SOCAR

SOCAR Proceedings

Reservoir and petroleum engineering

journal home page: http://proceedings.socar.az

ANALYSIS OF THE RESULTS OF FIELD TESTS OF VISCOELASTIC COMPOSITIONS UNDER THE CONDITIONS OF A COMPLEX TERRIGENOUS RESERVOIR IN THE CASPIAN SEA

R. U. Rabaev*, A. P. Chizhov, R. R. Gazizov, A. V. Chibisov, A. U. Abusal Yusef

Ufa State Petroleum Technological University, Ufa, Russia

A B S T R A C T

The publication analyzes the use of viscoelastic systems in order to increase the efficiency of oil production in the Caspian fields. The conducted studies of the results of pilot field work on the introduction of polymer flooding technologies in complexly constructed terrigenous reservoirs have shown a number of disadvantages of the systems used at the pilot site. In particular, the premature destruction of the polymer compositions used and the subsequent sharp watering of the extracted products were revealed. The research covers technology tests from November 2014 to October 2021, the results of which established the presence of deteriorating dynamics in the removal of polymer material, in addition, the study revealed a high influence of thermobaric and reservoir conditions on the polymer formation process and its subsequent properties. The classic solution to the described problem is the use of compositions with higher viscosity indices, however, laboratory experiments with the use of reservoir fluid have shown a decrease in the characteristics of the compositions used while maintaining conditions close to reservoir conditions. Based on the results of the research, an approach based on a systematic solution of the problem was proposed, the existing line of agents was modernized taking into account experimental data with the reaction of compositions to reservoir fluids, including elements of control and regulation of the oil recovery process during exposure, changes in the volumes of injected polymer solutions.

Keywords: water intrusion; systemic approach; viscoelastic systems; oil recovery.

© 2023 «OilGasScientificResearchProject» Institute. All rights reserved.

Pilot industrial tests (OPI) of polymer flooding technology (PF) began in November 2014 by pumping polymer solution at injection wells No. 11 and 55 based on the results of laboratory studies of polymers and the effectiveness of the impact on the residual reserves of terrigenous reservoirs of Neocomian deposits.

In September 2017, based on the positive results of the OPI at 2 wells, it was decided to expand the scope of the introduction of polymer flooding technology by connecting injection wells No. 34, 42 and transferring production wells No. 48 and 14A to injection of polymer solution.

According to the calculations of technological efficiency, there was a decrease in additional oil production throughout the entire section of the refinery from 4860.5 tons in April 2021 to 4782.6 tons in May and to 4458.3 tons in June, while there was an increase in liquid production from 79.5 thousand tons in April to 82-83 thousand tons in May-June 2021. In July 2021, there was a significant increase in additional oil production to 5292.5 tons (+634.2 tons compared to June 2021) with an increase in liquid withdrawals to 86.8 thousand tons. In August 2021, there was a decrease in additional oil production to 4,482.3 tons while maintaining liquid withdrawals at 85.9 thousand tons. t, increase in water availability (92.1% in August) it was 0.8% compared to July (91.3%) and 1.2% compared to April 2021 (90.9%). In September, additional oil production amounted to 4667 tons, with liquid production – 83.5 thousand tons, the water content was 91.8%, which is 0.3% lower compared to August.

The calculation of the forecast base production for the polymer flooding site was carried out using integral displacement characteristics (fig. 1). [1]

When calculating the forecast base production, the following displacement characteristics were selected, which showed the best convergence of indicators according to the correlation coefficient and the Tail criterion: Stasenkov, Revenko, Kambarov.

Equations of integral displacement curves:

Stasenkov:

$$Q_{oil} = 3.7 \times 10^6 - 6019421e^{(-2.25 \times 10^{-7} Q_{fluid})}$$

Revenko:

$$Q_{oil} = 4.3 \times 10^6 - \frac{1.336 \times 10^{16}}{Q_{fluid}^{1.447}}$$

Kambarov:

$$Q_{oil} = 4.4 \times 10^6 - \frac{1.383 \times 10^{13}}{Q_{fluid}}$$

Results and discussion

Current indicators of the technological efficiency of the PF technology. In order to assess the current efficiency, calculations of additional production using the PF technology were

