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EFFECT OF THE FREQUENCY OF THE EXTERNAL MAGNETIC FIELD ON THE BEHAVIOR OF THE ARC IN A TWO-JET PLASMATRON

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UDC 533.9

The results of studies of the frequency characteristics of an electric arc in a two-jet plasmatron in a transverse magnetic field are presented.

Interest in the dynamic characteristics of an electric arc has increased significantly in recent years. Thus in [1] the frequency characteristics of the shunting of the arc in the output electrode of the plasmatron with interelectrode inserts were studied. The frequency characteristics of the radial pulsations of the arc column in a longitudinal gas flow in different characteristic sections of the channel are also presented here. In [2], together with an analysis of the shunting of an arc discharge in a longitudinal channel, the oscillations of the electric arc in a transverse gas flow are described. In the cases studied the pulsational characteristics of the electric arc are determined primarily by the hydrodynamic parameters of the gas flows bathing the arc, for example, the degree of its turbulence [1], and depend on the form and proximity of the walls of the arc channel. The imposition of a magnetic field on the arc has a substantial effect on the behavior of the electric arc in a channel [1, 3]. In addition, diverse effects accompanying the burning of the arc in a limited channel, are superposed on the frequency characteristics of the electric arc itself, and they cannot be distinguished in a pure form.

The behavior of an open arc, stabilized by an accompanying gas flow, in a magnetic field has never been adequately studied, though it is of general scientific and practical interest because of the widespread use of and prospects for two-jet plasmatrons.

It is shown in [4] that the imposition of a transverse alternating magnetic field on the anodic and cathodic sections of an electric arc in a two-jet plasmatron enables the realization of effective control of the motion of its sections and the regulation of the power generated in it. The mathematical dependences describing the change in the angle of inclination of the electric field under the action of a constant or weakly varying magnetic field (the frequency of the external alternating magnetic field is equal to 50 Hz) are also presented there.

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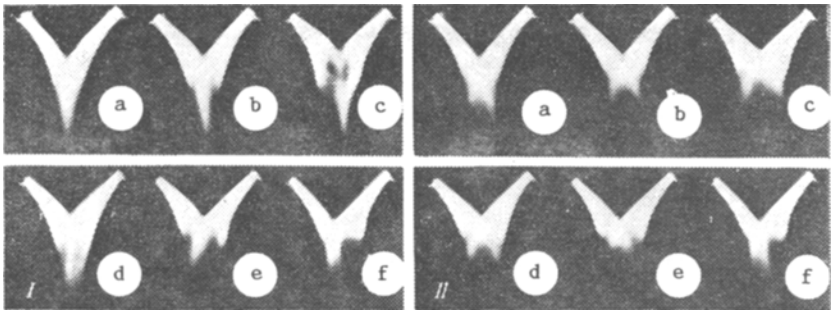

Fig. 1. Photograph of the electric arc in a two-jet plasmatron in a magnetic field of different frequency with the sections of the arc defected in opposite directions (I) and in the same direction (II): a) f = 25 Hz, b) 50, c) 100, d) 150, e) 300, f) 600 Hz.

The purpose of this work is to study the dependence of the basic characteristics of the electric arc in a two-jet plasmatron (voltage, current, and amplitude of the deviation of the anodic and cathodic sections of the arc) on the frequency of the external transverse magnetic field.

The experiments were performed on the setup described in [4]. A GZ-33 acoustic generator, providing an alternating voltage with fixed frequency ranging from 20 to 20,000 Hz on the coils of the magnetic deflection systems, was also used. We recorded the current and the voltage on the arc and on the coils of the magnetic deflecting system with the help of an N-117 oscillograph. The behavior of the electric arc was recorded with the help of a photographic camera and an SKS-1M high-speed motion picture camera. Because of the complicated dependence of the magnetic susceptibility of the ferromagnets on the frequency of the external field [5], the magnetic deflecting system was calibrated with the help of an induction converter [6]. The strength of the current flowing through the coils of the magnetic deflecting systems was adjusted during the course of the experiments so as to obtain a fixed value of the magnetic induction in different sections of the frequency range.

With the help of magnetic deflecting systems we put the anodic and cathodic sections of the arc into oscillatory motion; in addition, in one case we deflected the sections of the arc synchronously in the same direction, while in the other case we deflected them in opposite directions. During the oscillations of the sections of the arc in the same direction, as pointed out in [4], the magnitude of the change in the current and voltage on the arc is insignificant and it is more convenient to judge the amplitude of the deflection of these sections in a magnetic field from visual observations and photographs. In the case of oscillations of sections of the arc in opposite directions, however, because of the substantial change in the overall length of the arc and the concomitant electric indicators, oscillograms showing the change in the current and voltage on the arc are particularly convenient.

Figure 1 shows photographs of the electric arc in a two-jet plasmatron, whose anodic and cathodic sections are subjected to a transverse nonuniform magnetic field with variable frequency. The photographs were taken through a blue light filter. The exposure time was chosen to be longer than the period of change of the external magnetic field, which ensured that the position of the arc would be fixed in all phases of its motion. The arc studied had a current of the order of 100 A, a voltage of 140 V, an argon flow through each nozzle of the order of 0.12 g/sec, output nozzles separated by 80 mm, and an angle of 90° between the sections of the arc. The magnetic induction in the gap between the tips of the magnetic deflecting system was maintained at B = 0.25 mT.

