EFFECT ON THE DISCHARGE REGIME OF BLOWING PROTECTIVE GASES INTO THE LAYER CLOSE TO THE POROUS ELECTRODES OF AN MHD DEVICE

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One of the methods of combatting the erosive and corrosive action of corrosive oxygen-containing plasma streams on the electrodes of MHD devices is by blowing protective gases into the layer next to the electrode [1]. The problem of creating erosive resistant electrode materials has not yet been completely solved, and is, moreover, substantially complicated by the fact that the discharge passes to an arc regime at a certain stage [2]. Thus the application of a blast of protective gases is of interest both from the point of view of using a series of known metal-ceramic materials with restricted resistance to corrosion in the corrosive medium, as well as from the point of view of effecting some control over the processes close to the electrodes.

A series of metal-ceramic materials based on the refractory carbides and borides (TiC, ZrB_2, NbC + Co, $ZrB_2 + LaB_6$) in the form of porous (Π = 30-42%) gas penetrable samples [3] were used as electrodes in a model MHD channel. Graphite of the type PG - 50 was also used. The working stream (T = 2600 °K, V = 350 m/sec) consisted of a jet of air heated in a plasmatron [4], with a potassium additive (up to 1.2%). Argon or purified nitrogen (with oxygen content $O_2 \sim 0.003\%$) was blown through the porous electrode material to protect the surface of the electrodes.

It is well known [5] that the cathode of a MHD device can operate in one of three regimes; distributed discharge in the thermal emission regime, distributed discharge in the saturation regime and arc discharge. The present paper is devoted to the effect of a gas blast on the process of transition to the arc regime.

An analysis of oscillograms of the current-voltage characteristics obtained in the regime of an applied alternating electric field (f = 50 Hz), shows that for the majority of materials tried without a gas blast, the transition to the arc regime occurred for values of cathode potential drop ΔU_1^* = 30-50 V, for the experimental conditions.

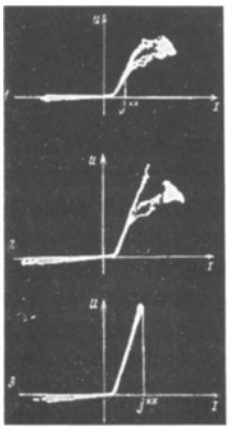

Fig. 1

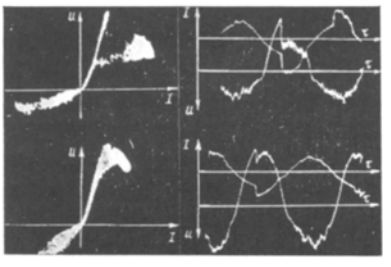

Fig. 2

Moscow and Kiev. Translated from Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, Vol. 11, No. 1, pp. 135-137, January-February, 1970. Original article submitted January 30, 1969.

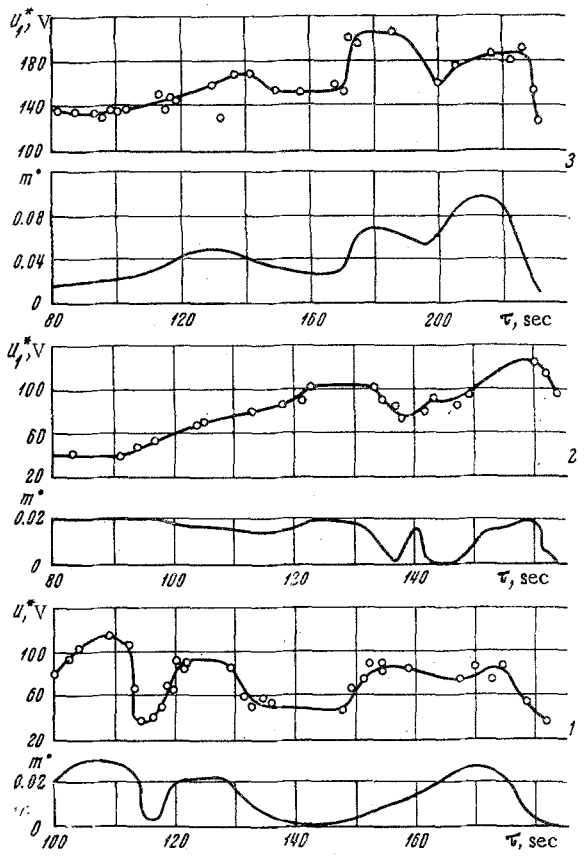

Fig. 3

In the experiments in which argon, and particularly nitrogen was blown in, the provision of the protective gas produced a considerable and marked effect on the transition to the arc discharge regime and on the form of the discharge itself. Characteristic oscillograms for electrodes of porous graphite PG - 50 protected by blowing in nitrogen are given in Fig. 1. For the same electrode surface temperatures and equal amounts of additive $\psi = 0.4\%$, the effect of blowing in more gas becomes evident in the "degeneration" of the arc discharge. The time interval between the oscillograms given here is $\tau = 1.5$ sec.

As more gas is blown in the arc discharge 1 passes to the unstable discharge 2, and in general vanishes within the limits of the applied potential 3. Comparison of the maximum current densities j**, drawn from the electrode in the distributed discharge regime shows that j** for frame 3 is twice as large as j** for frame 1.

