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LABORATORY STUDY OF ASP FLOODING FOR VISCOUS OIL

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ABSTRACT

This article presents results of laboratory investigation of ASP flooding technology for improving recovery of viscous oil from Karazhanbas oilfield. Oil displacement efficiency of two-component ASP formula consisting of polymer-surfactant (hydrophobically modified polybetaine CROHDA-MAA) and alkali (KOH) was tested by conducting filtration experiments on sandpack models. During the course of the experiments, 0.125, 0.25 and 0.5% concentrated aqueous solutions of polymer-surfactant and alkali were injected into the model as a result oil displacement coefficient varied from 31 to 37% in addition to water flooding. This technology has potential to become an alternative to the thermal oil recovery methods especially in cases, where application of these methods is restricted by geological, economical or ecological factors.

Key words: Oil reservoir, Water flooding, ASP flooding, Sandpack model, High viscosity oil, EOR.

INTRODUCTION

The world's high viscous oil reserves are calculated to be around 810 billion tons and this is much higher than medium- and low-viscosity oil reserves (162 billion tons)[1]. The main part of these reserves is concentrated in Canada and Venezuela. In Kazakhstan, the larger half of oil deposits is presented by viscous oils, which traditionally are determined as crude with the viscosity higher than 30 mPa·sec or 35 $mm^2 \cdot sec^{-1}$. According to the data from Kazakh Scientific Research Institute of Petroleum Geology, viscous oil deposits are mainly found in West Kazakhstan (Karazhanbas, Buzachi, Kalamkas, Kenkiyak)[2]. In general, 47 oilfields of viscous oil are found in Kazakhstan with total OIIP of 1.32 billion tons.

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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.

High viscosity oil production by means of traditional methods-low density well spacing patterns and water flooding, don't give positive results and accompanied with low oil flow rates and early water fingering through high permeability channels. In number of cases, calculated oil displacement coefficient doesn't exceed 25-30%[3].

To solve above mentioned problems in 1981 at the oilfield, two pilot projects of wet in-situ burning and thermal-steam treatment were initiated. In 1996 because of technological inefficiency, it was decided to stop the in-situ burning pilot test. Currently, the oilfield is developed by thermal treatment and water flooding. For the maintenance of reservoir pressure in 2014, 8 million cubical meters of water and 3.8 million tons of steam were injected into the reservoir. OOIP of Karazhanbas oilfield is 150 million tons and during the last 40 years, 42 million tons have already been produced. Today the company that exploits the field produces more than 2 million tons per year, in near future, it is planned to increase oil recovery up to 2.5 million tons per year by applying new technologies.

As it is seen from the above data, thermal EOR methods might be effective but in the same time are characterized by the following disadvantages:

- Steam generation is a costly process, which increases expenditures for oil production;
- Accessibility of big water volumes is required as well as special equipment for water treatment with high carrying capacity, steam-generation units, incinerators, air compressors, etc.
- For the effective application of the technology, homogeneous formation with high pay thickness is required[4].
- Environmental damage that is caused by application of these methods[5,6]

Nowadays, chemical EOR methods are being extensively used, the main aim of their application is displacement of discontinuous oil trapped after primary water flooding by improving macroscopic and microscopic displacement through increasing sweep efficiency and decreasing interfacial tension at the oil water interface, respectively.

ASP (alkali, surfactant, polymer) flooding deserves special attention. This method was developed in 1984 (R. C. Nelson, Shell) but only in recent years, it started to be applied throughout the world. In ASP flooding alkali, surfactant and polymer are injected into the reservoir simultaneously or as separated slugs[7-9].

Addition of surfactant, alkali and polymer in various combinations improves displacement properties of injected water. Presence of surfactant in injected brine causes decrease of IFT at oil-water interface down to ultra-low values 0,05-0,01 mN/m what allows mobilization of residual discontinuous oil droplets, which coagulate forming oil bank. Addition of high molecular weight polymers causes thickening of the aqueous phase, which leads to more even distribution of the displacement front and thus, improvement of macroscopic sweep efficiency.

