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# Study of the metal parts of the electrohydropulse drill

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The changes and the quality of the surface of the electrode system of the drill after electrohydraulic pulsed treatment were considered. Spectral analysis of the microstructure of melted regions of the drill electrode surface, formed as a result of the action of a spark discharge, was performed. The regularities of erosion wear of the electrodes depending on the energy parameters and the number of electrohydraulic pulses were experimentally established. This study is devoted to the method of electrohydraulic well-drilling based on the unique phenomenon of direct conversion of the electric energy into mechanical energy of shock waves that effectively crush rocks in a bounded spatial volume in the well bottom. The electric-pulse treatment developed here is based on the Yutkin electrohydraulic effect [1-3].

**Keywords:** Electrohydraulic pulse, erosion of the electrodes, high-voltage.

## INTRODUCTION

Electrohydraulic drilling is a basically new method that has not been used in industry as of yet. The main advantage of the proposed technology is its reliability due to the absence of friction and wear parts in the equipment, as well as the simplicity in operation and maintenance. However, the wide implementation of this technology in practice is hampered by undesirable effects and consequences. The processes occurring on the surface of the electrodes subjected to erosion and action of high-power underwater spark discharges require additional investigations. In electrohydraulic well-drilling, the cable of the positive electrode is also subjected to wear (is consumable). Melted regions appear on the surfaces of the positive and negative electrodes; their effect on the strength of the electrode system has not been studied comprehensively. In this connection, this study aims at experimental investigation of the degree and rate of electrode wear depending on the energy parameters and the number of electrohydraulic pulses.

### *Methods*

The electrohydraulic setup with a working cell for testing and studying various processes accompanying electrohydraulic drilling was designed and assembled at the Laboratory of Hydrodynamics and Heat Transfer of the Buketov State University (Karaganda). The operation principle of the electrohydraulic drill can be described as follows: first, the pulse capacitor is charged from a high-voltage generator. When a preset voltage is attained, the breakdown of the discharge gap occurs, and the entire energy stored in the pulse capacitor is transferred to the working gap *via* the cable-electrode. A pulsed electric discharge occurring in a fluid is a source of high-intensity mechanical shock waves, which are reflected from the bore bit and produce a focused action on the medium being processed, crushing it into small pieces [4-7].

In the system for well-drilling, RK-75-9-12 bared cable core connected to the positive terminal of the pulsed current source is used in the working cell for the central electrode, while the negative terminal is connected with the electrohydraulic bore bit. Such a design of the electrode is convenient in well-drilling for installing heat-exchange pipes.

## RESULTS

As a result of the redistribution of velocities, the forces emerging during the discharge due to a hydraulic shock and the hydrodynamic force facilitate self-centering of the cable-electrode. During prolonged operation, the central bared core of the cable-electrode becomes shorter due to erosion, and the insulation of its end part is damaged. The insulation is mainly cut along the central core, and efficiency of drill operation becomes lower. For this reason, after electrohydraulic crushing of hard rocks, it is necessary to replant insulation by baring the working end of the cable-electrode from the insulating layer.

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**Fig. 1.** Cable-electrode and characteristic failures during its operation (a) before treatment, (b) at W = 600 J, and (c) at W = 1350 J.

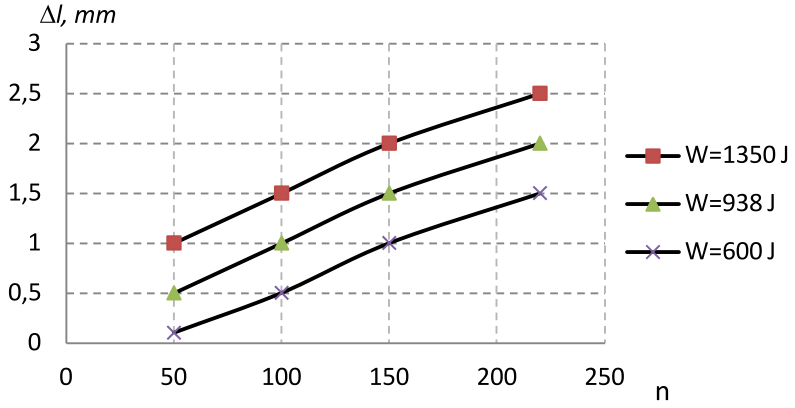


**Fig. 2.** Dependence of the change in the electrode length on the number of pulses

During operation, each discharge is accompanied with erosive wear of the electrodes, which depends on the voltage and energy per pulse, the electrode material, etc. As a result, the cable-electrode of the electrohydraulic drill fails.

