Evaluation of Bubbling Agent Performance and Optimization of Parameters in SuA Block of Surig Gas Field

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Abstract: Surig gas field is a typical "low-permeability, low-pressure, low-productivity" gas field, with rapid pressure decrease in gas wells after production, and serious fluid accumulation at the bottom of gas wells, which has a greater impact on natural gas extraction. In order to avoid the accumulation of fluids in the wellbore, the foam drainage process is commonly used in Sulige gas field, but due to the high content of light hydrocarbons and methanol in the gas field as well as the high mineralisation of formation water, and the implementation of downhole throttling in some of the gas wells, the actual application effect is not satisfactory. In response to the above problems, through data collection and experimental analysis, the water production characteristics and water quality characteristics of Su A block of Surig gas field were clarified, and it was believed that the formation water type of this block was CaCl2 type with high mineralisation. On this basis, the conventional performance evaluation and throughput effect experiments of the two in-use foaming agents were carried out, and it was found that the foaming power and liquid-carrying capacity of the two foaming agents were better at different concentrations and mineralisation degrees, and the mass fraction of 0.30% for both foaming agents when foaming was the optimal ratio in the process of draining and extracting gas from Sulige gas field Su A block.

Keywords: Surig Gas Field; Foam Drainage; Foaming Agent; Performance Evaluation

1. Introduction

Surig gas field is a "three-low" type gas field, and during its production process, formation water continues to accumulate due to the change of pressure in the wells, and the upward gas flow can not take the formation water away from the wellhead, which will bring a great impact on the production [1]. Firstly, it will lead to the decline of wellhead pressure and the decrease of gas well production capacity; then, it will cause the accumulation of wellbore fluids, formation "water intrusion", and the expansion of water-absorbent clay minerals, which will ultimately lead to the decrease of gas-phase permeability [2]. In response to the above problems, drainage gas extraction process is commonly used in Surig gas field, and drainage gas extraction is a key technology to control the water production of gas wells and increase the production capacity of gas wells at present and in the future for quite a period of time, and foam drainage gas extraction has the advantages of simple equipment, convenient construction, fast results, low cost, and does not affect the normal production of gas wells, which is the main way of extracting the liquids from the wells in the Surig gas field at present [3]. However, there are natural gas light hydrocarbons in the recovered fluid of Su A block, and these light hydrocarbons are easy to interact with the foaming agent, which has a great influence on its effect of soaking and draining, and most of the gas wells are installed with throttles, which affects the implementation of this technology to a certain extent [4]. Therefore, it is urgent to optimise the parameters of the bubbling process and improve the suitability of the foaming agent and block gas wells.

In this paper, we take the production wells of Su A block of Sulige gas field as the research object, clarify the characteristics of its produced water and the water quality characteristics of the produced water, study the comprehensive performance of its in-use foaming agent, screen out the foaming agent which is anti-hydrocarbon and salt-resistant, anti-miscible, with good compounding and good efficacy of bubbling and discharging, and carry out the optimisation of the concentration of the foaming agent, in order to provide the technical support for the development and utilisation of Su A block of

Sulige gas field, and to better safeguard the increase of the production of the gas wells.

2. Gas Field Water Production Characteristics and Water Quality Analysis

2.1 Water Production Characteristics of Gas Wells

The average daily water production of a single horizontal well in Su A block is 2.18m3/d, and the output water of the gas wells is mainly dominated by condensate water and stagnant water, with a water/gas ratio of 0.94m3/104m3, and a large difference in the amount of water produced, which is mainly concentrated in the range of 1-5m3/d. The average daily gas production of single well of horizontal well is 2.734×104m3/d, and the daily gas production is mainly concentrated between 1-3×104m3/d.

For gas wells with relatively large amount of formation liquid production, when their production and pressure can not reach the minimum conditions of bubbling drainage and carrying liquid, with the continuation of production, the bottom of the well gradually accumulates liquid and the amount of liquid accumulates more and more, and the back pressure of the bottom of the well increases more and more, and when it reaches a critical value, the bottom of the well pressure is difficult to lift up the liquid, and the amount of gas production will decline significantly.