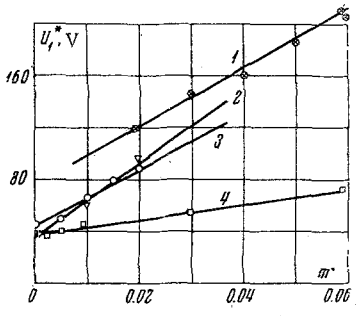

Fig. 4

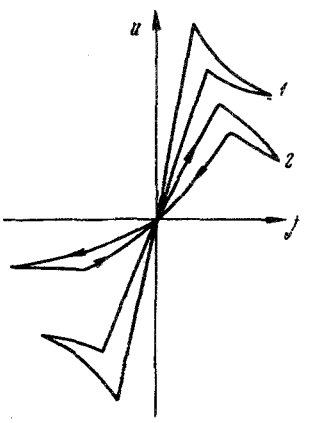

Fig. 5

Two characteristic oscillograms are given in Fig. 2 for electrodes of porous titanium carbide when nitrogen is blown in, as well as the corresponding time scans for current and voltage in the electrode circuit. These characteristics were taken for equal values of temperature and additive concentration and at the same value of the applied potential U = 150 V. It is well known [5] that in the arc discharge zone the specifying parameters for the current-voltage characteristics can be U_1^* the breakdown voltage, and U_2^* the arc extinction voltage, below which no transition to the arc regime for a given material is observed. It is clear that the voltage U_2^* changes by a factor of two on passing from a nitrogen blast corresponding to a parameter $m^* = \rho_W V_W / \rho_0 U_0 = 0.015$ to one corresponding to a parameter 0.025. The time interval between the frames is 10 sec. An increase in the gas blast leads to a decrease in arc intensity both as regards current amplitude, as well as regards the potential drop, which is clear from the time scans of current and voltage.

The voltage U_1^* and the blast parameter m^* are shown in Fig. 3 as a function of the running time for experiments with graphite electrodes, blowing in nitrogen 1 and argon 2, and with electrodes of titanium carbide and a nitrogen blast 3. It is clear that the values of U_1^* follow the pattern of change of the blast curve. It should be noted that the parameter U_1^* is also a weak function of the electrode temperature, and so the curve $U_1^* = f(\tau)$ does not always follow the shape of the blast curve exactly. The values of U_1^* are given for an electrode temperature $T_W = 1200 \pm 150°$ C. The effect of the electrode temperature on U_1^* is small in the range chosen.

The temperature and mass fed into the layer close to the electrode obviously affects the arc discharge regime by changing the resistance of the boundary layer.

With an increase of electrode temperature and the associated decrease in resistance in the boundary layer at the electrode, the discharge becomes more stable [5]. For a constant electrode temperature an increase in the blast of protective gases leads to an increase in the boundary layer resistance, which is clear in Fig. 2 from the increase of the angle of inclination α of the characteristic in the anode regime (for $j < 0$). It is clear that the value $\operatorname{tg} \alpha \sim R_a$ characterizing the boundary layer resistance increases. This increase can be connected both with the change in balance of charged particles in the zone close to the electrode where there is a velocity component normal to the electrode surface, as well as with a decrease in additive concentration in the zone of influence of the blast.

The functions $U_1^* = f(m^*)$ for various values of T_W and ψ are given in Fig. 4 for some materials tested, where curve 1 is for TiC (N_2), $T_W = 1200°$ C; curve 2 is for graphite (N_2, $T_W = 1200°$ C; curve 3 is for graphite (Ar), $T_W = 1000°$ C; curve 4 is for $ZrB_2 + LaB_6$ (Ar), $T_W = 1300°$ C. It is clear that the values of U_1^* can vary by a factor of 3 to 4 as the blast increases up to $m^* = 0.08$.

Distinct hysteresis phenomena for the direct and return path of the beam are clearly observed in the current-voltage characteristics for strong blasts ($m^* = 0.07$-0.1). These are associated with Joule heat liberation in the zone close to the electrode.

The appearance of this type of characteristic is shown in Fig. 5. Curve 2 is an electrode-probe type characteristic [5] for an electrode operating in the arc discharge regime with a strong nitrogen blast. Curve 1 is a typical dynamic characteristic (electrode-electrode type) of an alternating current arc [6]. There is a greater potential drop when the current increases than when it decreases, since in the first case part of the energy is lost in the liberation of Joule heat. The presence of hysteresis is characteristic for cold electrodes and vanishes as the temperature increases because of the thermal inertia of the electrode.

In order for electrode wear to be virtually negligible during the running time (up to 10 min) of experiments in protecting electrodes from oxidation and erosion, blasts of $m^* = 0.02$-0.03 were employed. No hysteresis phenomena are observed to arise in this blast range, but the transition to the arc regime is distinctly drawn out, and the arc at the cathode burns unstably.

We can thus conclude that in addition to thermal and chemical protection of cathode materials the application of a blast of neutral gases enables us to ensure a distributed discharge regime for higher values of the interelectrode potential, other conditions being equal. It also allows us to draw higher current densities without passing to the arc regime. The absence of arc burns also allows us to decrease the electrode erosion.

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