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Research Article

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Posted Date: July 6th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9878205/v1

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Additional Declarations: No competing interests reported.

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Abstract: To solve deep formation plugging (≥3 m) in Bohai Oilfield caused by long-term water/polymer flooding—where conventional acidizing fails—this study proposes a gas-assisted acidizing technology. The method alternates acid and nitrogen injection to delay acid-rock reaction, expand swept volume, and aid flowback. Laboratory experiments using three 1m-sand-packed tubes in series (simulating a 3 m damaged zone) compared four injection modes. Two cycles of gas - acid alternation led to an acid penetration of over 3 m, with a permeability recovery more than twice that of conventional acidizing. Numerical simulation defined optimal conditions: reservoir thickness <20 m, crude oil viscosity <500 mPa·s, plugged-zone permeability <100 mD. Recommended parameters: gas-liquid ratio 1:4–1:5, nitrogen rate 0.5–0.7 m^3/min, 2–3 cycles. A field test in Well A (damage radius 2.8 m) raised daily oil from 16 to 90 m^3/d, reduced water cut from 80% to 51.8%, and achieved 15,200 m^3 cumulative oil increase over one year. Gas-assisted acidizing offers a low-cost, deep plugging-removal solution for polymer-flooded heavy-oil fields, with clear field adaptability guidelines.

Keywords: gas-assisted acidizing; deep plugging removal; adaptability analysis; numerical simulation; Bohai Oilfield

1. Introduction

After years of water flooding and polymer flooding, many mature oilfields worldwide face severe near-wellbore formation plugging, which significantly reduces oil production (Zhao et al., 2020; Wang et al., 2023). The plugging mechanisms are complex, involving particle migration, organic scale deposition, polymer residue, and inorganic precipitation (Ba Alawi et al., 2020; Ramy et al., 2025). In the Bohai Oilfield, polymer flooding has been applied to hundreds of production wells, but polymer-flooded wells exhibit a composite plugging system where crude oil

components, polymers, and reservoir particles interact to form stable, deep-penetrating plugs with damage radii often exceeding 3 m and reaching up to 10 m. Conventional acidizing, typically using HCl/HF mixtures, has been the most common stimulation method due to its simplicity and low cost (Cheng et al., 2002; Letichevskiy et al., 2017). However, field practices show that the effectiveness of conventional acidizing deteriorates with repeated treatments, the plugging removal radius is limited (generally <2 m), and the post-treatment water cut often remains high.

To overcome the limited penetration depth of conventional acidizing, several enhanced acidizing techniques have been developed. Gelled acids and self-diverting acids use polymers or surfactants to increase viscosity, reducing acid fluid loss and improving diversion (Chen et al., 2025; Gao et al., 2025). However, polymer-based systems may cause additional formation damage, especially in low-permeability zones. Foam acidizing injects gas with acid to generate foam, which blocks high-permeability channels and diverts acid to deeper, damaged zones (Letichevskiy et al., 2017; Xin et al., 2025). Foam acidizing has shown success in carbonate reservoirs, but its application in sandstone reservoirs with heavy oil and polymer residues remains underexplored. Thermochemical fluids and microemulsion acids have also been proposed to improve deep penetration (Ba Alawi et al., 2020; Wang et al., 2023), yet these methods often require specialized chemicals and increase operational costs.

Despite these advances, none of the existing techniques specifically address the deep composite plugging (≥3 m) in polymer-flooded sandstone reservoirs with heavy crude oil (viscosity >100 mPa·s) under offshore platform constraints (limited space, high cost per operation). Conventional foam acidizing uses continuous gas injection, which is prone to gas channeling and does not fully exploit the synergistic effect of alternating small gas slugs. Moreover, quantitative adaptability guidelines—such as reservoir thickness, permeability, oil viscosity thresholds—are

lacking in the literature, making it difficult for field engineers to select suitable wells and design treatment parameters.

To fill this gap, this study proposes a gas-assisted acidizing technology based on alternating injection of small acid and nitrogen slugs. Unlike continuous gas injection, the alternating slug method induces repeated Jamin effects and bubble-enhanced viscosity, which delays acid-rock reaction, expands acid swept volume, and facilitates flowback. The objectives of this work are: (1) to experimentally evaluate the plugging removal efficiency of gas-liquid alternating injection compared with conventional acidizing using a 3m long sand-packed tube assembly; (2) to numerically simulate the effects of reservoir thickness, permeability, oil viscosity, injection rate, gas-liquid ratio, and alternating cycles on the acidizing radius; (3) to provide field-applicable operational guidelines; and (4) to validate the technology with a field test in a polymer-flooded well in Bohai Oilfield.

2. Experimental Evaluation of Gas-Assisted Acidizing Technology

Due to the characteristics of low density, low viscosity, low surface tension, high compressibility, fluidity, and dispersibility of gas, the gas-liquid alternating injection plugging removal acidizing technology has the advantages of retarding, diverting, and deep plugging removal effects, and is conducive to efficient flowback and isolation of formation fluids, which can significantly improve the acidizing effect.

