Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 11, No. 3, 2024

Research and Application of Intelligent Gel Chemical Sand Protection System in Sand Producing Gas Wells

Xueling Song [1,*], Shengsheng Li [1], Qing Feng [1], Haoxi Li [2]

[1] Cosl Oilfield Production Optimization Division, China
[2] First Gas Production Plant of Changqing Oilfield Branch, China

*** Corresponding author:** Xueling Song (Email: songxl28@cnooc.com.cn)

Abstract: The reservoir of a loose sandstone gas field has the characteristics of high clay, high mud, high mineralization, easy water invasion, etc. Sand production greatly limits the utilization of production capacity and the application of many drainage and mining technologies. Therefore, a simple construction and the cost is low and it can effectively control the problem of fine sand production which is difficult to be solved by mechanical sand control. based on the idea of coordinated water management, an intelligent gel chemical sand control system was developed through indoor experimental performance evaluation methods and applied in A The well was successfully applied. After the measures were taken, the well resumed production and its daily gas production capacity was better than the level before the well was shut down. The results show that the technology can significantly reduce the above research provides an effective solution for preventing and controlling the blockage of mud and sand particle migration in loose sandstone gas fields.

Keywords: Intelligent Gel Chemical Sand Control System; CSC Sand Control and Water Plugging Agent; Field Application; Performance Evaluation; Sand Production in Gas Wells.

1. Introduction

The gas well production process has unique characteristics: around the gas well area, the pressure drop funnel range is wide and the flow. The flow speed is faster and the ability to carry sand is stronger. In the late stage of exploitation of loose sandstone gas reservoirs, due to the reservoir energy Factors such as exhaustion, formation pressure drops, formation water breakthrough, and production system adjustment lead to sand production in gas wells, which has a great impact on the normal operation of gas fields. Frequent production brings many problems [1-5]. The characteristics of sand production in gas wells are high gas production, fast gas flow rate, and sand carrying capacity. Strong, penetrating power, gas wells produce sand after water appears, and traditional sand control technology is difficult to meet the requirements of gas well sand control in terms of strength. The sand production in gas wells has seriously restricted the improvement of gas field and gas well production speed and economic benefits. The problem of sand seriously affecting the normal production of gas wells, chemical sand control technology has a good control effect on fine sand [6-12]. The study applied the intelligent gel chemical sand control system to treat fine silt sand. Its mechanism of action is CSC Molecules adsorb and deposit on the pore surface of water-bearing formations and bridge between solid particles, thus connecting multiple solid particles to the water-bearing formation The particles are bonded together to form organic-inorganic two-phase aggregates, which bond the formation sand to the rock surface. This achieves the purpose of sand control in gas wells [13,14].

2. Indoor Performance Evaluation of CSC Sand Control and Water Blocking Agent

2.1. Appearance and Stability

(1) Experimental method

According to Table 1, take A certain amount of CSC agent and pour it into 2000ml beaker, then take a certain amount of clean water and formation water of oilfield A respectively and slowly add it into the beaker containing CSC agent, stir gently, and stand.

Table 1. Lists of different1 liquid configurations

Solution Categories	Dosage, ml		
	CSC	Clearwater	Formation water
1 #	50	700	
2 #	50		450

(2) Experimental results

Prepare CSC solution according to 1# liquid medicine, and observe the appearance: color, stratification, precipitation and other phenomena under natural light.

Table 2. Appearance and stability of different CSC solution

Solution Categories	Appearance	Layering or not	Precipitate or not
1# solution	Light yellow solution	Unstratified	None
2# solution	Milky white colloidal solution without stratification	Not layered	Precipitate after 24 hours

Figure 1. CSC solution and colloid

2.2. Bonding Test of Quartz Sand and Target Well Formation Sand

The cementation test was carried out by taking 4L of oil-water mixed sample and 1kg of formation cuttings from well A of the target oilfield M oilfield.

