rheology property of Fuzzy-ball fluid up to150 ºC.

Pressure bearing capacity tests: The main function of the Fuzzy-ball fluid is to plug formation when drilling wells, so the pressure bearing capacity in the downhole is one of the most concerned issues. A group of experiments were conducted in China University of Petroleum in Beijing to evaluate the pressure bearing capacity of coal rock cores.

Natural coal rock cores were processed into cylindrical plugs with diameter of 5 cm and length of 7.5 cm. After cleaned by soxhlet extraction method and dried in the vacuum dryer for 4 h, the cores were placed in the core holder. Keeping the back pressure and the confining pressure at 2 MPa at the beginning and increasing driving pressure by displacement pump from zero gradually, to observe whether or not the core leaks in the rear. If the core did not leak, we increased driving pressure by 0.5 MPa each time. The experimental setup is shown in Fig. 3.

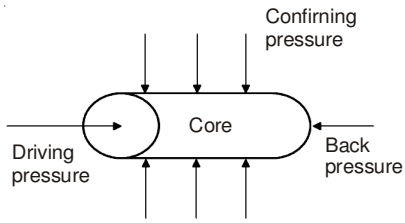

Fig. 3. Sketch of pressure-bearing experiments setup

In the first group of experiment,normal brine wasinjected into the coal rock core by displacement pump under different driving pressures. If the core did notleak, we increased driving pressure by 0.5 MPa each time. After the core startedto leak in the rear, we increased the pump inflow rate and recorded the driving pressure. The driving pressure *versus* time was shown in Fig. 4. Fig. 4 showed that the core leaked in the rear when the driving pressure was larger than 4.5 MPa. After the core began to leak, the diving pressure would not increase even though we increased the pump inflow rate gradually. The result proves that the original pressure bearing capacity of the coal rock core for normal brine is around 4.5 MPa.

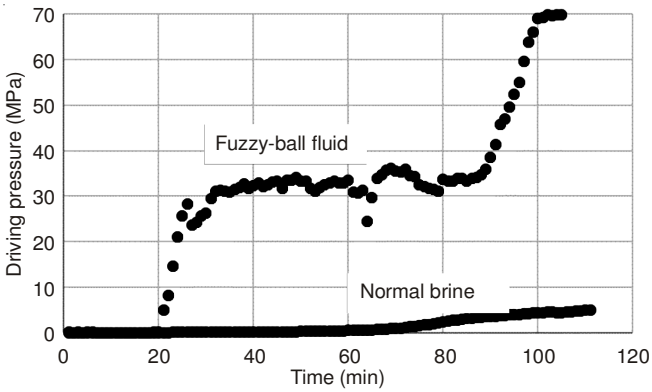

Fig. 4. Pressure-bearing performance of Fuzzy-ball fluid and normal brine

In the second group of experiment, the core was prepared by the same procedure as in the first group. A group of Fuzzy-ball Fluid was prepared with the composition shown in Table-1. The Fuzzy-ball fluid instead of normal brine was adopted this time to be injected into the core by the displacement pump. As shown in Fig. 4, there was no leak even the driving pressure increased to 70 MPa. It should be pointed out that the maximum driving pressure the device could provide is only 70 MPa.So it proves that the pressure-bearing capacity of the Fuzzy-ball fluid is more than 70 MPa.

TABLE-1
COMPOSITIONS OF FUZZY-BALL FLUID USED TO TEST THE PRESSURE-BEARING CAPACITY

	FGA	LGA	GA	MGA	PAC	KCl
Dosage (%)	1.5	0.3	0.05	0.3	0.3	3

FGA = Fuzz generating agent; LGA = Layer generating agent; GA = Generating agent; MGA = membrane generating agent.

Three similar groups of experiment were conducted and the same resultswere obtained. The results prove that the pressure bearing capacity of Fuzzy-ball fluid is larger than 70 MPa in this case and it can meet the requirement of practical drilling engineering in wells as deep as 5000 m.

Temperature bearing capacity tests: Fuzzy-ball fluid with specific rheological property can be preparedon the ground according to the actual demand[5]. However, temperature increases with the increasing depth of well, so the change inrheological property of Fuzzy-ball under different temperature has to be figured out.

Five groups of Fuzzy-ball fluid with different composition were prepared to test the temperature bearing ability. Each group of Fuzzy-ball fluid was heated by the Roller heating furnace for 16 h at 150 ºC. The rheological properties of each group before and after heating were shown in Table-2, where apparent viscosity means apparent viscosity, plastic viscosity means plastic viscosity and yield point means yield point.

The results show that the density and yield point of Fuzzy-ball fluid changed a little after heating with the maximum variation of 30 %, while the apparent viscosity and plastic viscosity increased after heating with the maximum variation up to 100 %. However, the rheological properties of Fuzzy-ball under 150 ºC are still in good condition to guarantee the excellent performance in plugging the formation when drilling in deep wells.

TABLE-2
RHEOLOGICAL PROPERTIES OF FUZZY-BALL FLUID BEFORE AND AFTER HEATING

		Density (g/cm^3)	AV (mPa s)	PV (mPa s)	YP (Pa)
Group 1	Before heating	0.88	62	38	24
	After heating	0.96	90	56	34
Group 2	Before heating	1.17	70	40	30
	After heating	1.17	97.5	78	19.5
Group 3	Before heating	1.14	50	31	19
	After heating	1.01	57.5	45	12.5
Group 4	Before heating	1.09	70	35	35
	After heating	0.92	112.5	70	42.5
Group 5	Before heating	1.14	63.5	36	27.5
	After heating	1.15	87.5	68	19.5

AY = Apparent viscosity; PV = Plastic viscosity; YP = Yield point

Conclusion

Experiments were conducted in this paper to evaluate the pressure and temperature bearing capacities of Fuzzy-ball fluid, which is a new-type polymer solution. The experimental results show that the Fuzzy-ball fluid can keep its plugging ability at up to 70 MPa and the rheological properties of the Fuzzy-ball fluid are still in good condition under 150 ºC. The results prove that the Fuzzy-ball fluid can be used to plug formations when drilling in the deep wells.

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