2.2 Water Quality Analysis

The overall liquid production of the gas reservoir is stable, and the mineralisation and ion concentration are higher overall. From the results of water quality analysis (Table 1), it can be seen that the formation produced water of Surig gas field has the following characteristics:

①The formation output water belongs to CaCl2 type, and the content of various ions in the water varies greatly;

② The pH value is low, generally between 5.53 and 6.4, weakly acidic;

③ The mineralisation is low, and the salt content is generally between 4880.90mg/L and 37058.45mg/L;

④ Ca2+ ion content generally ranges from 473.82mg/L to 6397.48mg/L; Mg2+ ion content generally ranges from 9.59mg/L to 350.78mg/L;

⑤ Oil content is generally in the range of 18.97mg/L to 88.29mg/L.

Table 1. Results of Analyses of Water Ion Content in Different Well Formations of Su a Block

Well number	pH (℃)	Na+K+ (mg/L)	Ca2+ (mg/L)	Total cations(mg/L)	Cl- (mg/L)	Total anion value (mg/L)	Total mineralization (mg/L)	Water-based
Su A-1	6.18	11187.7	1223.44	12658.51	19876.82	20306.08	32964.59	CaC12
Su A-2	5.8/9	7303.16	6214	14459.42	24407.33	25422.01	39881.44	CaC12
Su A-3	6.18/9	4246.77	3572.93	8129.29	13442.64	14004.16	22133.45	CaC12
Su A-4	6.22/6.5	547.24	558.11	95.49	85.25	610.88	706.38	CaC12
Su A-5	6.44/7	5278.16	6791.66	12862.11	22259.06	22605.04	35467.15	CaC12
Su A-6	6.12/16	6210.55	7420.61	13948.15	23779.86	24103.51	38051.66	CaC12
Su A-7	5.99/6.3	3759.36	100.04	3907.94	5734.39	6377.38	10285.32	CaC12
Su A-8	5.53/16	9330.39	6585.95	15916.33	25761.52	26225.81	42142.14	CaC12

3. Foaming Agent Conventional Performance Evaluation

3.1 Foaming Agent Selection and Performance Requirements

The foaming agent used in foam drainage is a kind of surfactant, and the surfactants currently used in oil and gas fields are anionic surfactants, cationic surfactants, nonionic surfactants and amphoteric surfactants [5], and in addition to the requirement that the foam drainage agent has a significant reduction in the surface tension in the drainage of gas extraction, it is also required that the foaming agent has the following special properties:

(1) Strong foaming ability. After the foam drainage agent is added to the bottom of the well, a large number of water-containing foams are generated through airflow perturbation, which changes the performance of the airflow that cannot automatically carry liquids, so that it carries water-containing foams (with low density) to reach the surface and discharges the wellbore fluids. The stronger the foaming ability of the foam-containing drainage agent, the lower the density of the water-containing foam. The easier it is to achieve the purpose of drainage and gas extraction.

(2) The foam carries a large amount of liquid. Foam drainage agent meets water, will be oriented in the gas-liquid surface arrangement,

in which the liquid phase is residual hydrophilic groups, the gas phase points to the hydrophobic groups, foam drainage agent molecules are adsorbed around the bubble to a certain concentration, in the bubble wall will form a layer of solid water film, the thicker the water film of the foam, the higher the unit volume of the foam water content, the stronger the foam liquid-carrying capacity will be.

(3) Foam stability should be good. If the foam stability is poor, the foam is likely to burst during the flow of thousands of metres from the bottom of the well to the wellhead, resulting in water loss, and the purpose of using the foam to carry liquids to the surface will be defeated.

(4) Good compatibility with other additives used in production. In the process of gas field development, often add antifreeze, emulsion breaker, defoamer and other additives, which requires the foam drainage agent and other additives with good compatibility, neither affecting the performance of the foam drainage agent itself, nor affecting the performance of other additives. Once incompatibility occurs, many problems will arise, which will certainly affect the normal use of the agent. Then the normal production of gas wells will also be affected, so better compatibility is an important requirement for the mixing of foaming agent and other additives.

