Laboratory studies of the exposure to the diffusion process with simultaneous application of nonionogenic surfactants and plasma-impulse technology

Aleksander Valerevich Maksyutin, Radmir Rasimovich Khusainov, Mikhail Konstantinovich Rogachev and Dmitry Sergeevich Tananykhin

National Mineral Resources University "University of Mines", 21st line, 2, St-Petersburg, 199106, Russia

Abstract. The method and results of laboratory studies of the plasma-impulse exposure to the diffusion process of the oil soluble components of nonionogenic surfactants (NIS) into the high-viscosity oil are presented. There is a scheme of experimental bench for simulating highly-viscous oil treatment with plasma-impulse technology. The optimal concentrations of the reagents and technological parameters of the simultaneous physico-chemical and physical impacts on the productive formations are substantiated.

[Maksyutin A.V., Khusainov R.R., Rogachev M.K., Tananykhin D.S. **Laboratory studies of the exposure to the diffusion process with simultaneous application of nonionogenic surfactants and plasma-impulse technology.** *Life Sci J* 2014;11(6s):276-279] (ISSN:1097-8135). http://www.lifesciencesite.com. 52

Keywords: surfactants, diffusion process, high-viscosity oil, viscosity, rheological studies, thixotrophy, plasma-impulse impact.

Introduction

Application of surface active agents (SAA) in the methods of enhanced oil recovery at the initial stage was ambiguous. In the 80es of XX century substantiality of the waterflood using nonionogenic surfactants was scientifically questioned. Two decades later, it has been proved and confirmed by field tests, that the application of SAA is one of the most effective methods of enhanced oil recovery (EOR) [1, 2].

One of the perspective ways of increasing the effectiveness of the surfactants application for enhanced oil recovery is its simultaneous application with physical EOR methods. Field tests, that were held in recent years, have shown that the effectiveness of treatments multiple increases when we simultaneously use physico-chemical and physical methods of stimulation. The penetration of agents in low permeability reservoir is improved during the simultaneous application of wave action and physico-chemical impact. What is important too is that, there are synergistic effects, leading to substantial improvements in the technology efficiency [2, 3].

In this paper we studied the effect of simultaneous application of NIS and effects of plasma-impulse technology to the diffusion process of oil soluble nonionogenic surfactant components into the oil.

Plasma-impulse technology (PIT) for a formation system was developed at the department of Geophysics of the St. Petersburg State Mining Institute (Technical University), led by prof. A.A. Molchanov, together with "Scientific and production center "GEOMIR". Impact on the formation is produced by equipment wirelined on a standard triple-cored cable using geophysical logging winches lift. The power to the downhole equipment, the management of the deep block, the communication mode control and processing parameters of the wells are supplied by logging cable. The processing time and the number of impulses of the stimulation is determined individually for each well based on geological characteristics of the productive formation and the physico-chemical characteristics of the oil [4, 5, 6, 7].

Description of the laboratory equipment and liquids

Laboratory studies were carried out for Usinskoye oil field. The development of this field (permo-carboniferous stratum) is complicated by the high viscosity of the oil. Oil relates to a class of: heavy (0,959 g/cm^3), high viscosity (670 mPa*s), sour (2,5 % wt.), low-paraffin (0,6 % wt.) and highly resinous (resin 23 % by wt. asphaltenes to 12 %) [8, 9, 10].

Reagent OP-10 is used as the surfactant during the laboratory studies, and it has been widely used in EOR methods. It is well known that a lot of different surfactants used in oil industry, but not all of them can be recommended for injection by flooding. Cost-performance ratio of the method with surfactant flooding is primarily determined by the intensity of surfactant adsorption on the surface of the porous medium. High adsorption value nullifies the effectiveness of the method, since it leads to the reagent concentration in the bottom hole formation zone. That's why the vast majority of the reservoir area is not covered by the influence of the reagent. OP-10 has the lowest rate of adsorption on layer among its class.

Reagent OP-10 is a monoalkylfenil ethers of polyethylene glycol based on polimerdistillate. It is intended for injection in the bottom hole formation zone for the enhance oil recovery. OP-10 belongs to the class of nonionogenic surfactants, alkylphenols oksilethylated group (monoalkylfenil polyethylene glycol ethers). This group of substances is prepared by condensing ethylene oxide with alkylphenols in the presence of catalysts.

At the first stage of the investigation, together with "Scientific and production centre "GEOMIR" experimental bench was developed to simulate the impact of PIT in the laboratory. The scheme of the developed experimental bench is shown in Figure 1.

