On implementation of polymeric watering at oil deposits of Ukraine

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The article considers the opportunity of polymer watering introduction in the Bugruvativske oil field. The analysis reports on an influence of temperature, water composition and mechanical degradation over the thickening ability of the polymer solution are given. The optimum polymer in solution and the amount of fringe polymer solution for effective displacement of residual oil was selected.

“Ukrnafta” PJSC which is one of the main companies of oil and gas complex of Ukraine (68,3 % of extraction of oil with condensate and 10,6 % gas), faced two negative trends. First of all it is delay in reproduction of mineral and raw material base from rates of extraction of hydrocarbons and for second it is the transit of the majority of highly effective mine holes to the final stage of development, which is characterized by progressive exhaustion of layer energy, watering of mine holes and increase of the share of hardly extracted reserves (figure 1).

If development of these trends will not be stopped, under the existing rates of extraction already till 2020 the viable (active) reserves of oil will reach exhaustion and not only further extraction, but also the maintenance of the reached level will be under question.

Development of deposits with hardly extracted reserves of oil is performed slowly, and, as the experience shows, the final oil recovery in such cases does not exceed 30% from initial balanced reserves [1]. In such conditions one of directions of stabilization and buildup of extraction of oil is implementation of the methods of increase of oil extraction. Now at mine holes of Ukraine, including “Ukrnafta” PJSC, among big number of known methods [2, 3] only watering is used, which gradually loses its efficiency with transfer of the majority of oil deposits to the late stage [4]. However, it causes early watering of the products of extraction mine holes, intensive decrease of debit of oil and at the result of this the cessation of mine holes and acquirement of the status of unprofitable ones by them [5]. It is particularly characteristic of the mine holes with high-viscosity oils, for instance of Buhruvativska (horizons B-18–B-14) covered by watering system, and current rate of water extraction is 6,9 % subject to realization of extraction reserves of 31,6 % and watering of 47,6 %.

Buhruvativske mine hole is characterized with high complexity of geologic composition and conditions of oil saturation of productive layers. Development of the deposits of oil is complicated with block geological composition, considerable homogeneity of collector features of productive layers with oil of viscosity of 19,9-40 MPa in layer conditions and density 892,1-898,5 kg/m^3 [6]. Reserves of oil of the deposit, according to project technical and economic indices, may be extracted only subject to use of known methods of increase of oil extraction.

For solution of this task in oil extraction field solutions of polymers characterized with high viscosity, thixotropy, pseudo plasticity, are applied in oil industry more and more often. The necessity of polymers is justified by their ability to influence reologic features of water systems and create gels of necessary viscosity.

Polymeric watering increases efficiency of supersede of oil and water $M = (k_в/\mu_в)/(k_н/\mu_н)$. *If M* rate is close to 1 supersede will be efficient.

Analysis of correlation shows that it is possible to get high effect from supersede with the help of:

Decrease of efficiency of penetration for water;

Decrease of viscosity of oil

Increase of viscosity of water

Increase of efficiency of penetration for oil

The easiest way is increase of viscosity of water by adding of polymers to it. Polymers are widely used in world practice as agents for increase of the rate of oil extraction.

Polymeric watering is the adding of polymer to water for decrease of its fluidity. Use of polymers gives opportunity to decrease penetration on water phase considerably, to level the front of displacement of oil by water, to continue waterless period of exploitation of mine hole, which finally facilitates increase of completeness of extraction of oil.

