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Study and Application of Oily Sludge Profile Control Technology in Heavy Oil Reservoir

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Abstract: In the process of steam injection development of heavy oil, due to the serious heterogeneity and interference of steam channeling in the high-permeability layer, there is a lot of oily sludge in the produced liquid of oil wells, which is difficult to deal with. According to existing profile control technology and the related properties of oily sludge, a profile control system was developed by using oily sludge as the main agent and by adding other additives. At the same time, *the properties of sludge, the matching relationship between the particle size of sludge and the formation of pore roar, the temperature resistance, the plugging ability*, and other contents were studied. The agent featured an adjustable curing time (3 to 300 h) and resistance to pressures greater than 6 MPa and temperatures greater than 350 °C. After the agent was injected into the high-permeability steam channeling, the system was cemented with the formation rock and the sealing rate was more than 85%, without any damage to the low- and medium-permeability layers. According to the different characteristics of the production well and steam injection well, the construction technology was optimized, the oily sludge profile control technology suitable for heavy oil reservoirs was formed, and the field test was carried out. At present, more than 150 wells have been used in the field, with a cumulative oil increase of 10,756 tons. The technology not only solves the environmental pollution caused by oily sludge but also reduces the cost of thermal recovery of heavy oil, with great significance for improving the final recovery efficiency and commercial benefits of the oilfield.

Keywords: heavy oil reservoir; oily sludge; profile control agent; steam injection

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1. Introduction

Most onshore heavy oil reservoirs in China are continental deposits with complex geological conditions and are dominated by multi-layer interbedded assemblages. The reservoirs are dominated by clastic rocks, which are characterized by high porosity, high permeability, and loose cementation. Steam injection thermal recovery is often used to develop heavy oil reservoirs, but there are two problems: First, there is serious heterogeneity, the utilization degree is low, the utilization condition of the middle- and low-permeability layer is poor, and there is serious interference of the high-permeability layer. Second, the loosely consolidated sandstone heavy oil reservoir has the characteristics of loose sand grains and a strong sand carrying capacity of heavy oil, resulting in a large sand output. According to statistics, more than 90% of the wells are accompanied by sand production. Due to the special nature of oily sludge, it is difficult to deal with and the cost is high. Related scholars have carried out a lot of exploration and practice on oilfield sludge treatment technology.

The treatment of the produced oily sludge involves the cleaning method, dry incineration method, biodegradation method, pit sealing method, solidification method, etc. [1,2], all of which have been stopped because of immature technology or environmental protection risks. In view of the nature, composition, discharge, treatment cost, benefit, and scale of emission reduction of sludge, various technologies have certain application prospects. However, there is no effective method in case the discharge of oily sludge is significant.

In the development of heavy oil thermal recovery, the high-temperature and high-pressure conditions of the formation require a very high-performance profile control agent. Currently, the commonly used profile control technology for high-temperature-resistant heavy oil includes a rubber particle profile control agent system, high-temperature resistant gel + inorganic particles, nitrogen foam, and thermal (reversible) gel. Chemical agents occupy the majority of these systems, the cost of the agents is high, and the scope of popularization and application is limited. Due to the large number of components used in the system, the commonly used profile control agent cannot be placed on the construction site. Therefore, the preparation of the site is usually made in a fixed liquid distribution station, which requires a lot of manpower and machinery to assist, and the preparation cost is high.

The two problems of oily sludge treatment and heavy oil profile control are solved in separate ways, which requires the separate treatment of sewage sludge on the ground and the separate consideration of the chemical system in the reservoir profile control. The input cost increases and the efficiency is low.

2. Oily Sludge Profile Control Agent System

2.1. Proposal of Profile Control Agent System for Oily Sludge

The profile control technology of heavy oil reservoirs improves the development effect by adjusting the steam absorption profile of oil wells [3–5]. At present, the Xinjiang Fengcheng Oilfield has entered the late stage of steam injection development. The oil wells have produced a large amount of sand and have produced a large amount of oily sludge in the treatment station, which is facing great environmental protection pressure. Adding chemical agents to the sludge makes it become a kind of profile control agent system, which is of positive significance to environmental protection and oilfield development.

