Activative-Modificating Effect of High-Voltage Electric Discharge in Solutions of Surface-Active Substances

O.N. Sizonenko, R.P. Kolmogorova, E.I. Taftay, A.K. Tkachenko, O.V. Khvoshchan

Institute of Pulse Research and Engineering
43A Zhovtnevy Ave., 54018 Mykolayiv, Ukraine
Phone: +38-0512-22-41-13, Fax: +38-0512-22-61-40, E-mail: ipre@iipt.aip.mk.ua

Abstract – The results of experimental investigations are stated on the electric discharge effect to the detergent and inhibitory properties of solutions of reagents of various kinds, synthetic surface-active substances (SAS) (VRK, NMK and NMK-21) and waste products of petroleum refining (PINOL and CARPATOL) as regards the asphaltic-resinous paraffin deposits. It was determined that high-voltage electric discharge has an activative-modificating effect in the SAS solutions, thus the foaming agent availability in the SAS solution makes for the improvement of washing and inhibitory action. The generated and expanding plasma channel carries through the ambient liquid decomposition, following by gas release. The emerging intensive hydraulic flows cause breaking and carry-over of gas-phase from discharge zone, and the SAS being in medium allows to stabilize forming foam, adsorbing on the covers of gas bubbles make for the better washing and obstructing to the formation of new sediment. The following compression waves extend in the medium with small gas inclusions and bring about bubble pulse around their balanced size, increasing the hydrodynamic impact in a well.

The performed work makes for the increase of the efficiency of sputter-ion effect at the usage of the SAS solutions with foaming component in the capacity of workspace, and extends the capabilities of using of high-voltage electric discharge in different technologies, related with regeneration of objects.

1. Problem Defination

It was determined by theoretical and experimental investigations, which were carried out last years, that the most effective technologies of the inflow of difficult-to-draw petroleum reserves are based on the combination of well-known methods of impact on oil pools, for example, the physicochemical methods. At that the principal aim is the selection of such combination of working substances, which ensures the most effective integral demonstration of factors of the oil inflow increase that are intrinsical to each method taken separately.

We suggested to apply complex action of electric discharge and solution of surface-active substances (SAS) for oil inflow intensification in low-permeable reservoirs with reduced permeability because of the asphaltic-resinous paraffin depositions (ARPD) [1], [2]. It was determined that complex action of electric discharge in the medium of the SAS aqueous solutions (the VRK and the NMK water-soluble multifunctional compositions) ensures synergetic effect in the change of wall-plastering properties of layers the reservoirs, which exceeds the amount of the effect of each component. In our opinion, this effect was produced in the first place due to the larger contact area of the SAS with the layer, in which fractures were formed by compression waves, and also due to the unsteady reagent filtration under the influence of compression waves and hydroflow, which in its turn results in the increase of permeability as a consequence of carryover of substances, polluting interstice.

But in the network of fulfilled work the electric discharge effect to the characteristics of the SAS solutions and the opportunity of their regulation in the process of action were not investigated, and that didn`t enable us to determine in full all factors, being in making of synergetic effect at the complex action on the porous saturated medium. Therefore in the present work we carried out the investigations of the activative-modificating effect of high-voltage electric discharge in the SAS solutions, and in particular the influence of electric discharge action on their detergent and inhibitory properties.

2. The Subjects of Inquiry

The SAS of two different kinds were used in the capacity of reagent:

– the VRK, the NMK, the NMK-21 multifunctional water-soluble compositions;

– the PINOL (PN) and the CARPATOL (CR) waste products of petroleum refining with solution concentration of 3%.

The VRK, the NMK and the NMK-21 multifunctional water-soluble compositions represent the multicomponent mixture of the anionic and nonionic synthetic SAS of different chemical structure and specific-purpose admixtures. In the work we used the solutions of these reagents of 0,1% and 0,3%, as it is the advisable concentration when acting upon the bottomhole formation zone (BFZ).

The waste product of petroleum refining the CR sulphonate micellar concentrate is a composition, consisting of sodium sulphonate or ammonium sulphonate, sodium sulphate or ammonium sulphate, sodium sulphite or ammonium sulphite, water, hydrocarbon thinner of petrolic oil, isopropyl alcohol and vat residue of alcohol production.