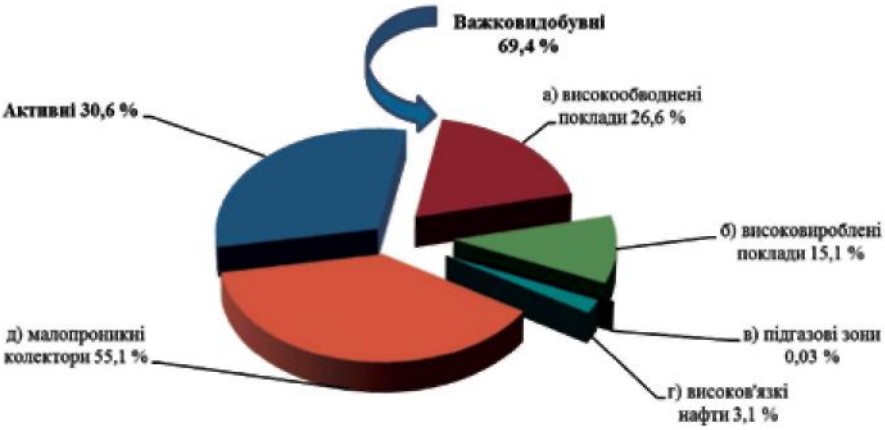


Figure. 1. Qualitative characteristics of extraction reserves of “Ukrnafta” PJSC

Polymeric watering is widely used at deposits with oils with high-viscosity. For instance, on base of reagents of SNF FlOERGEL reagents the following countries perform polymeric watering: USA (9 projects), Canada (33 projects), Brazil (4 projects), Indonesia (2 projects), Venezuela (2 projects), Argentina (1 project), Columbia (1 project), Angola (1 project), Oman (1) project, Austria (1 project), France (1 project), Great Britain (1 project) [7].

According to the results of many-year researchers and industrial trials of water soluble polymers in the processes of drilling and intensifying of oil extraction the main requirements which polymers shall satisfy are stated:

To dissolve in water quickly and completely;

Not to change physical and chemical characteristics in some time and under effect of temperature;

To be firm against salting out in layer waters;

To condense water effectively in case of little concentrations;

To filter through porous environment;

To have the factor of opposition, but at the same time adsorption of polymer from solution in porous environment shall be minimal for provision of advance of reagent to considerable distance in the layer;

Not to create unjustified high pressure on the layer un the process of injection;

Not to cause corrosion of equipment;

Not to be toxic.

“Ukrnafta” PJSC has performed a complex of geologic industrial and laboratory researches directed to implementation of the method of polymeric watering at research plot of horizon B-16 of Buhruvativska deposit with high-viscosity oils. This land plot is characterized with such conditions: average depth of bedding of effective horizon is 3306 m, type of collector is sandstone, layer temperature is 93 oC, viscosity of oil in layer conditions is 20 MPa, general mineralization of layer water is 175 mg/dm^3, pH=6, ferrum ions composition Fe^{+2} - from 56 to 140, and ions of Fe^{+3} – from 2 to 26.

In connection with high temperature and mineralization of layer water the series of researches for selection of optimal polymer of SNF FlOERGEL Company (France) was performed for watering of Nuhruvativska oil deposit. More than 20 trade marks of co-polymers of acryl amide of different kinds were researched (non-iogenic, anion active and cation active).

According to the results of researches it was stated that gel like polymers of PM450 and PM355 are not poured. At the same time the standard hydrolyzed polyacrilamides of FLOPAAM S series with molecular mass from 8 to 22 mln Daltons and level of hydrolyze з 20 – 30 mol. % have better characteristics of condensation of layer water. Thus, for 0,05 % of solution of polymers 3630S, 3530S, 3430S, 3330S dynamic viscosity under speed of shift 61,2 c^{-1} is changed within the limits from 2,0 to 2,35 MPa. Polymers of the same series 2530S, 2430S, 2330S with less level of hydrolyze have a little bit less condensation ability. Dynamic viscosity changes within the limits from 1,6 to 1,9 MPa under the same speed of shift.

Research of thermal destruction of polymers of FLOPAAM S series were performed through holding of these polymers at temperatures of 90 oC for not less than seven days. The highest efficiency for condensation of water is demonstrated also by sulphated co-polymers of AN series. Dynamic viscosity is 0,05 % of solution prepared on layer water of Buhruvativska deposit under speed of shift 61,2 c^{-1}, for polymers of series AN (AN945VHM, AN934VHM, AN132, AN132SH, AN125VLM, AN113, AN113SH, AN105, AN105SH, AN125, AN125SH) changes from 2,0 to 3,0 MPa. For watering of Buhruvativske deposit the most optimal sulphated polymers turned to be polymers AN 125, AN132 and their modifications.

