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Research Article

Preparation of Oil-Based Foam Gel with Nano-SiO_2 as Foam Stabilizer and Evaluation of Its Performance as a Plugging Agent for Fractured Shale

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The development of natural fracture will lead to lost circulation, which will be likely to cause economic losses and reduce drilling efficiency. In order to solve this problem, an oil-based pressure-bearing foam gel plugging agent for fractured shale was developed. The basic components such as foaming agent, foam stabilizer, and cross-linking agent were optimized and compounded, and the basic formula of the oil-based foam gel system was 0.6%DSFA foaming agent + 0.3%BPMO foaming agent + 0.5%EPDM + 1.5% SBS + 0.05%rigid cross – linking agent (DB) + 0.02%modified SiO_2 nanoparticles. Then, the performance of the oil-based foam gel plugging agent was evaluated through core plugging experiments, and the results showed that the prepared plugging agent had good stability and plugging performance with a plugging rate of about 90%.

1. Introduction

In recent years, as conventional crude oil reserves gradually decrease, the unconventional resources are gaining high demand [1]. Therefore, the shale resources including shale gas, shale oil, and oil shale have attracted attention worldwide [2]. However, during the drilling of shale reservoirs, due to the relatively developed natural fractures of the shale, the problem of lost circulation is serious [3]. Lost circulation refers to the phenomenon that a large amount of drilling fluid leaks into the formation during the drilling process. It is easy to induce wellbore instability and wellbore collapse, blowout, stuck drilling, and other drilling accidents, causing a lot of economic losses and reducing drilling efficiency. This problem deserves much attention in on-site operation, and the use of foam plugging agent is a new and low-cost plugging method [4–9].

The conventional foam plugging agents use water phase as continuous medium. Due to the high density of base fluid, the degree of reduction of system density is limited by objective conditions, especially in some high-pressure well sections that the plugging agent stability is easily affected. Moreover, shale hydration and expansion are likely to occur in low-pressure reservoirs with strong water sensitivity, and the use of water-based foam plugging agents in the oil layer will cause reservoir damage [10, 11]. In addition, conventional foam plugging agents are subject to formation factors, which will shorten their validity period and affect the application of this technology [12].

Polymer gel plugging agent is also one of the most widely used chemical plugging agents in oilfield plugging. It has the advantages of low cost, simple process, and good plugging effect. Foam gel plugging agent combines the advantages of foam plugging agent and gel plugging agent, which uses gel as the continuous phase and gas as the dispersed phase. It is composed of base liquid, polymer components, foaming agents, foam stabilizers, cross-linking agents, etc. The foam gel plugging agent is prepared by dissolving the foaming agent in a polymer solution of polymer and adding a cross-linking agent. The plugging agent preferentially enters the formation with high water saturation, and the foam with liquid as the dispersion medium is first generated in the

formation, and then, the polymer interacts with the cross-linking agent to form a gel. The properties of foam gel are very special. The system exhibits foam behavior before the cross-linking reaction and bulk gel behavior after the cross-linking reaction. Compared with oil-based foam, its continuous external phase is gel; compared with gel, it contains a large amount of uniformly distributed gas in the gel. Therefore, it can not only overcome the shortcomings of general oil-based foams that are easy to burst but also can overcome the shortcomings of poor gel diffusion performance [13–19].

At present, there are many researches on water-based foam gel plugging agents. However, due to the high cost of using oil as the continuous phase and the need to consider factors such as temperature resistance and pressure-bearing capacity, research on oil-based foam gel plugging agents is still lacking. In this paper, the oil-based foam gel plugging agent is studied in order to solve the problem of fractured shale leakage, and a preparation method of oil-based foam gel plugging agent is proposed. The plugging effect, pressure-bearing capacity, and temperature resistance capacity of the prepared loss plugging agent were evaluated.

2. Experimental Materials and Methods

2.1. Experiment Material. The materials used in the experiment were as follows: oil base fluid: diesel and kerosene; foaming agents: sorbitan monostearate (Span 60), sorbitan oleate dehydrated (Span 80), octadecyl trimethyl ammonium bromide (CTMAB), propylene glycol monooleate (BPMO), and DSFA (provided by Beijing Hanqian Technology Co., Ltd.); foam stabilizers: modified SiO_2 nanoparticles, styrene-isoprene-styrene block copolymer (SIS), ethylene-propylene-nonconjugated diene terpolymer (EPDM), and styrene-butadiene block copolymer (SBS); cross-linking agent: diethanolamine (DEA), rigid cross-linking agent (DB), and divinylbenzene (DVB); and shale core (diameter 25 mm and length 50 mm).

2.2. Experimental Methods and Procedures

2.2.1. Foaming Ability and Stability of Foam. The Waring blender method (the device is shown in Figure 1) is the most convenient way to evaluate the performance of foam. The specific method is as follows:

According to different mass concentrations (0.3%, 0.6%, 0.9%, and 1.2%), 5 kinds of foaming agents were foamed in 50 mL oil base liquid at 20°C without adding other substances. The Waring blender was used to stir at a high speed of 8000 r/min for 1 minute, and the stirred foaming agent solution was poured into a 500 mL large graduated cylinder. The initial volume of the foam was read immediately and was recorded as the foaming volume.

A stopwatch was used to measure the time required for the volume of the foam to decay by half and recorded it as the half-life. The comprehensive foaming index (F_q) was used to compare the foaming ability of different foaming agents, and the foaming agent with better foaming effect was screened out.

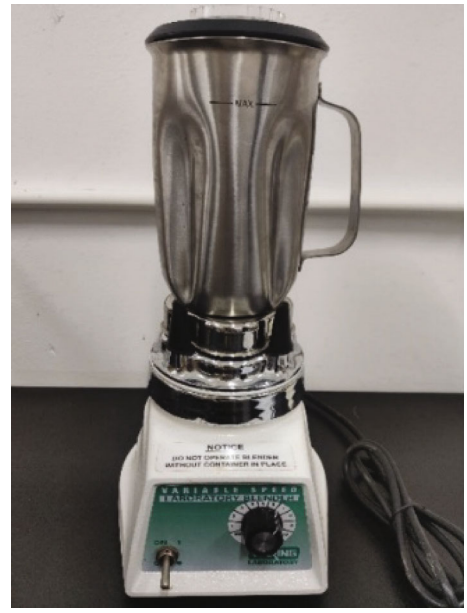

Figure 1: Waring blender.

$$F_q = \frac{3}{4} V_0 t_{1/2}. \quad (1)$$

In the formula, V_0 is the initial foaming volume, $t_{1/2}$ is the half-life of foaming liquid, and the experimental data is recorded in the table below.

