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CHANGING THE MICROSTRUCTURE OF THE ELECTRODE SURFACES DURING UNDERWATER ELECTRIC DISCHARGES

Stoev M. [1], Kussaiynov K.[2], Shuyushbayeva N.N.[2], Zhumabekov B.K.[2], Bekturganov Zh.S.[2], Ualiev E.B.[3]

[1]South West University of "Neofit Rilski", Blagoevgrad, Bulgaria;
[2]Karaganda State University named after E.A.Buketov, Karaganda, Kazakhstan;
[3]University "Turan-Astana", Astana, Kazakhstan; nn_shuish@mail.ru

The article considers the advantages of electro-hydraulic method of drilling. The wear process of drilling electrodes during operation and process of the metal electrode erosion of the drill electro-hydraulic system have been studied. The dependence of the electrode wear rate on number of electro pulses has been established. Based on the experimental studies the authors determined the boundaries of the electrical parameters of the processing for the intensive destruction of solid rocks. Quantitative dependencies, characterizing the beginning of the process of destruction of rocks of different thickness depending on the number and energy discharges, have been investigated.

Keywords: electro-hydraulic drilling, electrode system, underwater electric discharges, electrode wear.

Introduction

Currently, there are many kinds of drilling machines widely used in Kazakhstan. The existing drilling technologies of heat exchangers well holes are effective under soft ground conditions without hard rocks and stone slabs. Drilling to the depth of 25 meters with diameter well holes up to half may be difficult due to the solid rock [1]. Need for development of new technology, new highly efficient technological processes and equipment, means of mechanization and automation, has led to the research and development of a number of new techniques to disintegrate solids by drilling, based on different physical principles. Electric hydro-pulse drilling turned out one of the most promising methods, the essence of which is the destructive effect of electric pulse discharges in solid non-conductive and semi-conductive materials [2]. This paper deals with a new innovative way of making well holes using method of electric hydro-pulse drilling based on a unique phenomenon that is the way of direct conversion of electrical energy into mechanical energy of shock waves, efficiently destructing rocks at the well bottom.

Experimental equipment

Electro-hydraulic drilling is a fundamentally new way and has not yet found industrial application; the task of research and practical implementation of this technology remains important up to date. The main advantages of the suggested technology are as follows: the opportunity to carry out operations under conditions of a limited space, long-term reliable operation due to the absence of rubbing and wearing parts of the plant and simplicity in operation and maintenance that is achieved by using as an active part an electrode cable, which is the only consumable.

To form a pulse with a short front of the voltage applied to the discharge gap in a liquid the authors used a discharge gap in the air that is an air discharger; and to generate a pulse of certain energy they used energy storage electrical capacitor. In the laboratory of hydrodynamics and heat transfer of Karaganda State University named after academician E.A. Buketov, the authors have developed and tested an electro-hydraulic plant and a working area for drilling (Fig. 1).

