Study of the EOR Agents' Oil Displacing Properties Based on the Results of Filtration Experiments'

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Annotation. Are given results of filtration experiments on the physical model of the high viscous oil reservoir with the use of different compositions based on alkali, surfactants and polymer (ASP technology). Obtained results of the experiment agree with known results of ASP flooding.

Introduction. Today ASP flooding is one of the leading chemical enhanced oil recovery technologies used for viscous oil production [1]. General idea of ASP flooding is to reach synergetic effect [2]. Each chemical component in the mixture plays it role (fig. 1). For example alkali when reacting with hydrophobic rock decreases surfactant adsorption and changes contact angle between oil and rock by recharging its surface. Alkali in admixture with organic acids of the oil form natural surfactants (saponifying process). This leads to decrease of surface tension on the oil-water contact. Low surfactant concentration increases effect of interfacial tension reduction between oil and water up to ultra-low values 0,05-0,01 mN/m because hydrophobic part of the molecule enters oil phase.

At that time when hydrophilic "head" lines up on the oil/water phase interface and increases oil dispersibility in water. Following injection of high viscous polymer solution increases sweep efficiency. This method makes it possible to increase displacement efficiency of unrecovered oil which is trapped in capillary pits after flooding [2].

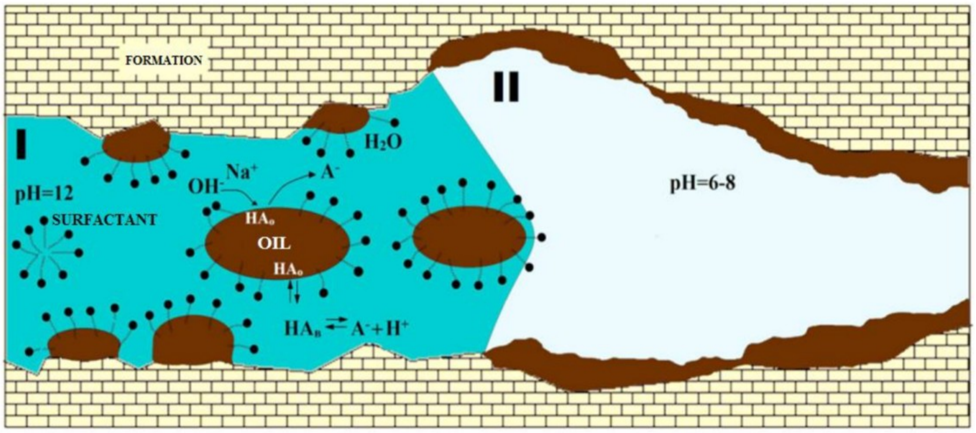


Figure 1. Mechanism of the ASP flooding of oil reservoir: I – alkali, II – neutral phase

Consideration of the experimental data. The Kazakhstani oil field with high viscous oil (viscosity in reservoir conditions vary from 30 to 242 mPa*sec) was chosen as an object of study. Core samples of the Jurassic horizon of the oil field with 3 cm in diameter was put into reservoir conditions artificially generated in the laboratory. Main parameters of physical model are given in Table 1.

Table 1. Basic parameters of the physical models

Compound concentration, %			Pore volume,cм^3	Porosity, units	Absolute permeability, mD	Initial water saturation, units	Initial oil saturation, units
NaOH 0,1	SLS 0,023	PHPA 0,05	8,035	0,1918	1416	0,262	0,738
NaOH 0,1	SLS 0,023	PHPA 0,05	7,813	0,1843	1385	0,274	0,726
NaOH 0,2	CRO-R-MAA (C13) 0,0125		7,58	0,1788	1377	0,218	0,782