The sludge of the super heavy oil field is mainly composed of heavy oil, water, degraded organic matter, mud, and super fine sand. The analysis shows that the water content of the sludge storage pool is 60~70%, the oil content is 10~15%, and the mud and sand content is 15~30%. In the solid phase, particle sizes of less than 100 μm account for more than 80%, mainly ranging from 10 to 50 μm, with an average of 48 μm. However, the average pore diameter of the reservoir is 200 μm, which is larger than the particle size of the sludge. Especially, some pore diameters of the steam channeling channel reach the level of millimeters and the sludge enters the large channel basically without obstacles. Figure 1 shows the oil sludge in the settling pool of an oilfield. The floating layer in the upper part is water and part of the flocs, the middle layer is oil sludge, and the bottom is sediment mud and sand. When used on-site, the top water layer is drained out first and then the excavator is used for stirring so that the remaining mud, sand, and free water in the settling tank are fully mixed. Finally, the mixture of water and oil mud is transported to the tank truck by pumping mud to the site. The manpower and machinery used on-site are simple and the system preparation cost is low. Therefore, the use of oil sludge is feasible.

2.2. Research Ideas and Principles of Oily Sludge Profile Control Agent System

The oily sludge containing 70% water in the storage pool has no fluidity, so a certain amount of water must be added to make it flow. However, the stability of the system becomes worse after water injection, and the stratification after standing for half an hour is not conducive to pumping, which cannot meet the requirements of the profile control agent system. Therefore, bentonite is selected as the dispersant so that the diluted sludge does not settle but is easy to pump. Driven by high-temperature and high-speed steam, the oily sludge pumped into the reservoir should remain in the large pore; otherwise, the profile control would still be ineffective. Therefore, adding a curing agent can make the oily sludge solidify in the reservoir and cement with the formation to achieve the purpose of profile control. In addition, the uncontrollable solidification time of the profile control system will bring security risks to the profile control construction, so it is necessary to add a coagulant to control the solidification time of the system. Finally, the basic formula of the sludge profile control system is determined to be oily sludge + water + dispersant + curing agent + coagulant.

Figure 1. Picture of oily sludge settling tank in an oilfield.

Figure 2 shows the system prepared in the laboratory. Sample No. 1 is the state of the system after adding various additives, while sample No. 2 is the state after standing for 24 h. The system is stable, not easy to settle, and can meet the requirements of field construction.

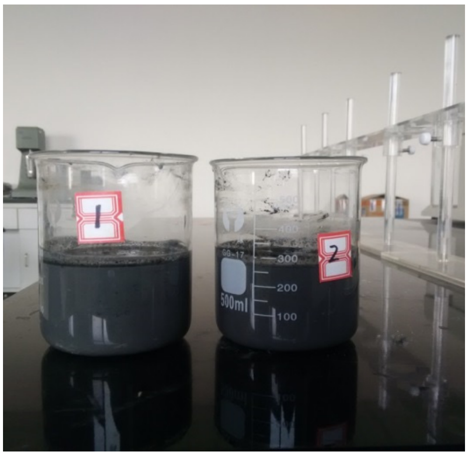

Figure 2. Picture of oily sludge profile control system prepared in the laboratory.

The main mechanism of profile control in oily sludge is the physical plugging of solid mineral particles. When the oily sludge dispersion system is injected into the pore channel of the formation, due to the principle of similarity and compatibility, part of the emulsion oil in the system can be adsorbed on the oil-friendly surface of the formation rock, while the separated inorganic minerals bridge and aggregate to form the aggregate structure, blocking the large porous channel, reducing the permeability of the large pore channel, and improving the steam absorption profile. After the construction, when steam injection is resumed, the steam flow direction will change, which will not affect the reservoir, will improve the utilization degree of the middle- and low-permeability layer, and will achieve the purpose of improving the oil–vapor ratio and recovery efficiency [6–9]. After the injection of the system into the formation, various additives and mud will consolidate under the specific temperature environment of the reservoir and accumulate in the pore throat and pores of the rock. Generally, they will not decompose and the validity period can be up to 1–2 years (Figure 3).