Application of alkali is motivated by its interaction with oil and rock. Almost all natural oils contain active components-organic acids, though their amount and composition vary. Reactions that take place *in-situ* between alkali and organic acids occurring in oil produce surfactants, which cause reduction of IFT at oil water interface. Increase of the amount of organic acids in crude oil increases the efficiency of alkali flooding[10]. In this article ASP (alkali, surfactant, polymer) flooding for viscous oil of Karazhanbas oilfield is studied.

EXPERIMENTAL

Materials

Hydrophobically-modified polybetain-poly(alkylaminocratonat)betain (CROHDA-MAA) and KOH were used as polymer soap and alkali. CROHDA-MAA was synthesized on the basis of acetacetic ester according to the methodology described in the literature source[11] as long chain alkylamine hexadecylamine was used. Molecular weight of obtained polymer was ~ 6000000 D.

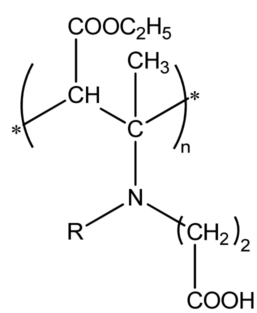

Fig. 1: Structure of polymer soap ROHDA-MAA

For sand pack filtration experiments, oil from Karazhanbas oil field was used. Density and viscosity of oil were measured by Stabinger viscometer SVM 3000 at 30°C. Table 1 presents some physical and chemical properties of the crude.

Table 1: Physical and chemical properties of Karazhanbas crude

Dynamic viscosity (mPa·sec)		300
Kinematic viscosity (mm^2/sec)		250
Oil density (Kg/m^3)		926
Acid number of the crude (mg of KOH/g of oil)		0,54
Content in oil (%)	Asphaltenes	5,9
	Resins	22,7
	Paraffins	3,1

Methods

For preparation of the sand pack models, reservoir rock grains from Karazhanbas oilfield were used. Porosity of each model was measured by volume saturation method. Air permeability of all models was measured to be 6 Darcy.

All filtration experiments were conducted by using apparatus for cores investigation "УИК-С(2)" (Russia) Fig. 2. The apparatus was equipped with sand pack model for conducting of filtration experiments. Sand pack model is 8.6 cm length still cylinder with diameter of 4.3 cm.

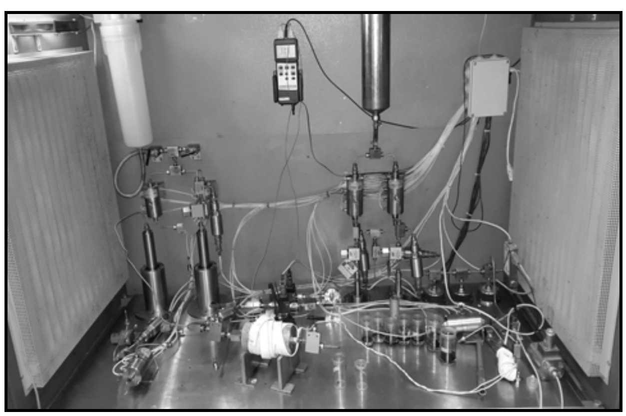

Fig. 2: Apparatus for cores investigation УИК-С(2)

All experiments were conducted in the following order:

(i) Preparation of the sand pack model

(ii) Determination of air permeability

(iii) Saturation of the model with brine

(iv) Water displacement by oil for the purpose of creation initial conditions

(v) Simulation of water flooding, determination of oil displacement coefficient

(vi) Injection of ASP solution into the water flooded sand pack, determination of oil displacement coefficient

All experiments were conducted at 30°C.

RESULTS AND DISCUSSION

In this work, new polymer material on the basis of betaine structure CROHDA-MAA was tested for ASP flooding. Usage of only two components is a distinguishing feature of the this article ASP formula due to which it stands out among other ASP formulas used in the industry.

Structure of polybetaine chain includes ionized groups (one base and one acid) as well as aliphatic "tail" consisting of thirteen methylene groups. In aqueous solution, carboxyl groups of polybetaine macromolecules ionize under the influence of alkali (KOH) and exhibit negative charge. As a result, due to the electrostatic repulsion between similar charges, adsorption by rock is minimized.