2.1 Experimental Materials and Design

The sand samples used in the experiment were taken from a sand production well in Bohai Oilfield. To control the permeability in the tube, sands of various particle sizes sieved from the sampled sand were filled in the tube in different proportions. The sands used for the tube mesh mainly include 20-40, 40-60, 60-90, 90-120, and 120-250 meshes. The experimental equipment includes sand-packed tubes, a constant temperature oven, an injection pump, an intermediate container, a pressure sensor, and a produced fluid collection system. The inner diameter of the

sand-packed tube is about 25 mm, and the length is 1 m. Due to the difficulty in controlling liquid nitrogen during the experiment and certain risks, high-pressure nitrogen was injected as gas during the experiment. The schematic diagram of the sand tube plugging simulation experimental device is shown in Fig.1, and the schematic diagram of the gas-assisted acidizing experimental device is shown in Fig.2. An environmental scanning electron microscope (ESEM, Quanta200FEG, FEI, USA) and a cathodoluminescence spectrometer were used to test and analyze the changes and composition characteristics of sandstone (magnification: 7-1,000,000×, maximum pixel: 3584×3094).

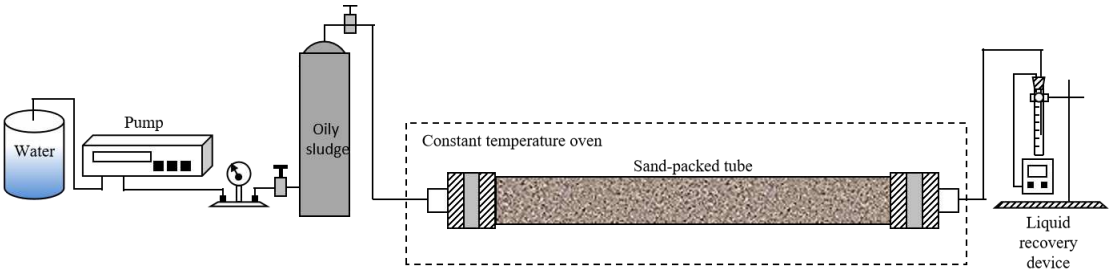


Fig. 1 Schematic diagram of sand tube plugging simulation experiment

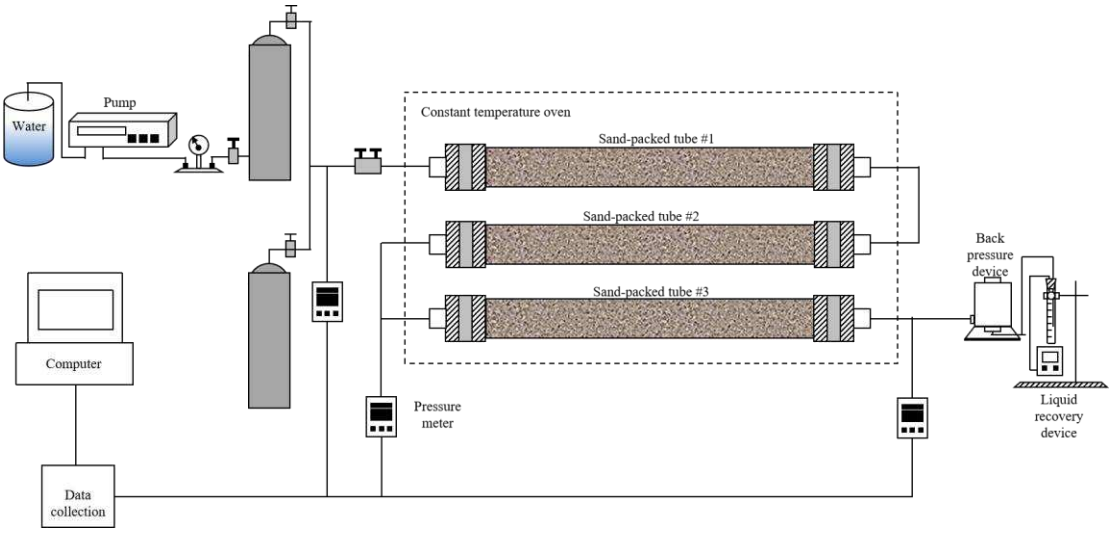


Fig. 2 Schematic diagram of gas-assisted acidizing experiment

A new experimental method was adopted: three sand-packed tubes with a length of 1 m were injected with oily sludge (a mixture of oil, water, and fine sand produced from oil wells in Bohai Oilfield) to simulate the plugging of the near-wellbore formation, and the three sand-packed tubes were connected in series to

simulate the formation about 3 m near the wellbore. The acid used was an aqueous solution of 12% HCl + 3% HF. Four injection methods were set: pure acid injection, pre-flush acid + gas, pre-flush gas + acid, and 2 cycles of gas-liquid alternation. The acid injection volume was the sum of the pore volumes of #1 and #2 sand tubes. The temperature of the constant temperature oven was controlled at 55 ℃ to simulate a 1000 m deep formation. The injection and production of liquid were controlled by the injection pump, pipelines, and valves, and the pressure data was transmitted to the computer through the pressure sensor. A backpressure device was used at the outlet of the sand-packed model to control the outlet pressure. The injection rate was controlled at 5 mL/min, and different experimental temperatures were set. After the experiment, the changes in sand tube permeability at different distances were tested.