3.2 Determination of Physical and Chemical Parameters of Foaming Agent

Liquid foaming agent SP-7 and solid foaming rod SP-10 were selected for indoor evaluation, and their related information is shown in Table 2.

Table 2. Vesicant Product Information

Form	Model number	Resistance to mineralisation /g.L
Liquid Foaming Agent	SP-7	≤250
Solid Foam Bars	SP-10	≤250

The basic parameters of the above liquid foam drainage agent and solid foam drainage agent are determined as follows:

(1) Appearance

Add 25mL of foaming agent in the colourimetric tube, shake well and observe whether there is turbidity and precipitation.

(2) Measurement of pH value of foam drainage agent

a) Specimen solution preparation:

Weigh the sample 10.0g in a beaker, weigh to 0.001g dissolved in distilled water, transfer to a volumetric flask, dilute to scale, shake well and standby.

b) Measurement:

Pour the above solution into the beaker, put on the magnetic stirrer stirring for 30s, stop stirring, insert the electrode, and wait for the pH meter to stabilise for 1min, and then read the number. Measure the same specimen 2 times in parallel, the difference between the measurements is not more than 0.1 pH unit.

(3) bubble discharge agent density measurement

a) First weigh the mass of the empty density bottle, then add the sample weighing, and then inject part of the measurement medium (distilled water), a slight shock, so that the sample is fully wet, and then continue to inject the density bottle, the sample and the media should not have air bubbles on the surface.

b) will be equipped with measuring medium (distilled water) and the sample of the density bottle tightly capped, into the (23 ± 0.5) ℃ water bath for more than 30 minutes, wipe dry immediately after weighing.

Figure 1. SP-7 pH

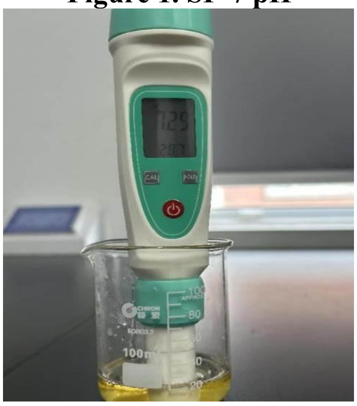

Figure 2. SP-7 pH

c) wash the density bottle, wipe dry, inject the measurement medium (distilled water), according to a density bottle into the (23 ± 0.5) ℃ water bath, began to repeat the above operation.

(4) Viscosity Measurement of Foam Discharge Agent

Measurement is carried out using a flat viscometer. Tube N is connected to a pumping device (true lumen table, earwash ball or syringe, etc.) and the sample is drawn into the timing ball. About 5 mm above the top line E, tube N is connected to the atmosphere and the sample flows down naturally. The flow time was measured twice without reloading the sample and averaged.

The physical and chemical performance indexes of the foaming agent SP-7 and SP-10 were measured under the condition of temperature of 24°C according to the above experimental contents and operation steps, and the results are shown in the following Tables 3 and 4. It can be found by the experimental results that the liquid foaming agent SP-7 has the appearance of a light yellow transparent liquid, with no impurities or suspensions visible to the naked eye, and the solid foaming rod SP-10 is a white solid, with no impurities visible to the naked eye after dissolution or precipitation after dissolution. Liquid foaming agent SP-7 pH value is 5.76, weak acidic, solid bubble bar SP-10 pH value is 7.29, weak alkaline. density of SP-7 is 0.9863 (g/cm3), solid bubble bar SP-10 density is 1.1218 (g/cm3).