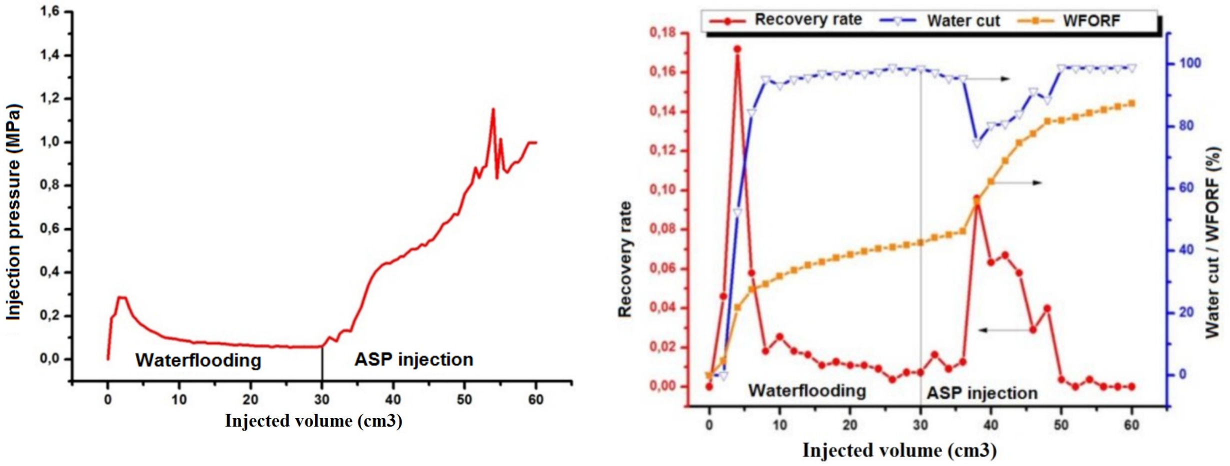
Filtration experiments on the physical model of the reservoir with viscous oil were conducted in order to compare oil displacing properties of water solutions with different composition of alkali, surfactants and polymers [3]. For these purposes were chosen following agents which demonstrated good results in previous experiments: alkali - NaOH, surfactant - C12H25SO4Na (sodium laurel sulfate – SLS) and CRO-R-MAA (C13). PHPA (Partially hydrolysed polyacrylamide) was chosen as polymer .

In order to verify applicability of displacing agents for the experiment conditions in question screening test in the test-glass conducted before the main filtration experiments. As surfactants reduce surface tension screening test shows how surfactants react with oil. As a result of screening tests in the test-glass were selected following displacing agents: 1) aqueous solution of NaOH 0,1%+ C12H25SO4Na 0,023% with further injection of PHPA 0,05%; 2) aqueous solution of NaOH 0,2% + CRO-R-MAA(C13) 0,0125%. Absence of polymer in second composition can be explained by nature of agents which has polymer in its structure. This polymer is bound to surfactant and forms polymerous surfactant. As a result this agent performs role of both surfactant and polymer.

At first stage cleaned and dried core samples are saturated with formation water, then with oil under reservoir pressure and temperature. After reservoir conditions are created filtration experiments start. Cores are flooding with 4 pore volumes of formation water (30 cm^3). At the end of all filtration experiments oil recovery factor after waterflooding reached 0.4-0.45 and water cut reached 92-97%.

In modeling alkali-surfactant-polymer flooding on physical model 4 pore volumes (30 cm^3) of alkali and surfactant mixtures were injected into core samples with following injection of polymer solution. During the experiments pressure was 2 MPa, temperature 30 ^{0}C and constant injection rate 0.15 cm^3/min.

During injection of solution with following composition NaOH 0,1% + SLS and NaOH 0,2% + CRO-R-MAA (C13) 0,0125% injection pressure and percent of oil displaced from the physical model actively increase (figure 2, 3). Additional oil recovery factor reached 0.42-0.43 (figure 2.b, 3.b).