*E-mail: ga3i3ov.renat@yandex.ru

http://dx.doi.org/10.5510/OGP20230400919

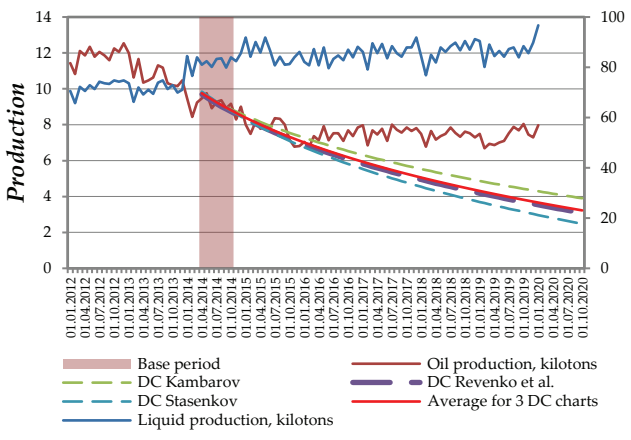

Fig. 1. Justification of the forecast base oil production using displacement characteristics

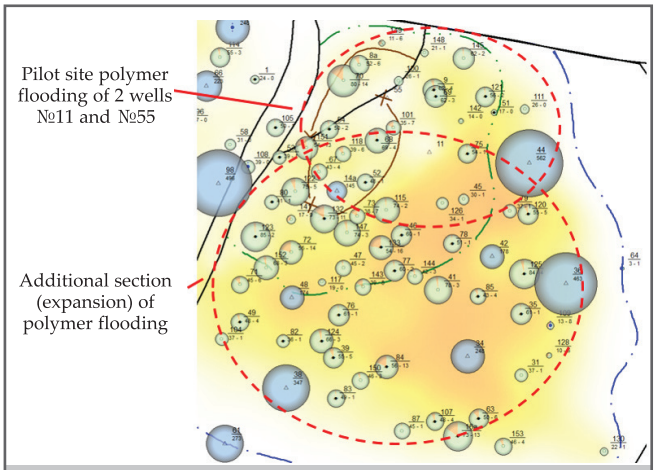

Fig. 2. Map of current selections along the horizon II–ne

carried out. As of 01.10.2021, additional oil production since the beginning of the PF amounted to more than 227 thousand tons. At the moment, the estimated filling of the pore volume of the PF site is 16.7%.

Analysis of polymer yield in producing wells. Various types of field and laboratory studies are used as tools to assess the effectiveness of monitoring polymer flooding technology, one of which is the so-called rapid polymer yield test using kaolin clay in order to qualitatively determine the presence of polymer in the products of reacting producing wells of the pilot site of the PF. Kaolin clay is flocculated in samples containing polymer, and, accordingly, its use is a simple way to detect polymer in the extracted liquid.

In July 2018, a qualitative analysis was carried out for the presence of polymer in simultaneously extracted waters using kaolin clay. The results of laboratory tests of qualitative analysis for the presence of polymer in the simultaneously extracted waters of the PF site showed that the polymer was present in samples from wells No. 100, 101 and 126. The wells are located in the area of injection wells No. 11 and No. 55, the injection of polymer solution into which has been carried out since November 2014.

In November 2018, an additional qualitative analysis was carried out for the presence of polymer in the extracted waters along the way. In the period from November 19 to November 23, 2018, 63 samples of liquid (oil-water emulsion) were taken, the 64th sample of liquid from well No. 104 could not be taken due to repair work. The results of laboratory tests of qualitative analysis for the presence of polymer in the produced waters of the field showed that the polymer was present in samples from wells No. 8A, 70, 100, 101 and 126. In addition to qualitative analysis of samples, it was decided to conduct tracer studies at the pilot site (fig. 2) in order to determine the impact of high-performance injection wells, so the greatest impact was detected in the area of wells No. 11 and No. 55. In this regard, it was recommended to conduct a quantitative determination of the polymer yield using a spectrophotometer.