2.2.2. Optimization of Foam Stabilizer. Despite of the good foaming capacity of a single foaming agent, its half-life is short; thus, the oil-soluble foam stabilizer was added, which can enhance the intermolecular adsorption strength through the synergistic effect between molecules and greatly improve the foam stability [20, 21].

The principles for screening oil-based foam stabilizers were as follows: (1) It can make the oil base fluid have proper viscosity. (2) The polarity is similar to the foaming agent (nonpolar) to enhance the synergistic effect and promote the interaction of molecules. (3) It is better for the molecule to have multiple nonpolar points to increase the strength of the mask. (4) It is also best to reduce the surface tension of the foam system. In accordance with the screening principle of foam stabilizers, a large number of foam stabilizers were investigated and finally selected: styrene-isoprene-styrene block copolymer (SIS), ethylene-propylene-nonconjugated diene terpolymer (EPDM), and styrene-butadiene block copolymer (SBS).

In addition, many scholars have found that nanoparticles can improve the stability of foam [22–25]. But the unmodified SiO_2 nanoparticles have a large specific surface area and have a tendency to agglomerate, so they have a tendency to precipitate at the bottom, especially for low-viscosity systems, which affects the application of silica. Therefore, the general silica needs to be chemically modified to improve its dispersion stability. For this reason, we used siloxane containing epoxy groups to modify the silica and then used the reactivity of amine groups with epoxy groups

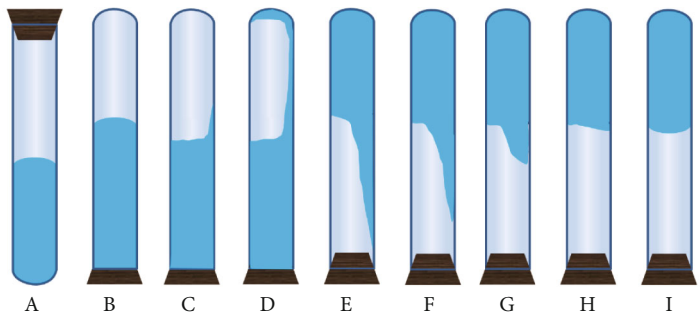

Figure 2: Schematic diagram of gel strength rating.

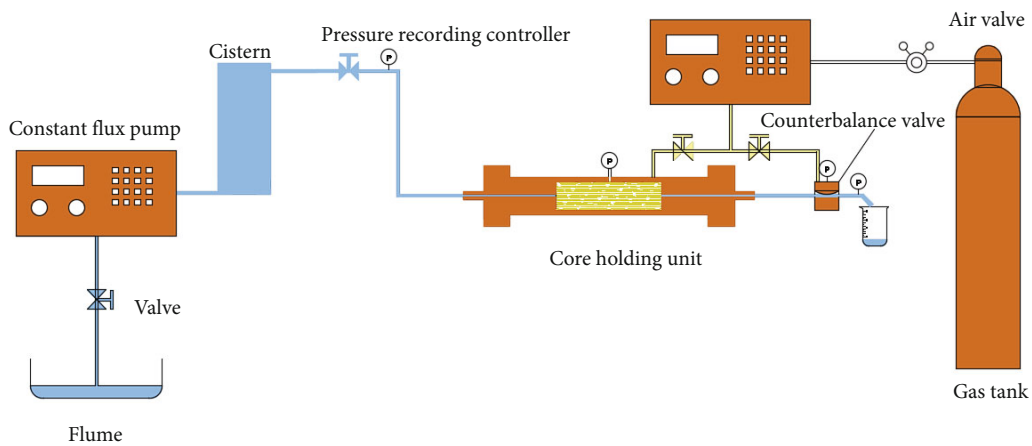

Figure 3: Diagram of the experimental device for core plugging.

for further modification. The amine group and epoxy were modified for the second time, so that the silica surface had long carbon chain functional groups with low surface energy, which can improve the dispersion stability of silica in oily systems.

In this paper, the optimized oil-based foaming agent system was added to 50 mL oil-based liquid, and SIS, EPDM, and SBS (1.0%, 2.0%, and 3.0%) were added in the solution. Its foaming volume and half-life were measured. Low concentration-modified SiO_2 nanoparticles were added into the optimized foam stabilizer system, and its foam stabilizer performance was determined.

2.2.3. Optimization of Gel System. As there is no standard for the evaluation method of gel-forming performance, the empirical method for evaluating gel strength in Figure 2 was used. When the gel strength is D to E, a small amount of gel can slowly flow to the other end when it is turned over, and most of it (greater than 15%) has no fluidity. At 80°C, simulated formation water or distilled water was used to prepare foam gel systems of different formulations, and the gel-forming properties of the system were examined. When the foam gel strength reaches D to E level, the configuration was completed.

The amount of cross-linking agent added will affect the strength of the gel and the gel time. If the amount of cross-linking agent is too high, the degree of cross-linking is too large, which will cause the stretching and rotation of the

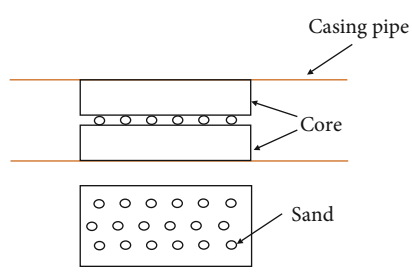

Figure 4: Spatial situation diagram of particle size distribution in the core.

gel molecules to be restricted, and the structure of the gel is likely to be destroyed under the action of external force. When the amount of cross-linking agent added is too low, the various reactive monomers cannot undergo sufficient cross-linking reaction, and the spatial network formed will be large, the elasticity of the product will decrease, and the impact resistance will decrease. The performance of DEA, DB, and DVB three cross-linking agents at different dosages was compared.

2.2.4. Preparation of Oil-Based Foam Gel System. The base fluid of oil-based foam gel must meet the requirements of environmental protection and reservoir protection, and at the same time, it must be economical. Therefore, diesel and kerosene were initially selected as the base fluid. Mix

Table 1: Experimental parameters.