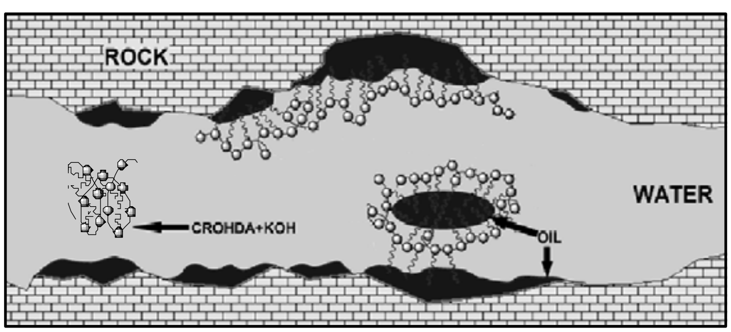

Fig. 3: Visualization of working mechanism of ASP flooding on micro level

The substance exhibits properties of surfactant forming stable micelle colloid systems as well as decreasing interfacial tension at the interfaces oil-water and water-oil. Critical micelle concentration (CMC) is much less ($1 \cdot 10^{-4}$) in comparison with low molecular surfactants, what allows CROHDA-MAA to form stable microemulsions in reservoir conditions as a result of IFT decrease and increase of oil mobility at the interface water-oil (Fig. 3).

With the aim to investigate oil displacement efficiency of the novel ASP formula, several experiments with varying concentrations of CROHDA-MAA were conducted. Through each model, 4 pore volumes of CROHDA-MAA solution were pumped. Results show that oil displacement coefficient after simulation of ASP flooding by using various concentrations of CROHDA-MAA dissolved in KOH solution varied from 31 to 37% in addition to water flooding (Table 2, Fig. 4).

Table 2: Characteristics of the filtration experiments

Conc. of CROHDA-MAA (%)	Porosity (%)	Permeability (D)	Saturation (%)		Chemical formulation	Water flooding oil recovery	Total EOR (%)
			Initial Oil S_{oi}	Initial water S_{wi}			
0,5	46,745	5,8	0,7557	0,2442	ASP	0,46	0,83
0,25	40,42	6,47	0,6872	0,3127	ASP	0,47	0,80
0,125	48,42	6,2	0,7749	0,2250	ASP	0,44	0,75

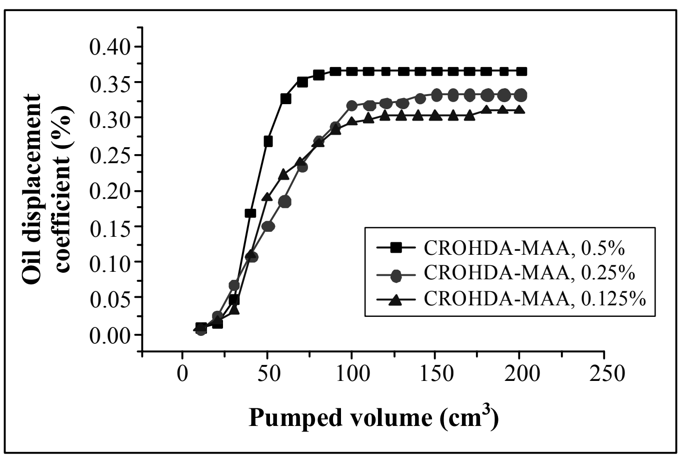

Fig. 4: Oil displacement coefficient versus pumped volume for various concentrations of CROHDA-MAA

Experiments showed that displacement ability of CROHDA-MAA is characterized by positive trend in the beginning of the experiment and stabilizes after pumping 1 pore volume. This fact testifies good displacement ability of the new polymer soap, moreover in all experiments after pumping 0.5 pore volumes water cut is decreasing on 50%. Thus, application of CROHDA-MAA accelerates oil displacement process and decreases water cut percentage.