The neutralization product of lake acid tar by aqueous solution of alkali and subsequent purification from sludgy deposits and the PN mechanical admixtures is a composition, containing the acids of ammonium and natrium, the sulphates of ammonium and natrium, carbohydrates of transformer oil and water.

The investigations were carried out on the experimental test bench, consisting of energetic and technological parts. The energetic part of the test bench is intended for the generation of current impulses in discharge gap of the technological chamber. The energetic part of the test bench includes control panel and pulse current generator, the technological part includes the chamber, where the SAS solutions were treated.

The chamber for investigation (Fig. 1) permitted to realize as the directly high-voltage discharge in the SAS solutions in flash chamber 1 with electrode system 2, and also to part the SAS solution with resilient rubber membrane, poured in working chamber 4, from the contact with plasma channel, made at the breakdown of the same SAS solution in chamber 1. The investigations were carried out at the initial characteristics of experimental plant, which are close to the nominal characteristics of electric discharge downhole devices like “Skif” [2].

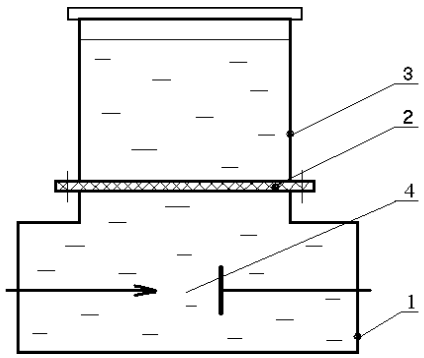

Fig. 1. The plan of the technological part of the test bench for the investigation of the SAS aqueous solutions

One of the most important qualifying standards to the SAS, used in engineering processes of oil extraction, is the assurance by them of high detergent and inhibitory properties as regards the ARPD. To estimate the effectiveness of investigated solutions of the SAS before and after electric discharge treatment we made use of the “cold” cylinder technique, developed in the All-Russian Research Institute of Oil (Moscow).

The detergent properties of the SAS were determined from the following technique. Mineral oil was warmed up to the temperature of 40 ^{0}C, then the oil of 0.3 litres was poured in a beaker with thermostatic casing 2. The “cold” cylinder 1 filled with water, the temperature of which was held at the level of 28 °C by means of the liquid thermostat 8, that corresponds to the temperature of the beginning of paraffin crystallization, was immersed into the beaker 2 with oil.

The oil was uninterruptedly mixed up with a magnetic stirrer 5, for half an hour and the conditions were created, at which the ARPD sediment was formedat the surface of the first cylinder due to the temperature difference in the first and second cylinders. The cylinder with the deposited ARPD was extracted from oil and kept to mature in the air during 20 minutes to remove watery residua from its surface. Then the cylinder was weight on analytical balance and put into the beaker, filled with the reagent of given concentration with the volume of 0.3 litres. The temperature of reagent was held about 40 °C, the reagent was mixed up with the magnetic stirrer 5 for half an hour, in this process the ARPD washing took place from the cylinder surface. Then the cylinder was extracted from the SAS solution, kept to mature in the air during 20 minutes and weighed on analytical balance. The efficiency of the reagent detergent property was determined from the correlation:

$$E_d = (m_2/m_1)\cdot 100\%,$$

where m_1 – the mass of sediment, formed at the surface of the “cold” cylinder; m_2 – the mass of swept sediment.

The SAS inhibitory property was determined on the same plant in the following way. Oil was heated up to 40 °C, blended with the SAS solutions of different concentration (on the basis of watering of produced emulsion of 30%) and poured into the beaker. The mass of sediment, precipitated on the “cold” cylinder walls was determined according to the technique cited above, and the efficiency of the inhibitory action of the SAS – according to the stated formula. The detergent and inhibitory properties of the investigated SAS were determined before and after electric discharge treatment.

The ARPD sediment on the “cold” cylinder was formed of tarry oil of the deposit of Malodevitsa in Chernigivska region (Ukraine), having the following characteristics: density at the temperature of 20 °C $p = 849$ kg/m^3; viscosity at the temperature of 20 °C $\eta = 9.36\cdot 10^{-3}$ Pa·s; chilling temperature $t = 30$ °C.

3. Experimental Results

In Table 1 the detergent property of the investigated solutions of the SAS is represented, which was determined by us on the “cold” cylinder. From this table we can see that the most effective solution is the NMK-21, the washing effectiveness of the CR and the PN is approximately on 20% lower at the concentration 10 times as much.

