UDC 621.314; 537.39

CHANGE OF ELECTRODE STRUCTURE AND THEIR DESTRUCTION IN ELECTROPULSE WATER TREATMEN

Shaimerdenova K.M., Aitpaeva Z.K., Khassenov A.K., Kutum B.B., Bulkairova G.A.

E.A. Buketov Karaganda State University, Karaganda, Kazakhstan, gulzhan.0106@mail.ru

The article is devoted to the development and creation of a discharge treatment technology and water activation. The effect of electric discharges on the structure and properties of the electrode system during hydropulse water treatment has been studied. Experimental studies have been conducted to identify disadvantages and advantages of the material cable electrodes. As a result, lengths of destructions of central tendon of electrodes revealed from time of hydropulse treatment. It was found that most effective is the central tendon of electrode, made from a copper.

Keywords: electrode system, hydropulse treatment, electrical discharge.

Introduction

Sources of water supply are polluted due to intensive development of industry and infrastructure. In many regions their quality cannot be considered satisfactory. Currently, there are various methods of water purification, such as chemical softening of water for removal of hardness; ion-exchange, electrodialysis, reverse osmosis, electrolysis, and adsorption methods. Despite some advantages, the listed methods have a significant disadvantage, which is in their harmful environmental impact.

There are known scientific developments using an underwater electrical discharge, which is called an electro-hydraulic effect. They are in the field of metallurgy (dressing a casting), mining industry (breaking and drilling of rocks), power industry (pipe cleaning and heat transfer augmentation), agriculture (seed treatment), medicine (litholysis), etc. [1].

The proposed method and setup will not only purify water from various microorganisms, microbes, but also activate it, making for a change in the water structure with a positive effect for the life of plants and living organisms. The basis of the developed electrohydropulse (EHP) processing is the electro-hydraulic effect of Yutkin [2, 3]. EHP water treatment technology is based on the unique effect of instantaneous energy release from a liquid at the instant of an electrical discharge and possesses tremendous potential and unexpected areas of wide practical application owing to its versatility.

1. The experimental plant

The general view and layout of the device for EHP disinfection of running water are shown in Fig. 1, 2. The EHP plant works as follows. A pulse capacitor is charged from a high-voltage generator fed from an adjustable current source (5), Fig. 1. When the preset voltage is achieved, a break down of the discharger takes place and all the stored in the condenser energy through the positive cable electrode (2) is transferred to the working clearance of the negative electrode. A pulsed electrical discharge takes place that disinfects the liquid flowing through the working chamber (1). A paraboloidal reflector is attached inside the working chamber by a fixing holder (4).

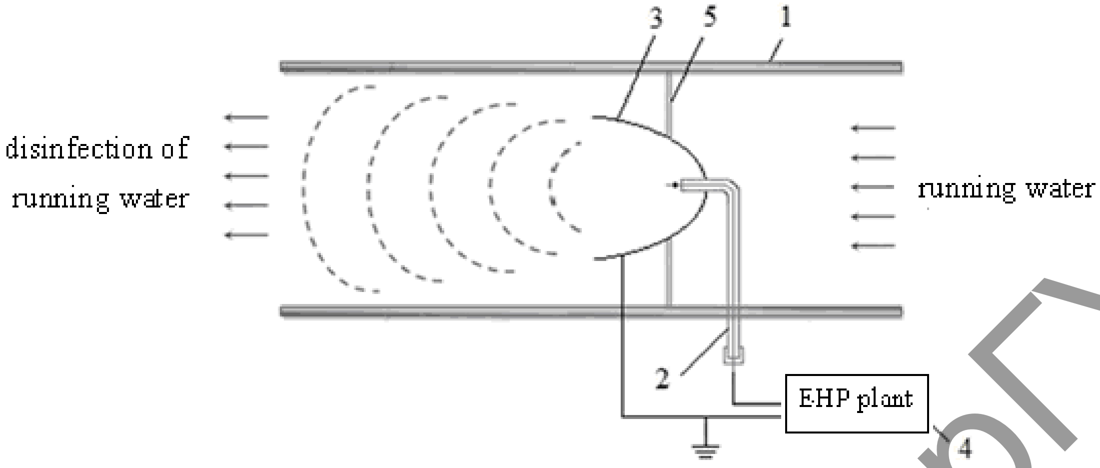


Fig. 1. The layout of the device for EHP disinfection of running water:
1 – a working chamber; 2 – an electrode of positive discharge; 3 – a paraboloidal reflector;
4 – an EHP plant; 5 – a fixing holder of the paraboloidal reflector.