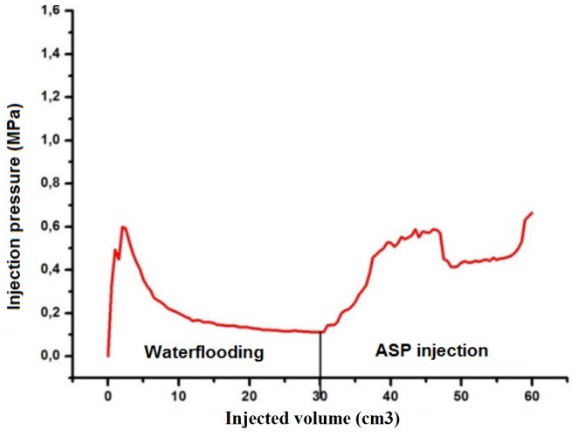


a) injection pressure curve

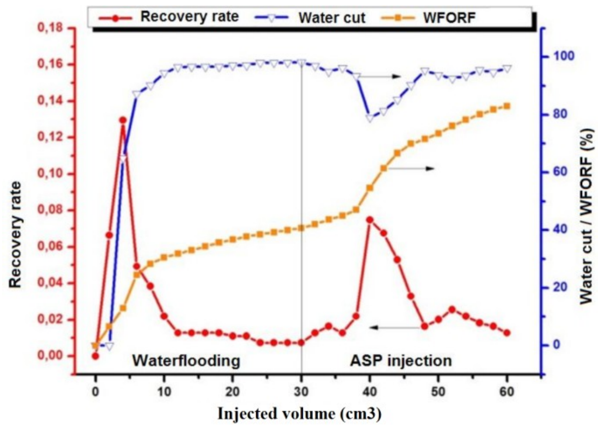
b) water cut, recovery rate and water flood oil recovery factor (WFORF) curves

Figure 2. Sequential injection of water, aqueous solution NaOH 0,1% + SLS 0,023% and aqueous solution PHPA 0,05%

Gained results on filtration experiments for ASP solution compositions NaOH 0,1% + + SLS 0,023% + PHPA 0,05% and NaOH 0,2% + CRO-R-MAA (C13) 0,0125% are in qualitative agreement with known studies on ASP flooding [4-6].



a) injection pressure curve



b) water cut, recovery rate and water flood oil recovery factor (WFORF) curves

Figure 3. Sequential injection of water and aqueous solutions NaOH 0,2% + CRO-R-MAA(C13) 0,0125%

When ASP solution goes through physical model concentration of alkali at the outlet becomes 2-3 times lower than its initial value (figure 4). It presumably verifies the fact that some part of alkali is sorbed on the rock surface and changes surface potential during ASP injection. As a result physical model becomes more ASP solution-wet. Hydrophobic parts of the rock become hydrophilic which prepares oil to come into contact with surfactants.

Wettability changes, thus electric attraction forces between oil and rock do not affect significantly on displacement, thus oil emulsion forms easily.

To prove the conclusion that alkali is sorbed on the rock surface NaOH concentration in the solution after flooding was measured at the outlet. After 30 cm^3 of agent was injected into physical model concentration of alkali at the outlet was 3 times lower than its initial concentration in the solution (figure 4).