After determination of washing property of the investigated solutions of the SAS each of them was exposed to the electric discharge treatment in such a way, that the quantity of energy in a pulse, released in

Table 1. The effectiveness of the investigated solutions of the SAS on the detergent property before the electric discharge treatment

SAS	VRK		NMK		NMK-21		PN	CR
Weight concentration, %	0.1	0.3	0.1	0.3	0.1	0.3	3	3
Detergent property, %	80.6	85.6	80.0	86.0	84.3	88.5	65.8	66.1

a cubic unit of each of the solution located in flat chamber 1 (Fig. 1), was the same in all cases. It was determined, that the effectiveness of the ARPD washing by all kinds of the SAS after the electric discharge treatment in a flash chamber dependence of washing property of the investigated solutions of the SAS is represented.

We can see, that detergent property of 0.1% of the VRK, the NMK and the NMK-21 solutions increased on about 10%, in all cases the largest growth rate is observed in the range from 100 to 200 pulses, in future the process becomes stabilize. The electric discharge treatment of the VRK, the NMK and the NMK-21 solutions of 0.3% (Fig. 2, *b*) at the same growth trend, as in the previous case, results in the increase of washing property on about 7%. The NMK-21 has the best washing property after the treatment, practically completely removing sediment (93%). After the electric discharge treatment of the VRK, the NMK and the NMK-21 solutions of 0.1% their washing properties can be compared (even slightly higher) with the 0.3% solutions before their treatment. The largest increase of detergent property (about on 13%) takes place in CR (Fig. 2, *b*), but its washing property remains as usual lower on about 20% in comparison with the above mentioned reagents.

Rich foaming took place in the NMK, the NMK-21 and the VRK solutions of 0.1% and 0.3% at the electric discharge. The research results, given in [4], showed that with the pressure increase the diameter of the bubbles in foam is reduced, the dispersion is on the increase, and the stability is on the rise. The foam bubbles stimulate the better adsorption of the SAS on the hard surface, especially at the small concentrations of the SAS (the NMK, the NMK-21and the VRK in this case), making better their detergent properties.

Somewhat different situation is observed in the reagents, which are separated by high-voltage breakdown from the processed volume by a rubber membrane (Fig. 2, *b*). At this the small increase (within the limits of 1% for all kinds of the SAS) of washing property is observed, and it is essentially lower than at their treatment directly by electric discharge.

One of the most important properties of the SAS is their inhibitory action (the prevention of the ARPD sorption by surface). The inhibitory properties of all kinds of the SAS as regards the ARPD after the electric discharge treatment improved (table 2). The NMK-21 has the best inhibitory action as well as the washing action. The electric discharge treatment of this reagent enabled to reduce the ARPD sediment on about 17%, at that the stabilization began at 200 pulses.