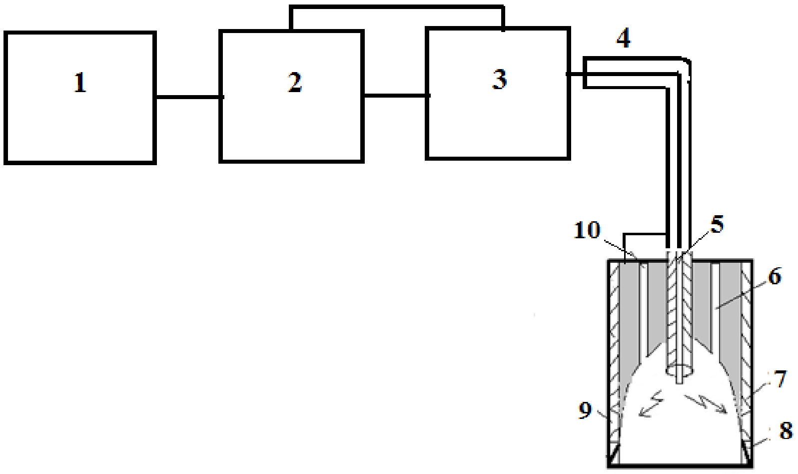


Fig.1. Scheme of electro-hydraulic apparatus and electro-hydraulic drill
1 – power supply, 2 – high-voltage generator, 3 – pulse capacitor, 4 –coaxial cable-electrode, 5 – centre electrode, 6 and 10 – water passages for injection the face, 7 – vent in the bit for gas outlet, 8 – teeth of the drilling bit, 9 – head of the drilling bit.

This technology, as compared to traditional ones, allows more efficiently and in the short term to destroy obstacles in the form of solid rock by the impact of shock waves at high-voltage discharges in aquatic environment, in well holes drilling for installation of heat exchangers. And also electro hydraulic method is used by to activate and water decontamination.

Results and discussion

As a result of the experimental study the authors defined the optimal values of time and the number of spark discharges in electro-hydraulic drilling the stones, and determined the time at which destruction of stones and hard rock occurs during the drilling.

Using the experiment results the authors plotted the dependence graphs of the number of discharges on the thickness of the stone at different values of discharge energy (Fig. 2).

The graph shows that at discharge energy of 288 J a stone can be destroyed to the thickness of (40-70) mm. The number of pulses is 370. The higher the discharge energy the thicker stones are destroyed; whereas the number of pulses required to break stones decreases. For example, at the discharge energy of 612 J, it is possible to disintegrate 70 mm thick stones. This requires a smaller number of pulses that is of the order of 175 pulses [3, 4].

Forces caused by discharge due to hydraulic impact and flow force, as a result of redistribution of velocities, stimulate self-centering of the electrode cable. During continuous operation the central bare cord of the electrode cable is shortened due to erosion, and the insulator of its end breaks down.

Insulation is basically breaks down along the central cord and the device loses its efficiency. In this case, after the solid rocks fracture it is necessary to periodically tinker the operating tip of the electrode cable giving it original shape.

While in operation, each discharge is accompanied by electrode erosion wear, the value of which depends on the energy of the pulse voltage, electrode material, etc. In the course of operation, the electrode cable of the electro-hydraulic drill typically breaks down. The result of the positive electrode wear is shown in Fig.3.

The exterior view of an electro-hydraulic drill and the scheme of the stand for electrode wear process study are shown in Fig.3.

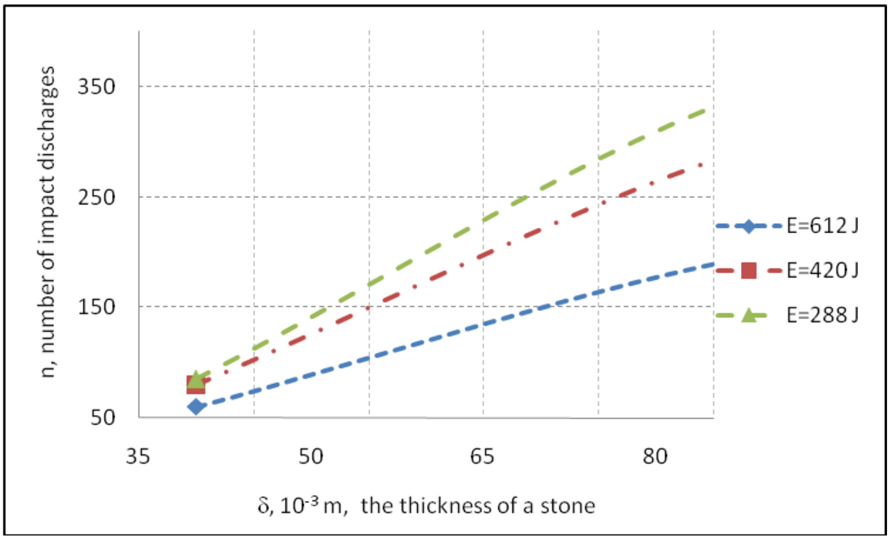


Fig. 2. Dependence of the number of impact discharges on the thickness of a stone prior to crushing