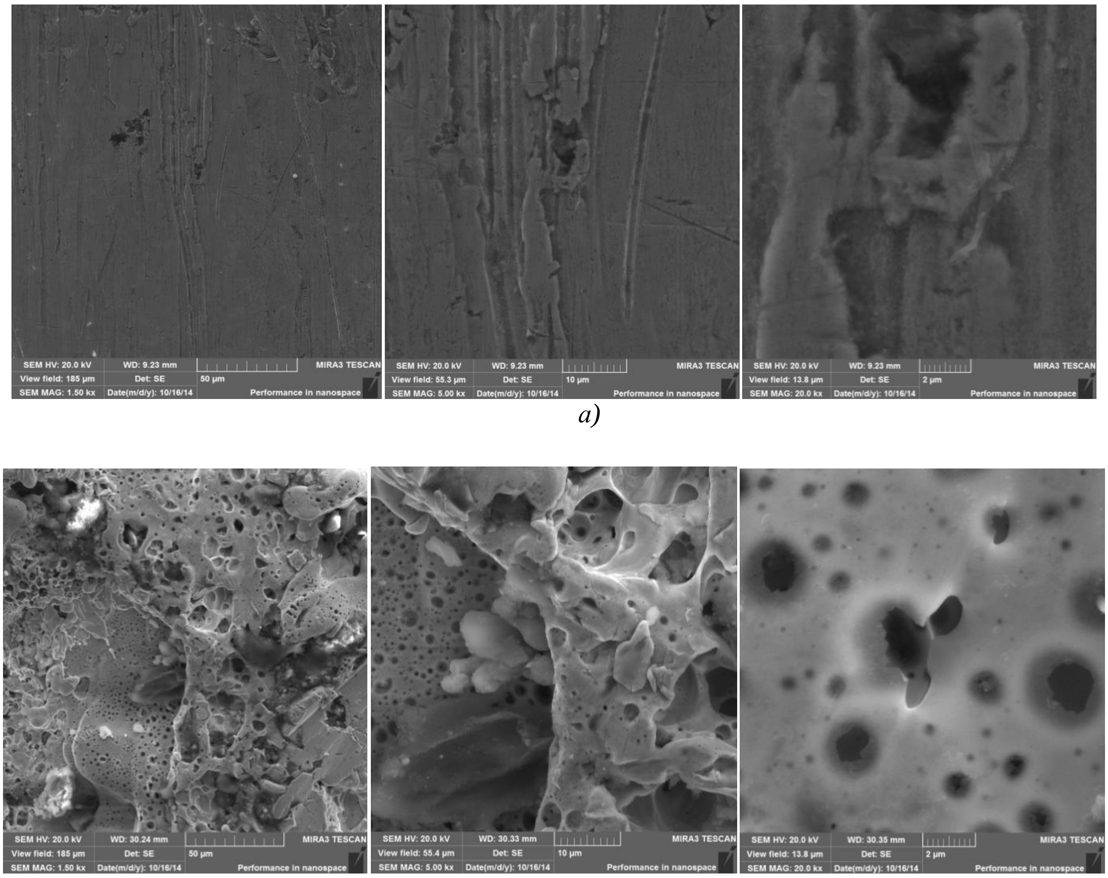
Figure 1 shows examples of melting and burning of the positive electrode. It is well known that during electrohydraulic drilling, spark eroding occurs, which is associated with emission of particles from the metal surface by the electric discharge pulse [8,9]. If the distance between the electrodes immersed into a liquid medium is preset, the decrease in the spacing between the electrodes initiates the breakdown, and the electric discharge occurs with the formation of a high-temperature plasma in the discharge channel. This property is used in electroerosive processing of materials, which is usually carried out by electric pulses with a duration not exceeding 0.01 s so that the released heat has no time to propagate to the bulk of the material. In addition, the pressure of the plasma particles during their impacts against the electrode facilitates erosion not only of the melted, but also of the heated substance. The electric breakdown always propagates *via* the shortest route; for this reason, the closest regions of the electrodes are first to erode. The nature of changes and the quality of the surface after the treatment depend on the duration, frequency, and energy of electric pulses.

It was found from the experimental results that at a voltage of 20 kV, an energy pulse of 600 J is released in the bulk. Then, the initial length of the positive copper electrode with a diameter of 2 mm becomes shorter by Δl = 1 mm as a result of 121 pulsed discharges and by 3 mm after 178 pulses. It was found in our experiments that when energy W = 600 J is released in the initiated discharge gap at a voltage of 20 kV, the erosion of the positive electrode is accompanied with a reduction of the electrode volume by approximately 3.14 – 9.42 $mm^3$.

Figure 2 shows the dependence of the length wear of the working electrode on the number of pulses for various discharge energies (from 600 to 1350 J). It can be seen from the curves that with increasing discharge energy, the working electrode is worn faster for the same number of pulses.

Figure 3 shows the microphotographs of the central cable-electrode before and after electrohydraulic treatment, obtained using the MIRA3 TESCAN microscope. The photographs obtained with the help of the electron microscope with different magnifications help to trace in detail the changes in the microstructure of the positive electrode.

Analysis of the photographs of the surface of the cable-electrode, obtained after electrohydraulic treatment, shows that the microstructure of the entire surface significantly changes, and large melted regions including spots with different densities and structures, as well as voids are observed. However, investigation of longitudinal and transverse metallographic sections using a microscope with 20 000-fold magnification showed no traces of cracks in the metal.



*a)*

*b)*

**Fig. 3.** Microphotograph of the central cable-electrode obtained with different magnifications (a) before and (b) after electrohydraulic treatment

## CONCLUSIONS

In our experiments we studied the erosion in the metal part of the electrode system of the electrohydraulic drill. We investigated the melted regions of the surface by analyzing the microstructural changes of the electrode surfaces before and after electrohydraulic action for various parameters of the electric discharges. Analysis of characteristic changes in the cable-electrode during electrohydraulic well-drilling shows that erosive wear of metals occurs in different ways depending on the electric parameters, frequency, and duration of discharges. The inner surface of the tubular shell of the electrohydraulic drill serving as the negative electrode is not torn and is not subjected to mechanical wear. Substantial wear occurs only in the central cable-electrode which is the only consumable material. Thus, the electrohydraulic pulsed method of well-drilling for heat-exchangers makes it possible to attain high efficiency of crushing with low energy expenditures as compared to mechanical methods.

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