Table 3. Physicochemical Performance Indexes of Sp-7 Foam Discharging Agent

Projects	Norm
Appearance	Light yellow transparent liquid, no visible impurities or suspended matter
Odour	Non-toxic
Density(g/cm3)	0.9863
pH value	5.76
Viscosity(mPa·s)	53

Table 4. Physicochemical Performance Indexes of Sp-10 Foam Discharging Agent

Projects	Norm
Appearance	White solid, no visible impurities or precipitate after dissolution
Odour	Non-toxic
Density(g/cm3)	1.1218
pH value	7.29

3.3 Evaluation of Foaming Performance of Foaming Agent

Preheat the Roche foam apparatus with a constant temperature water bath, and keep the temperature at 40 ℃, 60 ℃, 80 ℃, 85 ℃ ± 1 ℃ .3.00g/L test solution: weigh 0.80g of foaming agent into a 500ml clean beaker, measure 150g/L on-site water and 400ml and mix well, put the test solution in a constant temperature water bath and heat it to 40℃, 60℃, 80 ℃, 85 ℃ ± 1 ℃. Take 100 ml of the test solution and rinse along the wall of the foam meter tube, then put the remaining test solution into the 50 ml scale at the bottom of the Roche foam tube, then take 200 ml of the test solution and place it in the centre of the top of the Roche foam meter and put it down vertically against the liquid surface. After placing, read the maximum foam height in the Roche foam tube, i.e. the initial foam height. Repeat the foam height test for 30s, 3min and 5min 2 to 3 times respectively, with the absolute difference of the results of the parallel determination of the same sample not exceeding 5mm.After recording the foam droplets in the funnel, the foaming capacity and foam stability of each foaming agent were qualitatively compared. The experimental results are shown in Figures 3-Figures 6.

According to the experimental results, it is proved that liquid foaming agent SP-7 and solid foaming agent SP-10 have good foaming effect and foam stability and long foam half-life in the extracted water of Su A block.

3.4 Experimental Study of Surface Tension of Foaming Agent

Surface tension is an important physical property parameter of liquid, which is one of the key factors affecting various chemical and biological reactions, and it is also an essential basic physical property parameter in chemical engineering calculation. Surface tension is an important aspect in evaluating the performance of foam extractors. Practical foam extractors should not only have good foaming performance, but also have low surface tension. On the one hand, low surface tension is favourable to foam formation, and the smaller the surface tension, the easier the foam is formed. On the other hand, the lower the surface tension, the more convenient and timely the wellhead defoaming. Therefore, the surface tension of the two foam eliminators in different concentrations of distilled water and extracted water was tested, and the experimental results are shown in

Figures 7 and 8.

The comprehensive test results show that the surface tension of the two foam drainage agent solutions continues to decrease and stabilise after the addition of the foam drainage agent to the distilled water and the extracted water in Su A block. Under the same concentration, SP-7 and SP-10 have higher surface tension in the extracted water, which can reduce the surface tension of wellbore water more effectively.

3.5 Evaluation of Stability Performance of Soaking Agent

(1) Evaluation of stability performance of SP-10 soaking agent

The initial Roche bubble height of SP-10 solution without high-temperature treatment is 180mm, and after 5min it is 143mm, and the foam stability index is 79.0%; the initial Roche bubble height of SP-10 solution after high-temperature treatment is 112mm, and after 5min it is 102mm, and the foam stability index is 91.0%.

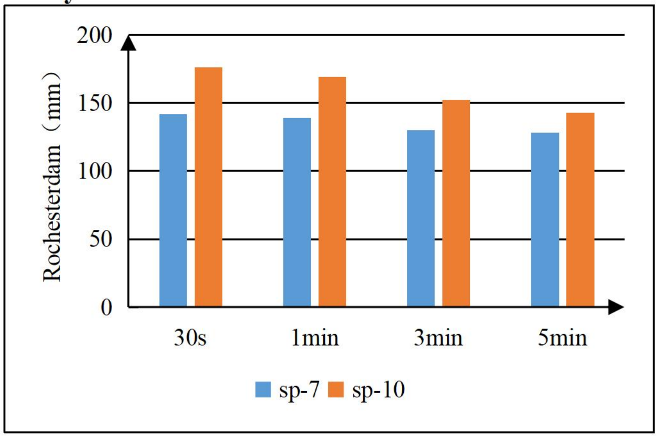

Figure 3. Evaluation of Foaming Performance of Blistering Agent at 40℃ in Su A Block Extracted Water