Fig. 3. The electrode cable and its typical fractures in the course of operation

Similar studies were conducted by the electro-hydraulics design office of the Academy of sciences of Ukraine. At the pulse energy of 10 kJ and 10 kV voltage, the length of the positive electrode steel rod of 10mm diameter was shortened by 1 mm after 50 pulses. A rod with a diameter of 16 mm at the energy of 100 kJ was shortened by 1 mm after every 10 pulses [5-6].

During the experiment, the dependence of the electrode wear rate on the number of pulses was defined (Fig. 4).

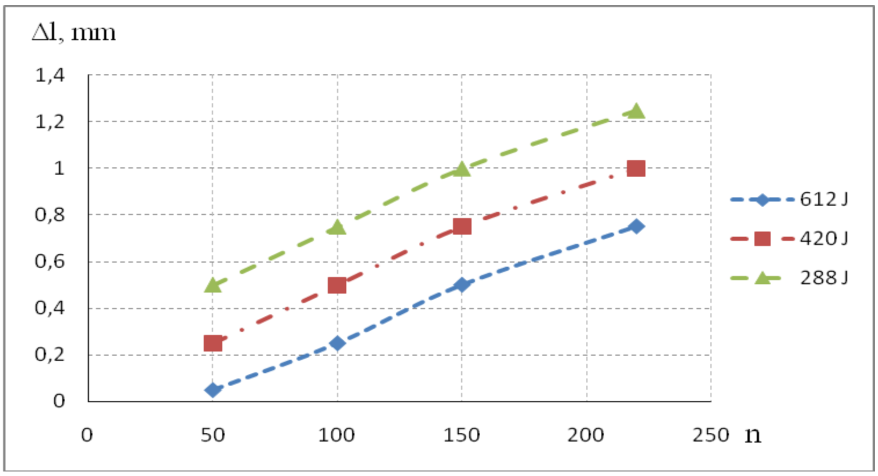
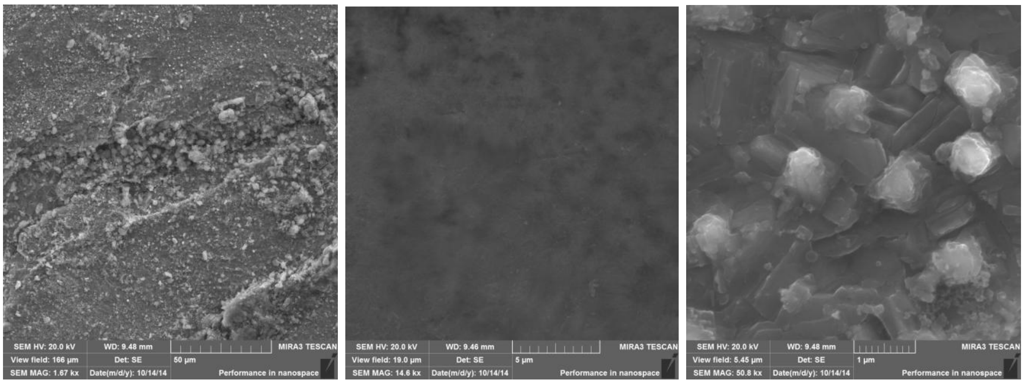


Fig. 4. The graph of the dependence of electrode wear rate on the number of pulses