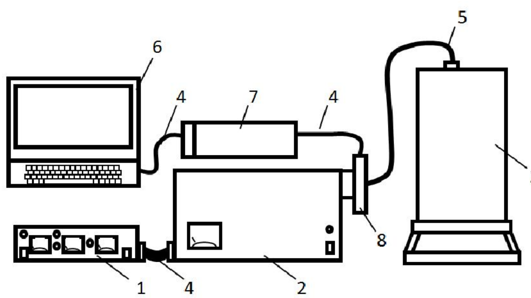

Figure 1 - Scheme of the experimental bench
1 - power supply and control; 2 - cumulative unit; 3 - chamber forming a broadband pulse; 4 - connection cable; 5 - high voltage cable; 6 – laptop; 7 - analog-to-digital converter; 8 - current transformer.

Developed experimental bench consists of a power supply and control, which provides power storage unit AC 400 Hz and 350 V with a connecting cable. The power supply and control unit is installed additionally with control the discharge of energy stored in the capacitors. Transfer of the stored energy to the chamber, where the broadband impulse is formed, is performed by a special high-voltage cable. In order to study the characteristics of impulses radiated by the device in real-time to the experimental bench via a daisy chain analog-to-digital converter and a current transformer a portable computer was connected, that allows monitoring the impulse parameters.

The main objective of this study was to determine the concentration of NIS components diffused from an aqueous solution of nonionogenic surfactant into the oil before and after exposure by the PIT. On the basis of the results the follow parameters were determined:

- the optimum concentration of the aqueous solution of NIS;
- diffusing time of the NIS components from an aqueous solution of nonionogenic surfactant into the oil;
- the concentration of the diffused oil soluble surfactants into the oil before and after exposure by the PIT.

Evaluation of the diffusion of oil soluble surfactants from the aqueous solution of NIS into the oil was conducted by an indirect method by modifying the interfacial tension at the interface with distilled water [11].

The following concentrations of nonionogenic surfactants: 0,05, 0,1, 0,5, 1, 1,5 and 2 % wt. are used during experimental studies.

Results of the laboratory experiments

At the first stage of the research 6 samples of aqueous solution of the NIS were prepared (concentration: 0,05, 0,1, 0,5, 1, 1,5 and 2 % wt.) (Fig. 2a). Then nonionogenic surfactant was added to the prepared oil samples in a ratio 1:1. Refloated oil periodically was stirred. Measuring of the interfacial tension of the hydrocarbon phase at the interface with distilled water was carried out every 24 hours until the stabilization was achieved. According to the results of the laboratory study the diffusion time of the NIS from an aqueous solution was determined, as well as the optimal concentration of nonionogenic surfactants in aqueous solution above which there is not significantly changing in the interfacial tension.

The second stage is the definition of diffused components of NIS into the oil from the calibration graph. To construct the calibration curve 6 oil samples with different content of nonionogenic surfactant (concentration: 0,05, 0,1, 0,5, 1, 1,5 and 2 % wt.) were prepared (Fig. 2b). Measurement of interfacial tension at the interface between the prepared samples and with distilled water was carried out every 24 hours until the stabilization was achieved. According to obtained values a calibration graph of interfacial tension was plotted.

At the third stage the impact of plasma-impulse technology on diffusion from an aqueous solution of NIS was evaluated. Oil processing was carried out using the developed experimental bench. Aqueous solution of nonionogenic surfactants (concentration chosen according to the results of the first stage of the laboratory study) and the oil sample consistently were poured in the chamber where broadband pulse is formed. Exposure was carried out at intervals of 10 impulses to stabilize the obtained values of interfacial tension with distilled water.

Surface tension of the studied oil samples was measured using a tensiometer EASYDROP. Assessment study of surface tension was produced by the pendant drop method.

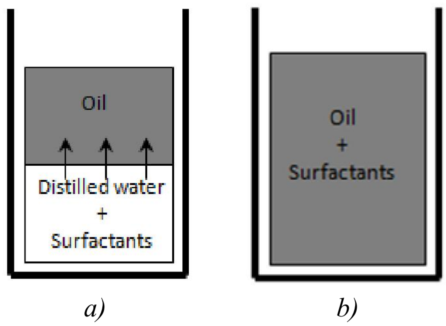

Figure 2 – Schematic presentation of the samples preparation for the determination of the interfacial tension between oil and distilled water:
a) after the diffusion of the surfactants components into the oil
b) an oil solution with surfactant (initial concentrations: 0,05, 0,1, 0,5, 1, 1,5 and 2 % wt.)