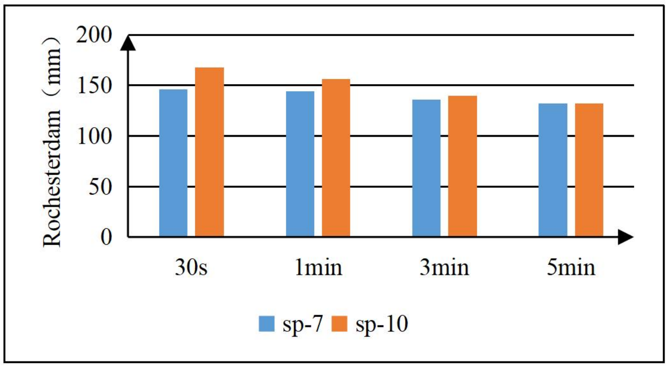

Figure 4. Evaluation of Foaming Performance of Blistering Agent at 60℃ in Su A Block Extracted Water

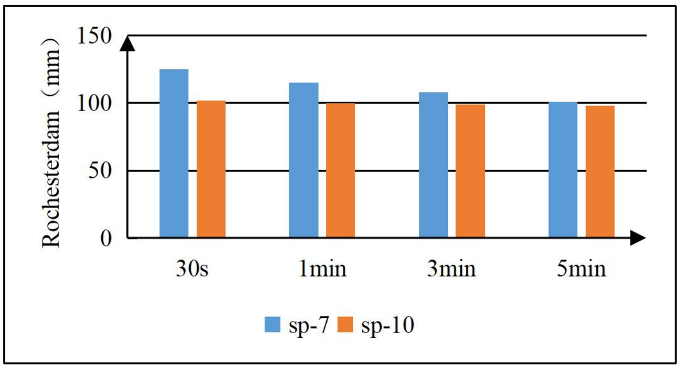

Figure 5. Evaluation of Foaming Performance of Blistering Agent at 80℃ in Su A Block Extracted Water

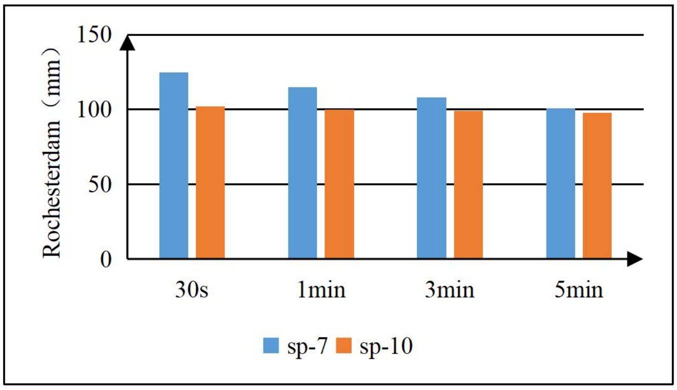

Figure 6. Evaluation of Foaming Performance of Blistering Agent at 85℃ in Recovered Water of Su A Block

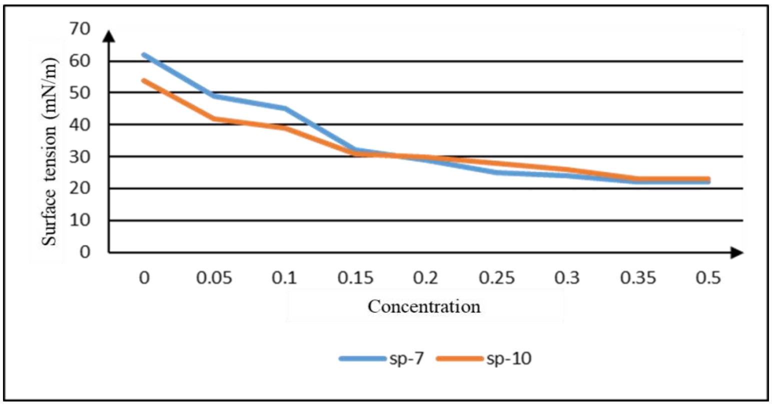

Figure 7. Evaluation of Surface Tension Properties of Vesicant in Distilled Water

