EROSION OF ALLOYED ELECTRODES IN A SUPERSONIC CHANNEL

M. G. Musaev

UDC 533.924

The study of the patterns of erosional destruction of the material of electrodes operating in the mode of cathode spots in the high-velocity flux of a conducting gas is of great significance for the design of the channels of magnetohydrodynamic pulse generators (MHD generators), which are widely used in the national economy [1].

The electric discharge at the electrodes in an MHD channel can be either contracted, with the electric current being concentrated in one or several current streams, or diffuse, for which an even distribution of the current density on the surface of the electrode is characteristic.

Arc discharge provides high current densities with a small voltage drop at the electrodes. However, the appearance of arcing on the surface of an electrode, accompanied by electrical breakdown of the layers close to the electrode and the boundary layers in the channel, causes erosion of the electrodes, decreasing their life and worsening the usage characteristics of the MHD pulse generator.

The goal of this article is to determine the optimum working modes of the electrode walls of the channel of an MHD pulse generator with minimal erosion.

In the experiments performed for this purpose an impact tube of the diaphragm type was used, consisting of two chambers [a high-pressure chamber (HPC) and a low-pressure chamber (LPC)], divided by a copper diaphragm 1 mm thick with a cross-shaped notch. The 1 mm HPC was filled with a hot oxygen–hydrogen mixture with a helium admixture of an initial pressure of $4 \cdot 10^5$ Pa. A 400 mm measurement channel was mounted at the section of uniform movement of the front speed of the impact wave in the HPC, which simplifies the tests. The design of the apparatus is given in more detail in [2].

An argon–hydrogen mixture with a hydrogen concentration in the mixture of 10% at an initial pressure in the HPC of $1.2 \cdot 10^3$ Pa was used in the HPC. The velocity of the impact waves was found with the aid of ionization sensors placed along the impact tube. The equilibrium parameters of the impact-compressed plasma were determined from the velocity of the impact waves and the initial pressure of the gas in the HPC. The Mach number of the impact waves was $M_1 \simeq 12$, the equilibrium temperature of the plasma was 10^4 K, the velocity of the plasma after the impact wave was 3500 m/sec, the Mach number of the flux was $M_2 \simeq 1.6$, and the pressure after the impact was about $2 \cdot 10^5$ Pa. The duration of the passage of the zone of the impact-compressed gas through the measurement chamber was about 250 μsec.

In investigating the processes in the vicinity of the electrodes we recorded current oscillograms of the pulse discharge of a battery of capacitors with an overall capacitance of $3 \cdot 10^{-3}$ F at an initial voltage of 100-600 V across the interelectrode gap with the impact-compressed plasma and a series-connected load resistance ($R_\ell = 4\ \Omega$).

The optimum conditions of operation were determined with the aid of the volt–ampere characteristics of the interelectrode gap processed in accordance with the oscillograms of the discharge current, together with study of a photographic scan of the luminescence of the discharge at the electrodes as a function of the state of the surface of the electrode and the thermophysical properties of the plasma in the channel.

Minimal erosion occurred in the case in which, during burning of the discharge, the mode of burning of spots of the first type occurred. Electrical discharge in the channel, leading to the appearance on the electrodes of group spots or spots of the second type, causes a marked increase in the speed of erosion [3, 4].

Moscow. Translated from Prikladnaya Mekhanika i Tekhnicheskaya Fizika, No. 3, pp. 3-5, May-June, 1993. Original article submitted June 27, 1990; revision submitted April 20, 1992.