In March 2019, studies were conducted on the quantitative determination of polymers in reservoir waters. As a result of studies of the produced reservoir water, the presence of polymer was found in wells: No. 9, 68, 70, 73, 100, 101, 126, 133, 8a. Analysis of the quantitative yield of the polymer showed a low concentration, when pumping a polymer solution with a concentration of 1950 micrograms/g, the yield at the wells is maximum 82 micrograms/G. At the same time, at wells 9 (1.14 mcg/g), 68 (1 mcg/g), 73 (4.24 mcg/g), 126 (1.75mcg/g), 133 (2.03 mcg/g), the concentration ranges from 1 to 4 mcg/g, which is within errors in the method of determination. The highest polymer yield is observed in the focus of injection wells No. 55 and 11.

In October 2019, repeated studies were carried out to quantify the residual polymer content on a spectrophotometer, as well as a qualitative analysis of the polymer yield by kaolin clay. The results of laboratory tests of quantitative analysis for the presence of polymer in the produced waters of the field show that the polymer is present in all wells, but to a greater extent in samples from wells No. 100, 101, 126 located in the area of injection wells No. 11 and No. 55, and to a lesser extent in samples from wells No. 8A, 67, 70, 100, 101, 126 and 151.

Due to the sharp increase in the water content of wells, as well as the high costs of RIR exceeding the planned indicators, it was decided to repeat the analysis of samples of producing wells for the presence of polymers. In August 2020, studies were conducted to monitor the polymer yield at the reacting production wells of the site. The result was the following – the polymer is present in all wells, but to a greater extent in samples from wells No. 100, 126, located in the area of injection wells No. 11 and No. 55. Polymer yield in the range of 300-400 micrograms/g for wells No. 151, 128, in the range of 200-300 micrograms/g – for wells No. 67, 70, in the range of 100-200 micrograms/g – for wells No. 8A, 16A. For well No. 101, the polymer concentration increased from 417 micrograms/g to 802 micrograms/g, for well No. 68 it more than doubled – from 225 micrograms/g to 584 micrograms/g.

The analysis of the site of application of the PF technology after various diagnostic graphs and integral characteristics of displacement [1, 4-7, 9, 10] shows an improvement in the production of oil reserves and oil displacement processes after the start of injection of a more viscous displacing agent. The use of polymer flooding has generally improved filtration processes inside the reservoir by increasing the coverage of the reservoir. Confirmation of the change in filtration processes and the increase in reservoir coverage by the displacing agent is the stabilization of the dynamics of product flooding and a drop in oil production as a whole in block III of horizon II-ne of the field. The results of the anal-

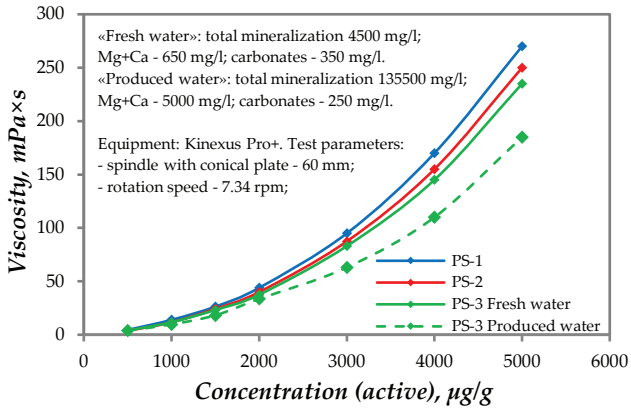

Fig. 3. Viscosity of various polymers depending on concentration [1]

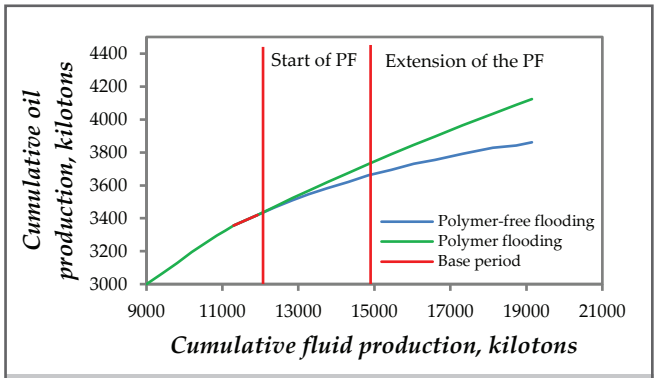

Fig. 4. Dependence of accumulated oil production on accumulated liquid production