The technical result is achieved by the fact that the device for disinfection of running water to reduce bacterial infestation consists of a pulse current generator and an air-gap discharger. In the interior of the process chamber there is a paraboloidal reflector which serves as a negative electrode. It is made of copper to ensure an increase in the shock wave force. Under an electric explosion, the energy of the shock wave isotropically propagates in all directions, but using the paraboloidal reflector it can be concentrated in a prevailing direction. The greatest efficiency was achieved when the cable electrode was located in the focus of the paraboloidal reflector [4, 5].

The main problem in application of EHP water treatment method is the resistance to destruction of the front part of the electrodes. This is due to the fact that part of streamers forming after the water treatment, have a thermochemical and mechanical effect on the insulation of the front part of the working electrode [3-7]. At rather extensive failure of the electrode insulation, mechanical impact factors come into effect. One of these factors is the effect of hydraulic shocks on the insulation of the front part of the electrode. These shocks, acting on the charred area of the electrode insulation, cause a mechanical rupture, i.e. ripping, which causes appearing of even more extended areas of insulation burn down. As a result of the failure of the insulation layer, the process of occurring super long discharges in water is impeded, energy losses increase, which in turn leads to the energy-intensive operation of electrohydraulic devices.

2. The composition and structure of cable electrodes

In the experiment, 3 types of cable electrodes were used. In each of them the central core were made of various materials, namely copper, aluminum and steel. To select the material from which the core of the electrode was made, the authors adhered to the following criteria: low inductance; heavy insulation, resistant to high operating voltages; a service lifetime significantly exceeding the service life of the other elements of the electrohydraulic plant.

Particularly, a radio-frequency coaxial cable-electrode with a copper central core, widely used in industry and in laboratories, was mainly used in the experiment. As a steel core, a low-carbon thermally treated steel spring wire was used. It had a heavy polyethylene insulation to ensure the safety of experiments. As an example of an aluminum core, an aluminum wire was used. The insulation of this wire, namely polyvinyl chloride insulation, was not sufficient for safe operation and therefore a hydraulic hose of HW-1SN-08 brand was used as an additional insulation.

The cable electrode with a copper core was tested as the first test sample. Initially, a copper coaxial cable electrode with a 1.6 mm central core diameter was prepared for processing. Particularly, a part of the external insulation and outer current draining net was removed and the prominent part of the electrode was stripped by 2 mm.

The second sample, an aluminum cable electrode, also underwent some amendment. Since the insulation of the aluminum wire was not designed for tensions above 1 kV, an additional insulation was made; and a hydraulic hose with an inner diameter of 8 mm was used as an insulation material. This design would provide a safe EHP effect in water.