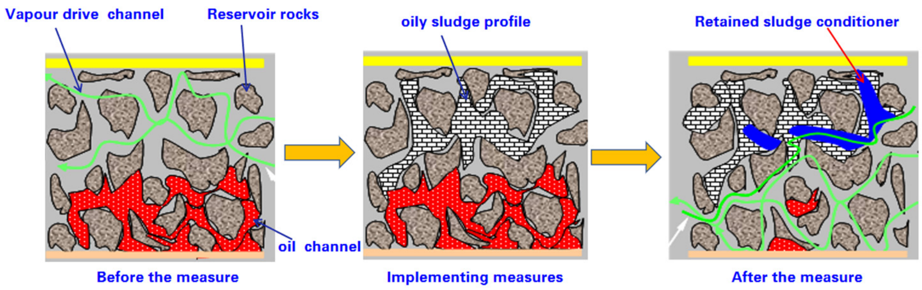

Figure 3. Plugging process of sludge profile control system.

2.3. Formula of Oily Sludge Profile Control Agent System

After a large number of experimental screening studies, a new composite plugging agent was independently developed, and its formula is as follows: 40.0% oilfield sludge +3.0~4.0% inorganic salt curing agent +0.6% bentonite dispersant +0.2% alkali coagulant + oilfield produced water. The density of the system is 1.15–1.35 g/cm^3 and the apparent viscosity is about 50 mPa·s. The agent system has the following advantages: ① the oily sludge treatment process is safe and environmentally protected, and the process is controllable; ② the profile control and plugging agent system is prepared with oilfield-produced water, which solves part of the water treatment problem; ③ regional profile control can be carried out as a whole, blocking the large pore or steam channeling channel; ④ oily sludge comes from the formation and has good compatibility with the reservoir; ⑤ the main raw material is the output of the oil field and the cost is low.

3. Performance Evaluation of Oily Sludge Profile Control Agent System

3.1. Solidification Time

According to the formula of the selected profile control agent system for oily sludge, a 500 mL beaker was used to prepare the system of different proportions, and the system was placed in the JK-3000 (Qingdao Jingke Testing Equipment Co., Shandong, China) high-temperature constant-temperature drying oven. The temperature was set at 100 °C, only the dosage of coagulant was changed, and the solidification time of the system was recorded by observing the state of the liquid in the beaker (Table 1).

Table 1. Experimental data of cementation and solidification.

Oily Sludge/g	Curing Agent/g	Dispersant/g	Water/g	Coagulant/g	Initial Solidification Time/h	Final Solidification Time/h
400	55	13	160	8	6	15
400	55	13	160	6.4	13	25
400	55	13	160	4.8	29	46
400	55	13	160	4	41	62
400	55	13	160	3.2	58	81
400	55	13	160	1.2	89	124
400	55	13	160	0.8	165	200

It can be seen from Table 1 that the solidification time increases as the dosage of coagulant decreases, indicating that the solidification time of the system is controllable, and the solidification time can be changed by adjusting the dosage of the coagulant to avoid premature or late plugging time.

3.2. Evaluation of Temperature Resistance

The heavy oil thermal recovery reservoir temperature is high, which requires a high-temperature resistance of the agent system. The Feng Cheng heavy oil steam injection temperature is 250~310 °C, which requires the temperature resistance of the agent system to reach 350 °C. Experimental equipment: JK-3000 high-temperature and constant-temperature drying oven. Different samples were prepared according to the preset oily sludge profile control agent system, and different temperatures were set in the incubator, ranging from 40 °C to 220 °C with a temperature interval of 10 °C. The cementation and solidification state of the above samples were observed and the final solidification time was recorded.

When the mass concentration of coagulant was 0.4%, the solidification time of the sludge system at different temperatures was measured by experiments (Figure 1). As can be seen from Figure 4, the solidification time of the system decreases slowly with the increase in temperature, and there is no significant change under the condition of high temperature, indicating that the temperature sensitivity of the system is low, which can ensure smooth construction on-site.