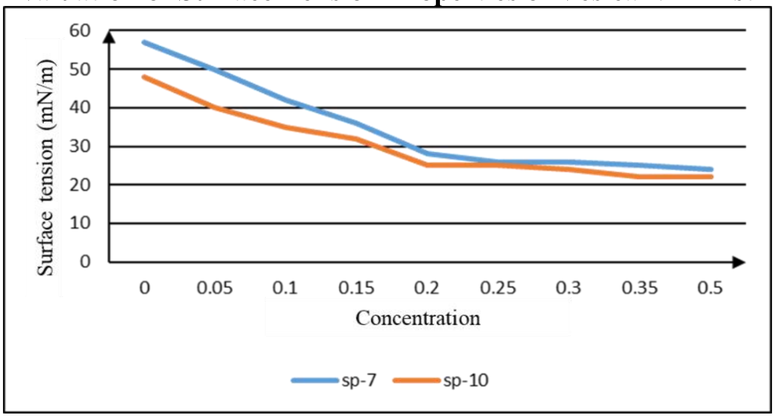

Figure 8. Evaluation of Surface Tension Performance of Soakaway Agent in Extracted Water

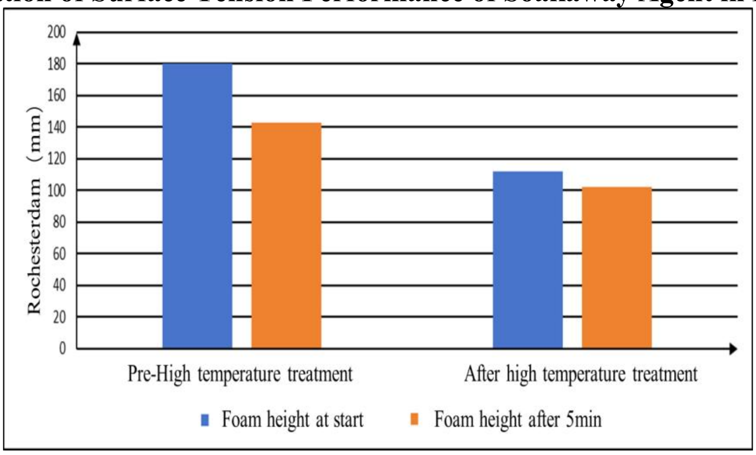

Figure 9. Stability Performance of Sp-10, A Foam Discharge Agent

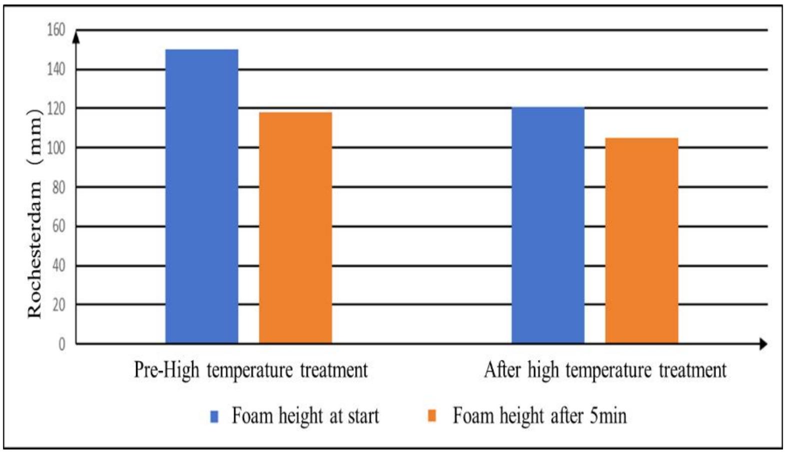

Figure 10. Stability Performance of Foam Discharge Agent Sp-10

The parameters show that the foam forming ability and foam stability of SP-10 solution after high temperature treatment are improved, indicating that SP-10 has good stability.

