Application of Depth Regulating and Displacing Technology of Nano-micron Hydrogel Microspheres in Oilfield

Li Tianyang
School of Petroleum Engineering
China University of Petroleum
Qingdao, Shandong, China
e-mail: litianyang116@hotmail.com

Li Jianguo
No.2 Oil Production Plant
Huabei Oilfield Company, PetroChina
Bazhou, Hebei, China
e-mail: cy2_jcljg@prtrochina.com.cn

Luo Sili
No.2 Oil Production Plant
Huabei Oilfield Company, PetroChina
Bazhou, Hebei, China
e-mail: cy2_gclsl@petrochina.com.cn

Li Shenghua
No.2 Oil Production Plant
Huabei Oilfield Company, PetroChina
Bazhou, Hebei, China
e-mail: cy2_gclsh@petrochina.com.cn

Abstract—The depth regulating and displacing technology to improve oil recovery efficiency in water injection oilfield is one of the most promising technical approach. Nano-micron hydrogel microspheres were injected into the depth of the injection wells, adjusting formation permeability, improving reservoir heterogeneity and increasing oil production. In this paper, polymer gel microspheres were laboratory evaluated to determine the site implementation plan and the injection process, and the field trials in six water flooding wells have proofed that gel microsphere flooding agent for water injection wells in Chaheji oilfield flooding is effective on accumulated increasing oil 4003 tons and decreasing water appears after the implementation. Using measurement pump injection technology is feasible, the average of injection 1m3 flooding agent is decreased from 11.6 to 0.29 KWH electricity.

Keywords-nano-micron; hydrogel microspheres; depth regulating; displacing; application

I. INTRODUCTION

Currently oilfield generally access to the phase of high water cut, reservoir heterogeneity and long-term water injection have made the heterogeneity further intensified, and gradually forming high permeability channels or large pores, so that the pressure of formation and flow line field unchanged, which cause water flooding "short circuit" [1-3], seriously affecting the reservoir water flooding effect.

The depth regulating and displacing technology centers around the deep profile control and combines with the effect of oil displacement based on the modification [4-5]. Production practice has proved that profile control and flooding technology is one of the essential recovery technologies.

A hydrogel is a network of polymer chains that are hydrophilic, sometimes found as a colloidal gel in which water is the dispersion medium. Oil displacement profile control agent of hydrogel microspheres is made up with polyacrylamide crosslinking gel microspheres which divided into nano and micron scale [6-8]. When the micron scale microspheres enter into the formation, they will produce crosslinking between the particles under formation temperature and water immersion, and then plug big holes. While the nanoscale microspheres into the formation will expand to adjust the formation of deep profile and can improve water flooding effect [9-10]. According to the actual circumstance of injection formation, choosing the diameter of injection microspheres and injection method is necessary to use gel microspheres in oilfield injection.

II. LABORATORY EVALUATION OF HYDROGEL MICROSPHERES

For researching the performance and mechanism of oil displacement profile control agent of the hydrogel microspheres, we have done three laboratory evaluation tests of hydrogel microspheres.

A. Swelling and Crosslinking under High Temperature and High Salinity

In order to test the swelling and crosslinking conditions under high temperature and high salinity condition, we put hydrogel microspheres in saturated brine (150000ppm) with aerobic, and kept water bath at 80°C for 40 days. Fig .1 shows swelling and crosslinking conditions by SEM.

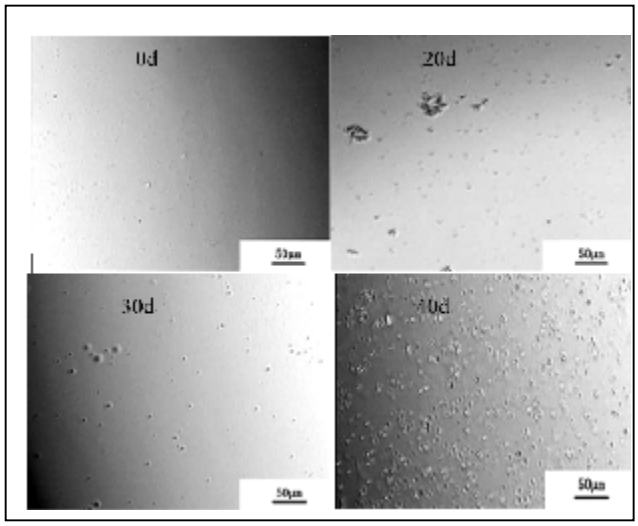

Figure 1. The SEM of swelling and crosslinking conditions of different days

SEM observations show that under high temperature and high salt, stable gel microspheres can exist and the edge of microspheres still keep smooth and clear. This feature determines the hydrogel microspheres can be used in oilfield water injection.

