Performance evaluation of foaming agent in high sulfur formation water environment

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Abstract. In order to increase gas production, the foaming agent is usually injected into the bottom of the well. This process can effectively reduce the backpressure at the bottom of the well, so as to achieve the ultimate goal of drainage gas recovery and enhanced oil recovery. Foam drainage efficiency is affected by many different factors, which makes its drainage efficiency change to a large extent. This paper has done a lot of research on the performance of foam drainage agents in high sulfur formation water environment. The foaming performance, foaming stability, liquid carrying performance, and the effect of foaming discharge agent on the COD value of formation water were experimentally studied in room temperature and high-temperature environment respectively, in order to find out the optimal parameters of foaming discharge agent performance in a high sulfur formation water environment.

1. Preface

During the production of a gas well, the reservoir pressure and gas flow rate decrease gradually, and the formation of water or hydrocarbon condensate in the gas reservoir often flows into the bottom of the well. When gas well productivity is low and fluid production is large, the fluid flow rate in the wellbore is low, so that the produced fluid can not be carried out of the wellbore completely, thus remaining in the wellbore and forming fluid accumulation. The liquid column pressure generated by the fluid accumulation will offset part of the formation pressure, and this situation continues to even reach a balance with the formation pressure, resulting in additional static water back pressure on the gas reservoir, which worsens the production conditions of the gas well, leading to the decline of the gas well production, and even the occurrence of water flooding and the shutdown of the gas well,. therefore, the use of a foaming agent with the aid of tubing or casing will take place after the bubble into the bottom stirring, use of a foaming agent to reduce the surface tension, make the combination of downhole gas and liquid two-phase contact after producing stable gas water bubble, can effectively reduce the backpressure of the bottom hole, to exhaust the ultimate goal of collecting water and increase oil recovery [2].

At present, some foreign countries have formed a relatively complete system in foam agent, foam wellbore flow, liquid carrying capacity research, and effect evaluation of foam drainage gas recovery. In recent years, overseas research of drainage gas recovery technology to reduce costs as the main target, focus on the single well drainage combined with the overall harnessing of the gas reservoir, involving multidisciplinary interaction study of a new type of drainage gas recovery technology, at the same time
and process of form a complete set of equipment, downhole operation, workover and related technology to carry out targeted research [1]. In the 1980s, Sichuan Gas Field in China began to study the "foam drainage gas recovery technology of gas Wells". Since 1980, Chinese scholars have learned from foreign research experience and gradually improved the foam drainage gas recovery technology over the past 40 years, making it gradually adapt to the gas Wells with high temperature and high salinity. Then, parameters such as high-temperature resistance, salt-resistance, and foaming ability of foaming agent were optimized and screened, forming a relatively perfect parameter optimization system of the foaming agent [3-7]. Previous studies have not conducted a detailed evaluation of the performance of foaming discharge agents in a high sulfur formation water environment. This paper will study the foaming performance, foaming stability, liquid carrying performance of foaming discharge agent and the influence of foaming discharge agent on the COD value of formation water at high temperature and room temperature respectively, and find out the optimal parameters of foaming discharge agent performance in high sulfur formation water environment.

2. Foam discharge agent foaming performance evaluation

Under certain experimental conditions, the 200 ml test solution preparation of good a certain concentration of bubble row agent with a custom bubble meter drip pipe from the calibration measurement is 90 cm from the bottom of the top place into 50 ml same bubble row of container agent test solution, record the stop when the flow of liquid foam height, as the bubble row of agent's initial foam height, stability, in order to improve the experiment and record the 30 s, 3 min and 5 min of the bubble meter height $H_t$, experiment device as shown:

![Figure 1. Foam evaluation device](image)

Under the temperature conditions of room temperature and 80°C, formation water from Wells YH29-1 and YB10-1H were selected for experiments, and the foaming capacity was recorded as follows:
Figure 2. Foaming effect of foaming agent

Table 1. Formation water test results of Well YB29-1 (room temperature)

| Bubble row agent | 0.1% | 0.5% | 1.0% |
|------------------|------|------|------|
| Resistance to sulfur | 63   | 157  | 150  |
| xuy-4            | 52   | 130  | 145  |
| sh-yb-f1         | 61   | 130  | 144  |
| XHG-10           | 47   | 126  | 141  |

Table 2. Experimental Results of Formation Water in Well YB29-1 (80°C)

| Bubble row agent | 0.1% | 0.5% | 1.0% |
|------------------|------|------|------|
| Resistance to sulfur | 101  | 206  | 215  |
| xuy-4            | 98   | 202  | 210  |
| sh-yb-f1         | 71   | 154  | 170  |
| XHG-10           | 82   | 169  | 181  |
3. Foam discharge agent foam stability performance evaluation

The evaluation of foaming stability is one of the basic indexes for the performance evaluation of foaming agents. When Ros-Mill (pour method) was used for evaluation, the foam heights $H_3$, $H_5$, and $H_8$ were recorded for 3min, 5min, and 8min. The foam height reduction and the half-life of the foam within a certain period of time could both indicate the stability of the foam. See Table 2 for the main experimental instruments needed for the project research and development.