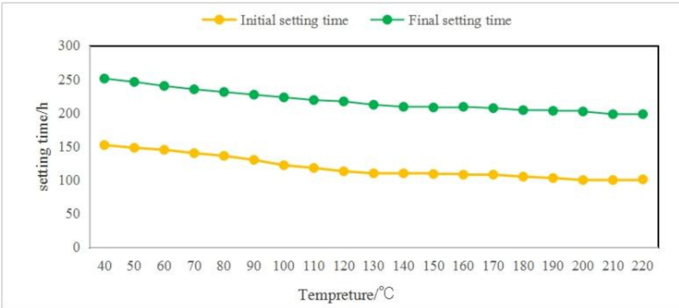

Figure 4. Variation in solidification time at different temperatures.

Five artificial cores with similar physical properties were injected with the compound plugging agent of the same proportion to test their permeability, plugging rate, and breakthrough pressure before and after plugging under different-temperature environments, and the results are shown in Table 2.

Table 2. Experimental data of core plugging rate at different temperatures.

Core Number	Temperature/°C	Injection Pore Volume Multiple	Before Plugging	After Plugging	Blocking Rate/%	Breakthrough Pressure/MPa
			Permeability/mD	Permeability/mD		
1	200	0.25	1230	140	88.6	6.5
2	240	0.25	1250	125	90	6.1
3	300	0.25	1210	146	87.9	7
4	340	0.25	1320	128	90.3	7.3
5	380	0.25	1245	134	89.2	6.8

As can be seen from Table 2, under different temperatures, the plugging rate of the profile control plugging agent is above 85.0% and the plugging effect is good. The breakthrough pressure is above 6.0 MPa and the plugging strength is high. The comprehensive results show that the system has good temperature resistance and can meet the requirements of thermal recovery.

3.3. Plugging Effect

Experimental equipment: high-temperature and high-pressure core displacement device (Nantong Yi Chuang experimental Instrument Co., Jiangsu, China), intermediate vessel (Hai'an County Petroleum Research Instruments Co., Jiangsu, China,1000 mL; able to withstand a pressure of 50 MPa), steam generator, and electronic balance (Figure 5).

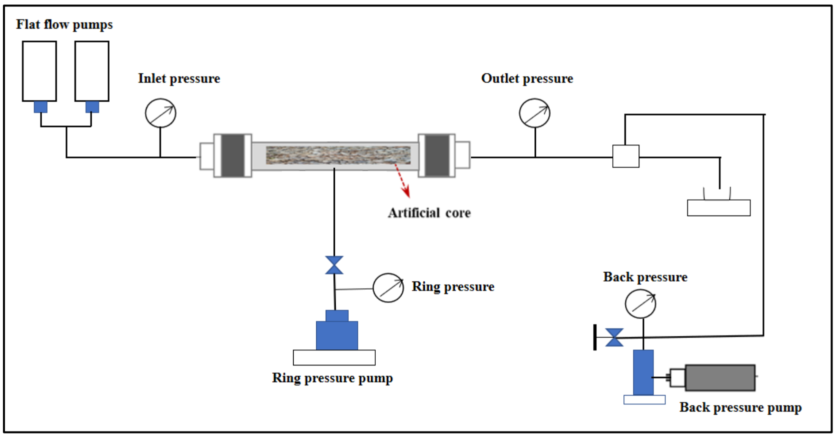

Figure 5. Experiment apparatus.

Six samples were prepared according to different concentrations of the curing agent and added to the intermediate container for the experiment. Six kinds of artificial large-channel cores with similar permeability were formed by the sand filling pipe, with a permeability of about 12,000 mD. In order to simulate formation conditions, the confining pressure and outlet pressure were artificially added at 5 MPa, and the pressure was gradually increased at the entrance. During the period, the flow and pressure changes at each outlet were observed and recorded.

The steam outlet temperature was set at 200 °C and the injection rate was 5 L/h. Six parts of the compound plugging agent with the same ratio were injected into six groups of artificial large pore cores with similar physical properties. The permeability before and after plugging under different injection amounts was tested and the plugging rate was calculated. As can be seen from Table 3, with the increase in injection amount, the plugging effect improves.

Table 3. Core plugging experimental data under different permeabilities.