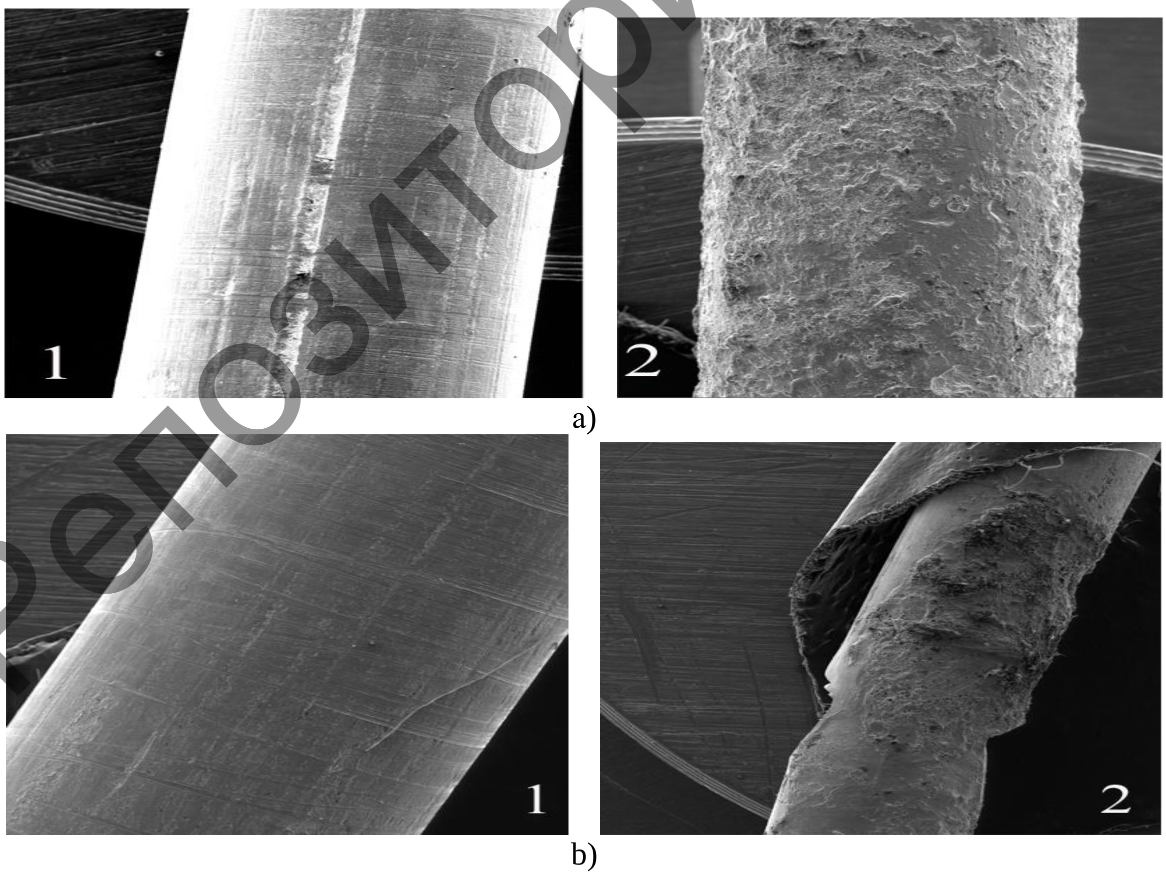
As the third sample, a steel cable electrode was used, in which the central core was made of steel processed wire and its diameter was 3 mm. Vinilplast was used as the insulation. When carrying out the experimental tests, these cable electrodes were alternately attached to the electrohydraulic facility.

3. Results and discussion

After carrying out EHP processing, the experimenters obtained 3 samples of cable electrodes, which in turn were divided according to the time frames of the treatment process. In order to conduct more thorough examination of the destruction processes in the central core of electrodes, a microscopic analysis of the samples using a scanning electron microscope was conducted.

3.1 The copper cable electrode

Figures 2 (a), (b) show photographs of the copper cable electrode before and after the EHP processing for 2 minutes and 4 minutes respectively. As a conductor, copper is considered to be the second best conductor after silver.



b)

1 – the sample before the experiment; 2 – the sample after the experiment

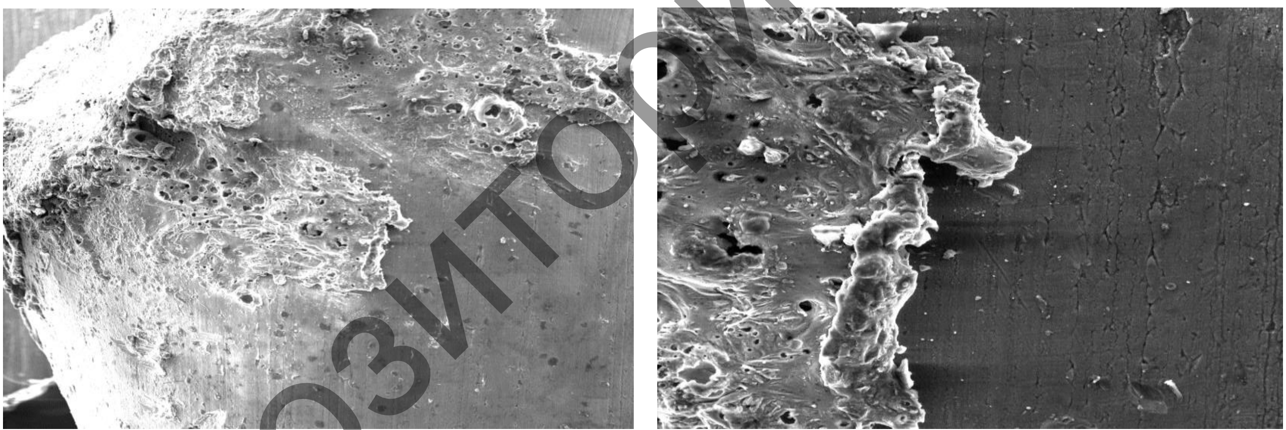
Fig. 2. Surface structure of copper electrode samples before and after EHP processing within: a) 2 minutes; b) 4 minutes

