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Results of Experimental Researches of Plasma-Pulse Action Technology for Stimulation on the Heavy Oil Field

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Abstract: Provides information on the current high-viscosity oil in Russia and the world, as well as the main challenges for their development and possible potential ways of this crude hydrocarbon stimulation from the depths. The experimental researches technique and results of studying the influence of the plasma-pulse action technology on the rheological properties of highly viscous oil is analysed.

Key words: Highly viscous oil · Viscosity · Rheological researches · Thixotrophy · Plasma-pulse action

INTRODUCTION

Now the majority of large oil deposits in Russia have a high degree of developed reserves. The part of abnormal (Non-Newtownian) oil in the reserves structure is achieving an increasing value. In the Russian Federation well balanced residual reserves with highly viscous oil belonging to A+B+C1 categories amount to 6,2 billion tons. Resources of natural bitumens and bitumen oil, by various estimations, change from several billions up to tens of billion tons. The problems concerning the involvement of highly viscous oil deposits and natural bitumen in active production along with the light oil development are becoming more and more topical [1].

The development of heavy oil deposits is negatively influenced by the anomalies in viscosity and the presence of rheological properties (visco-elastic and thixotropy). The specific feature of such an exploration is a low oil output and well fast drowning. But viscosity anomalies are observed at oil filtration low speeds when the dynamic pressure gradient in a layer is lower than the dynamic pressure gradient of a shear [2, 3]. This circumstance has allowed to recommend some ways of improving the rheological properties of abnormal layer oil: thermal and hydrodynamical influence on a productive layer, use of superficial-active substances and carbon dioxide at oil field flooding. However, the application of the existing methods of exploring the abnormal oil deposits allows to achieve 25 - 30 % from the initially recovered reserves. In this regard it is necessary to actively carry out researches and perfect intensification technologies with the purpose of increasing the layers oil output in abnormal (Non-Newtonian) oil deposits. Perspective but poorly investigated direction in this area is the application of the wave vibration method which decreases the anomalies of heavy oil viscosity. The present article is concerned with the research of the influence of plasma-pulse action performed to reduce oil-in-place viscosity anomalies [4, 5, 6].

The idea to use the vibroseismic impact on oil reservoirs as whole was stated in the beginning of the 70s by the academician Mikhail Aleksandrovich Sadovskiy due to the discovered correlation between the seismic activity and the level of oil recovery and water from the deposits located nearby. (His findings were connected with the correlation between a seismic activity and the level of oil recovery and water from the deposits located nearby). Over the last years a whole range of technologies regarding wave impact on productive formations have been developed and are widely being introduced on oilfields (wave vibration, hydroacoustic, seismoacoustic, chemico-acoustic, electro-acoustic, etc. methods) [7, 8]. The given work concentrates on the technology of plasma-pulse influence on productive layers developed in the geophysics faculty of Saint-Petersburg State Mining Institute (Technical University) under the guidance of the

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professor Anatoly Aleksandrovich Molchanov in cooperation with the research-and-production center "Geoworld" [7, 8].

The exploitation well processing is carried out by lowering the equipment on a standard three-wire cable with the help of a geophysical winch of a logging hoist. The geophysical cable serves to provide power supply for the well equipment, manage the deep block operation as well as control the equipment operating mode and well processing parameters. Processing time and quantity of influence pulses on a layer are determined by the capacity and productive interval parameters. The basic equipment characteristics are as follows:

- Depth of treated wells - up to 3 km;
- Operating temperature - up to 100 C;
- Power consumption - 1,5 kj;
- External diameter - 102 mm;
- Device length - 2400 mm;
- Power supply voltage - 220 V/50 Hz;
- Power supply capacity - 300 Wt.

To carry out the influence on a modelled layer oil an experimental stand, filled in with tested liquid, was constructed. Samples of highly viscous oil with high carbon atoms predominantly found in the Republic of Tatarstan and the Usinskiy field of the Komi Republic are investigated in this research work. Decontaminated oil was processed as per the plasma-pulse action technology with the intensity of 10 - 40 pulses. Further, the oil samples were investigated on a modern close control equipment presented by the Coretest Systems Corporation company:

- Automated Viscometer Herzog - HVM 472;
- Rotational Viscometer Rheotest RN 4.1.

Automated viscometer Herzog allows to carry out measurements of oil kinematic viscosity within the interval of 0,5 - 5000 mm^2/sec at the temperatures of 20-150 °C. To study viscosity change, researches of oil samples were carried out at various temperatures within the interval of 20-80 °C and in a time interval after the treatment. Rotational viscometer Rheotest RN 4.1 is provided with software and allows to carry out researches in an automatic mode. Studying the liquid rheological properties is carried out with an established and controlled value of shear speed (as the research result, the parameters of shear stress are determined) or shear stress (as the research result, the parameters of value of shear speed are determined) and also in the oscillatory mode (at constant fluctuations, frequency fluctuations or amplitude).