Experiment number	Inflow velocity (mL/s)	Temperature (°C)	Annulus pressure (MPa)	Sand diameter (mm)	Whether to add plugging agent	Core diameter/length(mm)	Porosity (%)	Permeability ($10^{-3}\mu$ m^2)
1	1	80	6	0.850	No	25/50	6.2	1.790
2	1	80	6	0.850	Yes	25/50	6.2	1.790
3	2	80	7	0.850	No	25/50	5.4	0.981
4	2	80	7	0.850	Yes	25/50	5.4	0.981
5	1	80	6	0.425	No	25/50	4.8	0.869
6	1	80	6	0.425	Yes	25/50	4.8	0.869
7	2	80	7	0.425	No	25/50	4.6	0.808
8	2	80	7	0.425	Yes	25/50	4.6	0.808
9	1	80	6	0.180	No	25/50	4.4	0.782
10	1	80	6	0.180	Yes	25/50	4.4	0.782
11	2	80	7	0.180	No	25/50	4.2	0.691
12	2	80	7	0.180	Yes	25/50	4.2	0.691

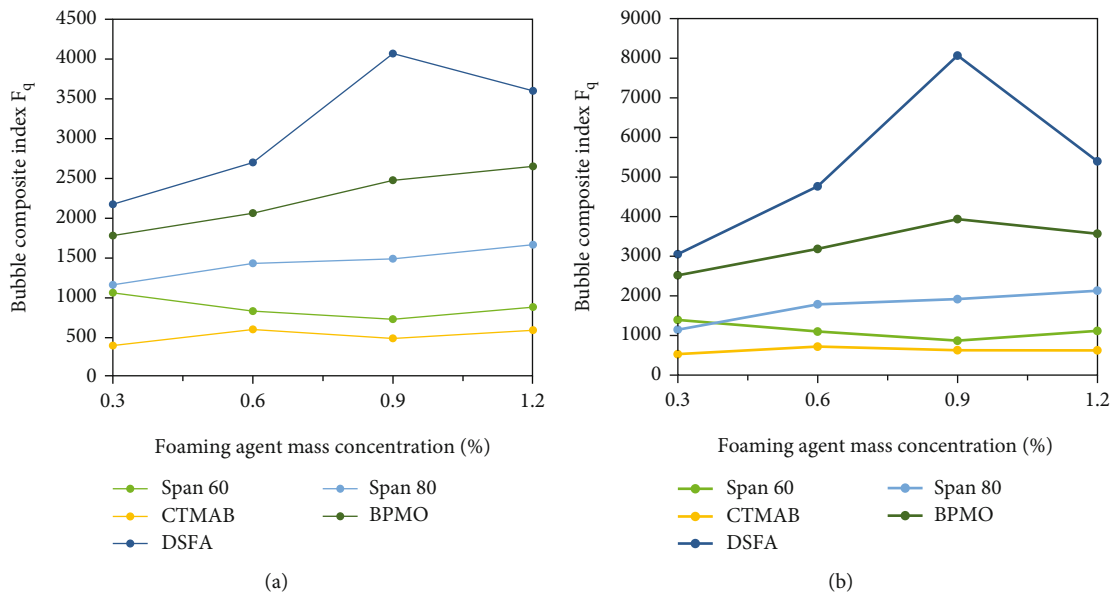

Figure 5: The foaming performance of different foaming agents in kerosene (a) and diesel (b).

700 mL diesel (or kerosene) with 300 mL water, add 2% emulsifier, add 2 g sodium carbonate and 40 g sodium bentonite, and stir at 8000 r/min for 20 min to obtain water-in-oil emulsion. Then, we add the appropriate amount of foaming agent, foam stabilizer, and cross-linking agent to the base fluid, and the mixture was poured into the Waring blender. The mixture was mechanically agitated at 8000 rpm for 1 min in the Waring blender, and then, the resulting foam was poured into a sealed cylinder and placed in an oven at 80°C until a foam gel formed.

2.2.5. Core Plugging Experiment. In order to meet the actual requirements of the site, we need an oil-based foam gel plugging agent with a pressure-bearing capacity of 6 MPa or more. In order to determine the plugging performance under this pressure, we have developed a comparative experiment plan. The experimental device diagram is shown in Figure 3. The overall experimental process was to take white sand and place it in the middle of the core to simulate cracks and put the core into the core holder. The foam gel plugging agent was added on the left side of the core, the drilling fluid was replaced with groundwater, and the plugging agent was driven into the core fractures. The flow rate of groundwater flowing into the annulus of the core, annulus pressure, and core back pressure parameters were set. A graduated cylinder was placed at the exit, and the amount of drilling fluid lost during this time period was recorded. For comparison, we did not add a plugging agent in the comparison experiment to test the leakage of drilling fluid through different degrees of fractures in a certain period of time. Sand particle size was used to simulate different permeability, and spatial situation diagram of particle size distribution in the core is shown in Figure 4. The specific experimental parameters are shown in Table 1:

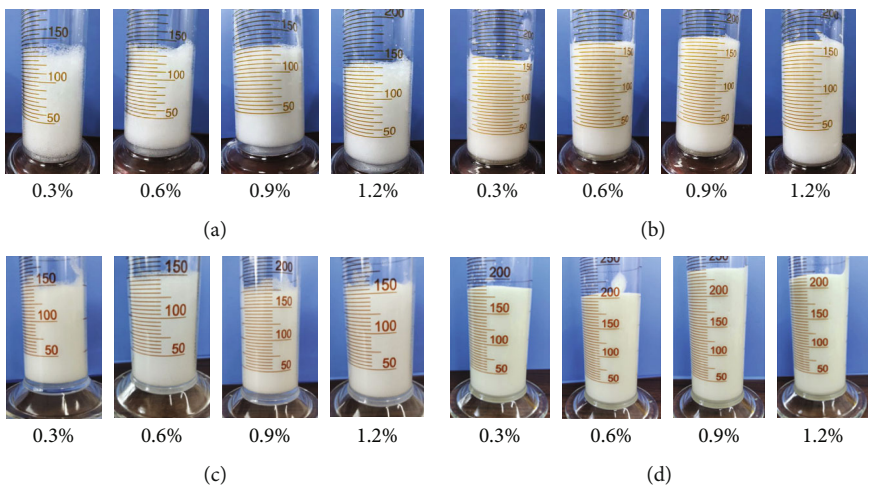

Figure 6: (a) Foaming situation of different mass concentrations of BPMO in kerosene. (d) Foaming situation of different mass concentrations of BPMO in diesel. (c) Foaming situation of different mass concentrations of DSFA in kerosene. (d) Foaming situation of different mass concentrations of DSFA in diesel.