2.2 Experimental Procedures

Before the experiment, the sand tube needs to be treated:

The sieved sand is filled into the sand-packed tube according to a certain proportion;

The air in the sand tube is removed by a vacuum pump, and the tail end absorbs water to ensure that the sand tube is saturated with aqueous solution. The porosities of #1, #2, and #3 sand tubes are calculated by the volume method, and the sand tube permeability is measured with water;

The oily sludge produced from the oil well is injected into the sand tube, and the permeability of the sand tube after plugging is measured with water. These steps are completed before the experiment, and the relevant data are shown in Table 1.

Then, the pipelines are connected according to the schematic diagram, the constant temperature oven is turned on to the predetermined temperature, and wait for 4 hours until the internal temperature is stable. In the first group of experiments, the intermediate container filled with acid is connected, and acid is injected at an injection rate of 5 mL/min. In the second group of experiments, the injection pump also injects acid at an injection rate of 5 mL/min, and then injects the same volume of nitrogen at

the same rate. The third group of experiments is the opposite of the second group: first inject high-pressure nitrogen, and then inject acid after the injection is completed, with the same volume of both; in the fourth group of experiments, first inject half of the nitrogen and half of the acid, and then inject the remaining nitrogen and acid.

Table 1 Experimental design data

No.	Type	Injection Rate (mL/min)	Porosity(%)			Permeability (mD)		
			#1	#2	#3	#1	#2	#3
1	acid	5	0.25	0.28	0.26	1225	1379	1382
2	Pre-acid + gas	5	0.23	0.28	0.29	1139	1490	1403
3	Gas + Post-acid	5	0.28	0.28	0.26	1515	1366	1517
4	2 cycles of gas-acid alternation	5	0.25	0.29	0.24	1285	1209	1374

2.3 Results Analysis

Fig.3 shows the sand samples in the sand-packed tube after injecting oily sludge, and Fig.4 shows the micrographs and energy spectrum analysis of the corresponding sand samples under a scanning electron microscope. In the plugging simulation, oily sludge was injected into 12 sand-packed tubes in 4 groups of experiments to simulate the plugging in the near-wellbore area, and the permeability of the sand tubes decreased by 70%~85%. From the energy dispersive spectrometer (EDS) test results, the contents of C, O, Fe, and Ca in the plugging substances are prominent. It is analyzed that the oily sludge mainly exists in the form of a mixture of heavy oil, rust, calcium deposits, and fine sand. During the migration of crude oil in the formation, sand grains or particles on the rock surface are carried and entrained by the formation fluid to migrate to the near-wellbore area and the sand control layer, providing a large number of crystal nuclei for the flocculation and adsorption of gum and asphaltene. The formed organic scale aggregates around the sand grains,

becoming a damage source or auxiliary agent for formation plugging. At the same time, some small-diameter sand grains that could have been discharged through the sand control layer are retained in the near-wellbore area and the sand control layer, resulting in double plugging of particle migration and organic scale during oilfield development. In addition, iron-oxidizing bacteria in the formation can convert divalent iron (Fe^{2+}) in the produced fluid into trivalent iron (Fe^{3+}), thereby forming water-insoluble $Fe(OH)_3$ gel that precipitates from the water, causing formation plugging.