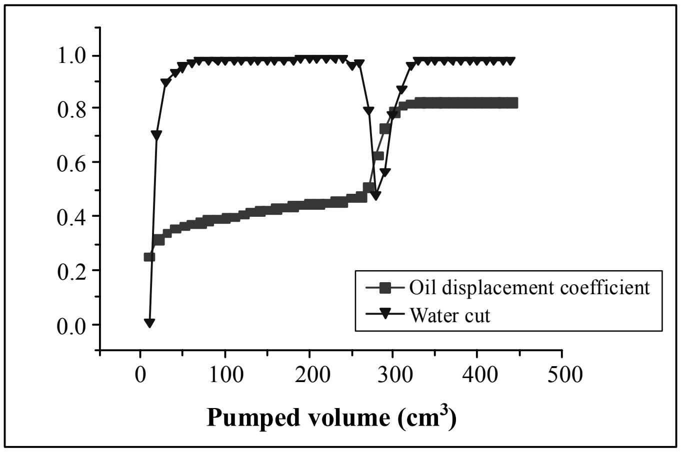

Fig. 5: Oil displacement coefficient and water cut percentage versus pumped volume for 0.5 % concentrated CROHDA-MAA solution

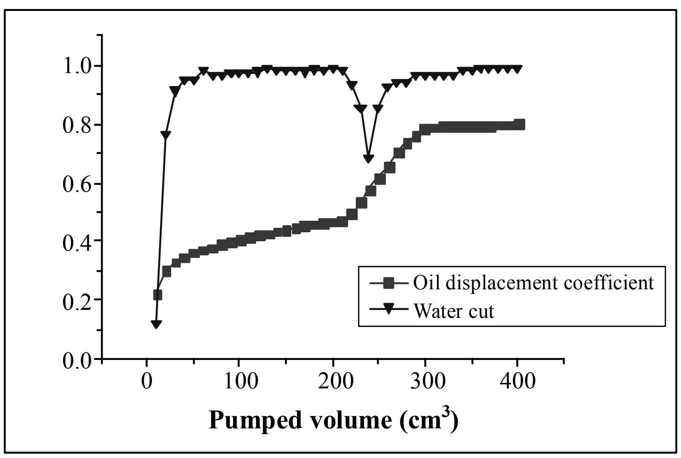

Fig. 6: Oil displacement coefficient and water cut percentage versus pumped volume for 0.25% concentrated CROHDA-MAA solution

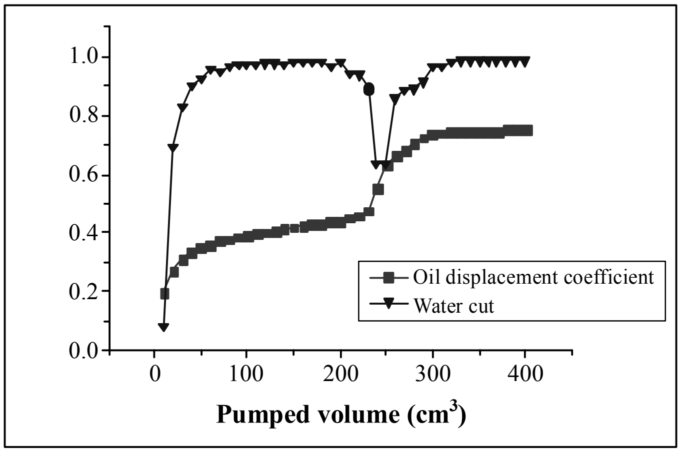

Fig. 7: Oil displacement coefficient and water cut percentage versus pumped volume for 0.125 % concentrated CROHDA-MAA solution

CONCLUSION

With the aim to determine viscous oil displacement efficiency of the new polymer soap CROHDA-MAA, series of filtration experiments were conducted. It was determined that oil displacement coefficient after simulation of ASP flooding by using various concentrations of CROHDA-MAA dissolved in KOH solution varied from 31 to 37 % in addition to water flooding. Taking into account world energy demand and oil prices, this new polymer soap CROHDA-MAA may be competitive with other EOR methods. This technology has big potential to become an alternative to the thermal oil recovery methods for production of viscous oil.

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