The results of the laboratory study have shown that the interfacial tension of oil from Usinskoye oilfield on the interface with distilled water is 32,4 mN/m. At contact of the oil samples with an aqueous NIS (concentration: 0,05, 0,1, 0,5, 1, 1,5 and 2 % wt.) interfacial tension gradually decreased within 15 days (Fig. 3).

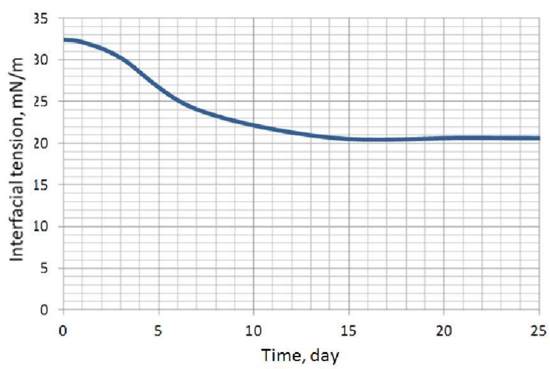

Figure 3 – Example of the reduction depending of the interfacial tension at the interface between oil and distilled water after a contact with an aqueous solution of NIS (2 % wt.)

The obtained values of the interfacial tension of oil that is in contact with aqueous solutions of NIS at concentrations of 0,05, 0,1, 0,5, 1, 1,5 and 2 % wt. are presented in Figure 4. Reduction in oil interfacial tension of Usinskoye oilfield on the interface with distilled water associates with the transition from an aqueous solution of nonionogenic surfactants oil soluble components.

According to the presented results it is evident that the amount of oil diffused into the oil soluble nonionogenic surfactant component is increased by increasing its concentration in the aqueous solution. However, this process has a limit at which a subsequent increase in the concentration of NIS in aqueous solution does not affect the further reduction of the interfacial tension. Limiting concentration of nonionogenic surfactant plays an important role in flooding using aqueous solutions of nonionogenic surfactant. According to a survey for Usinskoye oilfield limiting concentration of NIS in aqueous solution is in the range from 0,5 to 1 % (Fig. 4). This range was chosen as the optimal concentration of maximal optimum concentration of the aqueous solution of nonionogenic surfactant is equal to 1 %wt.

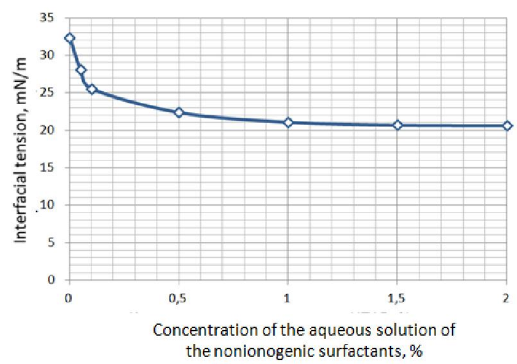

Figure 4 - Dependence of the interfacial tension of oil on the interface with distilled water after a contact with an aqueous solution of NIS

At the next stage the effect of exposure to the PIT on the diffusion of NIS from the aqueous solution into the oil was assessed. The results of the studies are presented in Figure 5.

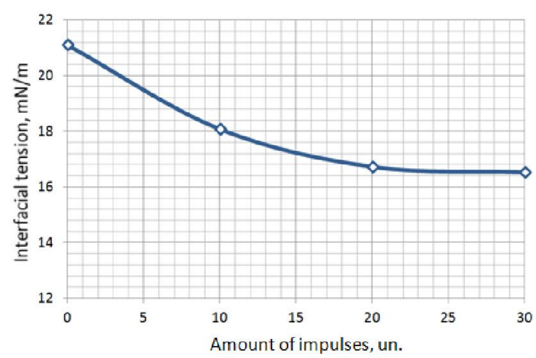

Figure 5 - Interfacial tension of oil with dissolved NIS on the interface with distilled water after exposure by PIT

During the laboratory studies some intermediate interfacial tension measurements were carried out every 10, 20 and 30 impulses. The results showed that the optimal number of impulses of PIT, which exposed to the oil from Usinskoye oilfield, is

20. Further exposure to the sample of oil does not lead to a significant reduction in interfacial tension. As for the presented results it is obvious that the impact of PIT of 20 impulses can reduce the interfacial tension value of an additional 13.5% of the original oil.

To estimate the amount of NIS that dissolved into the oil the dependence of the interfacial tension of oil samples (concentration of nonionogenic surfactant: 0,05, 0,1, 0,5, 1, 1,5 and 2 % wt.) at the interface with distilled water was plotted (Fig. 6). Stabilization time of interfacial tension was 5 days.

