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A comprehensive review of polymer and alkaline/surfactant/polymer flooding applied and researched in Kazakhstan

Polymer flooding and alkaline/surfactant/polymer flooding have been applied throughout the world for more than 30 years. However, they were not as popular as other types of enhanced oil recovery methods such as thermal methods and gas injection in Kazakhstan. To date, the polymer and alkaline/surfactant/polymer (ASP) flooding processes have been applied successfully in several Kazakhstan oil fields due to technology progress and changes in chemical costs and successful polymer and ASP flooding experiences in the world. This paper shows application of chemical enhanced oil recovery methods in several oil fields in Kazakhstan, where pilot on-site experiments and core flood tests on chemical flooding methods were carried out. The paper describes the latest pilot tests on polymer flooding in oil fields such as Nuraly, Zaburunie and Kalamkas, where polymer flooding alone contributed approximately 150 000 tons of produced crude oil. Several ASP floods also have been tested in local fields. Laboratory researches were carried out in core samples of Eastern Moldabek and Karazhanbas oil fields. Increase in oil recovery up to 80 % have been reported, however pilot tests have not been implemented yet. This paper discusses researches conducted in these fields including field / laboratory results, methods of flooding, polymer types and concentrations used.

Keywords: oil fields, pilot test, polymer flooding, recovery factor, concentration, water cut.

Introduction

The use of chemical flood is not a new technology in enhanced oil and gas recovery methods in local fields. However, recently oil companies in Kazakhstan express their interest in this type of tertiary method again, due to technology progress, changes in chemical costs and successful polymer and ASP flooding in the USA, China and Russia. Several chemical enhanced oil recovery methods such as polymer and ASP flooding are used and are planned to use in Kazakhstan. These methods are based on interfacial tension reduction between oil and water contact, increasing water viscosity as a result improving oil mobility.

Polymer flooding has been applied in Nuraly, Zaburunie and Kalamkas fields. Because of the high water cut in these fields, primary goal of polymer flooding was reduction the amount of water being produced with the oil, while increasing the recovery of the original oil in place. Addition of polymer increases the viscosity of aqueous phase, bringing it closer to that of the heavy oil in place, consequently, decreasing water mobility.

With the polymer flooding ASP flooding is also included to the experiments. Core flood tests on ASP flooding were conducted on core samples of Moldabek and Karazhanbas fields. This type of chemical method integrates the advantages of alkali, surfactant and polymer use. Adding surfactant reduces interfacial tension, injecting alkali results in wettability alteration. Alkali with dilute surfactant solution can change the wettability, the alkali can reduce the surfactant adsorption. Polymer in ASP acts as the mobility control agent. The combination of alkali, surfactant and polymer effects enables ASP process a great potential for enhanced oil recovery. Core flood tests showed optimistic results.

Pilot on-site experiments

Nuraly field

Pilot on-site experiments were carried out on Nuraly field. Polymer flood pilot was started on June 2014. Two injection wells and eight reacted production were used for the polymer application. Location of wells and polymer pilot area are shown in Figure 1.

Field information

The proven oil resource is estimated at 2,712,500 tons, reservoir is located on South Torgai basin, thickness varies in between 3.4 to 24.2 meters. Reservoir is characterized by layered, fissured, heterogeneous sandstone. The reservoir porosity is 22–24.5 % and permeability intervals are in the range of 2 to 2200 md. The

field produces light oil (API 40º) with paraffin and asphaltine compounds. Oil production was started in 1996 and water cut before polymer flooding reached 90 % [1].

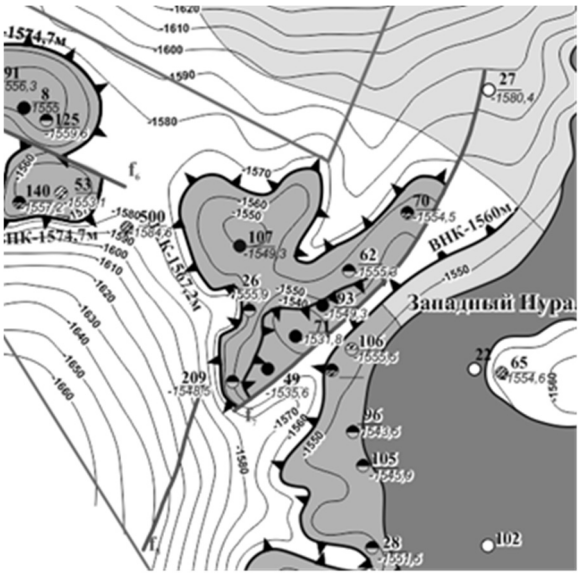

Figure 1. Pilot test area on Nuraly field

Experimental

The Nuraly polymer core flood study was conducted under reservoir conditions with objectives of screening and evaluating suitable polymer and its concentration for the field application. The results of the study showed 10 % increase in oil recovery. After the study it was decided to fill 30 % of pore volume of the reservoir starting from higher concentration slowly lowering it. Therefore, from September until December 2014 the injected polymer concentration was decreased from 6000 ppm to 3000 ppm for well No. 26 and from 4000 ppm to 2000 ppm for well No. 106. Detailed information about results is given in Table 1.