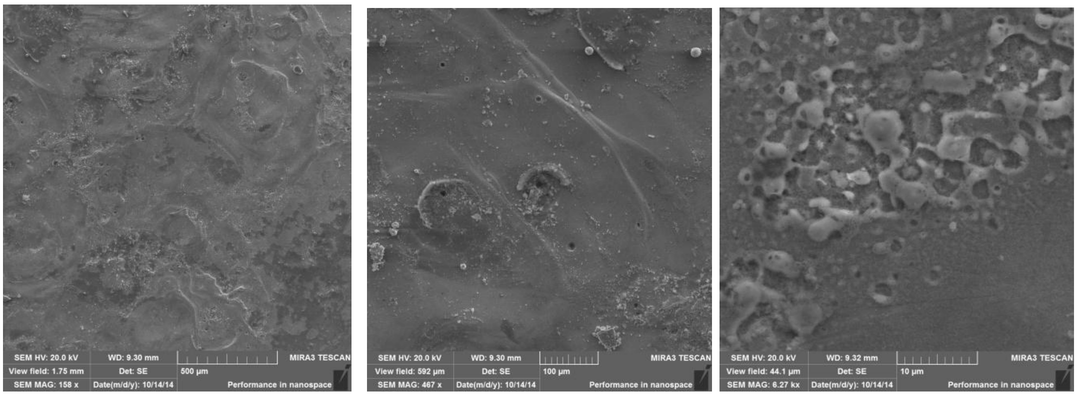
The experiments showed that at the pulse energy of 288 J and a voltage of 20 kV, the length of the positive electrode copper rod having the diameter of 1 mm is shortened by 0.5 mm after 121 pulses during 2 minutes and in 3 minutes after 178 pulses the length of the electrode is shortened by 1,5 mm. Thus, if we calculate the positive electrode erosion for these conditions, it turns out that the energy release in the initiated discharge gap of 612 Joules of energy at a voltage of 20 kV is accompanied by a decrease in the volume of the electrode of about (1.57-3.21) mm^3. Also, we carried microstructural assays electrode system electro hydraulic drill before and after processing of the destruction stones. Figures 5 - 7 show a micrograph of the electrode system drills before and after processing with different electro increase in the microscope brand Mira 3 Tescan. The negative electrode is a tubular exterior side of the drill.

Figures 5 and 6 show the pictures of the inside of the drill of before and after processing at multiple scales.The pictures show that after the electro-hydraulic processing, the microstructure of the negative electrode does not change and scuff. After the electro-hydraulic processing burns of different types were found on the tube surfaces: they were in the form of points, spots and of prolate form. The metal surface in areas of burns was rougher than it had been initially; the maximum height of asperities reached 0.086×10^{-3}m. The concentration of point burns ranged within 1/sm^2 and depended on the position of the movable electrode at the time of its passage through the tube and its speed.



a b c

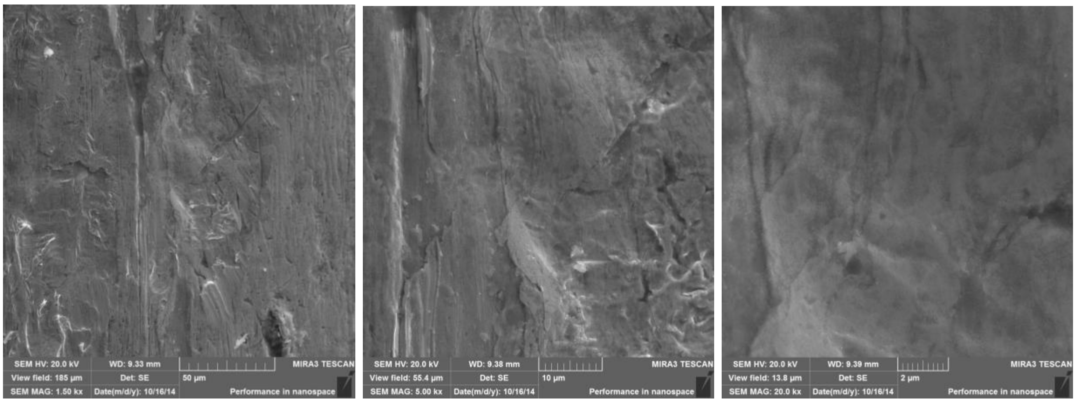
Fig. 5. Pictures of a steel tube surface before processing with magnification on:
a) × 1.67 ; b) ×14.6; c) ×50.8.



a b c

Fig. 6. Pictures of a steel tube surface after processing with magnification on:
a) × 158; b) × 467; c) × 6.27.