(1) Analysis of formation water samples from Well A

Because the agent is sensitive to the PH of water, the PH of the formation water in well A was determined to be 6.9. It shows that the formation water does not affect the application of the process in this block, as shown in Figure 2.

Figure 2. Measurement of formation water PH value

(2) Effect of formation water in Well A on cemented sand mass

1) Take 10.0gCSC reagent and dilute it with 80g of clean water to the phase change point of the solution. According to the experimental records, the phase transition point concentration of the agent is 20%;

2) Then pour 5-6g formation sand into the solution, stir gently, and start timing to observe when the solids form clumps. The consolidation speed at different temperatures was measured. The results are shown in Table 3. The state of cemented formation sand is shown in Figure 3.

Table 3. Consolidation rates of CSC for different solid particles

Temperature, °C	Quartz sand consolidation speed, min
Room temperature	10
60	8
80	5

Figure 3. Bonding of the agent to the formation sand

3) The formation sand was immersed in formation water at 60°C for 24 hours and 72 hours respectively. It can be seen that the formation water has no effect on the cemented sand clusters, as shown in Figure 4.

Figure 4. Shape of formation sand clusters after 24 hours and 72 hours

The results show that the higher the temperature, the faster the consolidation rate of CSC on the particles, but it shows a nonlinear relationship. Well formation water has no effect on the cemented sand mass.

2.3. Determination of Sand Output by Gas Drive

2.3.1. Preparation of Experiment

(1) Filling the sandstone core: refer to 5.5 methods and steps in the standard "Q/SH1020 2377-2015 Technical Requirements for sand control Agent". First, prepare 500mm×25mm sand filling pipe, each weigh an appropriate amount of quartz sand (40~70 mesh), calcium carbonate or bentonite, the two are fully mixed evenly, into the sand filling pipe, while loading the shock.

(2) Saturated core: the three core tubes are respectively loaded into the displacement process, the sand control agent and water are prepared in the ratio of 1:15, and the prepared sand control agent is injected into the appropriate amount at 1mL/min by the advection pump, and the aging is put into the oven at 60°C for 24h.

2.3.2. Sand Production by Displacement Measurement

1. Nitrogen drive

(1) Take a sand tube filled with 401.1g quartz sand and 18.9g calcium carbonate, stand in saturated formation water for 1h, and load it into the displacement process.

(2) Take a sand tube filled with 401.1g quartz sand and 18.9g calcium carbonate, saturated with sand control agent and aged for 24h. Load it into the displacement process.

(3) The on-site gas production is 600,000 m^3/d, the horizontal well length is 370m, and the outer diameter of the casing is 139.7mm. The sand-filled pipe used in the laboratory is 500mm×25mm, and the gas drive flow rate in the experiment is about 23L/min through calculation. The nitrogen injection pressure was basically stable at 0.6MPa, and the ventilation displacement was 2h. Calculate the amount of nitrogen injected during the process. Take a large beaker, add 500mL pure water to it, and stick the outlet of the sand fill pipe below the liquid level to trap the outlet sand.

(4) After displacement is completed, shake the outlet sand-containing liquid well, pour it into a constant amount of glass sand core funnel under stirring conditions and filter it. After filtering, put the glass sand core funnel into the oven at (105±2) °C for at least 2h, take it out and put it in the dryer to cool for 30min before weighing it.

(5) Take another sand tube filled with 401.1g quartz sand and 18.9g bentonite, stand saturated formation water for 1h,

then load it into the displacement process, and repeat steps (2) ~ (3).

(6) Take another sand tube filled with 401.1g quartz sand and 18.9g bentonite, saturated with sand control agent and aged for 24h, put it into the displacement process, and repeat steps (2) ~ (3).

(7) Take another 500mm×25mm sand-filled tube and weigh 401.1 g of quartz sand (40-70 mesh). 18.9g calcium carbonate, mix the two thoroughly, and then put them into the sand filling tube, shaking them while filling. The stock solution of the agent and tap water were prepared in a ratio of 1:15, and the flow rate was 1 mL/min using a horizontal flow pump (2.5 PV control Sand agent + 1PV tap water + 2.5PV sand control agent) After injecting the sand control agent, age it at 60ÿ for 24h and put it into the displacement process. Repeat steps (2) to (3).