When using it as a conductor, basically oxygen-free copper is used, since it is less erodible. In the pictures of the copper electrode it is possible to see minor structural failure. A 2-minute-long EHP treatment is sufficient to form small dimples and micro-hollows on the surface of the copper electrode. These defects on the surface of the copper core are formed due to the passage of streamers, the effect of hydro-cavitation forces and high pressures in water. The length of the destroyed part of the copper core of the electrode with a 2-minute-long treatment is 2-3mm.

For a more thorough study of the pattern of failure and wear, the copper cable electrode was exposed to EHP treatment for 4 minutes. Fig. 3b shows more significant fractures in the copper core of the electrode, almost complete destruction of the working core of the electrode is observed. A longer EHP processing results in similar fracture processes, the copper part of the electrode is peeled off and deeper hollows are formed. The length of the destroyed part of the central core of the copper electrode with a 4- minute-long EHP processing is 6-8 mm.

3.2 The aluminum cable electrode

When carrying out the experiment using the aluminum cable electrode, it was visually observed that its fracture properties under EHP effect are worse than that of the copper electrode. The sample of the aluminum electrode was also subjected to 2- and 4- minute-long processing, respectively. Figure 3 (a) shows a sample of the end of the core of an aluminum electrode with 6.4 mm core diameter. It can be seen that after a 2- minute-long treatment, a part of the metal melts under the high-voltage tension, and the cable is also exposed to high pressures and hydro-cavitation forces. The length of the destroyed part of the aluminum cable electrode with a 2-minute-long EHP processing was 8 mm.



a) b)

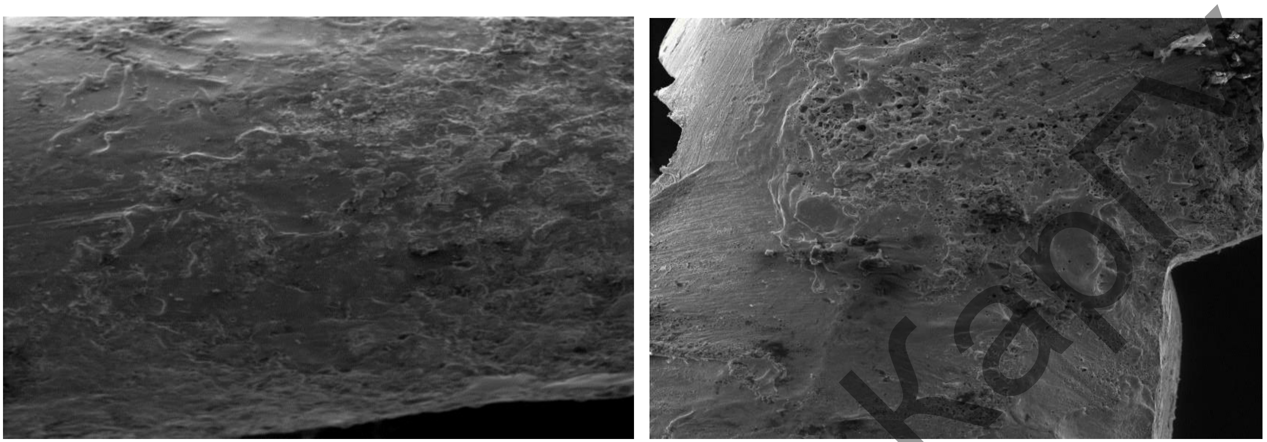
Fig. 3. The surface structure of the aluminum cable electrode sample before and after EHP processing within: a) 2 minutes; b) 4 minutes.

With a 4-minute-long treatment (Fig. 3, b), the aluminum cable electrode was destroyed even more than after a 2-minute-long processing. The length of the destroyed part of the central core of the cable electrode was about 17-20 mm, that was a very large indicator. The part of the core of the electrode, where there is a boundary between the completely destroyed part, as a result of the treatment, and the untreated part, is seen.