B. *Heterogeneous Oil Reservoir Plugging Experiment*

For utilizing the stable gel microspheres to change the formation character under high temperature and high salt, heterogeneous reservoir plugging experiments were prepared.

Simulation conditions: 150000mg/L of artificial seawater (1500ppm).

Physical models: sand filling tube with length 1m, diameter 2.5cm and the cross-section 5.3cm2.

Quality of sand from oilfield: 840g.

Injection and production rate: 0.5mL/min.

Injection of gel microspheres: the expansion has not been dispersed to inject seawater immediately after simulation.

Injection volume: 0.2pV.

The results are shown in table 1 and Fig .2 and 3.

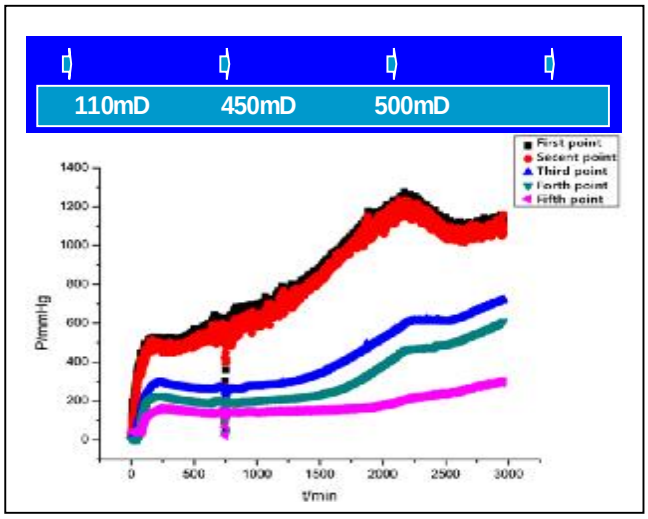

Figure 2. The variation of injection pressure in different pressure detecting point

From the figures, we can find that through the adoption of hypotonic section, in the middle section can still form an effective infiltration block, which is cut resistant, resistant to break through, and removable.

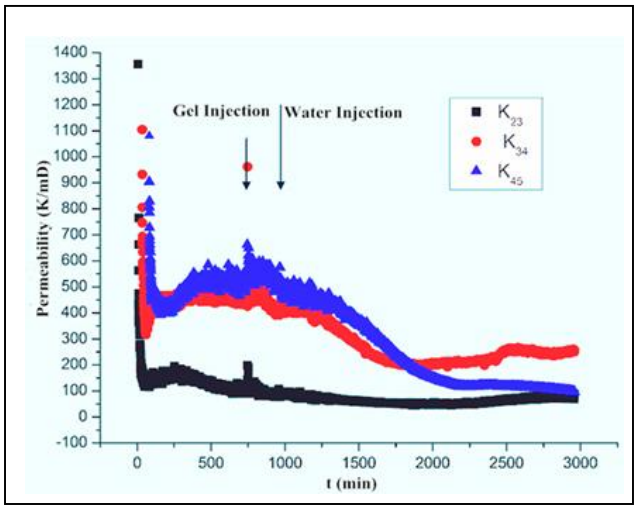

Figure 3. The variation of permeability caused by microsphere injection

TABLE I. Variation of permeability caused by microsphere injection of 3 models

MODEL	Permeability		
	Initial permeability(mD)	*Ultimate permeability (mD)*	*Variation rate(%)*
K23	110	50	55
K34	450	200	55
K45	500	100	80

Fig .3 and table 1 show that after the injection of gel microspheres the permeability of three models decrease significantly, which indicate that the microspheres detained and migrated repeatedly. Large channels and pores have been effectively blocked, which played a better effect of depth regulating and displacing.

C. *Flooding experiment of low viscosity and low permeability*

In the experimental models, we prepared two different kinds of filling pipes with sand (high permeability and low permeability), and set the model condition simulated the real reservoir formation.

Hypertonic pipe: 450mD. Hypotonic pipe: 24mD.

Crude oil: 50mPa.s viscosity at 75°C.

Water: Analog oil sewage, salinity 100000 mg/L.

Deep profile control agent: nano-micron gel microspheres which have swelled 5 days at 75°C.

Concentration: 4000mg/L.

Injection volume: 0.15pV.