(8) Take another 500 mm × 25 mm sand-filled pipe and follow the procedure in (5), but with two 2.5 PV sections. The sand control agents for plugs are prepared before used.

(9) The result is calculated according to formula (1)

$$Q=\frac{m_2-m_1}{V} \tag{1}$$

In the formula:

Q -- sand content, in grams per liter (g/L);

$m1$ -- quality of filter paper, in grams (g);

$m2$ -- the mass of the dried residue and the filter paper, in grams (g);

V -- total volume of displaced nitrogen, in liters (L).

2. Nitrogen + water drive

(1) According to the liquid quantity specified in the "Q/SH1020 2377-2015 Technical Requirements for sand control agent" standard, take a 500mm×25mm sand filling pipe, weigh 401.1g quartz sand (40~70 mesh) and 18.9g calcium carbonate, mix the two fully and evenly, load them into the sand filling pipe, and shock while loading. The sand control agent was prepared in 1:15 ratio with tap water, and the sand control agent was injected into the sand control agent with the advection pump at the flow rate of 1mL/min in stages (2.5PV sand control agent +1PV tap water +2.5PV sand control agent), aged at 60°C for 24h, and then put into the displacement process. (2.5PV sand control agent in the front and back slug are prepared before use).

The on-site gas production is 600,000 m³/d, the length of the horizontal well is 370m, and the outer diameter of the casing is 139.7mm. The sand-filled pipe used in the laboratory is 500mm×25mm, and the gas drive flow rate in the experiment is about 23L/min through calculation. The nitrogen injection pressure was set at 0.5~1.2MPa, and the ventilation displacement was 2h. According to the standard, the liquid flow ratemis 30mL/min. Take a large beaker, add 100mL pure water, and extend the outlet of the sand filling pipe below the liquid level to trap the outlet sand.

(2) After displacement, shake the outlet sand-containing liquid well, pour it into a constant amount of glass sand core funnel under stirring conditions and filter it. After filtering, put the glass sand core funnel into the oven at (105±2) °C for at least 2h, take it out and put it in the dryer to cool for 30min before weighing it.

2.3.3. Experimental Conclusion

Table 4. Summary of test results of gas drive sand control

Test items	Total nitrogen flow, L	Sand production, g	Test result, g/L	Remarks
Gas drive sand 1# (displacement 2h, gas flow rate 23L/min)	2760	3.036	1.1×10^{-3} (calculated by total gas injection)	1PV of formation water, 401.1g of quartz sand, 18.9g of calcium carbonate
Gas drives out sand 1# (Displacement 2h, gas flow rate 23L/min)	2760	0.2357	8.54×10^{-5} (based on total gas injection)	Sand control agent 2PV, quartz sand 401.1g, calcium carbonate 18.9g
Gas drive sand 3# (displacement 2h, gas flow rate 23L/min)	2760	0.414	1.5 × 10^{-4} (in terms of total gas injection)	1PV of formation water, 401.1g of quartz sand, 18.9g of bentonite
Gas drives out sand 2# (Displacement 2h, gas flow rate 23L/min)	2760	0.0037	1.34 × 10^{-6} (based on total gas injection)	Sand control agent 2PV, quartz sand 401.1g, bentonite 18.9g
Gas drive out sand 3# (Displacement 2h, gas flow rate 23L/min)	2760	0.0061	2.21 × 10^{-6} (based on total gas injection)	The sand control agent is prepared 5PV at one time, injected in sections (2.5PV sand control agent +1PV water +2.5PV sand control agent), 401.1g quartz sand, 18.9g calcium carbonate
Gas drive out sand 4# (Displacement 2h, gas flow rate 23L/min)	2760	0.00038	1.38 × 10^{-6} (in terms of total gas injection)	The sand control agent of the two slugs is provisioned and injected into the block (2.5PV sand control agent +1PV water +2.5PV sand control agent), 401.1g quartz sand, 18.9g calcium carbonate
Gas-liquid codrive sand out (Displacement 2h, gas flow rate 23L/min, gas injection flow rate 30mL/min)	Total injected water 3.6L	0.1159	3.22 × 10^{-5} (based on total water injection)	The sand control agent of the two slug are provisioned and injected in stage (2.5PV sand control agent +1PV water +2.5PV sand control agent), 401.1g quartz sand, 18.9g calcium carbonate