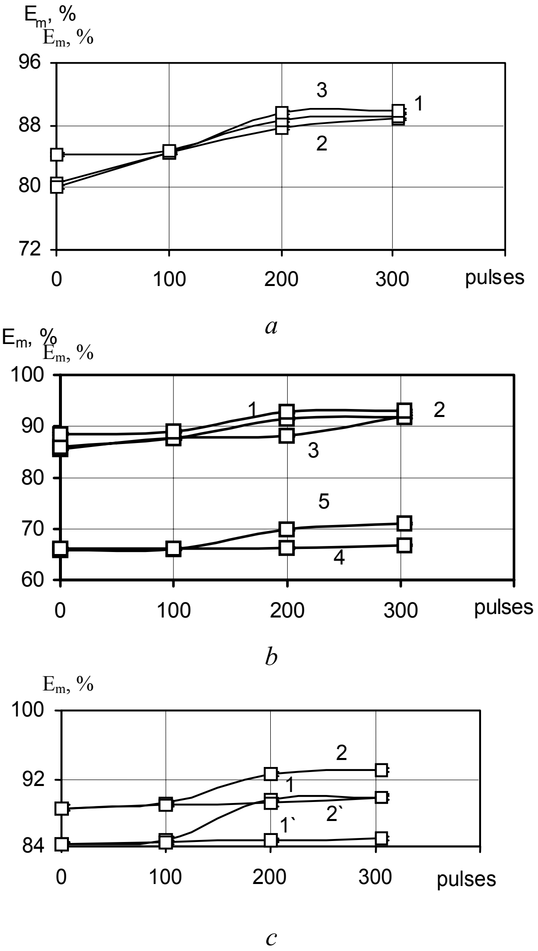

Fig. 2. The effect of the electric discharge treatment to the detergent property of the SAS solutions of 0.1% (*a*), of the SAS solutions of different concentration (*b*) and of the NMK-21 solution (*c*): *a*: 1, 2, 3 – the NMK-21, the VRK and the NMK solution in the flash chamber accordingly; *b*: 1, 2, 3 – the NMK-21, the VRK and the NMK solution of 0.3% in the flash chamber accordingly; 4, 5 – the CR and PN solution of 3% accordingly; *c*: 1, 1` – the NMK-21 solution of 0.1%, being in the flash and working chamber accordingly; 2, 2` – the NMK-21 solution of 0.3%, being in the flash and working chamber accordingly

The inhibitory action of the PN and the CR turned act to be worse than that of the NMK, the VRK and the NMK-21 even at the concentration of these solutions of 0.1%. At the same time the electric discharge treatment enabled to increase the efficiency of the inhibitory action of the CR on about 13%, and the PN – on about 8%. The efficiency of the inhibitory action of the SAS of all kinds, which were exposed to electric discharge through a membrane, as well as the efficiency of washing action, practically didn`t increase (within the limits of 1%).

Table 2. The inhibitory properties of the SAS as regards the ARPD after the electric discharge treatment

Reagent	Concentration, %	The ARPD inhibition before the treatment, %	Total number of pulses	Number of pulses before stabilization	The ARPD inhibition after the treatment, %	Treatment efficiency, %
VRK	0.1	74	300	300	69.0	7.0
VRK	0.3	72	300	300	67.0	7.0
NMK	0.1	69.5	300	200	62.0	7.0
NMK	0.3	63.0	300	200	55.0	8.0
NMK-21	0.1	65.0	300	200	50.5	10.0
NMK-21	0.3	57.3	300	200	47.6	17.0
PN	3	82.7	300	300	74.3	8.4
CR	3	81.0	300	300	71.8	11.3

4. Resume

The fulfilled work allows to substantiate the activative-modificating effect of high-voltage electric discharge in the SAS solutions.

At high-voltage electric discharge in liquid, the high-conductive channel is generated there, and electric energy is put in this channel for the items of microseconds, at that the electric current grows, reaching the amplitudes of 10 kA. At flowing of such currents the substance in the electric discharge channel gets warm to plasma state. This plasma is a complex mixture of different neutral atoms, ions and electrons [5], formed due to the overheating of thin layer of liquid, surrounding the conductive channel, the temperature of plasma here achieves the quantity of 10^4 K. At the contact of ambient liquid with plasma channel its decomposition takes place, accompanied by gas released. The foam former molecules, adsorbing on the gas bubbles strengthen the hydrate layers of bubble covers, and it results in the increase of mechanical stableness of bubbles and prevents from their collapse at collision. When mixing gas-liquid medium, if there is a foam former, the airing of the medium takes place. The foam bubbles make for the better adsorption of the SAS on the hard surface, improving the washing and preventing from the formation of new sediment. The following compression waves extend in the medium with small gas inclusions and bring about bubble pulse around their balanced size, increasing the hydrodynamic impact in a well.

The carried out work makes for the increase of the effectiveness of the electric discharge effect at the use in the workspace capacity of the SAS solutions with foaming component and enlarges the availabilities of using of high-voltage electric discharge in different technologies, related with object regeneration.

References

[1] O.N. Sizonenko, N.M. Sherstnev, Neftyanoe khozyaystvo **4**, 49 (2001).

[2] O.N. Sizonenko, I.S. Shvets, A.V. Kutchernyuk, Neftyanoe khozyaystvo **12**, 133 (2000).

[3] N.M. Sherstnev, L.M. Gurvitch, M.G. Bulina, *Primeneniye kompozitsiy PAV pri ekspluatatsii skvazhin*, Moscow, Nedra, 1988, 184 pp.

[4] V.A. Amiyan, A.V. Amiyan, N.P. Vasilieva, *Vscrytiye i osvoyeniye neftegazovyh plastov*, Moscow, Nedra, 1980, 380 pp.

[5] K.A. Naugolnyh, N.A. Roy, *Electricheskiye razryady v vode*, Moscow, Nauka, 1971, 155 pp.