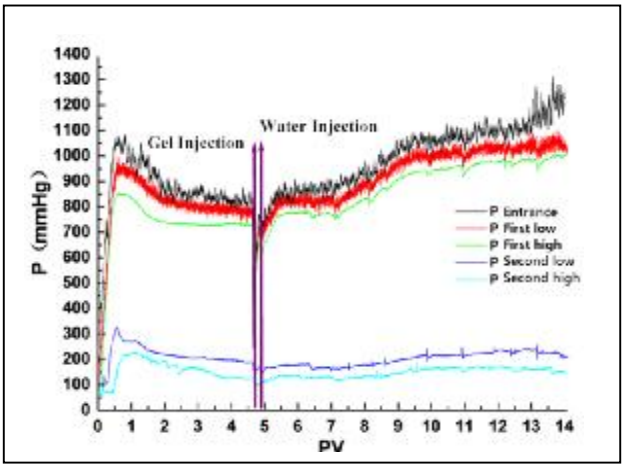

Figure 4. The variation of flooding pressure

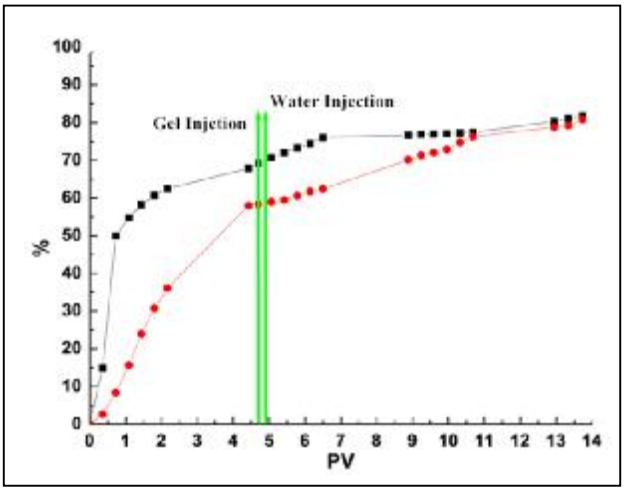

Figure 5. The case of enhancing oil recovery agent

Fig.4 shows that pressure of the high and low permeability measuring points in filling pipes. Flooding pressure increases after microspheres injection. From the curve of enhancing oil recovery agent (Fig. 5) by using depth regulating and displacing technology of hydrogel microspheres, it can be seen that in the injection of microspheres and subsequent water flooding process, little recovery improved in high permeability pipe, while in low permeability pipe recovery greatly improved.

More indoor simulation tests can fully explain the nano-micron hydrogel microspheres can greatly improve water injection efficiency. In the practical application, through choosing different sizes and different types of matching microspheres can achieve plugging high permeability reservoir efficiently.

III. Field Application and Effect

A. *New construction process of injection*

In order to apply the gel microsphere effectively in field application, we have established a new construction process of injection technology. Construction of single well put in the metering station, injection pump and injection wells were connected. The agent liquid or high concentrations of drug injected into the single well pipeline, and mixed the injected water with a certain percentage (according to the design concentration) then injected to the goal wells. The specific process is shown in Fig .6.

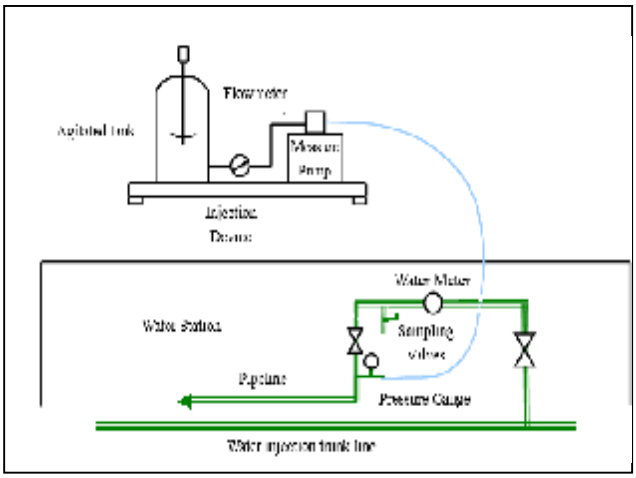

Figure 6. The process chart of field construction

Place your cursor to the right of the last character of the last affiliation line of an even numbered affiliation (e.g., if there are five affiliations, place your cursor at end of fourth affiliation). Drag the cursor up to highlight all of the above author and affiliation lines. Go to Format > Columns and select “2 Columns”. If you have an odd number of affiliations, the final affiliation will be centered on the page; all previous will be in two columns.

