Electrohydraulic effect as an example of electrophysical technologies application in the oil industry

A N Drozdov*, I M Narozhnyy, D X Pak, V B Ludupov and G S Zemlianskii
Peoples' Friendship University of Russia (RUDN University), Moscow, Russia

Email: drozdov_an@pfur.ru

Abstract. This work was devoted to studies of electrohydraulic effect applicability in the oil industry. The major aim was to determine if the effect would be really useful in cleaning field pipelines from different precipitations such as calcium and barium sulphates, calcium and magnesium carbonates, sodium chloride salts and also tar and paraffin. In addition to it, another fields of possible applicability of the electrohydraulic effect were supposed to be find. Realisation of purposes put was achieved though reconstituting Lev Yutkin's layout for electrohydraulic impact and conducting several special experiments. Their thoughtful description with necessary accompanying illustrations can be find at the pages of this article. Results of experiments carried out, have proved the electrohydraulic impact effectiveness as a mean for cleaning pipes. Moreover, some results gave a reason to think that the effect worth applying to for increasing of the wellbore zone permeability as well as for extracting of solid minerals.

1. Introduction
Electrohydraulic technologies occupy a separate niche in the series of electrophysical technologies. Despite the relative simplicity of the execution, due to their specific features, they allow to effectively perform tasks that are not solved or difficult to solve by traditional methods. According to scientists involved in this issue (Mayer V.V. [5], Merin B.V [1], Blazin B.S. [2], Kurets V.I., Eremin V.Ya. [3],. Perevyazkina E.N. [4] and others) such technologies are used in mechanical engineering, agriculture, construction, hydrometallurgical production, in medicine, and even in oil industry [12].

For example, electrohydraulic effect (EHE) processing is applied to: reduce stress in welds (EHE produced in the casting cleaning bath, allows to reduce the residual stresses in the weld by 50-70%) [1], to destroy large boulders (in cases when explosives cannot be used due to the risk of clogging up the area with debris) [2, 3], to create organic fertilizer (thanks to EHE effect, it can be easily produced from peat) and food (especially meat) [4,5], to disinfect water (the effect is based on rendering pathogenic bacteria, even the most unpleasant, like E-coli.) [6], for the destruction of stones in the bladder and the removal of kidney stones with the help of an external source of electrohydraulic exposure.

The main reason for carrying out new experiments, during which it became possible to identify the strengths of the electrohydraulic impact (EHI), was the desire to find a new efficient and inexpensive way to clean the field pipelines from various types of precipitations. In addition to this, the research tasks included the search for other areas of electrohydraulic effect applicability in the oil industry.

The operation of oil wells and field pipelines is often complicated by precipitations of various composition and genesis. Clogging conglomerations in most cases are represented by salt sediments: calcium and barium sulphates, calcium and magnesium carbonates, sodium chloride, as well as asphalt-resin and paraffin sediments.

Precipitating on the walls of the producing strings and field pipelines, such sediments effect on the equipment operation process extremely negatively. There is a risk of the development of metal corrosion, energy losses significantly increase either. Besides that a need to increase the pressure arise
some cases when the pressure in the pipeline was increased by 3.5 times are already known), which is
certainly a negative factor too.

Popular Methods of combating undesirable sediments are divided into chemical (the use of
inhibitors of salt sedimentation), physical (usually presented by the effects of a magnetic field and
ultrasonic vibrations) and technological.

In this scientific article, the effectiveness of another physical method based on the use of
electrohydraulic effect was analyzed. The discoverer of the mechanism of this phenomenon allowing
transform electric energy into mechanical energy was the Soviet physicist Lev Aleksandrovich Yutkin.
Thanks to the EHE model that was recreated according to his schemes, it became possible to carry out
a number of tests, the results of which can be found on the pages of this work. The results of these
tests are an interesting material which can be highly valued in the oil industry.