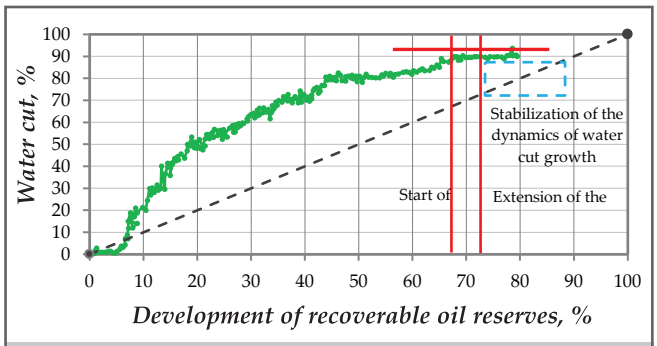

Fig. 5. Dependence of water availability on the production of NCD

Table

Analysis of the production of reserves for the PF

Initial geological oil reserves, thousand tons	Initial recoverable oil reserves, thousand tons	Approved ORF, D. ed.	Accumulated oil production, thousand tons	Selection from recoverable reserves, %	Current increase in ORF (from the base), %
9 911	5 105	0.515	4 102	80.3	4.6

ysis of the efficiency of PP are presented in figures 3-4 and in table. However, the evaluation of the results of quantitative analysis of samples in August 2020 showed the presence of negative dynamics in increasing the concentration of polymer in wells No. 68 and No. 101, also increased indicators were observed in wells No. 151, 128.

In order to solve the problem, various samples of reservoir fluid were taken and experimental studies were conducted on the effect of the gelation medium and temperature conditions on the strength characteristics of polymers.

Based on the experience of previous events, several of the most resistant polymers were selected for testing. Based on the results of studies conducted in foreign companies [3, 8] and studies [1, 2], the stability assessment was carried out taking into account adaptation to the thermobaric conditions of the deposit. Thus, it was revealed that the use of a number of polymer lines (sodium acrylate) with a temperature resistance below 75 degrees was prevented.

The next step was to compare the technological characteristics of the obtained gels depending on the reservoir fluid and its mineralization. To conduct the study, a mother liquor with a concentration of 10000 micrograms/g was prepared and then, at a temperature of 20 °C, the viscosity of the formulations was tested as a function of their concentration in the initial solution.[1] Viscosity was measured at a static shear rate of 7.35 s-1 figure 3.

According to the schedule, the lowest viscosity of the obtained polymer is observed in reservoir conditions, the hypothesis was confirmed that it is necessary to modify the polymers used by introducing special monomers into its composition and bringing it into compliance with reservoir conditions – an increase in the thermal stability of gels, its viscosity and salt resistance. [2]

Analysis of the results of quantitative studies of samples and the results of tracer studies allowed us to conclude that the effectiveness of the existing flooding system has decreased. So, in order to optimize the project in 2020, 2 wells No. 11 and No. 55 were temporarily disconnected, where the injection of polymer solution has been carried out since 2014 and the current filling of the pore volume with polymer solution amounted to more than 25% of the site. At the same time, it was decided to continue pumping polymer solution in the remaining 4 wells (No. 14A, 42, 34, 48).

In November 2020, in order to evaluate the optimizations of the system, studies were conducted on the polymer yield in the area of injection well No. 34. Measurements were also carried out at the nearest wells No. 31, 63, 128, 130. The polymer concentration at well No. 153 was about 18 micrograms/g, which is lower than the background concentration at the BCNS (61 micrograms/g), respectively, there are no breakthroughs of the injected agent from well No. 34 to well No. 153.

In October 2021, studies were carried out on the polymer yield in the PF section. According to the results of laboratory tests conducted to determine the concentration of polymer in the reacting producing wells of the field, it was shown that at wells No. 8A, 67, 68, 70, 100, 101, 107, 126 the polymer concentration is above 200 mcg/g.

Conclusions

Application of an integrated approach to the problem of solving the problems of increasing the efficiency of oil recovery to find a solution to the problems of reducing the water content of products, stabilizing hydrocarbon production.

The methodology of research allows to further improve the efficiency of field development, reduce the capital costs of the mining company. The ways of solving problems proposed in the work can be further used in other objects of the field.