Fig. 3 Sand samples in the sand tube after injecting oily sludge

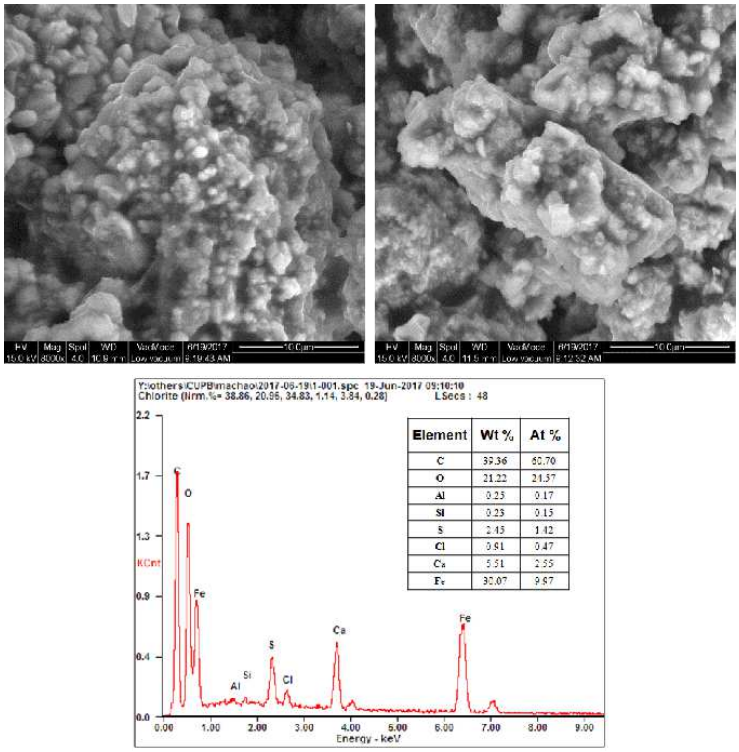


Fig. 4 Microscopic changes and energy spectrum analysis of sand samples before and after plugging removal

Table 2 details the changes in permeability of each sand-packed tube before and after the experiment. After injecting 10 PV of acid, the permeability was improved to varying degrees, and the corresponding improvement degree is compared in Fig.5.

In the plugging removal simulation, the permeability of #1 sand-packed tube was greatly improved after acid injection in the first and second groups of experiments, with an increase of more than 8.5 times before and after plugging removal. However, the acid consumption rate was fast, making it difficult to restore the permeability of #2 and #3 sand-packed tubes, and the permeability of the subsequent sand tubes basically did not change.

Table 2 Experimental simulation results

Experimental Type	**Sand Tube No.**	**Original Permeability (mD)**	**Permeability After Plugging (mD)**	**Permeability After Plugging Removal (mD)**	**Permeability Change Amplitude Before and After Plugging Removal**
acid	#1	1225	309	2724	8.82
	#2	1379	271	366	1.35
	#3	1382	353	384	1.09
Pre-acid + gas	#1	1139	230	3872	8.52
	#2	1490	422	506	1.69
	#3	1603	409	332	1.16
Gas + Post-acid	#1	1515	455	1449	6.29
	#2	1366	299	1282	3.04
	#3	1517	285	536	1.31
2 cycles of gas-acid alternation	#1	1285	275	1429	5.20
	#2	1209	295	1082	3.67
	#3	1374	271	700	2.59

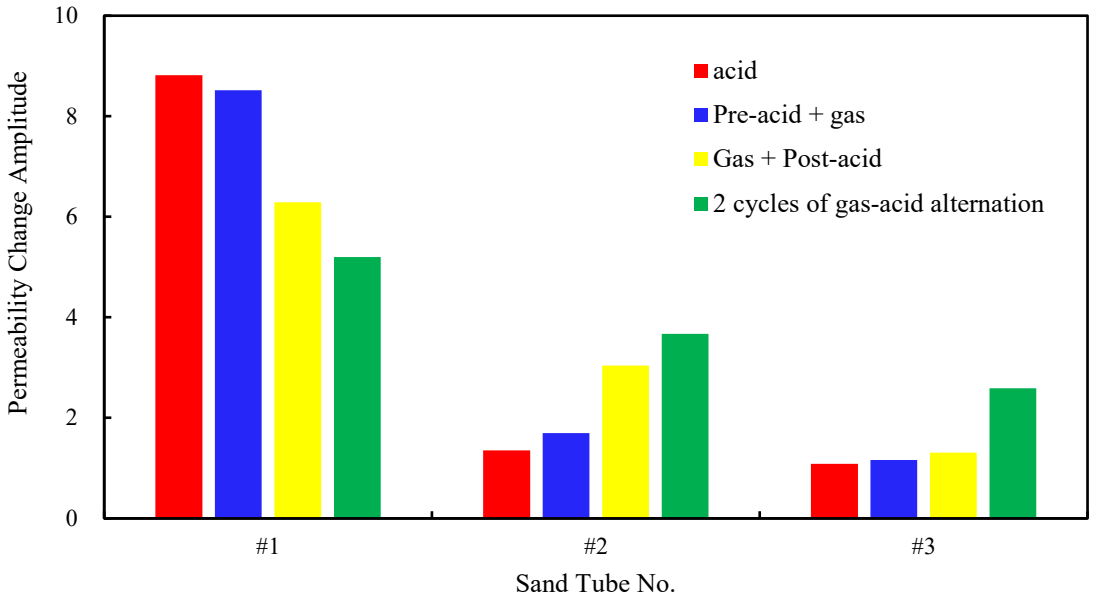


Fig. 5 Comparison of permeability change amplitude at different distances

In the third group of experiments, the pre-flush gas delayed the acid consumption in #1 sand-packed tube to a certain extent, but the acid still could not reach #3 sand-packed tube, and the swept distance was less than 2 m. Under the same acid injection volume, the effect of injecting pre-flush gas first and then acid was significantly better than that of conventional acidizing. In the fourth group of experiments under gas-liquid alternating injection, the permeability of #1 sand-packed tube was restored while the permeability of #3 sand-packed tube was also improved to a certain extent. Compared with conventional acidizing, injecting pre-flush gas before acidizing or adopting gas-liquid alternating injection can effectively improve the effect of acidizing operations, making the sand tube permeability increase significantly. Gas injection can obviously improve the deep acidizing effect, and the permeability recovery value reaches more than 2 times. The comprehensive injection method of gas-liquid alternating injection of treatment fluid and nitrogen has the best effect, and finally, the acid swept distance reaches more than 3 m.