In the burn areas the surface was flowed, inclusions of copper (electrode material) of rounded shape with a diameter up to 0.055×10^{-3}m were seen. Figure 7 shows the pictures of central electrode cable before and after processing scaled up as 1×1.5, 1×5.0 and 1×20.0.



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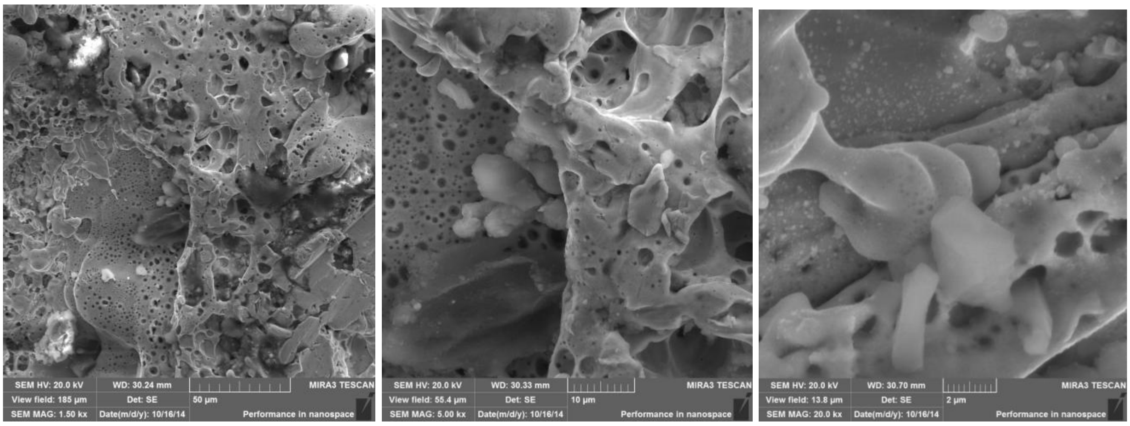
A)



a b c

B)

Fig.7. Pictures of central electrode cable A) before and B) after processing with magnification on:
a) × 1.5; b) × 5.0; c) × 20.0.

The analysis image obtained after processing surface at central electrode cable showed the following. In general, the microstructure of the entire surface and observed substantially unchanged extensive molten portions includes spots of different density and structure, as well as voids. But these survey longitudinal and transverse sections under a microscope at 20.0 times magnification of cracks in the metal traces are not shown.

Conclusion

It is experimentally proved that burns and inclusions of electrode material of the mentioned sizes have no impact on the an inner shell of the drill. The analysis of the results shows that the shock wave generated by a spark discharge within the range of pulse voltage values at a switching device does not affect the structure of the drill surface.

Thus, as compared with traditionally used methods the electro-hydraulic drill allows to achieve higher drilling speed. The electric pulse destruction is implemented without using a drilling bit, it does not require special tightness of electrodes to bottom hole surface with considerable force; therefore, the wear of the electrodes at electro-hydraulic pulse drilling is relatively minor.

Using a result of the experimental study, the authors have defined the optimal values of electro-physical parameters, within which the intensive destruction of solid and super solid rocks starts. The dependence graphs characterizing the beginning of the process of destruction of rocks of different thickness depending on the number and energy discharges are plotted. The processes of erosion at the metal part of electrode system of the electro-hydraulic drill have been studied and micro-structural analyses of the drill with different properties before and after processing have been carried out. Using the experiment results the authors plotted the dependence graph of the electrode wear rate on the number of pulses.

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