A significant increase in polymer concentrations in producing wells in a short time period is explained by the high production of reserves of the site. The conducted tracer studies recorded the presence of highly conductive channels on the site. High injection volumes, including polymers, and the connection of new wells to testing as part of the expansion of the polymer flooding experiment does not have sufficient economic efficiency. This is due to the appearance of highly filtering channels during the long-term development of the deposit, which are the main factors of the subsequent physical destruction of polymer chains and their subsequent filtration through channels. To combat it, a variant of injection of high-viscosity fringes has been proposed, which has been repeatedly tested and allows to obtain high efficiency from the impact on residual and hard-to-recover oil reserves.

In order to solve the problem of premature breakthrough of polymers to the faces of producing wells in the process of polymer flooding, it is proposed to use compositions with higher viscosity characteristics, the initial shear rate after polymerization. The use of high-viscosity edges will allow to increase oil recovery rates without significant modernization and technological costs for equipment.

The study was supported by the Ministry of Science and Higher Education of the Russian Federation under agreement No. 075-15-2020-900 as part of the program for the development of the World-Class Scientific Center (WCSC).

References

1. Chizhov, A. P., Doskazieva, G. Sh., Andreev, V. E., et al. (2021). Factors affecting the stability of polymers under flooding conditions at vostochny Moldabek field. *Problems of Gathering, Treatment and Transportation of Oil and Oil Products*, 6(134), 52-69.

2. (2010). Proekt razrabotki mestorozhdeniya Zaburun'E. *Atyrau: Otchet TOO «Kaspian Ehnerdzhi ReserCH».*

3. Manichand, R. N., Serajt, R. S. (2014). Field vs. laboratory polymer-retention values for a polymer flood in the Tambaredjo field. *SPE Reservoir Evaluation & Engineering*, 17(03), 314–325.

4. Algharaib, M., Alajmi, A., Gharbi, R. (2011, May). Investigation of polymer flood performance in high salinity oil reservoirs. SPE-149133-MS. In: *SPE/DGS Saudi Arabia Section Technical Symposium and Exhibition, Al-Khobar, Saudi Arabia. Society of Petroleum Engineers.*

5. Farouq Ali, S. M., Thomas, S. (1989, September). The promise and problems of enhanced oil recovery methods. PETSOC-SS-89-26. In: *Technical Meeting / Petroleum Conference of The South Saskatchewan Section. Society of Petroleum Engineers.*

6. Delamaide, E., Tabary, R., Rousseau, D. (2014, March). Chemical EOR in low permeability reservoirs. SPE-169673-MS. In: *SPE EOR Conference at Oil and Gas West Asia, Muscat, Oman. Society of Petroleum Engineers.*

7. Stoll, U. M., Shureki, Kh., Finol, Dzh., et al. (2011). Potok shchelochej / poverkhnostno-aktivnykh veshchestv / polimerov: iz laboratorii v pole.

8. Tovar, F. D., Barrufet, M. A., Schechter, D. S. (2014, April). Long term stability of acrylamide based polymers during chemically assisted CO2 WAG EOR. SPE-169053-MS. In: *SPE Improved Oil Recovery Symposium, Tulsa, Oklahoma, USA. Society of Petroleum Engineers.*

9. Yerramilli, S. S., Zitha, P. L., Yerramilli, R. C. (2013, June). Novel insight into polymer injectivity for polymer flooding. SPE-165195-MS. In: *SPE European Formation Damage Conference & Exhibition, Noordwijk, The Netherlands. Society of Petroleum Engineers.*

10. Zekhner, M., Clemens, T., Suri, A., Sharma, M. M. (2014, April). Simulation of Polymer injection under fracturing conditions - a field pilot in the Matzen field, Austria. SPE-169043-MS. In: *SPE Improved Oil Recovery Symposium, Tulsa, Oklahoma, USA. Society of Petroleum Engineers.*

Анализ результатов промысловых испытаний вязкоупругих составов в условиях сложного терригенного коллектора в Каспийском море

Р. У. Рабаев, А. П. Чижов, Р. Р. Газизов, А. В. Чибисов, А. У. Абусал Юсеф
Уфимский государственный нефтяной технический университет, Уфа, Россия