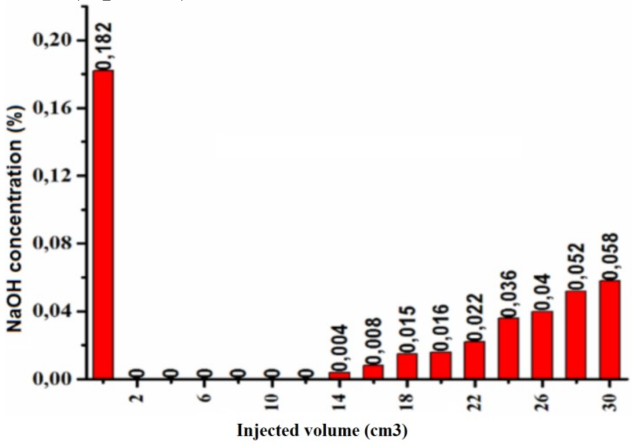
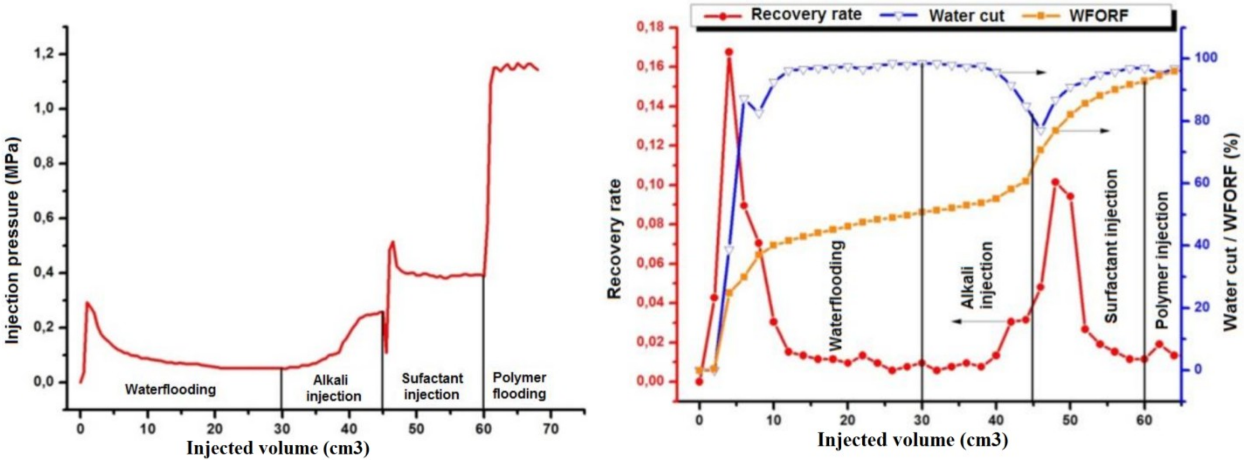


Figure 4. Change of NaOH concentration during agent filtration through physical model of the reservoir

In order to verify the results obtained during experiments and to prove the fact that alkali concentration after filtration decreases significantly at the outlet sequential injection of alkali and surfactant took place. At first stage 15 cm3 (2 pore volumes) of pure alkali solution was injected into preflooded core, after that additional 15 cm3 of surfactant was injected. During alkali injection recovery factor was low and reached only 0.10. However when surfactant and polymer injection took place oil was actively displaced and recovery factor increased for additional 0.32.

As a result after sequential injection of alkali, surfactant and polymer total recovery factor was equal to 0.42 (figure 5).



a) injection pressure curve

b) water cut, recovery rate and water flood oil recovery factor (WFORF) curves

Figure 5. Sequential injection of aqueous solutions containing NaOH 0,1% (15 sм3), SLS 0,023% (15 sм3) and PHPA 0,05%

Main results of experiments of injecting water and aqueous solution with alkali, surfactant and polymer through the physical model of the reservoir are given in table 2.

Table 2. Main results of experiments of injecting water and aqueous solution with alkali, surfactant and polymer to the physical model of the reservoir

Compound concentration, %			WFORF, units	Additional WFORF, units	Total WFORF, units
alkali	surfactant	polymer			
NaOH	SLS	PHPA			
0,1	0,023	0,05	0,4258	0,4379	0,8637
0,1	0,023	0,05	0,4074	0,4209	0,8283
NaOH	CRO-R-MAA				
0,2	0,0125		0,4075	0,4432	0,8507

As it can be seen from the table both agent demonstrate significant increase in recovery from the core and verify displacing efficiency of ASP technology.

Conclusion.

1.Filtration experiments on selection of the most suitable composition of the ASP agent come up with the results that oil recovery from the preflooded model increases and reached value of 42- 44%. These results are in agreement with known studies on ASP flooding [4-6];

2.Experiments on the physical model of the reservoir show that dependence “high concentration of the agent – better result” is not always reasonable;

3.It was experimentally demonstrated that solution with composition of 0,1% NaOH + 0,023% SLS + 0,05% PHPA is more effective among traditional ASP agents for the reservoir containing viscous oil;

4.Two component solution containing polymerous surfactant (CRO-R-MAA(C13)) and alkali (NaOH) show good oil displacing properties and maintain ground of traditional ASP agents. Use of this agent can simplify technological aspects of the injection process and assists in gaining synergistic effect in comparison to three component agents.

Literature

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