(2) Evaluation of stability performance of SP-7 foam discharging agent

The initial Roche bubble height of SP-7 solution without high-temperature treatment was 150mm, 118mm after 5min, and the foam stability index was 78.6%; the initial Roche bubble height of SP-7 solution after high-temperature treatment was 121mm, 105mm after 5min, and the foam stability index was 86.7%. The results show that the foam forming ability and foam stability of the high-temperature-treated solution of the soaking agent SP-7 have been improved, indicating that SP-7 also has good stability.

3.6 Compatibility Test of Foaming Agent And Formation Fluid

Through the compatibility test, it can be seen that the foaming agent SP-7, SP-10 and different mineralisation, condensate content and site water have good compatibility, no precipitation phenomenon occurs.

Table 5. Mineralisation Matching Test

Mineralisation (104mg/L)	5	10	15	20	25
Compatibility	No precipitate	No precipitate	No precipitate	No precipitate	No precipitate

Note: Concentration of bubbling agent 2%; test temperature 80～85℃; test time 24h.

Table 6. Condensate Formulation Tests

Condensate concentration (%)	5	10	15	20	25
Compatibility	No precipitate	No precipitate	No precipitate	No precipitate	No precipitate

Note: Test medium: mineralised water + condensate oil; bubbling agent concentration 2%; test temperature 80～85℃; test time 24h.

Table 7. Field Water Compounding Tests

Foaming agent concentration (%)	0.1	0.2	0.3	0.4	0.5
Compatibility	No precipitate	No precipitate	No precipitate	No precipitate	No precipitate

Note: Test medium: on-site water samples; test temperature 80～85℃; test time 24h.

4. Evaluation of Soaking Agent Throughput Effect

The results of evaluation of throughput effect of soaking agent SP-10 are shown in Table 8, and its liquid-carrying capacity does not change with salinity. With the increase of salinity, the liquid-carrying capacity and liquid-carrying rate decreased, but the decrease was small. Under the water quality conditions of the same salinity, the liquid-carrying capacity and liquid-carrying rate increase with the increase of foaming agent concentration, and the liquid-carrying capacity and liquid-carrying rate basically do not decrease with the increase of the concentration when the concentration is 0.3%~0.5%.

Table 8. Evaluation of Soaking Agent Sp-10 Throughput Effect

Name of the medicine	Temperature	Mineralisation (g/L)	Chemical concentration	15min liquid volume(ml)	Liquid-carrying capacity(%)

	(℃)		(%)		
SP-10	90	5	0.1	815	81.2
			0.3	874	86.7
			0.5	901	91.5
		20	0.1	815	82.9
			0.3	868	87.4
			0.5	314	92.3
		50	0.1	802	82.6
			0.3	885	88.6
			0.5	920	91.1
		80	0.1	795	81.3
			0.3	873	85.6
			0.5	912	90.2
		100	0.1	807	81.7
			0.3	884	87.3
			0.5	916	92.0

The results of the evaluation of the effect of soakaway agent SP-7 throughput are shown in Table 9, and its liquid-carrying capacity does not change with the change of salinity. With the increase of salinity, the liquid-carrying capacity and liquid-carrying rate decreased, but the decrease was small. Under the water quality conditions of the same salinity, the liquid-carrying capacity and liquid-carrying rate increased with the increase of foaming agent concentration, and when the concentration was 0.5%, the liquid-carrying capacity and liquid-carrying rate basically did not decrease with the increase of concentration.

Table 9. Evaluation of Soaking Agent SP-7 Throughput Effect

Name of the medicine	Temperature (℃)	Mineralisation (g/L)	Chemical concentration (%)	15min liquid volume(ml)	Liquid-carrying capacity(%)
SP-7	90	5	0.1	786	78.2
			0.3	835	85.3
			0.5	937	89.7
		20	0.1	815	83.1
			0.3	889	86.4
			0.5	913	91.7
		50	0.1	806	83.3
			0.3	882	87.6
			0.5	907	90.6
		80	0.1	803	82.4
			0.3	873	86.7
			0.5	907	91.2
		100	0.1	798	80.7
			0.3	876	88.3
			0.5	902	92.6

5. Foaming Agent Concentration Optimisation

Through the Roche Foam High Concentration Optimisation experiment, two foam draining agents were formulated into solutions (0.05%, 1.0 g/L, 2.0 g/L, 3.0 g/L, 4.0 g/L and 4.5 g/L) by using the output water from the Su A-1 well area, and the foaming capacity of each foaming solution was determined.