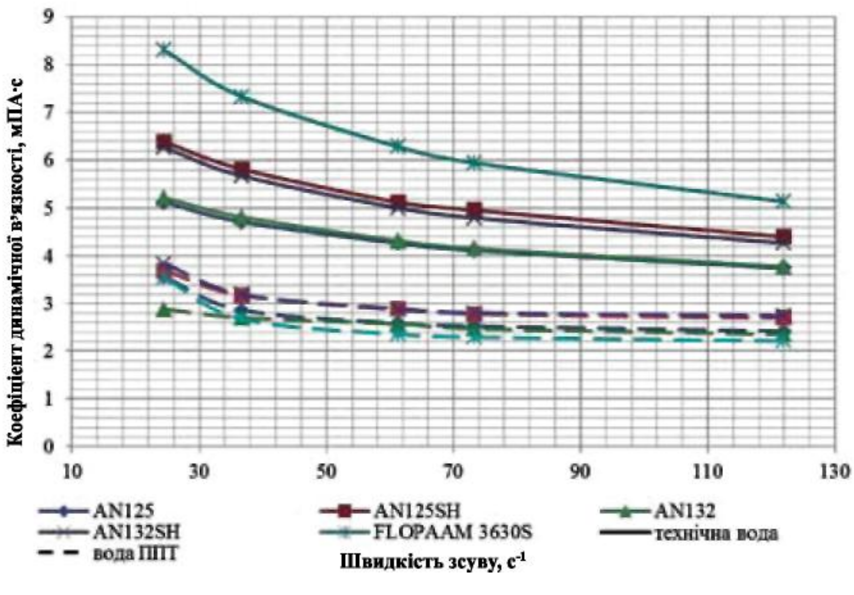


Figure. 2. Dependence of the rate of dynamic viscosity on speed of shift for 0,05 % polymeric solution

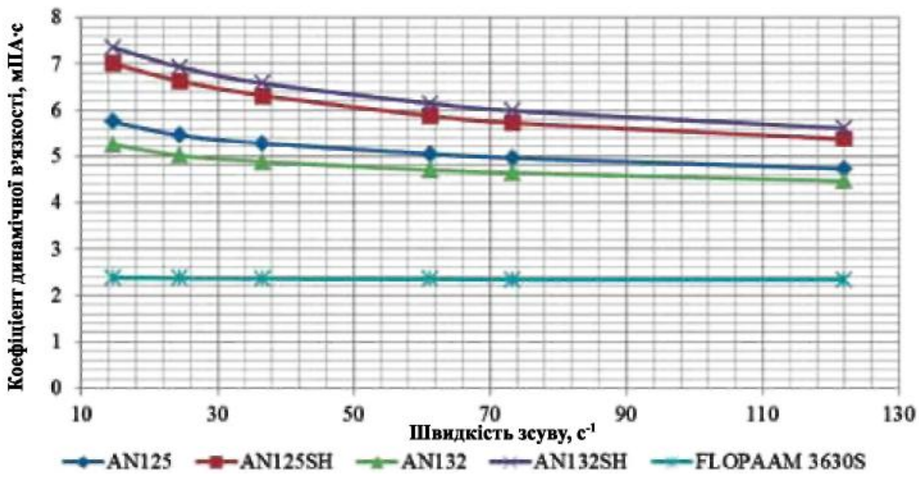


Figure 3. Dependence of the rate of dynamic viscosity on speed of shift for 0,2 % polymeric solution prepared on water from watering system

For comparative characteristics: polymeric solutions were prepared on layer water used in the system of watering of Buhruvativske deposit and on technical water. For determination of viscosity of polymer a viscosity meter with low speed of flow of Brookfeld LVT type with UL-adaptor was applied.

On Figure 2 the dependence of dynamic rate of viscosity on speed of shift for 0,05 % of polymeric solution prepared on technical and layer water is shown.