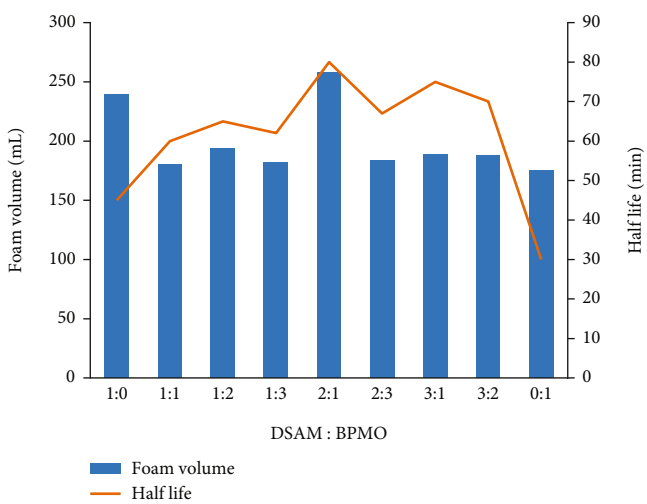

Figure 7: The foaming performance of the compound system of DSFA and BPMO in different proportions.

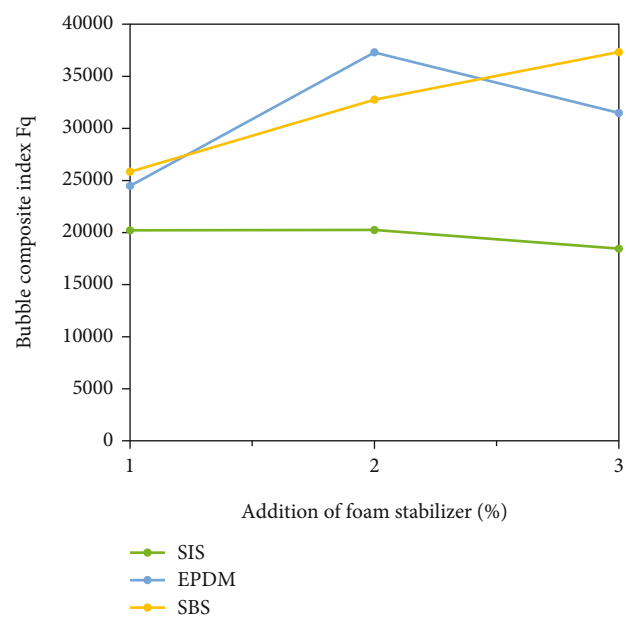

Figure 8: Foam stabilization performance of different oil-based foam stabilizers.

The following formula was used to express the blocking rate:

$$\text{plugging efficiency} = \frac{(\text{water loss volume} - \text{lost circulation material volume})}{\text{water loss volume}} \cdot 100\%. \quad (2)$$

3. Results and Discussions

3.1. Optimization of Oil-Based Foaming Agent System. Foaming agent is a surfactant that can increase the gas-liquid ratio of the foam gel and increase the stability of the foam [18]. The foaming ability of five foaming agents, sorbitan monostearate (Span 60), sorbitan oleate (Span 80), octadecyl trimethyl ammonium bromide (CTMAB), propylene glycol monooleate (BPMO), and DSFA, were evaluated.

As shown in Figure 5, DSFA and propylene glycol monooleate (BPMO) have better foaming performance. And when diesel is used as the base fluid, the foaming agent has better foaming performance.

Figure 6 shows the foaming of BPMO blowing agent and DSFA blowing agent in kerosene-based fluid and diesel-based fluid. It can be seen that when diesel is used as the base fluid, the foam is denser.

Propylene glycol monooleate (BPMO) and DSFA were combined in pairs, and the sum of the mass concentration (0.3%, 0.6%, 0.9%, and 1.2%) and the foaming agent addition ratio (1 : 0, 1 : 1, 1 : 2, 1 : 3, 2 : 1, 2 : 3, 3 : 1, 3 : 2, and 0 : 1) was changed, foaming in diesel base. The foaming ability and foaming performance of the compound system were

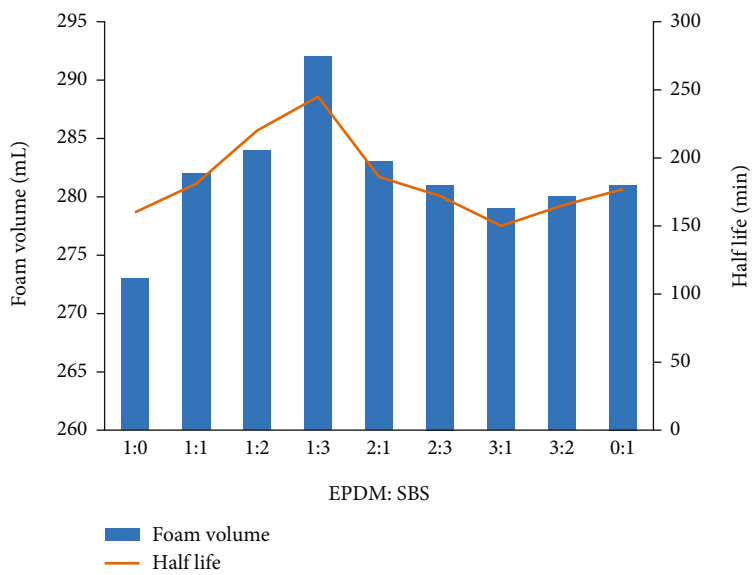

Figure 9: Foam stabilization performance of the mixed system of EPDM and SBS in different proportions.

evaluated, the best compound ratio was determined, and it was compared with a single foaming agent.

The foaming performance of DSFA and BPMO with different compounding ratios is different. With the increase of the mass concentration, the foaming performance of the compound system with different ratios has been improved, but when the mass concentration is greater than 0.9%, the foaming performance shows a slight change, indicating that increasing the foaming agent concentration can improve the foaming performance. The best foaming mass concentration is 0.9%. Comparing the foaming performance of different ratios, it can be seen that the foaming performance is best when DSFA/BPMO = 2 : 1. When the mass concentration is 0.9%, the foaming volume can reach up to 258 mL, the half-life can reach 80 s, and the comprehensive foam value can reach 15480. Therefore, if DSFA is compounded with BPMO, the best compounding ratio is DSFA/BPMO = 2 : 1 , and the best compounding mass concentration is 0.9%. The experimental data with a mass concentration of 0.9% was analyzed, as shown in Figure 7. It can also be clearly seen from Figure 6 that the optimal ratio of DSFA and BPMO is 2 : 1.