No.	Injection Pore Volume Multiple	Permeability before Plugging/mD	Permeability after Plugging/mD	Plugging Rate/%
1	0.25	12,540	1320	89.5
2	0.35	12,480	1136	90.1
3	0.45	12,030	1108	90.8
4	0.55	12,922	182	98.6
5	0.65	12,816	164	98.7
6	0.75	12,684	148	98.8

3.4. Protection Effect of Reservoir

The steam outlet temperature was set at 200 °C and the injection rate was 5 L/h. The composite plugging agent with the same ratio was injected into three groups of double-tube parallel cores with different permeability levels to test the core permeability before and after plugging and to calculate the plugging rate (Table 4). As can be seen from Table 4, the mud profile control agent system basically only enters the large pore channel, and the blocking rate of the large pore channel is high, indicating that the composite plugging agent can effectively protect the reservoir.

Based on the above experiments, it can be seen that the oily sludge profile control agent system enters the large pore in the fluid state, solidifies in the large pore, and cements with the formation to achieve the purpose of plugging the large pore. It has the following characteristics: (1) The initial viscosity is lower than 150 mPa·s, the pumping performance is good, and deep profile control can be realized. (2) When the settling time is greater than 4 h, the suspension performance is good. (3) The solidification time of cementation can be controlled within 3~300 h to ensure the construction safety. (4) The temperature that can be withstood is 350 °C, which can meet the requirements of thermal injection production. (5) The blocking rate is greater than 85.0%, and the blocking effect is good.

Table 4. Core plugging experimental data under different permeability ranges.

No.	Injection Pore Volume Multiple	Permeability Stage Difference	Permeability before Plugging/mD	Permeability after Plugging/mD	Plugging Rate/%
1	0.5	4.57	12,149 2654	128 2598	98.9 2.4
2	0.5	43.27	11,642 269	137 266	98.8 1.1
3	0.5	9.57	12,843 1342	1265 1327	90.2 1.1

4. Construction Scheme Design

Factors such as perforation thickness, porosity, permeability, sedimentary microfacies, opening horizon, cumulative production, profile control radius, and steam channeling channel are fully considered to design the profile control scale. The construction is divided into four slug sections (Table 5): forward slug—main slug—sealing slug—final slug [10–14].

Table 5. Different slug systems and their functions.

No.	Slug	Profile Control Agent System	Profile Control Radius (m)
1	Forward slug	0.3% Resin gel	1.0
2	Main slug	40% oily sludge, 4% curing agent, 0.6% dispersant, 0.2% coagulant, water	10
3	Sealing slug	40% oily sludge, 11% curing agent, water	4
4	Final slug	Oil field produced water	4

The forward slug is used to temporarily plug into the middle- and low-permeability layer to improve the entry performance of the superior channel.

The main slug is used to block steam channeling in the greater-permeability layer of the reservoir.

The sealing slug is used to block the steam channeling channel near the well and to ensure no backflow.

The final slug is oil field water, which is used to push all the slugs into the formation and to keep the wellhole safe and clean.

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The scale and slug design are carried out according to the types of production wells and steam injection wells to ensure "one well and one policy" and ensure the efficiency of measures.

The configured profile control solution is injected into the formation from the tubing through the 400-type pump truck. In accordance with the design of four slug plugs, "Forward + Main + Sealing + Final", the injection quantity is self-cementing under the formation conditions to form the slug, which is no longer produced.

(1) The forward slug and sealing slug are calculated according to the following formula:

$$Q = \pi R^2 h \varphi \tag{1}$$

Q—Profile control agent dosage, m^3;
R—Profile control radius (refer to Table 4-1 design), m;
h—Thickness of profile control layer, m;
φ—Porosity of profile control layer, %.

(2) The main slug is calculated according to several types: huff and puff wells, steam flooding production wells, and steam flooding injection wells.

In huff and puff wells and steam flooding production wells, the dosage of the profile control agent can be calculated as follows:

$$Q = k\pi R^2 h \varphi \tag{2}$$

Q—Profile control agent dosage, m^3;
k—Adjustment coefficient (represents the proportion of large channels);
R—Profile control radius, m;
h—Thickness of profile control layer, m;
φ—Porosity of profile control layer, %.