The specific experimental results are shown in Table 4. The experimental results show that: under the same gas drive flow rate, different sand types After the core was treated with CSC sand control agent, the sand production was reduced by 95.7% on average (compared with the core saturated with formation water); Under the same CSC sand control agent injection rate, the sand production rate after gas-liquid co-drive is higher than that after single gas drive, and the average sand production is 98.9% reduction (compared with cores saturated with formation water); under the same other conditions, gas flooding has a significant effect on CSC The sand control performance of sand control agent is not significantly affected

Figure 5. Experimental sample

Figure 6. Saturated CSC sand control agent and aged

Figure 7. Core gas drive

2.4. Permeability Retention Determination

2.4.1. Experiment Preparation

(1) Fill the sandstone core: refer to the 4.6 methods and steps in the standard of Q/SLCG 0097-2014 Molecular Film sand Inhibitor, combined with the actual situation on site. Prepare a 500mm×25mm sand filling pipe, weigh 405.3g quartz sand (40~70 mesh) and 14.7g calcium carbonate, mix the two thoroughly and evenly, load them into the sand filling pipe, and shock them while loading.

(2) Saturated core: Load the filled sandstone core into the displacement process, and inject about 2PV of tap water at 1mL/min with an advection pump.

2.4.2. Experimental Determination

(1) Determination of initial gas phase permeability: the filled sandstone core is inserted into the gas drive process, and the gas drive is carried out with nitrogen at a flow rate of 500mL/min. After the flow rate and pressure are stabilized, the initial gas phase permeability K_1 of the filled sandstone core is determined.

(2) Aging of sand suppressant injection: the sand suppressant and water are prepared in a ratio of 1:15, and the prepared sand suppressant is injected into 2PV at 1mL/min by an advective pump, and is aged in a 60℃ oven for 24h.

(3) Determination of gas phase permeability after the action of sand inhibition agent: after the aging is completed, the filling sandstone core is taken out and inserted into the gas drive process, and gas drive is carried out with nitrogen at the flow rate of 500mL/min. After the flow rate and pressure are stabilized, the initial gas phase permeability K_2 of the filling sandstone core is determined.

(4) Calculation: The permeability retention rate of sand suppressor is calculated according to formula (2)

$$\eta = \frac{K_2}{K_1} \times 100\% \quad (2)$$

Where:

η --Permeability retention rate, %;

K_1 -- The initial gas phase permeability of the filled sandstone core, $10^{-3}\mu m^2$;

K_2 -- Gas phase permeability after sand inhibitor injection and aging, $10^{-3}\mu m^2$.

2.4.3. Experimental Conclusion

See Table 5, Figure 8 and Figure 9. The experimental results show that: There is no significant difference in permeability retention rate between injection of formation water and injection of CSC sand control agent, and the recovery rate of core permeability after injection of CSC sand control agent is 83.1%, indicating that the damage rate of agent to gas drive core is small.