3.2. Optimization of Foam Stabilizer System

3.2.1. Selection of Optimum Foam Stabilizer. In this section, the foam stabilizing performance of several oil-based foam stabilizers was evaluated. The data is recorded in Figure 8. It can be seen from the table that EPDM and SBS can significantly increase the half-life of the foam.

The optimized foam stabilizers were tried to mix and use. The foam stabilizer system at different ratios (1 : 0, 1 : 1, 1 : 2, 1 : 3, 2 : 1, 2 : 3, 3 : 1, 3 : 2, and 0 : 1) and different mass concentrations (1.0%, 2.0%, and 3.0%) was investigated, and the best compound ratio was determined. According to the experimental data, the optimal mass concentration is 2.0%. The experimental data with a mass concentration of 2% was analyzed. And the results are shown in Figure 9. The best ratio of EPDM/SBS is determined as 1 : 3.

3.2.2. Optimization of Modified Nanosilica Concentration. The adsorption of modified nanosilica particles on the oil-gas interface can significantly improve the mechanical strength of the interface film and reduce the occurrence of bubble merging (as shown in Figure 10). The particles dispersed in the bubble liquid film can slow down the liquid film drainage speed and increase the stability of the foam.

The foam stabilization performance of different concentrations (0.016%, 0.018%, 0.02%, 0.022%, 0.04%, and 0.026%) of modified nanosilica was evaluated. The tracker automatic interface rheometer was used to study the gas-liquid interface properties of the system and to measure the surface tension of the sample after adding modified nanosilica particles. The surface tension of the sample after adding different mass concentrations of modified SiO_2 nanoparticles is shown in Figure 11. After adding modified nanosilica particles, the surface tension is greatly reduced. When the dosage is 0.02%, it drops to a minimum of 16.0mN/m and continues to increase the dosage and the change is not obvious. The foam stability is obviously improved after adding modified SiO_2 nanoparticles.

3.3. Optimization of Cross-Linking Agent. 200 mL of foam system solution with simulated formation water was prepared, and 0.05% diethanolamine (DEA), rigid cross-linking agent (DB), and divinylbenzene (DVB) were used as cross-linking agents. Waring high-speed stirring was used. The samples were stirred uniformly for 3 min with a Waring stirrer and aged at 80°C for 24 h. The foaming volume and half-life of the foam gel system were investigated.

The cross-linking agent was added to the basic formula at 0%, 1%, 2%, and 3% of the volume of the base liquid. The experimental results are shown in Table 2.

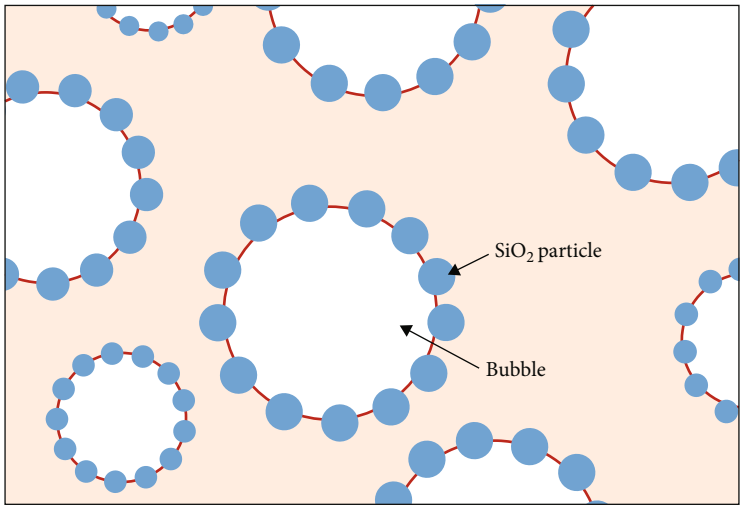

Figure 10: Schematic diagram of stable bubbles of SiO_2 nanoparticles.

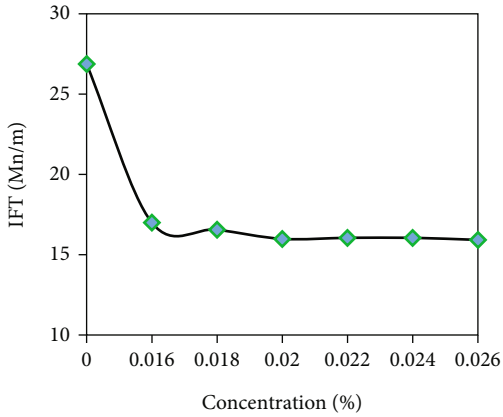

Figure 11: Surface tension of the sample after adding different mass concentrations of SiO_2 nanoparticles.

From the experimental results, it can be seen that when the amount of cross-linking agent DEA is too small, the cross-linking reaction between the monomers cannot be fully carried out, and no solid-like gel is formed. With the increase of DEA addition, the strength of the gel was improved, but after exceeding a certain amount, the strength of the gel changed less. On the other hand, the time to form the gel gradually decreased with the increase of cross-linking agent addition. This is due to the fact that the cross-linking point, which plays a bridging role, increases with the increase of the addition amount, which accelerates the polymerization cross-linking reaction.

The cross-linking agent DB was added to the base formulation at 1%, 2%, 3%, and 4% of the base volume, and the experimental results are shown in Table 3. Table 4 shows the performance of the cross-linking agent DVB.

It can be seen from the above experimental results that the cross-linking agent DB forms a gel system, and compared with other gel systems, the gel formation time is faster, the initial viscosity is controllable, the final set viscosity is large, and the stability is good. So the cross-linking agent DB was chosen as the cross-linking agent.

Table 2: The influence of cross-linking agent DEA on gel.

The amount of cross-linking agent DEA	0	1%	2%	3%
Gel formation time (min)	—	78	49	67
Strength of the gel	A	B	C	C

Table 3: The influence of cross-linking agent DB on gel.

The amount of cross-linking agent DB	1%	2%	3%	4%
Gel formation time (min)	72	67	50	50
Strength of the gel	B	C	D	D

Table 4: The influence of cross-linking agent DVB on gel.