Experiments have proved that the gas dispersed in the acid in the formation forms bubbles, which increases the viscosity of the mixed fluid and can improve the acid's own fluid-loss control capability; the bubbles migrate with the acid in the

formation and accumulate at some throats to produce the Jamin effect (a phenomenon where gas bubbles block pore throats), which can effectively block some large pores and micro-fractures in the formation and reduce acid fluid loss. In the contact between injected gas and the rock surface, part of the acid is replaced, reducing the effective acid-rock contact area, playing a certain retarding role, increasing the acidizing depth, and achieving deep penetration. The low-temperature liquid nitrogen used on-site also has the effect of reducing the acidizing reaction rate. Although this low-temperature effect was not reflected in the experiment, the gas-assisted effect can still be observed.

3. Adaptability Analysis of Gas-Assisted Acidizing Technology

Through the method of reservoir numerical simulation, the applicability and process design method of gas-liquid alternating acidification technology are clarified, which provides guidance for well selection and scheme design of oilfield.

3.1 Simulation Scheme Design

To further improve the synergistic effect of gas, reservoir simulation of different parameters of gas-assisted acidizing was carried out on the actual field scale. First, a three-dimensional grid system with a length and width of 400 m was established. The grid unit length in the I and J directions is 10 m, the grid unit length in the K direction is 1 m, and the thickness is 10 m~40 m. To more accurately observe the acid action distance, the 4 m grid near the production well was refined, and the grid unit length after refinement is 2 cm. The well pattern type is inverted nine-spot water flooding (fig.6). Initial reservoir pressure: 5~25 MPa; initial reservoir temperature: 40~60°C; initial water saturation: 0.3; initial oil saturation: 0.7. The crude oil viscosity at reservoir temperature is 10~1000 mPa·s.

According to the geological conditions and on-site process requirements of Bohai Oilfield, different parameters such as thickness, permeability, reservoir pressure, crude oil viscosity, liquid nitrogen alternating cycles, injection rate, and gas injection volume were designed. Conceptual models were used for reservoir

numerical simulation, and the parameter table is shown in Table 3. Among them, permeability refers to the permeability of the formation near the wellbore after plugging, and the wellbore skin factor is converted into formation permeability.

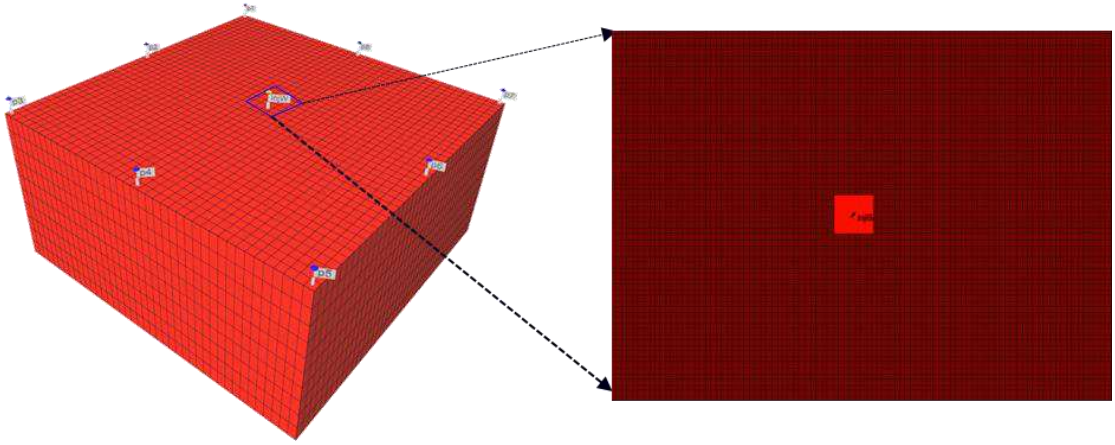


Fig. 6 Schematic diagram of reservoir model

Table 3 Simulation parameter design

Parameter Setting	**Parameter 1**	**Parameter 2**	**Parameter 3**	**Parameter 4**	**Parameter 5**	**Parameter 6**
Thickness (m)	5	10	15	20	30	40
Permeability (mD)	30	50	70	100	200	300
Reservoir pressure (MPa)	5	10	15	20	25	
Crude oil viscosity (mPa·s)	10	50	100	150	200	300
Alternating cycles	1	2	3	4	5	
Liquid nitrogen injection rate (m^3/min)	0.3	0.5	0.7	0.85	1	1.2
Gas-liquid ratio	1:2	1:3	1:4	1:5	1:6	

In the simulation process, facing the situation of multiple variables and parameters of the research object, the comprehensive experiment has a large workload

and complex data. In the single-factor simulation, other parameters take intermediate values, and a total of 39 gas-liquid alternating acidizing simulation schemes were designed (the acid injection volume of each scheme is 2 m pore volume). The simulation results record the acidizing radius, and combined with on-site expectations, 3 m acidizing radius is set as the standard line for comparison.