According to previous profile control experience, the profile control radius R is 1/3 of the well spacing. Adjustment coefficient k refers to the proportion of large pore channels to the whole pore space. When designing a single well, the proportion of large pore channels is determined according to the ratio of single-well recovery degree and oil saturation, and then the size of adjustment coefficient k is determined.

In steam flooding injection wells, the dosage of the profile control agent can be calculated as follows:

$$Q = k\pi h \varphi \left(R_{outside}^2 - R_{inner}^2\right) \tag{3}$$

Q—Profile control agent dosage, m^3;
k—Adjustment coefficient, f (represents the proportion of large channels);
$R_{outside}$—Outside diameter of plugging belt, m;
R_{inner}—Inner diameter of the plugging belt, m;
h—Thickness of profile control layer, m;
φ—Porosity of profile control layer, %.

The aim of profile control of the steam flooding injection well is to form a plugging zone between the injection well and production well by injecting a profile control agent to achieve the purpose of depth profile control (Figure 6).

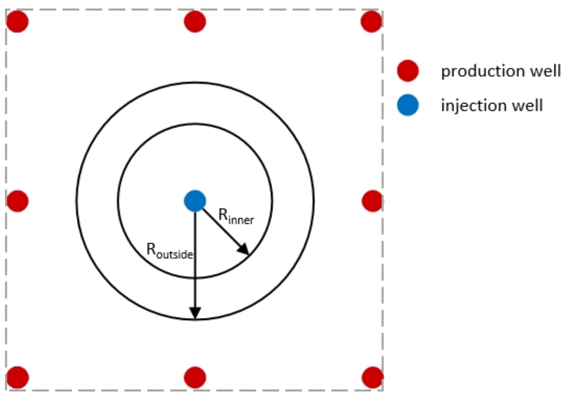

Figure 6. Blocking design diagram.

The final slug shall be calculated according to the following formula:

$$Q = V_1 + V_2 + V_3 + V_4 \tag{4}$$

Q—Profile control agent dosage, m^3;
V_1—Surface manifold volume, m^3;
V_2—Downhole string volume, m^3;
V_3—Annulus volume, m^3;
V_4—Additional displacement fluid volume, m^3.

5. Application

From 2019 to 2022, 153 sludge profile control operations were carried out in blocks Z32 and Z18 of the Fengcheng heavy oil reservoir in Xinjiang. The depth of the reservoir is 200–500 m, the thickness of the reservoir is 8~25 m, the porosity is 27~31%, the permeability is 425~2550 mD, and the oil viscosity is 8500~15,000 mPa·s at 50 °C. By the end of 2022, the recovery degree was 16–22%, with an average of 18.2%, and the comprehensive oil–vapor ratio was 0.07.

After the measure, the wellhead steam injection pressure was increased by 1.4 MPa, Steam channeling interference dropped in 316 wells, and the profile-log of steam injection showed that the lower reservoir utilization increased from 38.2% to 67.1% (Figure 7).

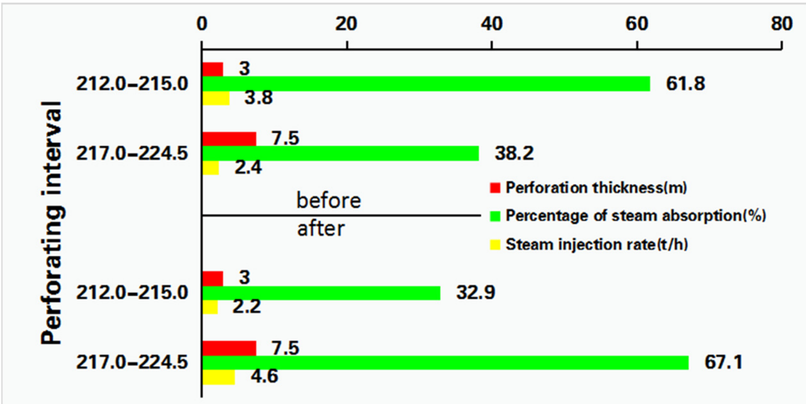

Figure 7. Comparison of Profile-log of steam injection before and after the measure.