The amount of cross-linking agent DVB	1%	2%	3%	4%
Gel formation time (min)	82	75	63	64
Strength of the gel	B	C	D	D

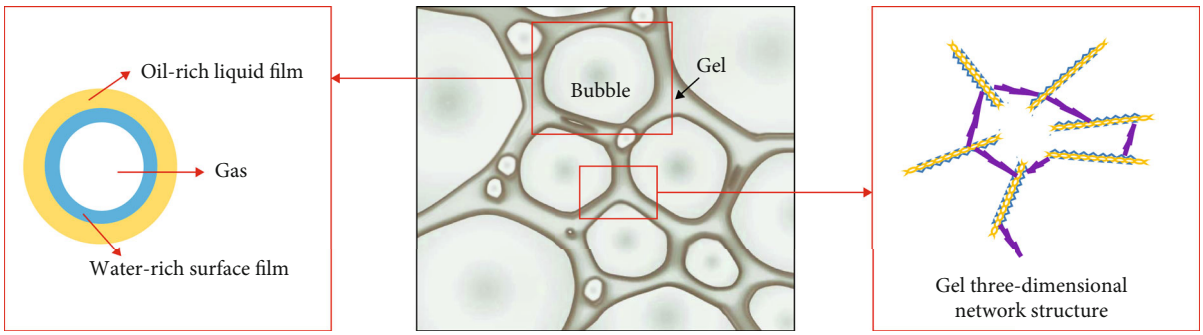

Figure 12: Schematic diagram of oil-based foam gel structure.

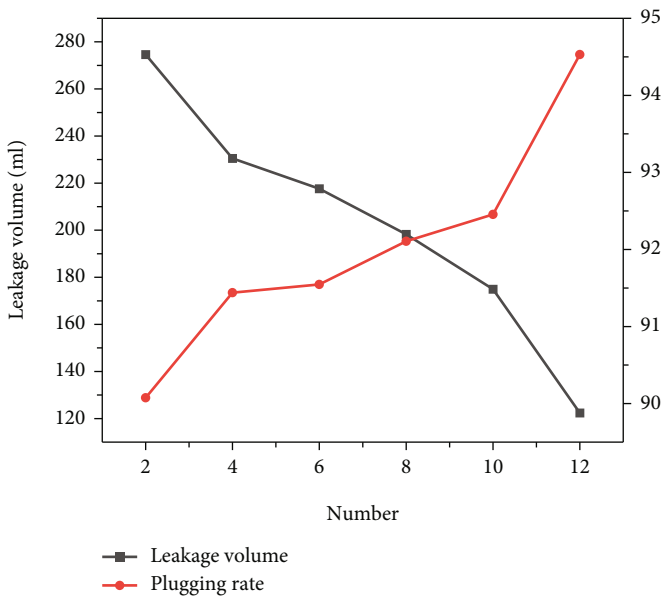

Figure 13: Change of plugging agent performance.

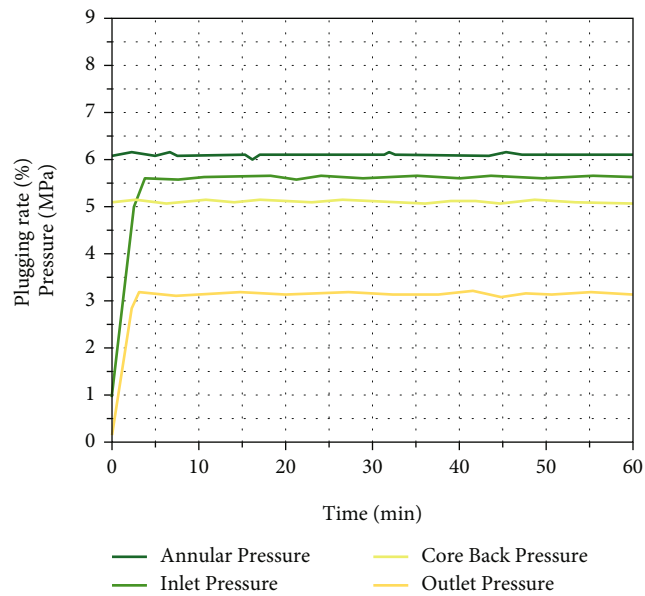

Figure 14: Experiment 3 plugging pressure change.

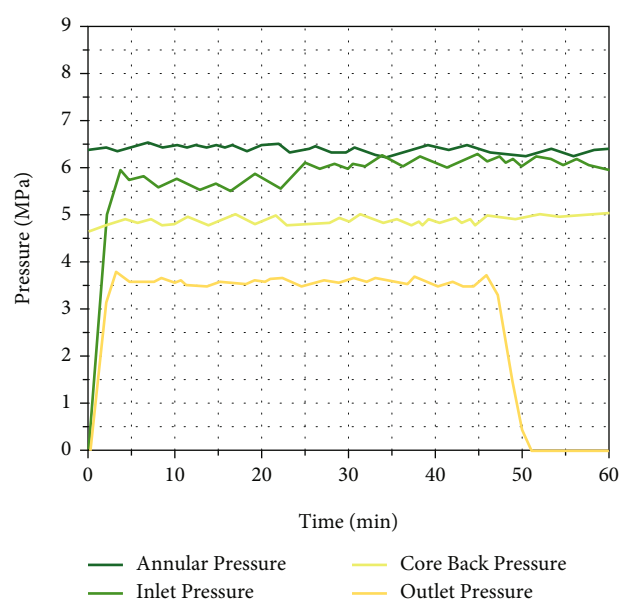

Figure 15: Experiment 4 plugging pressure change.

Therefore, the basic formula to determine the oil-based foam gel system was as follows: 0.6%DSFA foaming agent + 0.3%BPMO foaming agent + 0.5%EPDM + 1.5%SBS + 0.05%crosslinking agent DB + 0.02%modified SiO_2 nanoparticles.

3.4. Analysis of Plugging Mechanism. The structure of the oil-based foam gel is shown in Figure 12. The formation process is that the base liquid forms under the action of the oil-based foaming agent, and the liquid in the foam wall gradually turns into gel under the action of additives and finally forms a mixed system of solid gel and gas. Foam gel has the characteristics of foam before gelling, at which time the viscosity is relatively low. The large-flow foam gel has good fluidity and diffusibility before gelation, so it can spread quickly and eventually wrap the shale cracks. After gelation, the viscosity gradually increases, and it has the characteristics of gel, thereby greatly improving the plugging performance. In addition, the use of oil-based foam gel does not cause shale hydration.