Реферат

В статье анализируется использование вязкоупругих систем для повышения эффективности добычи нефти на месторождениях Каспия. Исследования результатов опытно-промысловых работ по внедрению технологий полимерного заводнения в сложнопостроенных терригенных коллекторах показали ряд недостатков систем, использованных на опытном участке. В частности, выявлено преждевременное разрушение используемых полимерных композиций и последующее резкое обводнение извлеченных продуктов. Исследование охватывает технологические испытания с ноября 2014 года по октябрь 2021 года, по результатам которых установлено наличие ухудшающейся динамики удаления полимерного материала, кроме того, исследование выявило высокое влияние термобарических и пластовых условий на процесс образования полимера и его последующие свойства. Классическим решением описанной проблемы является использование композиций с более высокими показателями вязкости, однако лабораторные эксперименты с использованием пластовой жидкости показали снижение характеристик используемых композиций при сохранении условий, близких к пластовым. По результатам исследований предложен подход, основанный на системном решении проблемы, проведена модернизация существующей линейки реагентов с учетом экспериментальных данных по реакции композиций на пластовые флюиды, включая элементы контроля и регулирования процесса нефтеизвлечения в процессе воздействия, изменения объемов закачиваемых полимерных растворов.

Ключевые слова: водопроявление; системный подход; вязкоупругие системы; извлечение нефти.

Xəzər dənizində mürəkkəb terrigen kollektor şəraitində özlü-elastik tərkiblərin mədən sınaqlarının nəticələrinin təhlili

R. U. Rabayev, A. P. Çijov, R. R. Qazizov, A. V. Çibisov, A. U. Abusal Yusef
Ufa Dövlət Neft Texniki Universiteti, Ufa, Rusiya

Xülasə

Məqalədə Xəzər yataqlarında neft hasilatının səmərəliliyini artırmaq üçün özlü-elastik sistemlərin istifadəsi təhlil edilir. Mürəkkəb qurulmuş terrigen kollektorlarında polimer şulaşdırma texnologiyalarının tətbiqi ilə bağlı təcrübə mədən işlərinin nəticələrinin tədqiqi təcrübə sahəsində istifadə olunan sistemlərin bir sıra çatışmazlıqlarını göstərmişdir. Xüsusilə, istifadə olunan polimer kompozisiyalarının vaxtından əvvəl dağılması və çıxarılan məhsulların sonradan kəskin sulaşması aşkar edilmişdir. Tədqiqat 2014-cü ilin noyabrından 2021-ci ilin oktyabrına qədər texnoloji sınaqları əhatə etmişdir. Tədqiqat nəticələrinə görə polimer materialının çıxarılması dinamikasının pisləşməsi müəyyən edilmişdir, əlavə olaraq tədqiqat termobarik və lay şəraitinin polimerin əmələ gəlməsi prosesinə və sonrakı xüsusiyyətlərinə yüksək təsirini aşkar etmişdir. Tədqiqatın nəticələrinə görə, polimer materialının kənarlaşdırılmasının pisləşməsi dinamikasının olması müəyyən edilmişdir, bundan əlavə, termobarik və lay şəraitinin polimerin əmələ gəlməsi prosesinə və onun sonrakı xüsusiyyətlərinə yüksək təsirini aşkar edilmişdir. Təsvir olunan problemin klassik həlli daha yüksək özlülük göstəriciləri olan kompozisiyaların istifadəsidir, lakin, lay mayesinin istifadəsi ilə aparılan laboratoriya təcrübələri, lay şəraitinə yaxın olan şəraiti qoruyarkən istifadə olunan kompozisiyaların xüsusiyyətlərində aşağı düşməsini göstərmişdir. Tədqiqatın nəticələrinə əsasən problemin sistemli həllinə əsaslanan yanaşma təklif edilmişdir, kompozisiyaların lay flüidlərinə reaksiyasına dair eksperimental məlumatlar, o cümlədən təsir prosesində neftin çıxarılması prosesinə nəzarət və tənzimləmə elementləri, vurulan polimer məhlullarının həcmindəki dəyişikliklər nəzərə alınmaqla mövcud reagentlər xətti modernləşdirilmişdir.

Açar sözlər: su təzahürü; sistemli yanaşma; özlü-elastik sistemləri; neftin çıxarılması.