3.2 Analysis of Simulation Results

(1) Influence of reservoir thickness

To verify the influence of different reservoir thicknesses on the plugging removal radius of the gas-liquid alternating technology, 6 groups of simulation schemes were established with a thickness variation range of 5~40 m, and other parameters take the second column parameters in Table 3. Among them, the gas injection volume is the pore volume of the 2~3 m range of the reservoir wellbore in each scheme. Comparison was made with 3 m as the standard line, and the simulation results are shown in Fig.7a. From the simulation results, with the increase of reservoir thickness, the gas injection volume increases, and the plugging removal radius decreases due to the gas overriding effect. The gas-liquid alternating acidizing can effectively improve the treatment depth when the reservoir thickness is less than 20 m.

(2) Influence of permeability after plugging

To verify the influence of different plugging permeabilities on the plugging removal radius of the gas-liquid alternating technology, 6 groups of simulation schemes were established with a permeability variation range of 30~300 mD, and other parameters take the second column parameters in Table 3. Comparison was made with 3 m as the standard line, and the simulation results are shown in Fig.7b. From the simulation results, the permeability near the oil well decreases after plugging, and the gas channeling capacity is different under different permeabilities. High permeability will cause gas channeling. To ensure the deep swept effect, the

lower the permeability of the polluted zone, the larger the swept depth of gas-liquid alternating plugging removal.

(3) Influence of reservoir pressure

In reservoir numerical simulation, reservoir pressure can simultaneously characterize the reservoir depth. To verify the plugging removal radius of the gas-liquid alternating technology under different reservoir pressures, 5 groups of simulation schemes were established with a reservoir pressure variation range of 5~25 MPa, and other parameters take the second column parameters in Table 3. Comparison was made with 3 m as the standard line, and the simulation results are shown in Fig.7c. From the simulation results, the implementation of the gas-liquid alternating technology has little correlation with reservoir pressure.

(4) Influence of formation crude oil viscosity

To verify the plugging removal radius of the gas-liquid alternating technology under different crude oil viscosities, 7 groups of simulation schemes were established with a crude oil viscosity variation range of 10~1000 mPa·s, and other parameters take the second column parameters in Table 3. Comparison was made with 3 m as the standard line, and the simulation results are shown in Fig.7d. From the simulation results, injecting liquid nitrogen will cause the temperature near the bottom hole to drop by 10~20℃. The temperature drop during oil well acidizing will cause changes in crude oil viscosity, resulting in an increase in injection pressure. When the crude oil viscosity is greater than 150 mPa·s, there are problems of high injection pressure and difficult gas injection.

(5) Optimization of liquid nitrogen injection rate

To verify the plugging removal radius of the gas-liquid alternating technology under different liquid nitrogen injection rates, combined with on-site construction requirements, the injection rate of 0.3~1.2 m^3/min was selected for simulation, and 6 groups of simulation schemes were established, with other parameters taking the second column parameters in Table 3. Comparison was made with 3 m as the standard

line, and the simulation results are shown in Fig.7e. From the simulation results, too fast gas injection rate will lead to gas channeling, and too slow will lead to formation consumption of acid. During on-site construction, the liquid nitrogen injection rate should be controlled at 0.5~0.7 m^3/min.

(6) Optimization of gas-liquid ratio

To verify the plugging removal radius of the gas-liquid alternating technology under different gas-liquid ratios, combined with on-site construction requirements, 5 groups of simulation schemes were established with the ratio of injected liquid nitrogen volume (surface) to plugging removal liquid as 1:2, 1:3, 1:4, 1:5, 1:6. Comparison was made with 3 m as the standard line, and the simulation results are shown in Fig.7f. From the simulation results, due to the channeling characteristics of gas, the ratio of injected liquid nitrogen volume to plugging removal liquid volume is between 1:4~1:5, which can realize deep acidizing while controlling economic costs.

(7) Optimization of gas-liquid alternating cycles

To verify the plugging removal radius of the gas-liquid alternating technology under different gas-liquid alternating cycles, combined with on-site construction requirements, 5 groups of simulation schemes were established with alternating cycles of 1-5 for simulation. Comparison was made with 3 m as the standard line, and the simulation results are shown in Fig.7g. From the simulation results, when injecting gas-liquid slugs, the smaller the liquid column slug, the easier the gas breaks through and channels in the formation, and the liquid-carrying capacity decreases. During on-site construction, the number of gas-liquid alternating cycles should be 2-3. Fig.8 shows the distribution of acid content in the pores of two cycles of gas injection reservoirs.