2. Methods

To conduct research, a special replica of the EHI was decided to be recreated according to the scheme
proposed by L.A. Yutkin [7].

The principle of the installation is based on the interaction of high-voltage electrical pulses with a
liquid [8]. Between the electrodes lowered into a vessel with water (ordinary running water was used
as a liquid), a spark jumps, and results in instant excitement of the interelectrodes water. This happens
due to the fact that "cavitation seeds" (gas bubbles) generated by a spark expand and collapse with the
release of large energy (many times greater than the energy expended to start the process) [9,10,11].

The process itself can be described as follows. At first, the transformer generates a low voltage of
24V and transmits it to the ignition coils, which, in turn, rise this voltage. Then the high voltage is
transmitted to a diode rectifier, designed to "cut off" the negative half-cycles of the signal. After that
the signal goes to a capacitor. To regulate both the required values of the voltage and the capacitance
accumulated by the capacitor, a formative gap, acting as a simple spark gap, was introduced into the
circuit. It transmits the charge from the capacitor to one of the electrodes through the air, while the rest
of the charge from the capacitor goes straight to the other electrode. As a result of the interaction of
the electrical impulses (which are emitted by the electrodes) with the liquid, a cavitation process
occurs, it being accompanied by high and super high excess hydraulic pressures capable of performing
useful mechanical work. After termination of the overpressure action, a condensation (relaxation) of
previously formed liquid vapors occurs [9].

After the layout of the EGW was assembled, researches were carried on. The experimental part of
the work consisted of two stages. So, at first, experiments on cleaning pipes with the help of EHE
were carried out, then experiments on the destruction of solid rock - diorite took place.

To carry out the experiment on the cleaning of pipes from contamination, a small metal tube 150
mm long and 26.8 mm in diameter with a wall thickness of 3.2 mm was used. In order to simulate
sediments of salts, asphaltenes and paraffins, this tube was filled with plaster. After solidification, a
hole with approximate diameter of 14.5 mm was drilled (figure 1a) in the plaster. The tube was placed
in a plastic dish and filled with water, so it was possible to lower the holder of electrodes into the hole
drilled and realize the EHE.

When carrying out this experiment, some measurements of the voltage values at the output from
the capacitor were made thanks to using of Hantek DSO5202P oscilloscope. As a result the character
of relationship between voltages, intershock period and the distances in the forming gap (in this case, 3
mm) was determined. The measurement results can be seen at the figure 5a.

Due to getting good results in the experiment, it was decided to continue this studies, but already
with more powerful precipitation model. For this purpose a tube of larger diameter and all the same
plaster should have been used. But, in order to follow the development of cracks, a transparent
cylindrical vessel with a diameter of 100 mm was used (figure 2a) was used instead of standard iron
tube. Since such a replacement does not affect the quality of the experiment, it can be considered to be
absolutely reasonable.
As previously, the vessel was filled with plaster, the height of the cylinder of plaster being equal to the same 150 mm. The only difference was that, this time, not all the cross-sectional area of the transparent vessel was filled in with plaster (alabaster), but only the space between its wall and a special tube (diameter 20 mm), installed in advance in the center of the vessel. Then, the tube was removed after the plaster got hardened. This decision made it possible not to drill a hole in the plaster.

As a result, all conditions for accurate repeat of the previous experiment (but already with a more powerful clogging imitation) were created.

The next stage was devoted to experiments on the destruction of the diorite core sample. These experiments were carried out in order to find out how significant the EHE effect can be while destroying more or less hard rocks (diorite takes the 6th line in the Mohs scale).

Initially, several whole core samples (diameter 62.9 mm, length 110 mm) and several semi-cylindrical samples were available. In order to assess the physical characteristics of the material (diorite), it was decided to place one of the whole core samples under a press (figure 3). The results gave an opportunity to judge the hardness of the rock.

To make the realization of the experiment more convenient, two semi-cylindrical core samples were selected for further working at. Both halves were placed in a special plastic form filled with water. Electrodes were placed directly between them. The forming spark gap was adjusted to the meaning of 4mm.