The received results evidence that non-iogenic polymer 3630S and sulphated polymers AN132SH and AN125SH have the highest condensation ability. Some lower indices of polymers AN132 and AN125 are explained by the fact that their molecular mass is lower than the molecular mass of the above-stated ones on the same stage of sulfuring.

On Figure 3 dependance of dynamic rate of viscosity on speed of shift for 0.2% polymer solution prepared on water injected to the layer is shown.

Having analyzed the results of researches shown on figures 2 and 3 we see that dynamic rates of viscosity in fresh and mineralized water differ considerably. It is explained by the fact that in fresh water solution in the process of ionization of polyelectrolyte between monomeric pin holes the forces of electrostatic repulsion occur which causes the spread of the coil of macro-moleculas and increase of their linear sizes. In mineralized water these processes are subsides by proto-ions and spread of macro-moleculas does not take place. So subject to use of layer water of reach of one and the same mean of dynamic viscosity rate

Table 1 Change of viscosity of 0,05 % polymer solution prepared on technical water depending on intensity of interfusion

Mode of interfusion. Turnovers/min ,	Dynamic rate of viscosity, MPa/sec				
	AN125	AN125SH	AN132	AN132SH	FLOPAAM 3630S
Before interfusion	4,27	5 ,13	4,32	5,01	6,29
500	4,2	4,95	4,13	4,18	4,76
2000	3,3	4,6	3,14	4,09	3,52

Almost four times more any dry polymer of AN series is required.

Taking into account the above-stated the further researches were performed for polymeric solutions prepared on technical water with concentration of 0,05 % and on layer water with concentration of 0,2 %. For above-stated group of polymers the researches of thermal stability of their solutions (figure 4) were performed. Polymeric solutions were held for seven days at 90 ^{o}C, after which they were cooled down to 20 ^{o}C and dynamic viscosity rate was measured.

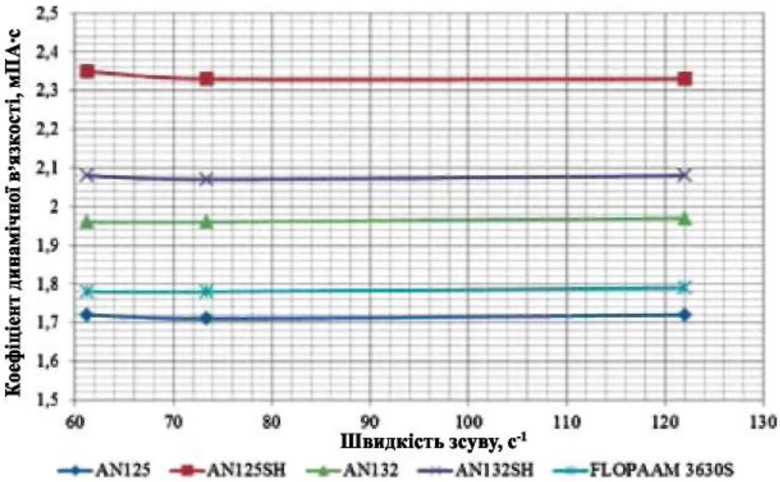
Having compared the results of researches (see figure 4, graphics a and b) we see that in solutions prepared on mineralized water decrease of viscosity of polymer solutions is manifested less than in solutions with fresh water.

In addition to temperature the stability of polymer solutions are influenced by mechanical destruction caused by hydraulic oppositions in the process of injection to the layer (interfusion, isolation valve, bends and narrowings of the pipeline etc).