| The name of the instrument | model       | The manufacturer                      |
|----------------------------|-------------|----------------------------------------|
| Electronic balance         | JM-B30001   | Yuyao Jiming Weighing Calibration Equipment Co. Ltd |
| Automatic surface tensiometer | K100MK2   | Kreus GmbH, Germany                    |
| Roche foam apparatus       | —           | processing                             |
| Liquid carrying device     | —           | processing                             |

At room temperature and 80℃, formation water from Wells YH29-1 and YB10-1H were selected for experiments, and the bubble stabilization performance (half-life time) was recorded as follows:

a. Stabilizing effect of anti-sulfur foaming agent

b. Stabilizing effect of XUY-4 foam discharge agent
c. Stabilizing effect of sh-yb-f1 foam discharge agent
d. XHG-10 foam discharge agent foam stabilizing effect

Figure 5. Stabilizing effect of four kinds of foaming agents

| Table 4. Formation water test results of Well YB29-1 (room temperature) |
|-----------------------------------------------|
| Concentration | Bubble row agent | 0.1% | 0.5% | 1.0% |
| Resistance to sulfur | xuy-4 | 44.03 | 47.02 | 47.42 |
| | sh-yb-f1 | 29.23 | 32.20 | 33.02 |
| | XHG-10 | 39.24 | 42.35 | 42.56 |

Figure 6. Half lifetime at room temperature

Figure 7. Half-lifetime at 380℃

4. Evaluation of liquid carrying performance of foam discharge agent

Dynamic carrying performance is an indoor evaluation parameter to simulate actual production in foam drainage applications. Dynamic liquid carrying capacity evaluation refers to the standard SY/T6465-2000 foaming agent evaluation method for bubbling gas extraction, and four liquid foaming agents are configured respectively, namely sulfur resistance, XUY-4, SH-YB-F1, and XHG-10. In the foam dynamic performance evaluation device, the liquid volume carried by four kinds of liquid foam discharge agents in 2 medium and high sulfur formation water within 15min was measured at room temperature and 80℃.

1. Experimental instruments
The physical measuring device is shown in Figure 8.
Figure 8. The device for measuring the performance of the bubble bar

At room temperature and 80℃, formation water from Wells YH29-1 and YB10-1H were selected for experiments, and the liquid carrying capacity (foam carrying rate) was obtained through experiments as follows:

Table 5. Formation water test results of Well YB29-1 (room temperature)

| Concentration | 0.1% | 0.5% | 1.0% |
|---------------|------|------|------|
| Bubble row agent |      |      |      |
| Resistance to sulfur | 0.57 | 0.74 | 0.78 |
| xuy-4 | 0.56 | 0.68 | 0.71 |
| sh-yb-f1 | 0.53 | 0.63 | 0.63 |
| XHG-10 | 0.51 | 0.59 | 0.61 |

Table 6. Formation water test results of Well YB29-1 (80℃)

| Concentration | 0.1% | 0.5% | 1.0% |
|---------------|------|------|------|
| Bubble row agent |      |      |      |
| Resistance to sulfur | 0.54 | 0.72 | 0.75 |
| xuy-4 | 0.52 | 0.67 | 0.69 |
| sh-yb-f1 | 0.46 | 0.54 | 0.57 |
| XHG-10 | 0.44 | 0.51 | 0.52 |
5. Test the influence of foam discharge agent on the COD value of formation water

Chemical oxygen demand (COD) refers to the amount of oxidizing agent consumed when treating water with a strong oxidizing agent under certain conditions. COD reflects the degree of pollution by reducing substances in water. The reducing substances in water include organic matter, nitrite, ferrite, sulfide, and so on, so the determination of COD can reflect the content of organic matter in water.
By observing the variation of the COD value of four types of foaming agents with a concentration in different formation water, it can be seen that the contribution value of XHG-10 foaming agents is the largest, and the contribution value of the four types of foaming agents is in the order of XHG-10 > XUY-4 > anti-sulfur > SH-YB-F1. The COD value of the well YB10-1H water sample is obviously higher, which may be due to the fact that formation water contains more sulfur components.

6. Conclusion

(1) At room temperature, resistance to sulfur frother foaming ability is stronger, but under the environment of high temperature, foaming ability can have a small cut, xuy-4 better foaming capacity of foaming agent, temperature resistance is stronger, either at room temperature or high-temperature environment, higher foaming ability, sh-yb-f1 of foaming agent temperature tolerance, under the environment of high temperature, foaming ability has declined dramatically, XHG-10 frother foaming capacity at room temperature is lower, but the temperature resistance is stronger, in a high-temperature environment, foaming ability is relatively stable.

(2) The foaming stability of anti-sulfur foaming agents is the best among the four kinds of foaming agents. The foaming stability of XUY-4 foaming agents is relatively low, but the foaming stability of the four kinds of foaming agents is relatively stable under different formations of water and different temperature environment.

(3) The liquid carrying rates of the three types of foam discharge agents all have a certain correlation with the change of the concentration of the foam discharge agent, among which the liquid carrying rates of SH-YB-F1 and XHG-10 foam discharge agents are not obvious with the increase of the concentration of the foam discharge agent; When the concentration of anti-sulfur and XUY-4 foam discharge agents was less than 0.5%, the liquid carrying rate of the foam increased rapidly with the increase of the concentration, but when the concentration was greater than 0.5%, the increase slowed down.

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