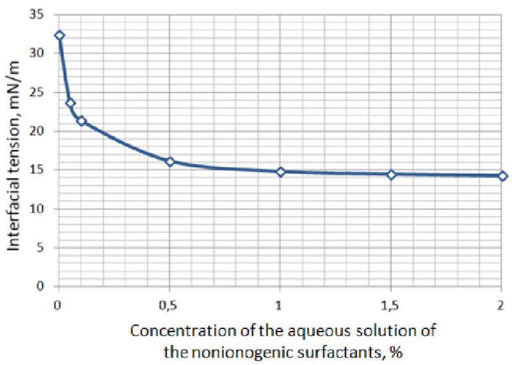

Figure 6 - Oil interfacial tension from Usinskoye oilfield (with different amount of dissolved NIS) on the interface with distilled water

The results in Figure 4 show that at the concentration of the aqueous solution of nonionogenic surfactants equal to 1 % oil interfacial tension is 21,1 mN/m. As for the figure 6 interfacial tension of 21,1 mN/m corresponds to the concentration of NIS in the oil approximately equal to 0,09 %. Interfacial tension at the interface with oil treated by PIT of 20 impulses on contact with 1 % aqueous solution of NIS is equal to 16,7 mN/m (Fig. 5), which corresponds to 0,41 % of nonionogenic surfactant dissolution.

Conclusion

Laboratory studies of the diffusion properties of surfactants have established depending reduce of the interfacial tension of oil from Usinskoye oilfield versus various NIS content in it. It is found that the diffusion process of the oil soluble components from aqueous solutions of nonionogenic surfactant allow reducing the interfacial tension value up to 34,8 % (the actual content of NIS in the oil equals 0,09 % wt.). Simultaneous effect of nonionogenic surfactant and plasma-impulse technology allows intensifying the process of moving the oil soluble components from an aqueous solution into oil, so the value of the interfacial tension of the samples for oil reduced to 13,6 % (the actual content of NIS in the oil equals to 0,41 % wt.).

This article was prepared within a grant of the President of the Russian Federation for young scientists – PhD. # MK-315.2014.5.

Corresponding Author:
Dr.Maksyutin Aleksander Valerevich
National Mineral Resources University "University of Mines", 21st line, 2, St-Petersburg, 199106, Russia

References

1. Muslimov, R.H., 2005. Up-to-date methods of enhanced oil recovery. Design, optimization and evaluation of the performance: Textbook. Kazan: "FEN", pp: 300.
2. Ibatullin, R.R., N.G. Ibragimov, S.F. Tahautdinov and R.S. Hisamov, 2004. Enhanced oil recovery at the late stage of field development. Theory. Methods. Practice. Moscow: LLC "Nedra- Business centre".
3. Altunina, L.K. and V.A. Kuvshina, 1995. EOR surfactant compositions. Novosibirsk: Science. RAS Siberian Publishing House, pp: 198.
4. Antoniadi, G.D. and O.V. Savenok, 2012. Stranded oil - structure and trends. Petroleum engineer, 3: 5-9.
5. Maksyutin, A.V., 2009. Experimental studies of the rheological properties of heavy oil in the elastic wave action. Automation, telemetry and communications in the oil industry, 5: 4-8.
6. Maksyutin, A.V. and R.R. Khusainov, 2010. Experience and perspectives of the technology of plasma-pulse action on the fields with stranded oil. Geology, geography and global energy, 3: 231-235.
7. Molchanov, A.A., A.V. Maksyutin and P.G. Ageev, 2011. The use of plasma-pulse technology to increase recoverable reserves of high-viscosity oil fields with hard stocks. STJ "Logger", 3 (201): 3-14.
8. Mishenko, I.T., T.B. Bravicheva and A.I. Ermolaev, 2005. Choice of a way of operation of chinks with hardly exploiting stocks. Moscow: publishing house "Oil and gas" Gubkin Russian State University of Oil and Gas.
9. Ruzin, L.M., 2009. Status and prospects of development technologies abnormally viscous oil deposits. Materials Interregional Scientific and Technical Conference "Problems of development and exploitation of heavy oil and bitumen", Ukhta: UGTU, pp: 7-15.
10. Burhanov, R.N. and M.T. Hannanov, 2004. Geology of natural bitumen and high-viscosity: Textbook. Almetyevsk: AGNI.
11. Babalyan, G.A., I.I. Kravchenko, I.L. Markhasin and G.V. Rudakov, 1962. Physico-chemical basis for the application of surfactants in the development of oil reservoirs. Москва: Gostoptekhizdat, pp: 283.

4/16/2014