It should be noted that the voltage values were measured using an oscilloscope like in the case of the previous experiment, but this time the forming gap was 4 mm (figure 5b).

3. Results

During the first experiment (cleaning of small-diameter tube from plaster clogs), electrohydraulic impact was being applied for 1 minute. Forming gap at the beginning of the experiment was approximately equal to 3 mm. After each electrohydraulic shock, the electrode holder was moved along the drilled hole (on average, at 5 mm distance). This was done to have the entire contamination area under the effect. As a result, the tube was cleaned from gypsum (figure 1).

![Figure 1](image1.png)

**Figure 1.** The result of usage of electrohydraulic effect in the tube (a - before EHE realization; b - after EHE realization).

Keeping on carrying out the same experiment in a cylindrical vessel, a decision of leaving the distance in the forming gap unchanged (3 mm) while changing longitude of the experiment in time was taken. Since the thickness of the gypsum wall this time was significantly greater, EHI was being used for 7 minutes. During this time, a whole network of cracks in the workpiece was successfully formed (figure 2b).
Figure 2. Results of the EHE application in a transparent cylinder (a - before EHI realization; b - after EHI realization).

At the second stage of the laboratory tests, while preparing for the experiments with diorite, a CYBER-PLYS EVOLUTION press was used to determine the physical characteristics of the core sample: the maximum load of power that the sample withstood was 706.285 kN, while the maximum pressure was 212.630 MPa. Basing on the data obtained, it was concluded that the compressive strength of the material is quite high, comparable to the strength of granite, which everybody knows.

Figure 3. Diorite core sample in compression tests (a - before testing; b - after testing).

The experiment with diorite lasted for 3 minutes (results can be seen at the figure 4). During this time, about 30 electro-hydraulic shocks were carried out. As a result, semi-cylindrical samples split in halves.

Figure 4. Diorite semicylinders split as a result of EHE application.
As mentioned above, during the experiments, an oscilloscope was used. It measured the voltage at the output from the capacitor in dependence on the time between electro-hydraulic shocks. From figure 6a it becomes clear that with a three-millimeter forming gap, a peak voltage of 8.8 kV was recorded; the interstrike period was 2.12 sec. In the experiment with a 4 mm gap, the oscilloscope gave the following data: the peak voltage slightly increased to 10.2 kV, and time between shocks increased to 3.08 seconds (Figure 5b).

**Figure 5.** Dependence of the voltage at the outlet of the capacitor on the time between electro-hydraulic shocks (a - with a forming gap of 3 mm, b - with a forming gap of 4 mm).

Summing up the results, it should be noted that the EHE happened to be rather effective in all experiments. Electrohydraulic impact succeed in: clearing of the tube from mechanical clogs; creating a network of cracks in massive plaster billet and in splitting the diorite core sample.

4. Discussion

Studies have confirmed the assumption that the Yutkin electrohydraulic effect can be successfully applied in the oil industry.

It should be emphasized that all the experimental studies were successfully completed: local tube resistances represented by gypsum precipitations were removed, and diorite was split. No occurrence of any negative consequences of EHE usage was noticed during the tests.

Data on the dependence of the voltage and the period between shocks on the length of the forming gap were also obtained.

Based on the results of the experiments, alternative ways of using the electro-hydraulic effect in the oil industry were proposed (in addition to cleaning pipes from salt, resins and paraffins).

The results of tests done have become a reason to think that such effect would be very effective for increasing of the wellbore zone permeability (this could be achieved through increasing amount of fractures and clearing from clogging particles). Perhaps it will be possible to perform a number of studies in this field in the future.

In addition to this, the fact that Yutkin effect can be used while extracting solid minerals has become obvious. Its ability to chop rather hard rocks likely to be very useful during extraction (According to the Mohs scale diorite has a hardness of 6).

5. References

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