3.5. Performance Evaluation of Plugging Agent

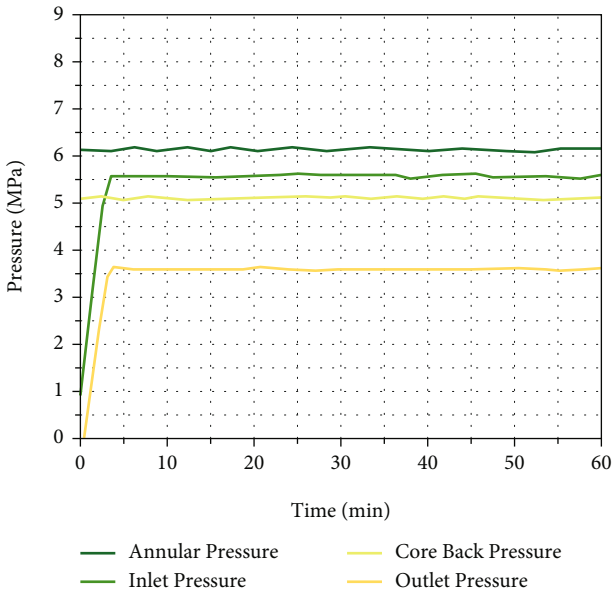

Figure 16: Experiment 7 plugging pressure change.

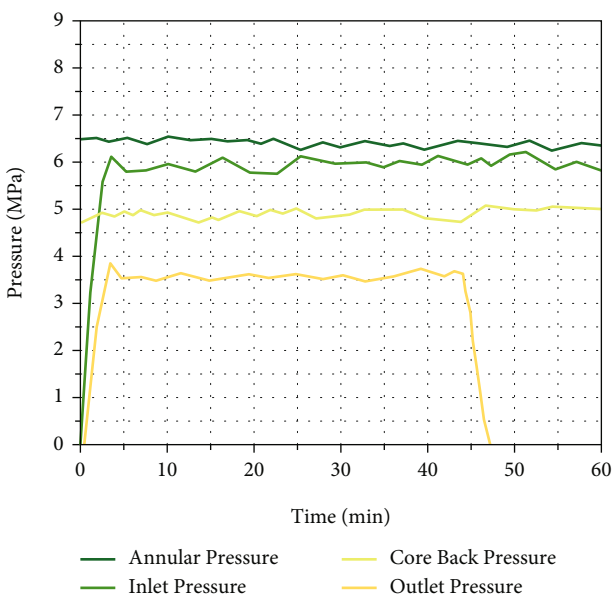

Figure 17: Experiment 8 plugging pressure change.

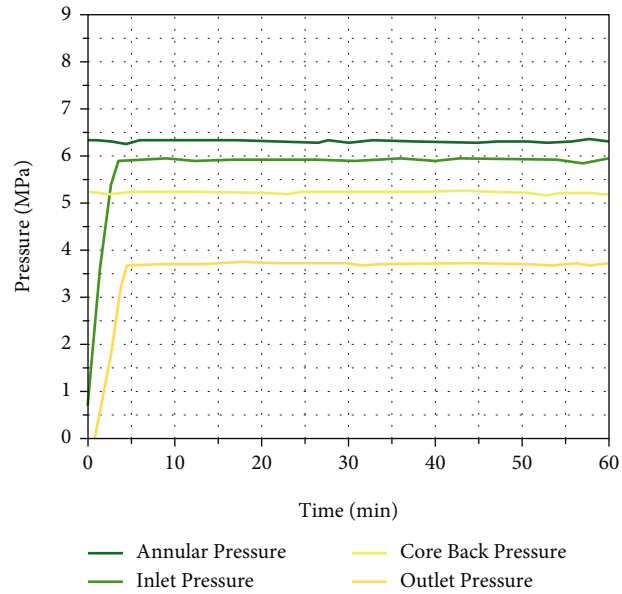

Figure 18: Experiment 11 plugging pressure change.

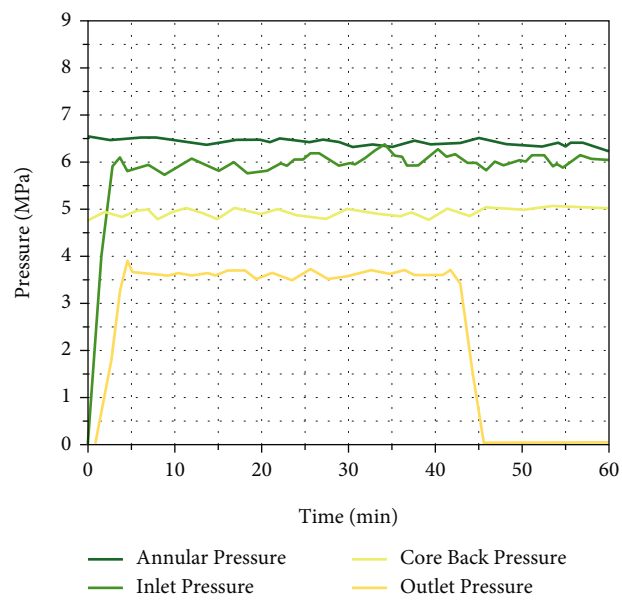

Figure 19: Experiment 12 plugging pressure change.

3.5.1. Core Plugging Experiment. The results of the core plugging experiment are shown in Figure 13. Figure 13 selects the leakage and plugging rate data with a pressure of 6 MPa. It is not difficult to see that under the condition of constant pressure, as the particle size of the sand decreases, its leakage gradually decreases, and the corresponding plugging rate is gradually increasing.

Select experiment 3, 4, 7, 8, 11, and 12 with a pressure of about 6 MPa and observe the pressure changes, as shown in Figures 14–19. Figures 14, 16, and 18 are graphs showing the pressure change trends of water passing through fractures in the cores with different particle sizes. As the sand size gets smaller and smaller, the annulus pressure begins to increase, but the increasing trend is not obvious. Similarly, the outlet pressure also increases with the increase of the sand size.