3.3 The steel cable electrode

The operating cable electrode, the central core of which was made of steel, during the experiment on treatment in water, showed itself as follows: the processing required more energy. This is due to the fact that the electrical conductivity of steel is 6-7 times less than that of copper. The photograph of the sample of the steel cable electrode after a 2-minute-long water treatment is shown in Figure 4 (a).

The process of wear of the steel core of the cable electrode is seen. It shows the effect of the formation and passage of streamers along the front part of the electrode core, as well as that of the processes of erosion and hydrocavitation forces. Despite the high resistance of this metal, under high-voltage discharges in water micro hollows were formed, i.e. the steel did not withstand the tension even within a 2-minute-long treatment. The length of the destroyed part of the cable electrode at a 2-minute-long processing was 4 mm.



a) b)

Fig. 4. The surface structure of a steel cable electrode sample before and after EHP processing within: a) 2 minutes; b) 4 minutes.

Figure 4 (b) shows a photograph of a sample of the steel cable electrode after a 4-minute-long EHP processing. As well as in the case of the copper cable electrode, a considerable failure is observed. The picture clearly shows micro-hollows, as well as areas where the process of destruction of the central core of the cable electrode took place. The experiments showed that the resistance of a steel electrode at EHP treatment was lower than that of a copper one. The length of the area of the cleaned pipe when using a steel electrode after a 4-minute-long EHP processing was 45 mm.

On the basis of the obtained results, it can be concluded that the central core is exposed to considerable failure under EHP effect. The reason for this is the passage of streamers along the front end of the electrode, as well as the thermochemical and mechanical effects on the cable electrode. In addition, cavitation, i.e. formation of cavitation bubbles influences on the electrode core surface. These bubbles due to their chemical aggressiveness and a sufficiently high water temperature cause erosion of the surface of the electrodes.

Conclusion

The introduction of this EHP technology and widespread use in practice is troubled by some undesirable effects and consequences. The processes occurring on the surfaces of electrodes subjected to erosion and the impact of powerful underwater spark discharges require additional investigation. Under EHP water treatment, the electrode cable of positive polarity wears out as well; it is an expendable material. Melted areas appear on the surfaces of both positive and negative metal electrodes, the effect of which on the strength of the electrode system has not been fully studied.

The authors made experiments to study the degree of electrode wear and change in their structure depending on energy parameters and the number of EHP treatments. As the result of study of the resistance of the three different electrode samples under EHP effects of various durations it was found that the most effective, reliable and optimal is the electrode with a copper central core.

Acknowledgments

The work was carried out within the framework of the project "The method of water resources recovery by the electric discharge technology of purification and activation with a positive effect on the life of plants and living organisms" No. 529

REFERENCES

1 Kussaynov K. *Electrohydropulse technology for cleaning pipes and bundles of pipes of heat exchangers*. Karaganda: KSU Publishing house, 2016, 256 p. [in Russian]

2 Spirov V.G. *A device for electrohydraulic effect on liquid media*. No. 2009117948/15 of May 14, 2009.

3 Nazarov U.S., Mamajanov E.U. *An electrohydraulic method and device for desalination and activation of highly mineralized water.* No. 20060338 of September 14, 2006.

4 Shaimerdenova K.M., Bulkairova G.A., Suleimenova S.E. The effect of the electropulse discharge on the change in the mass fraction of elements in water. *Proceeding of the republican scientific-practical conference «EXPO-2017: Technologies of the future»*. Karaganda, 2016, pp. 238 – 242.

5 Kussaiynov K., Bulkairova G.A., Shaimerdenova K.M., Kutum B.B., Turgunov M.M., Ranova G.A., Tanasheva N.K. *Electrohydropulse method and device for disinfection of running water.* I.S. of RSE on REA SRIS MJ RK No. 12017 of May 13, 2016.

6 Russov, V.A. *Measurement of partial discharges in the insulation of high-voltage equipment.* Ekaterinburg, USUPS, 2011, 368p.

7 Shuyushbayeva N., Altayeva G., Stoev M., Akhmadiev B. Influence of pulse electrical discharges on the microstructure of the electrode system drill. *Eurasian Physical Technical Journal.* Karaganda, 2016, Vol.13, No.2 (26), pp. 112 – 117.