Table 1

Program of the polymer flooding in Nuraly field

Date	Days	Concentration of polymer FP5205VHM (ppm)		Viscosity of polymer, cP		Injection rate, m^3/day		Polymer (tons)	Cumulative polymer (tons)
		Well 26	Well 106	Well 26	Well 106	Well 26	Well 106		
Stages of polymer injection									
23.09–30.11.2014	70	6000	4000	135	53	130	90	84.14	140.80
01.12–09.12.2014	9	5000	3000	89.2	28.4	130	90	8.76	149.56
10.12–14.12.2014	5	4000	2000	50	9.75	130	90	3.72	153.28
15.12–31.12.2014	17	3000	2000	28.4	9.75	130	90	10.44	163.72

For this period of time additional oil recovery was 7005.5 tons. Two wells No. 28 and No. 66 were added to the polymer injection in 2016. Overall, the polymer pilot has been in place for over three years and incremental oil recovery of 92551.4 tons has been obtained on September 2017. Experiment will continue before 30 % of pore volume is filled with polymer.

Zaburunie field

The field is at the final production stage. Therefore, engineers are trying to recover as much as possible of oil original in place (OOIP). Recoverable reserves are estimated at 7065 thousand tons. Before the polymer flooding water cut was 90 %, daily oil production was 5 tons per day [2].

Field information

In this section, we consider only the part of Zaburunie field, where polymer test was applied. Polymer was injected in Neocomian II division, covering 2573 thousand square meters. Reservoir is represented by

sandstones, aleuritic and shale deposits with an average net pay 17 meters. The test area has an average porosity of 30 % and permeability reaches maximum value of 2000 md.

Experiment

Pilot on site experiment started on November 22, 2014. The pilot area had 2 injection and 38 reacted production wells. Several polymers were screened on core samples to find the suitable type for reservoir characteristics. In the experiment 4 types of polymer were tested, they are FP 5115 SH (green line), FP 5115 VHM (blue line), FP 5205 SH (red line) and FP 5205 VHM. Relation of viscosity and polymer concentration were found and based on results Flopaam 5205VHM polymer was chosen to the pilot test. Results of the experiment are shown in Figure 2.

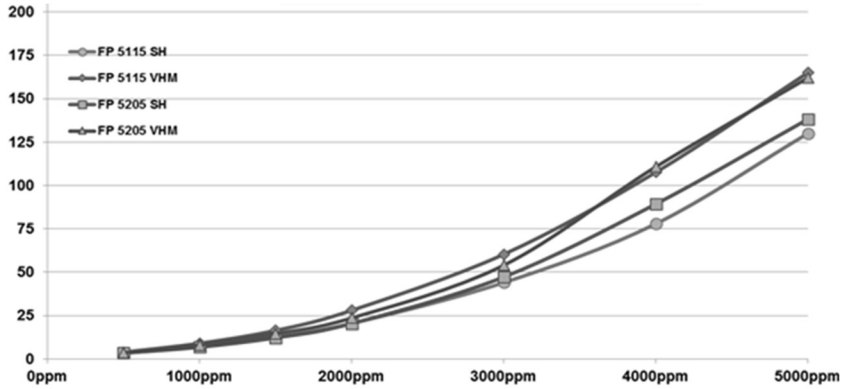

Figure 2. Relation of viscosity and concentration

Different slug process was designed in the following way:

– The concentration of the polymer in the two injection wells increased during the first 15 days from 500 to 1000 ppm in order to track formation response, well reactions for polymer injection, changes in wellhead and bottom hole pressure of injection wells and operation of all units and assemblies.

–As soon as a stable injection volume was established, the injection continued at the required concentration of 2000 ppm.

– Then injection of the polymer at a concentration of 1000 ppm was followed for the next 110 days.

– In the last 50 days of polymer injection, concentration decreased to 500 ppm.

Detailed program of the polymer flooding is shown in Table 2.