Table 5. Experimental data of core permeability recovery rate

Test items	Nitrogen flow rate, mL/min	Steady pressure, MPa	Gas phase permeability, $10^{-3}\mu m$
Gas phase permeability K before injection of sand inhibitor	500	0.072	5805
Gas phase permeability K after injection of sand suppressor	500	0.079	4822
Penetration retention	83.06%		

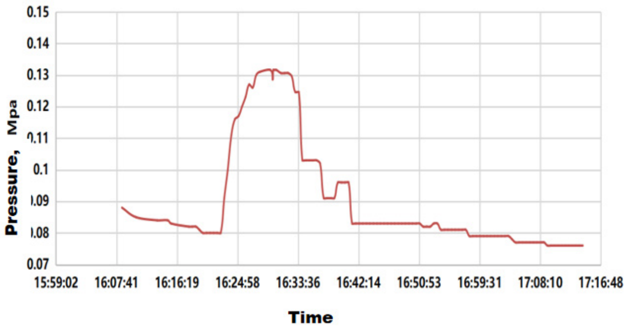

Figure 8. Gas phase permeability measurement pressure curve after injection of formation water

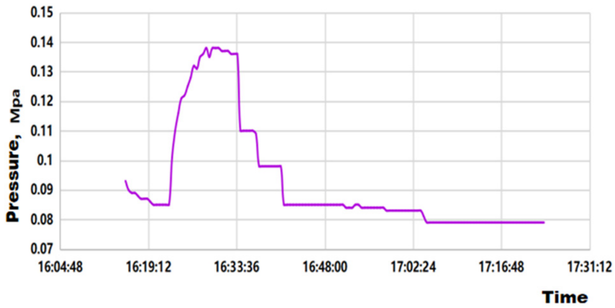

Figure 9. Pressure curve of gas phase permeability measurement after CSC sand control agent injection

3. Field Application

Well A of M oilfield was produced in the mode of oil sleeve inverted production. In the initial stage of operation, the oil pressure was 5.4MPa and the casing pressure was 6.7MPa, and the daily gas was 15,000 m^3. With the production, the well-produced sand frequently, and until August 21, 2022, the oil pressure of the well was 0.6MPa and the casing pressure was 0.7MPa, and the intermittent daily gas was 101,000 m3. Before shutting down, the daily gas was 0.3 thousand cubic meters, and the total gas production in this well section was 6.76 million cubic meters. On July 29, 2023, well A adopted CSC sand control and water blocking agent, and used multiple slug and variable displacement injection methods to construct the operation, the lower pump successfully resumed production, and the daily gas production was stable at 40,800 cubic meters. The sand was detected for 60 consecutive days, and the cumulative gas increase was 280,000 cubic meters, which is still in effect.

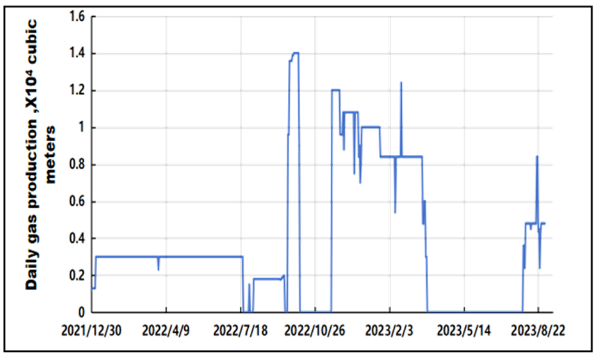

Figure 10. Production situation of well A in M oilfield after chemical sand control and production resumption

4. Conclusion

CSC agent is A supramolecular sand and water blocking system, with good sand control performance and oil-water selective water blocking performance. It can quickly adsorb and cement formation sand quickly under the temperature, salinity and water saturation of an oilfield. The agent reacts a lot in water-bearing pores, while only a small amount reacts in oil-bearing pores, which has the characteristics of water blocking and not oil blocking. CSC intelligent gel chemical sand control technologyhas been successfully applied in M oilfield, indicating that this technology can be used for the prevention and control of mud and sand clogs in similar unconsolidated sandstone gas fields, and can provide a reference for the sand control of similar reservoirs.

References

[1] Liu Wang, Xiao Yongjun, Shi Kai, et al. Development and application of sand control agent for fracturing of low permeability oil and gas reservoirs [J]. Fine Petrochemical Industry, 2021, 224 (5): 1-4.