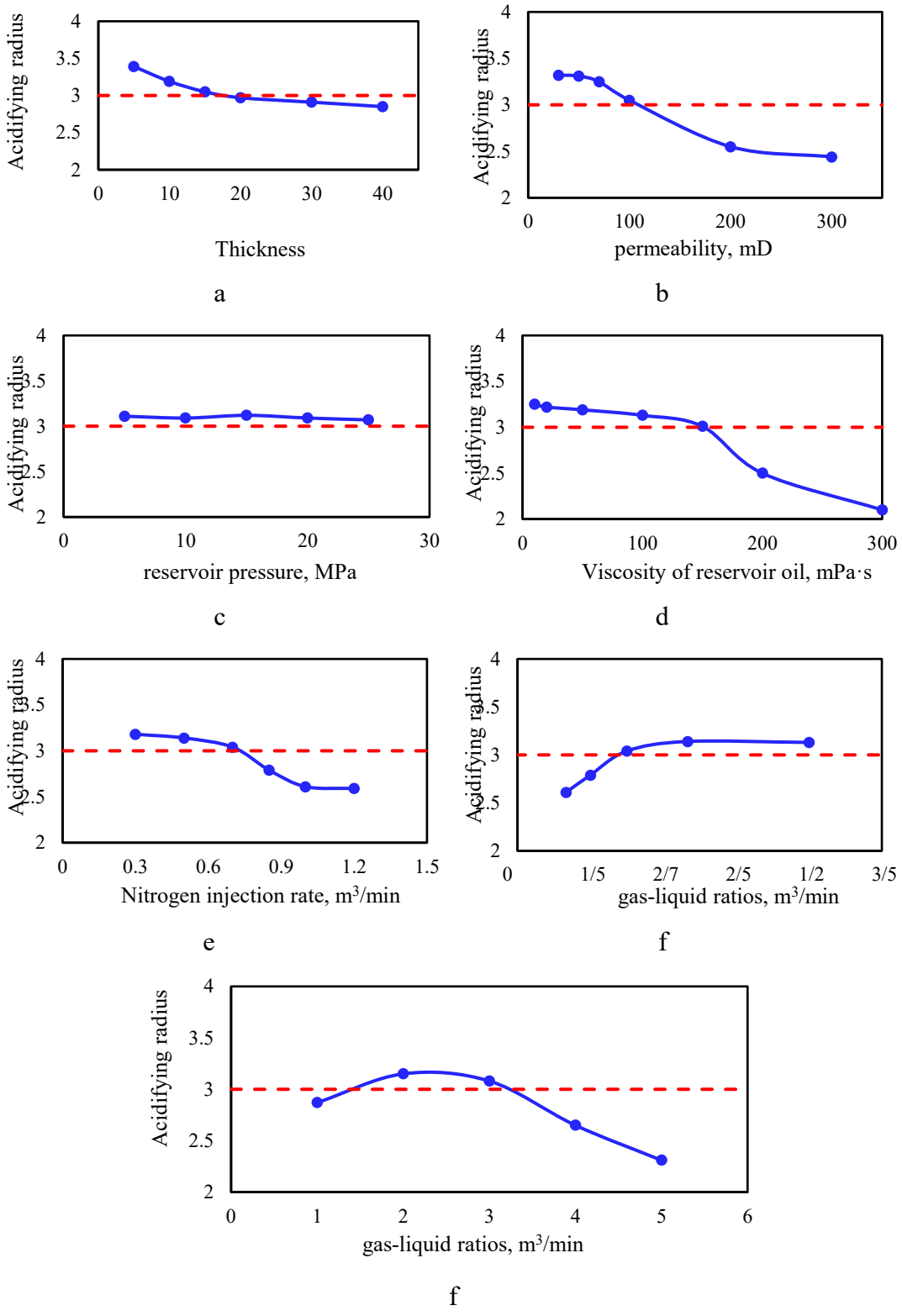


Fig. 7. Comparison of acidification radius under different simulation parameters

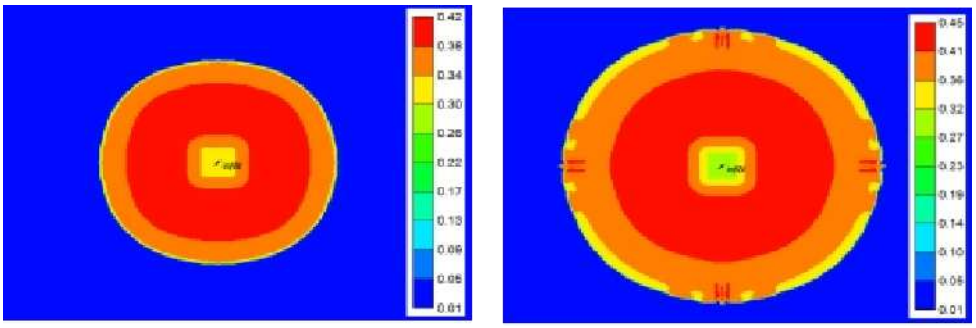


Fig. 8. Acid distribution in the formation under different cycles (within 4 m range)