Table 2

Program of the polymer flooding in Zaburunie field

Days	Concentration of polymer FP5205VHM (ppm)	Viscosity of polymer (cP)	Max injection rate (m^3/day)		Polymer (tons)	Cumulative polymer (tons)
			Well 11	Well 55		
1st stage. Pilot on site experiment (6 month)						
5	500	2.5	205	200	1.11	1.11
5	750	4	205	200	1.67	2.78
5	1000	6	205	200	2.23	5.01
169	2000	21	205	200	150.58	155.59
2nd stage. Industrial application (3 years)						
936	2000	21	205	200	833.98	989.57
110	1000	6	205	200	49.01	1038.57
50	500	2.5	205	200	11.14	1049.71

In about a year of the experiment increase in oil production was about 19 086 tons of crude oil and water cut decreased from 87 % to 82 %. Permeability declined to 30 % after the polymer injection. This project is now on industrial application stage. For the period of 2014–2017 an incremental oil recovery is estimated at 89 tons. To the next year of 2018 it is planned to increase the number of injection wells from 2 to 6. Following wells will be added to the polymer flooding area (Fig. 3) No. 14, 48, 42, 34.

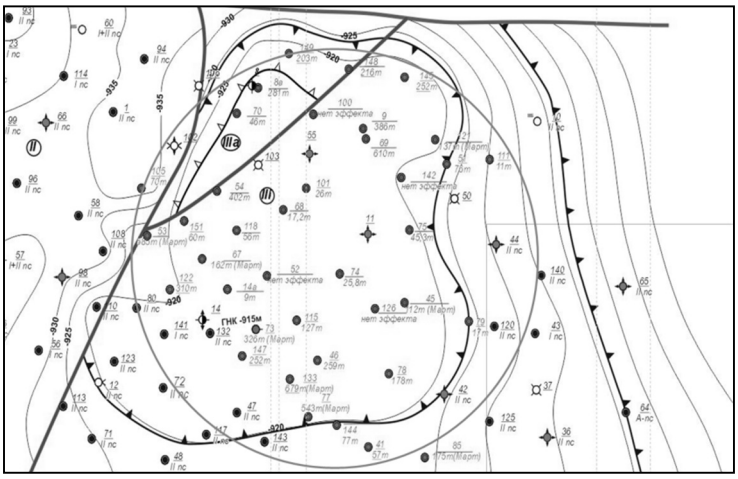

Figure 3. Pilot test area on Zaburunie field

Kalamkas field

The field was discovered in 1976 and the primary production in the field began in 1979. In 2004 oilfield achieved first 100 million tons of crude oil produced [3]. The proven oil resource is estimated at 207883 thousand tons. Field produces a medium viscous oil (API 24º, oil viscosity varies 11.5–21.2 cp) with paraffin and Sulphur compounds [4].

Field information

The field is located on the Buzachi Peninsula in the western part of Kazakhstan.

The reservoir depth is 500–1000 meters, deposit is a complex combined type of massive reservoir with a single hydrodynamic system (reservoirs are combined into one powerful oil and gas reserves). Productive layers are characterized by the terrigenous deposits [5].

Experiment

This field is the pilot test as well. The polymer slug was injected on September 27, 2014. For the polymer program, 2 injection wells (No. 2041, 2049) and 21 reacted production wells were chosen. In about a half of the year increase in oil production was about a thousand ton of crude oil and water cut decreased to 3 %. One more well No. 1580 was added to polymer test in March 2015 and an industrial application is planned before 2020 with 6 % predicted increase in oil recovery. In the history of this oilfield there was a polymer flooding in yearly 1983 and it was a successful project with additional 53920 tons of produced oil [6]. Operating company of the Kalamkas field «Mangystau munaigas» plans to expand polymer flooding to the field «Zhetybai».

Laboratory researches

After these experiments of polymer flooding, chemical enhanced methods are taken into account as alternative production on the latest development stages on the other local fields. For example, several ASP laboratory flood tests were conducted in Eastern Moldabek and Karazhanbas oil fields.

Karazhanbas

Karazhanbas oilfield is located at Buzachi peninsula. It was discovered in 1974 and put into the production in 1980. The reservoir is multi-layered, oil accumulations were discovered in six Lower Cretaceous layers (A1, A2, B, V, G, D) and in two upper Jurassic formations (U-1, U-2). Karazhanbas crude is high viscous oil. It has high-sulfur and resin content.

Experiment

For sand pack filtration experiments, crude oil with 926 kg/m^3 density and 300mPa sec viscosity was used. Models in the experiment were 8.6 cm in length, 4.3 cm in diameter with average permeability 6 Darcy. All filtration experiments were conducted by using «UIK-S(2)» apparatus for cores investigation (Russia). To investigate the oil displacement efficiency by using ASP formula, several experiments with varying concentrations of CROHDA-MAA (0.5 %; 0.25 %; 0.125 %) dissolved in KOH solution were conducted. Results of experiment were optimistic showing decrease in water cut on 50–60 % in all models. Oil displacement coefficient varied from 0.3 to 0.35, maximum was reached by solution with concentration of CROHDA-MAA 0.5 % [7].