Before the implementation, the average daily fluid production in a single well was 11.2 t/d, the average daily oil production was 0.6 t/d, the cycle production time was 86 days, and the oil–vapor ratio was 0.056; after the implementation, the average daily fluid production was 14.3 t/d, the average daily oil production was 0.9 t/d, the cycle production time was 118 days, the oil–vapor ratio was 0.072, and the accumulative oil increase was 10,756 tons. The average amount of profile control agent injected into a single well was 2200 tons, including 1170 tons of oily sludge, and the input–output ratio was 1:3.

6. Conclusions

(1) With oily sludge as the main raw material, a profile control agent system for heavy oil reservoirs can be formed by adding a specific proportion of dispersant, curing agent, and coagulant. Through testing the solidification time, temperature resistance, plugging effect, and protection effect of the reservoir, it is clear that the system has the characteristics of adjustable curing time (3~300 h), a pressure resistance greater than 6 MPa, a temperature resistance greater than 350 °C, and a plugging rate greater than 85.0%. Compared with the conventional profile control system, the system has the technical adaptability for thermal recovery of heavy oil.

(2) The construction technology of four slug types, namely front + main + sealing + displacement, was formulated. The concentration of various additives was defined according to the function of each slug, and the dosage was designed to ensure that the profile control agent system could play a role in the composition of the reservoir.

(3) Field application showed that the system can effectively block the steam channeling channel, improve the steam injection capacity in the low-permeability section, increase the volumetric sweep efficiency, and increase oil production and the oil–vapor ratio of the oil well after injection into the reservoir.
(4) Oily sludge profile control technology not only solves the problem of sludge treatment but also improves the thermal recovery and development effect of heavy oil, which is of great significance to improve the ultimate oil recovery and economic benefits.

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References

1. Yanqing, M. *Synthesis and Performance Study of Oily Sludge Profile Control Agent in Changqing Oilfield*; China University of Petroleum (Beijing): Beijing, China, 2017.
2. Wei, G.; Bin, L.; Zhanhui, G. Prospect of oily sludge profile control and flooding technology. *Energy Chem. Ind.* **2019**, *40*, 18–22.
3. Xin, S. *Study on Oily Sludge Profile Control Technology in Sabei Oilfield*; Northeast Petroleum University: Daqing, China, 2017.
4. Rujie, L. Research and application of composite profile control technology for super heavy oily sludge. *Unconv. Oil Gas* **2019**, *6*, 58–64.
5. Jin, H.; He, Z. Super heavy sump oil treatment technology in Fengcheng Oilfield. *Spec. Oil Gas Reserv.* **2016**, *23*, 146–150.
6. Yingjun, L.; Feng, O.; Yingying, W. Research on the sealing capacity of an oil-bearing sludge profile control system in oilfield. *Ind. Water Treat.* **2018**, *38*, 82–85.
7. Qianru, S. A study and application of deep profile control technology for activated sludge. *Environ. Prot. Technol.* **2019**, *25*, 20–23.
8. Liyong, T.; Yao, W.; Yonghong, Z. Profile-control with heavy-oily sludge in Liaohe Oilfield. *Spec. Oil Gas Reserv.* **2016**, *23*, 134–137.
9. Yanling, L. Study and application of profile control agent for oily sludge. *Chem. Eng. Equip.* **2019**, *44*, 277–288.
10. Chaoli, G.; Yonghui, L. Application of fine deep drive technology for oil-bearing sludge in Wuqi Oil Production Plant. *Unconv. Oil Gas* **2019**, *6*, 41–47.
11. Yuemin, L.; Meilong, F.; Songlin, Y. Study and application of water plugging and profile control system of heat and salt resistant gel. *Spec. Oil Gas Reserv.* **2019**, *26*, 158–162.
12. Liyong, T.; Hua, S.; Zhaobiao, J. Migration of oily sludge in formation. *Spec. Oil Gas Reserv.* **2018**, *25*, 159–164.
13. Congling, W.; Luying, X. Research and application of oil-bearing sludge conditioning agents. *Pet. Geol. Eng.* **2010**, *24*, 10–12.
14. Yunxiao, C. Research and application of deep dissection process technology for oil-bearing sludge. *J. Oil Gas* **2004**, *26*, 93–94.