4. Field Test

Well A in Bohai Oilfield is a production well seriously affected by polymer flooding. The polymer concentration in the produced fluid is about 230 mg/L, the daily fluid production is 80 m^3/d, the daily oil production is 16 m^3/d, and the water cut is 80%. The pressure build-up test results show that the damage skin factor is 15.6, and the simulation calculation results show that the damage radius is about 2.8 m. The plugging is serious and the damage range is deep, so conventional acidizing cannot effectively remove the plugging. The new gas-assisted acid injection deep plugging removal technology was used to perform plugging removal operations on this well. During the design, multi-cycle treatment and liquid nitrogen slugs were considered, and the construction procedures are shown in Table 4.

Table 4 On-site construction procedure table of Well A

No.	Construction Content	Pumping Pressure (MPa)	Injected Fluid Volume (m^3)
1	Cleaning fluid	<12	10
2	Formic acid	<12	20
3	Strong oxidant	<12	20
4	Positive squeeze treatment fluid (10% HCl + 3% clay acid + 4% polybasic acid)	<12	20
5	Positive squeeze liquid nitrogen	<14	8
6	Strong oxidant	<12	10
7	Positive squeeze treatment fluid (10% HCl + 3% clay acid + 4%	<12	10

	polybasic acid)		
8	Positive squeeze liquid nitrogen	<14	5
9	Formic acid	<12	15
10	Fresh water	<12	10

After the measures, the daily fluid production of the well is 187 m^3/d, the daily oil production is 90 m^3/d, and the water cut is 51.8%. Both the daily fluid production and daily oil production have been greatly improved, the flowing pressure has increased by 6 MPa, and the water cut has further decreased to 38% after a period of fluid production. The effective period has reached one year and is still effective, with a cumulative oil increase of 15,200 m^3. The comparison of production conditions before and after the measures shows that the new technology can effectively remove the composite plugging substances in the polymer-producing wells, expand the acid plugging removal radius, effectively adjust the production profile, activate the medium and low permeability layers, reduce the water cut, and the measure effect is remarkable with a long effective period.

5. Conclusions

This study proposed a gas-assisted acidizing technology to address deep formation plugging (≥3 m) in polymer-flooded sandstone reservoirs of the Bohai Oilfield, where conventional acidizing fails due to limited acid penetration and high cost. The research combined laboratory experiments using three 1-m sand-packed tubes in series, numerical reservoir simulation, and a field test.

(1) The gas-liquid alternating injection method significantly improves acid penetration depth compared to conventional acidizing. Two cycles of gas-acid alternation achieved an acid swept distance exceeding 3 m, with permeability recovery more than double that of acid-only treatment. The enhancement is attributed to the Jamin effect of gas bubbles and bubble-induced viscosity increase, which delay acid-rock reaction and divert acid to deeper damaged zones. This finding fills the gap

that previous foam acidizing studies focused on continuous gas injection rather than small-slug alternation, and none quantified the effect in a 3-m long sandpack representing polymer-flooded composite plugs.

(2) Numerical simulation established quantitative applicability criteria for the technology. The plugging removal effect is optimal when reservoir thickness is less than 20 m, crude oil viscosity below 500 mPa·s, and plugged-zone permeability lower than 100 mD. Reservoir pressure has negligible influence. Recommended operational parameters are: nitrogen injection rate 0.5–0.7 m^3/min, gas-liquid volume ratio 1:4 to 1:5, and 2–3 alternating cycles. These guidelines were previously unavailable in the literature, providing field engineers with a practical decision-making basis.

(3) The field test in Well A (damage radius 2.8 m, polymer concentration 230 mg/L) demonstrated the effectiveness of the proposed technology. After treatment, daily oil production increased from 16 to 90 m^3/d, water cut dropped from 80% to 51.8%, and the cumulative oil increment reached 15,200 m^3 over one year. The sustained effect (>12 months) confirms that gas-assisted acidizing can remove deep composite plugs and activate medium-low permeability zones.

In summary, gas-assisted acidizing offers a low-cost, deep plugging-removal solution for offshore heavy-oil fields developed by water and polymer flooding. It specifically addresses the previously unsolved problem of polymer-flooded production wells with damage radii >3 m. The technology is ready for broader application in similar reservoirs after site-specific parameter optimization.

Statements

Competing Interests: The authors report there are no competing interests to declare.

Data Availability Statement: The experimental, numerical simulation, and field production data that support the findings of this study are available from the corresponding author upon reasonable request. No publicly archived dataset was generated or used in this study.

Funding Declaration: This research was financially supported by the CNOOC China Limited under the project “Deep Plugging Removal New Technology”.

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