Comparing Figure 14 with Figure 15, the pressure fluctuation trend of Figure 15 is greater than that of Figure 14. Comparing the various pressures, the annulus pressure in experiment 4 is obviously greater than that in experiment 3. The annulus pressure, core back pressure, and inlet pressure in experiment 4 all have an upward trend, while experiment 3 tends to be stable. This can be understood as follows: the viscosity of the plugging agent is relatively large, and the inflow of drilling fluid is organized when the core is plugged, thereby increasing the pressure. When the pressure gradually increases, it can reflect that the plugging agent starts to work. These changes can also be seen in the pressure

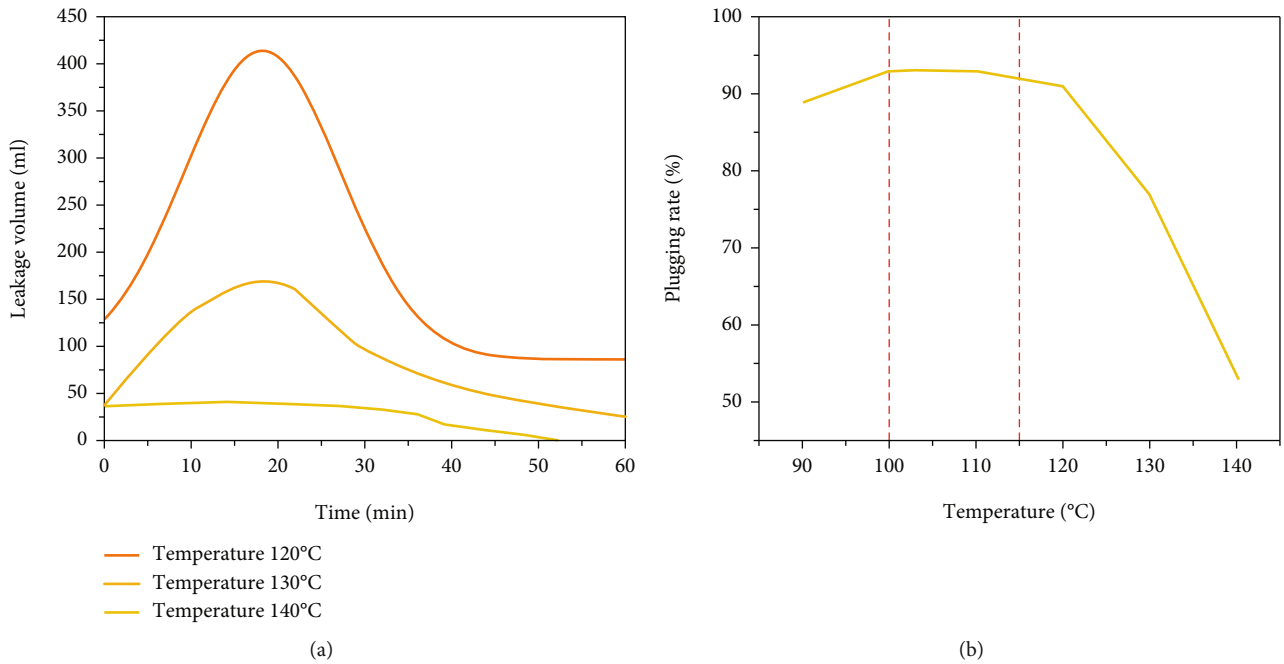

Figure 20: (a) The change in leakage over time at different temperatures. (b) The plugging rate of the plugging agent at different temperatures.

diagrams of experiment 7 and experiment 8 and experiment 11 and experiment 12.

As shown in Figure 15, the inlet pressure at the beginning of the experiment showed a linear upward trend, and at about 2 minutes, it began to gradually stabilize, showing signs of a slow rise. Because of the increase in inlet pressure, the annulus pressure rises, exceeding the set value of 6 MPa and hovering around 6.5 MPa. We mainly observe the changes in outlet pressure and back pressure. The outlet pressure is 0 at the beginning of the laboratory, and until 1 min later, the drilling fluid drives the plugging agent into the core and flows out from the pores of the core. The inflection point appeared at 45 min, and the inlet pressure began to decrease linearly at 45-50 min. Then, observe the core back pressure, the fluctuation range began to decrease at 45-50 minutes, until the beginning of 50 minutes, and the core back pressure gradually stabilized. The corresponding outlet pressure starts to be 0 at 51 min, indicating that the plugging agent starts to work at this time. The inlet pressure rises slowly as a whole.

In Figure 17, the overall pressure changes in the experiment are not much different from those in Figure 15. However, at 45 min, the outlet pressure appeared an inflection point until the outlet pressure at 47 min was 0, indicating that the plugging agent had begun to plug the core. This situation can be attributed to the fact that when the cracks are smaller, the starting time of the plugging agent will be shortened. In Figure 19, the inflection point of the outlet pressure appears at 42 minutes, and the pressure drop is at 45 minutes when the pressure drops to zero. The plugging time of the plugging agent changes with the size of the crack.

Combining the above experimental phenomena, we can find that when the gap of the crack is smaller, the plugging efficiency of the plugging agent is higher, and the plugging time is shorter. The overall plugging rate is above 89%, indicating that the plugging effect of the plugging agent is more prominent. In the field, we can increase the gel composition of the plugging agent accordingly, which can shorten the action time of the plugging agent.

3.5.2. The Influence of Temperature on the Performance of the Plugging Agent. Temperature has a certain effect on the performance of the plugging agent. The experimental temperature was changed to test the plugging performance of the plugging agent at different temperatures. Figure 20(a) shows the change in leakage over time at different temperatures, and Figure 20(b) shows the plugging rate of the plugging agent at different temperatures.

It can be seen from Figure 20(a) that when the temperature is 130°C and 140°C, as time increases, the amount of leakage increases significantly. When the temperature is 120°C, the leakage change is small. It can be seen from Figure 20(b) that when the temperature increases to 100-115°C, the plugging rate is higher. When the temperature exceeds 120°C, the plugging rate gradually decreases. Therefore, the best operating temperature range of this oil-based foam gel plugging agent is 100-115°C.

4. Conclusion

(1) In order to solve the leakage problem of fractured shale, an oil-based pressure-bearing foam gel plugging agent was developed through laboratory experiments. The foaming agent, foam stabilizer, cross-linking agent, and other components were optimized, and the optimal addition amount and compounding ratio were determined. The basic formula of the oil-based foam gel system was determined:

0.6%DSFA foaming agent + 0.3%BPMO foaming agent + 0.5%EPDM + 1.5%SBS + 0.05%crosslinking agent DB + 0.02%modified SiO_2 nanoparticles

(2) The oil-based foam gel plugging mechanism was analyzed. The properties of oil-based foam gel before gelation are similar to foam, and it is easy to spread and wrap cracks. The gel formed after gelation has good stability and blocking properties, and the oil-based foam gel will not cause shale hydration and expansion

(3) Then, a core plugging experiment device was designed, and the oil-based pressure-bearing foam plugging agent was evaluated for its plugging performance. Results of the study showed that the prepared plugging agent had good stability and plugging performance with a plugging rate of about 90% and the plugging agent still has a good plugging rate under the pressure of 6 MPa

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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