0021-8944/93/3403-0297$12.50

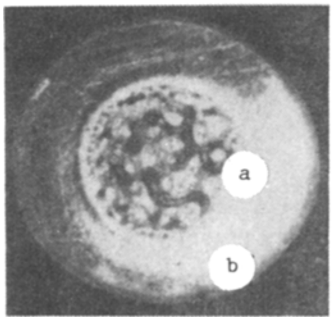

Fig. 1

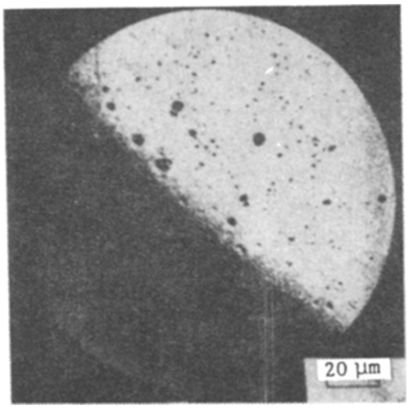

Fig. 2

To begin with, mechanically polished copper electrodes of circular cross section and 10 mm in diameter were used. For I ≥ 20 A, spots of the second type appeared on the electrodes. They were brought together by the flux and situated on the back notch along the electrode flux. Then copper electrodes were used that were subjected to electroarcing processing in the following manner. The working gas (H_2 – 10% + Ar – 90%) was compressed in the HPC. At an initial pressure in the chamber of $p = 1.3 \cdot 10^3$ Pa, a voltage of $U_0 \approx 600$ V was fed to the electrodes. Then at the edges of the electrodes a diffuse orange-violet luminescence was observed by degrees with evacuation of the chamber. When the front of the impact wave arrived, the current flowed in the contracted mode in the center of the electrode.

It is interesting that in the center of the electrode, where the current in the contracted mode flowed (Fig. 1a), fused irregularities, with a clearly expressed boundary in the form of a circumference separating the region of diffusion luminescence (Fig. 1b), are visible. By selecting an electrode surface shape closer to spherical, a uniform diffusion luminescence of the electrode surface was achieved. In this case when interelectrode breakdown occurred, fused irregularities were not observed on the electrode interelectrode breakdown occurred, fused irregularities were not observed on the electrode surface. By this method electrically alloyed electrodes were used in a supersonic channel. Unlike electrodes before alloying, on the alloyed electrodes in the supersonic channel only spots of the first type were observed over a wide range of currents (Fig. 2). On the basis of analysis of the volt–ampere characteristics of the interelectrode gap, it was shown that the resistance of the regions close to the electrodes was lower for the fissionable spots than for the peripheral arc streams [5].

Erosion loss was determined from the size of the holes left by the cathode spots. Optical profilography was used to measure the size of the erosive marks. The relative error reached 10%, while the relative error of measurement of the holes did not exceed 30%. The difference between the true shape of a hole and the assumed shape also affected the measurements. In our measurements the true configuration of the surface of the holes approximated a circle or rectangle. The profiles of the depths of the holes were averaged and in almost all measurements to find the volume of an erosion hole the area of its surface was multiplied by the average value of the hole depth. The intensity of the erosion of the copper electrodes in the supersonic pulse channel in the 10-30 A current range was from 20 to 40 $\mu g \cdot C^{-1}$, which agrees with the data given in [4, 6].

LITERATURE CITED

1. E. P. Velikhov and Yu. M. Volkov, Promising Developments in MHD Pulse Energetics and Its Applications in Geology and Geophysics [in Russian], IAÉ Preprint No. 3436/6, Moscow (1981).
2. M. G. Musaev, É. K. Chekalin, and L. V. Chernykh, "Properties of contracted discharge in a nonhomogeneous boundary layer on an electrode in a high-velocity plasma flux," Prikl. Mekh. Tekh. Fiz., No. 3 (1988).
3. N. M. Zykova and T. S. Kurakina, "An investigation of discharge on cooled copper electrodes in a plasma of combustion products," Teplofiz. Vys. Temp., 14, No. 5 (1976).

4. V. I. Zalkind, V. V. Kirillov, and A. P. Markina, "Cathode spots and erosion of metal electrodes in the channel of an open-cycle MHD generator," Teplofiz. Vys. Temp., 20, No. 6 (1982).
5. M. G. Musaev, V. A. Tishchenko, É. I. Chekalin, and T. V. Yurevich, "An investigation of the mode of nonstationary cathode spots on electrodes in a supersonic pulse plasma flux," in: Engineering Problems at Thermonuclear Power Stations [in Russian], G. M. Krzhizhanovskiy Institute of Power Engineering, Moscow (1981).
6. A. V. Bogdonas, V. A. Bashilov, V. M. Gribkov, et al., "A study of the processes occurring on cold electrodes in the channel of an MHD generator," in: First Soviet–American Colloquium on MHD Energy Conversion [in Russian], Institute of High Temperatures of the Academy of Sciences of the USSR, Moscow (1974).