Eastern Moldabek

Eastern Moldabek is a part of the Kenbai oil and gas deposits. Production was started in 1999. Ten productive layers which are characterized by Cretaceous and Jurassic layers were included to the production stage. The reservoir is terrigenous, porosity is about 30–34 % and produced oil is highly viscous with sulphur and paraffin compounds [8].

Experiment

For the filtration experiment, 4 core samples of Eastern Moldabek field, crude oil and model of the produced water were used. Core samples had porosity about 22–27 % and different permeability values ranged between 393–2370 md were used. The aim of the experiment was to compare polymer and ASP flooding and determine the effective one for this field. Based on geological characteristics of the field FloPaam 5205 polymer with concentration 2500 ppm was chosen. Experiment was conducted at reservoir conditions, for which the PLS-200 system with 4 coreholders was applied. Results of the experiment showed increase in oil recovery up to 68 % in both cases, in polymer and ASP injections.

The results of filtration experiments in Eastern Moldabek and Karazhanbas fields were successful and for both of these fields they can be considered as enhanced oil recovery method.

Conclusion

Overall, the application of polymer flooding in all three oilfields showed optimistic results on increasing additional oil recovery and decreasing water cut. However, it is too early to make a decision on economic profitability of the projects. Nevertheless, these site experiments help to progress enhanced oil recovery methods and give experience to improve polymer flood technology, including the development of the project, design of polymer type and concentration to better fit reservoir characteristics in order to maximize economic returns.

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Қазақстан кен орындарында өткізілген полимерлік және полимер/БАЗ/сілті суландыру бағытындағы зерттеулерге кешенді шолу

Мақалада қазақстандық мұнай кен орындарында қолданылған полимерлік суландыру әдістерін зерттеулері мен оның нәтижелері қарастырылған. Нұралы, Забурунье және Қаламқас кен орындарындағы

тәжірибелі-кәсіпшілік сынау сипатталды. Осы кен орындарында тәжірибелік-өнеркәсіптік сынақтар кезеңінде қойнау қабатқа полимерлік әсер етудің есебінен қосымша өндірілген шикі мұнай көлемі шамамен 150000 т құрады. Сондай-ақ авторлар полимердің БАЗ және сілтілермен комбинациядағы ерітінділерімен керндік материалдарды суландыру бойынша зертханалық зерттеулерге тоқталған. Шығыс Молдабек және Қаражанбас кен орындарының керндік үлгілеріне қойнау қабат жағдайында эксперименттер жүргізілді. Сүзгілік зерттеулер нәтижелері оптимистік болып саналады, максималды ығыстыру коэффициенті 80 %-ға дейін артты. Жоғарыда аталған зерттеулер сынақ өткізілген кен орындарының геологиялық қысқаша деректері, полимерлі және аралас суландыру бағдарламасы, пайдаланылған полимер түрі мен концентрациясы көрсетіле отырып берілген және соңғы сынақтардың нәтижелері келтірілген.

Кілт сөздер: мұнай-кен орындары, тәжірибелік-өнеркәсіптік сынақ, полимермен сутоғыту, комбинациялық сутоғыту, итергіштік коэффициенті, кенорнының суланғандық көрсеткіші, концентрация.

А.Ж. Наукенова, Н.Д. Сарсенбеков, Б.Е. Бекбауов

Комплексный обзор исследований на месторождениях Казахстана по полимерному и ПАВ/щелочь/полимерному заводнению

В статье представлены исследования и результаты их полимерных заводнений, применённых на нефтяных месторождениях Казахстана. Описаны опытно-промысловые испытания на месторождениях Нуралы, Забурунье и Каламкас. На данных месторождениях только за счет полимерного воздействия на пласт дополнительно добыто приблизительно 150000 т сырой нефти за период опытно-промышленных испытаний. Также авторами проведены лабораторные исследования по заводнению керновых материалов растворами полимера в комбинации с растворами ПАВ и щелочи. Эксперименты проводились в пластовых условиях, применялись керновые образцы месторождений Восточный Молдабек и Каражанбас. Результаты фильтрационных исследований считаются оптимистичными, максимальный коэффициент вытеснения увеличился до 80 %. Перечисленные выше исследования приведены с указанием кратких геологических данных месторождений, программы полимерного и комбинированного заводнения, концентрации и типа применяемого полимера, а также даны последние результаты испытаний.

Ключевые слова: нефтяные месторождения, опытно-промышленные испытания, полимерное заводнение, комбинированное заводнение, коэффициент вытеснения, обводненность, концентрация.

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