The experimental results are shown in Fig. 11. When the mass fraction of the blowing agent is low, the foam height increases with the increase of the mass fraction of the blowing agent. When the mass fraction of the blowing agent is increased to 0.30%, the foam height reaches the maximum. Then, the foam height does not change much even when the mass fraction of blowing agent is increased. Therefore, the mass fraction of 0.30 per cent in the foaming process gives the best ratio of SP-10 and SP-7 blowing agents in the drainage process of Su A block.

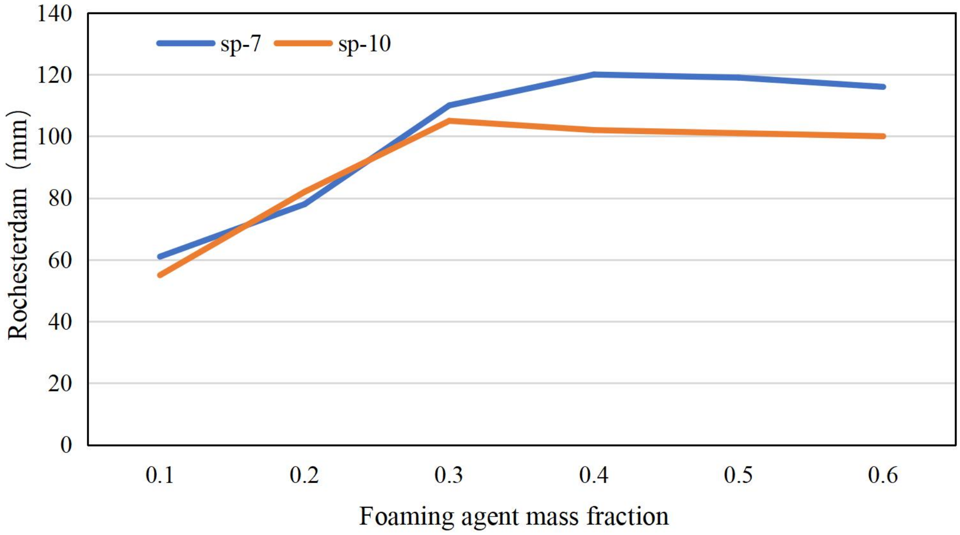

Figure 11. Optimisation of Roche Bubble High Concentration

6. Conclusion

Based on the water production and water quality of the test wells in SuA block of Surig gas field, the performance standards of blowing agents applicable to SuA block of Surig gas field are determined, so as to evaluate the performance of commonly used blowing agents in this block and optimise the relevant parameters. The main results are as follows:

(1) The average daily water production of a single horizontal well in Su A block is 2.18m3/d. The output water of gas wells is mainly dominated by condensate and formation stagnant water, with a water/gas ratio of 0.94m3/104m3, and there is a big difference in the amount of water produced, with the daily water production mainly focusing on the range of 1-5m3/d.

(2) The overall liquid production of the gas reservoir is smooth, and the mineralisation and ion concentration are higher. From the results of water quality analysis, it can be seen that the output of Surig gas field formation belongs to CaCl2 type, and the content of various ions in the water varies greatly.

(3) Liquid blowing agent SP-7 and solid blowing agent SP-10 have good foaming effect and foam stability in the produced water of Su A block, with long foam half-life, larger surface tension in the produced water, which can reduce the surface tension of the wellbore water more effectively, and have good compatibility for the field water with different mineralisation and condensate content.

(4) The two foaming agents SP-10 and SP-7 are guaranteed to have a mass fraction of 0.30% in foaming, which is conducive to enhancing the effect of drainage and gas extraction in Su A block.

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