This research work concentrates on studying the features of viscosity anomalies appearance, influence of oil structurization, determination of the methods which promote easy display of thixotropic properties of highly viscous oil. The hysteresis loop area which is formed by liquid current curves at the shear speed change serves as a quantitative characteristic of the thixotrophy phenomenon. However it should be considered that the rate of oil thixotropic hardening grows with the increase of asphalt contents leading to the strong structure formation. The hysteresis area is made within the limits of 3 current curves, received in a single measurement cycle [9, 10]:

- Forward motion (smooth shear speed increase from 0 up to 300 1/s within 300 seconds);
- Expectation of the full structure destruction (rotation within 300 seconds with constant shear speed at 300 1/s level);
- Reverse motion (smooth shear speed decrease from 300 up to 0 1/s within 300 seconds).

The area has energy dimension related to volume of the sample subjected to shear and determines the energy value necessary for the thixotropic structure destruction. The study of the liquid rheological properties were carried out with the established and controlled value of the shear speed with the values of shear stress parameters being determined. The subject-matter of this research work concerns the study of the highly viscous oil rheological properties (effective viscosity, limiting shift voltage, thixotrophy energy and viscoelastic properties) before and after the elastic pulses action within the frequency range of 0,1-10 Hz created by the electrohydrodynamical resonant influence equipment. The figure demonstrates the hysteresis loop general view received during the investigation before and after the plasma-pulse action technology influence [4].

The basic results of highly viscous oil rheological researches are represented in the table 1.

Reduction of the hysteresis loop area and shear stress values after the plasma-pulse action processing is distinctly visible. As the table shows, the application of plasma-pulse action technology enables to reduce the effective oil viscosity up to 30% and thixotropic

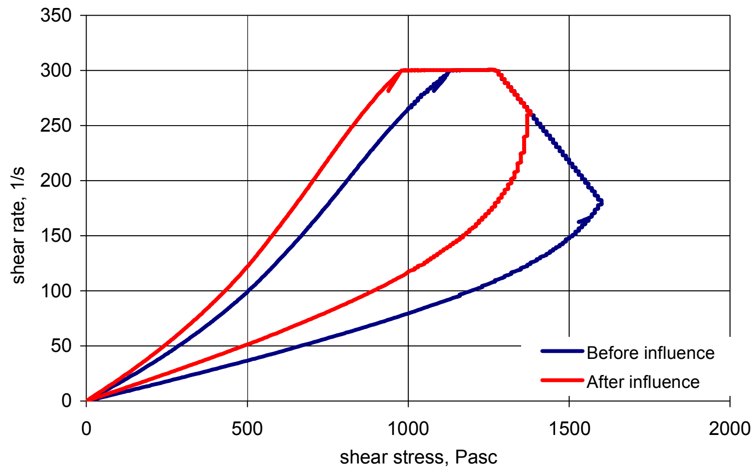

Fig. 1: Rheological curves showing forward and reverse motions of highly viscous oil (based on the hysteresis loop) at T=10 C

Table 1: Research results of the highly viscous oil rheological properties under the application of the electric-wave influence technology in the intensification of viscous oil exploration.

	Effective oil viscosity, Mpasc.s		Hysteresis loop area, J/m^3		Thixotropy energy, J/m^3	
# oil samples	Before processing	After processing	Before processing	After processing	Before processing	After processing
1	682	620	5,72	4,20	$1{,}49*10^4$	$1{,}31*10^4$
2	642	605	5,32	3,95	$1{,}35*10^4$	$1{,}18*10^4$
3	212	149	2,11	1,43	$1{,}24*10^3$	$0{,}95*10^3$
4	235	172	2,53	1,57	$1{,}78*10^3$	$1{,}02*10^3$
5	14550	9877	87,15	75,72	$1{,}85*10^5$	$1{,}33*10^5$
6	1792	1367	20,30	15,63	$1{,}17*10^4$	$0{,}73*10^3$
7	407	329	5,19	3,11	$7{,}80*10^2$	$4{,}03*10^2$

properties appearance up to 48% depending on the processed oil type. At the present, the filtration research works upon the joint application of physico-chemical and plasma-pulse action with the purpose to improve the effect of reducing the layer oil viscosity anomalies and increase the final oil output of the viscous oil deposits are being carried out.

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