[2] Wang Lizhi, Dong Changyin, Hu Zegen, et al. Experimental evaluation and parameter optimization of chemical sand consolidation and sand suppression assisted sand control in Enping Oilfield [J]. Journal of Shengli College, China University of Petroleum, 2021,129 (3): 62-67.

[3] Wang Zenglin, Li Peng, Wei Fang, et al. Progress of chemical sand control technology in ultra-high water cut period in Shengli Oilfield [J]. Oilfield Chemistry, 2021,149 (3): 560-563.

[4] Malining, WANG Xiaolu, Zhu Yujie, et al. Progress of natural gas development technology in Qaidam Basin [J]. Natural Gas Industry, 2007, 27 (2): 77-80. MA Lining, WANG Xiaolu, ZHU Yujie, et al. Introduction of tech- nology improvement on natural gas development in the Qaidam ba- sin[J]. Natural Gas Industry, 2007, 27 (2): 77-80.

[5] Zong Yiping, Li Yong, Wei Yamin, et al. Research and Application of effective development technology of Quaternary unconsolidated sandstone gas reservoir in Sebei Gas Field [J]. Natural Gas Geoscience, 2010,21 (3) : 357-361. ZONG Yiping, LI Yong, WEI Yamin, et al. Research and applica- tion of production techniques for Quaternary loose sand reservoirs in Sebei gas field[J]. Natural Gas Geoscience, 2010,21 (3): 357-361.

[6] Rao Peng, FENG Shengli, GU Xiaofeng, et al.Experimental study and evaluation of sand control technology for Quaternary loose silty sandstone gas reservoir in Sebei Gas Field, Qinghai Province [J]. Natural Gas Geoscience, 2006, 17 (2) : 196-200. RAO Peng, FENG Shengli, GU Xiaofeng, et al. The research and evaluation of sand - control methods for the Quaternary unconsoli- dated siltstone gas reservoir in SGF, Qinghai[J]. Natural Gas Geo- science, 2006, 17 (2) : 196-200.

[7] Wu Shaowei, Lin Kexiong, Peng Jianfeng, et al. Research on a new water-based sand consolidation fluid system suitable for offshore gas Wells [J]. Chemical & Biological Engineering, 2021, 38(03):59-63.

[8] Zhang Zhen. Research and application of sand control technology in gas Wells [J]. Inner Mongolia Petrochemical Industry,2021,47(08):82-83.

[9] Li Xiaonan, Zeng Ming, Feng Qing, et al. Integration of sand control in offshore oil field FSG water plugging technology research and application of [C] / / xi 'an petroleum university, shaanxi institute of petroleum, Beijing zhenwei exhibition co., LTD. Proceedings of 2019 international petroleum and petrochemical technology. [publisher unknown], 2019, 5. DOI: 10.26914 / Arthur c. nkihy. 2019.003500.

[10] Zhang Yunfei, Su Yanhui, Huang Yuxiang, et al. A chemical sand control consolidated core erosion resistance test and evaluation device: cn212568343u[p]. 2021-02-19.

[11] A field sand producing Wells Xu Sheng. Sea chemical sand control technology research [D]. Southwest petroleum university, 2020. The DOI: 10.27420 /, dc nki. Gxsyc. 2018. 000151.

[12] Liao Li, Opal Ming, Chen Jun, et al. Reservoir plugging mechanism and application of plugging removal technology for unconsolidated sandstone gas reservoir in Sebei Gas field [J]. Xinjiang Petroleum Geology,2023,44(01):100-104.

[13] TALAGHAT M R, ESMAEILZADEH F, MOWLA D.S and production control by chemica consolidation[J]. Journal of Petroleum Science and Engineering, 2009, 67(1/2) :34-40.

[14] Wang Zenglin, Li Peng, Wei Fang, et al. Shengli oilfield for determining chemical sand control technology progress [J]. Journal of oilfield chemistry, 2021, 38 (03): 560-563. The DOI: 10. 19346 / j.carol carroll nki. 1000-4092.2021.03.032.