B. *Incremental Oil Effect*

With foundation of laboratory feasibility research, gel microsphere flooding technology has been promoted to apply in six water injection wells (48-119, 30-7-8, 20-12, 15-141, 30-14) which connect 28 production well-groups in Chaheji oilfield. The effects demonstrate that production wells accumulated oil increase has reached 4003 tons. 15-141 wells group was significantly effective, which has a total of 2948 tons of oil increased. And 15-145 well, before flooding the average daily oil production was only 4.88 tons, while 6.5 tons after flooding average daily oil production, cumulative incremental oil has reached 474 tons. Also average daily production of 15-146 wells increased from 4.3 tons to 11.3 tons, cumulative incremental oil has reached 1909 tons.

C. *Power Saving Effect*

Conventional flooding process through field testing (install the transformer meters) shows that electricity was consumed 2100~2300 KWH per day with 180~200m3 daily injection rate, so the average of injection 1m3 flooding agent was consumed 11.6 KWH electricity. While after using gel microsphere injection pump (metering pumps) electricity, that electricity was consumed 2288 KWH per day, and daily injection rate was 7908 m^3 (Cha 30-7-8), so the average of injection 1m3 flooding agent was decreased to 0.29 KWH electricity.

IV. Conclusions

1) Nano-micron microspheres composed of polymer gel, possess well mechanical flexibility, and the implementation of the deep reservoir seepage channel and

pore throat plugging achieved objective. By controlling the composition of the material, expansion rate and a maximum expansion volume of the material can be controlled in the water phase, and also the plugging position in the formation to improve producing reserves. It is applicable for any water flooding oilfield, since the reservoir salinity and temperature conditions is not restricted.

2) Through field trials in six water flooding wells proof that gel microspheres flooding agent for water injection wells in Chaheji oilfield flooding is effective, and has a significant increasing in oil effect. This flooding agent can be promoted in other water injection well applications.

3) Using the new measurement pump injection technology is feasible to achieve the effect of depth regulating and displacing, while greatly reduced construction electricity and costs of construction personnel and vehicles moving. The features of simples and convenient injection mode, less site area and lower power equipment, made it save more than 90% of electricity power compared with conventional flooding process mode.

REFERENCES

[1] Guolin L, Yuming K, Jingcai Z, et al. The mechanism research of production reduction caused by water blockage in Shuanghe Oilfield[J]. Complex Hydrocarbon Reservoirs, 2012, 2: 023.

[2] Ruiquan L, Yonggao X, Xuebin H. Damage to low-permeability reservoir by water locking effect and its inhibiting and removing methods[J]. Natural Gas Industry, 2002, 22(6): 87-88.

[3] He Z, Zhong C, Huang X, et al. Simultaneous enhancement of open‐circuit voltage, short‐circuit current density, and fill factor in polymer solar cells[J]. Advanced Materials, 2011, 23(40): 4636-4643.

[4] Fu-ming C. Overview of deep profile control of polymer flooding in Daqing oilfield [J]. Petroleum Geology & Oilfield Development in Daqing, 2004, 5: 026.

[5] Yurong LIUCAN. Research and application of polymer microspheres deep profile control technology [J]. Drilling & Production Technology, 2010, 5: 021.

[6] Kawaguchi H, Fujimoto K, Mizuhara Y. Hydrogel microspheres III. Temperature-dependent adsorption of proteins on poly-N-isopropylacrylamide hydrogel microspheres[J]. Colloid and Polymer Science, 1992, 270(1): 53-57.

[7] Ozin G A, Arsenault A C, Cademartiri L. Nanochemistry: a chemical approach to nanomaterials[M]. Royal Society of Chemistry, 2009.

[8] Choi C H, Kim J, Kang S M, et al. Controllable Preparation of Monodisperse Microspheres Using Geometrically Mediated Droplet Formation in a Single Mold[J]. Langmuir, 2013, 29(27): 8447-8451.

[9] Yao C, Lei G, Li L, et al. Selectivity of pore-scale elastic microspheres as a novel profile control and oil displacement agent[J]. Energy & Fuels, 2012, 26(8): 5092-5101.

[10] Cao Y, Yue X A, Yang S R. Experimental Study on Polymer Microsphere Emulsion Profile Control and Flooding in Heterogeneity of Reservoir[J]. Advanced Materials Research, 2012, 361: 437-440.