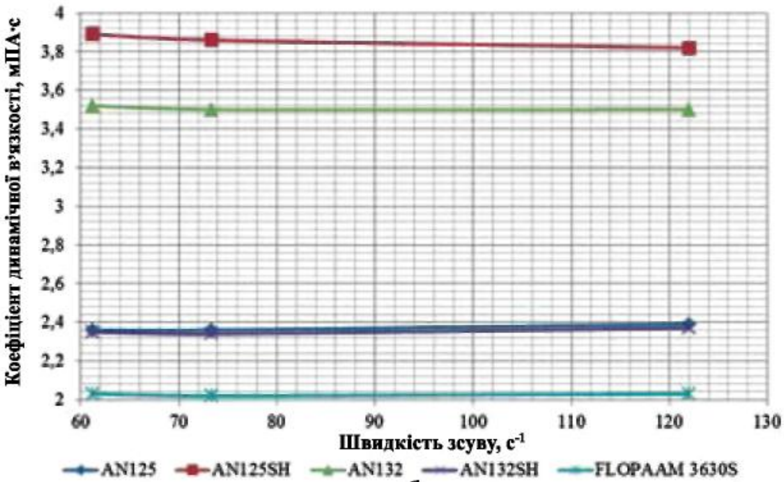
Selecting the mode of effect on polymeric solution, it is necessary to use for orientation the exiting modes of interfusion of solutions in technological processes during their application at production fields. Two modes of interfusion differing in speed of rotation of laboratory ,impeller were selected namely: circle interfusion with number of rotations 500 and 2000 per minute respectively. Time of interfusion and temperature of experiment in the first and the second case were the same and were 3 hours and 20 ^{o}C respectively.

Table 2 Change of viscosity of 0,05 % polymeric solution prepared on layer water depending on intensity of interfusion

Режим перемішування,	Динамічний коефіцієнт в'язкості, мПа•с				
	AN125	AN125SH	AN132	AN132SH	FLOPAAM 3630S
до перемішування	5,05	5,88	4,7	6,15	2,35
500	4,93	4,95	4,23	4,69	1,87
2000	2,86	4,18	2,88	3,89	1,78



a



б

Figure. 4. Thermal stability of polymer solutions: *a* – 0,05 % polymer solution on technical water; *б* – 0,2 % polymer solution on water from watering system

For researches of influences on mechanic destruction two kinds of polymers were selected – sulfated and hydrolyzed ones. Polymeric solutions were prepared on technical and layer water with respective concentrations of 0,05 and 0,2 %. Before and after interfusion measurements of viscosity were performed. The results are stated in tables 1 and 2.

On the ground of stated data we see that small speed of interfusion almost does not cause destructive changes of polymeric solution. Visible change of viscosity is seen in sulfated co-polymers AN125 and AN132 during more intensive interfusion (2000 turnovers/minute), which is the evidence of mechanic destruction of polymer.

Summarizing the results of tables 1 and 2 we can say that with increase of rotations of impeller during interfusion for high-molecular sulfated co-polymers of acryl amides AN125SH and AN132SH intensity of destruction of polymer solutions increases, but does not cause dramatic decrease of viscosity. Obviously it is explained by the fact that intensity of interfusion under conditions of experiment was not sufficient for abruption of molecular connections in the whole volume of polymeric solution.

For the above-stated polymers the series of researches on bulk models for determination of oil supersede ability was performed. The rate of porosity is 30%, penetration is 150 mkm^2, temperature is 95 ^oC.

For conditions of Buhruvativske deposit supersede of oil was modeled by various agents, namely the following ones:

experiment 1: by layer water till ceasing of removal of oil from the layer, rate of supersede during the waterless period was 42 %, final one 45 %;

experiment 2: 0,05 % polymer solution prepared on layer water in volume of 0.2 porous space, then the solution was pushed by layer water, rate of supersede during the waterless period was 43 %, final one 45 %;

experiment 3: 0,05 % polymer solution prepared on technical water in volume of 0.2 porous space, after which technical water (buffer) in volume of 0.1 of porous space was injected, then the solution was pushed by layer water, rate of supersede during the waterless period was 48 %, final one 53 %.

Speed of pumping of these agents in the process of supersede was about $0,1710^{-9}$ m^3/s.

So for the conditions of Buhruvativske deposit the most acceptable for polymeric watering are polymers AN125SH and AN132SH, use of which provides for increase of rate of supersede of oil for 8 % comparing with use of layer water in existing system of watering.

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