It is evident from Fig. 1 that the amplitude of the oscillations of the anodic and cathodic sections of the electric arc as well as the regions of their coalescence depend substantially on the frequency of the external field. Thus the amplitude of the oscillations of the region of coalescence of sections of the arc is equal to 28 mm at a frequency of 25 Hz, 41 mm at 100 Hz, and 29 mm at 300 Hz. An analogous conclusion can be drawn from the analysis of curves showing the change in the voltage on the arc as a function of the frequency of the external field (Fig. 2). The broken curve shows the voltage on the arc with no magnetic field

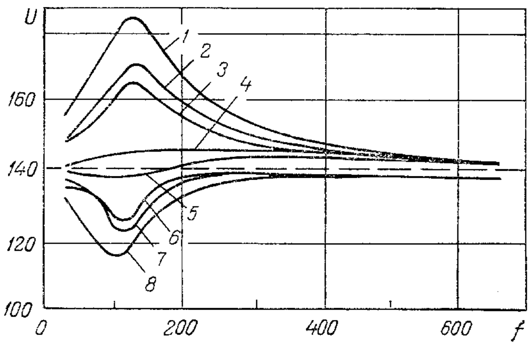

Fig. 2. Voltage on the arc of a two-jet plasmatron versus the frequency of the external magnetic field: 1, 8) the maximum and minimum values of the voltage on the arc of a plasmatron with sections of the arc deflected in opposite directions; 4, 5) same with the sections of the arc deflected in the same direction; 2, 7) same with oscillations of the anodic section of the arc; 3, 6) same with oscillations of the cathodic section of the arc. U in V; f, in Hz.

imposed on it. It follows from the figure that together with the amplitude deflection of the sections of arc the frequency of the external magnetic field strongly affects the change in the voltage in it. In addition the maximum is achieved in the same region of the frequency range 105-115 Hz.

It should be noted that the frequency characteristics of the anodic and cathodic sections of the arc, obtained with their separate oscillations (Fig. 2), are similar to the frequency characteristic of the entire electric arc. The latter apparently permits transferring the results obtained to the behavior, for example, of unilaterally stabilized arcs with direct and reverse polarity [7].

Figure 3 shows curves characterizing the relative changes in the amplitude and voltage on the arc in the course of a full period of the change in the external magnetic field as a function of its frequency. The amplitudes of the deflection of the sections of the electric arc were determined by measuring the width of the illuminated zone on the photographs, obtained in the course of the oscillations of the arc (see Fig. 1). It is evident from the figure that at a frequency of the order of 105-115 Hz a distinct (according to the type of resonance [8]) maximum of the absolute and relative change in the amplitude of the oscillations and voltage on the electric arc is achieved.

To clarify the dependence of the position of the peaks studied on the corresponding frequency characteristics as a function of the magnitude of the magnetic induction of the external field and the operational states of the plasmatron (gas flow rate, current strength, angle between the axes of the anodic and cathodic sections of the plasmatron), a series of additional experiments were performed. In the course of these experiments the indicated parameters were both higher and lower than the previously described parameters, which were used as a base. Thus we varied the induction of the external magnetic field from 0.12 to 0.50 mT, the flow rate of the plasma-forming gas from 0.06 to 0.24 g/sec the current strength from 60 to 140 A, and the angle between the axes of the nozzles of the anodic and cathodic sections of the plasmatron from 60 to 120°.

It should be noted that at the same time the amplitudes of the oscillations of the sections of arc and the regions where they coalesce varied directly proportionally to the change in the magnitude of the induction of the external magnetic field and inversely proportionally to the flow rate of the plasma-forming gas and the current strength in the arc The indicated amplitudes were virtually independent of the mutual arrangement of the anodic and cathodic sections of the two-jet plasmatron. In addition, no changes were observed in the positions of the peaks in the absolute and relative changes of the amplitude of the oscillations of

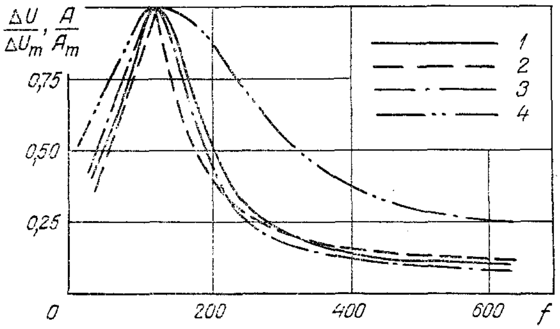

Fig. 3. Relative changes in the magnitude of the oscillations of the voltage on the electric arc and the amplitude of its deflection in an alternating magnetic field as a function of the frequency of the field: 1) change in the voltage accompanying a simultaneous oscillation of the anodic and cathodic sections of the arc in opposite directions; 2) same with oscillations of only the anodic section; 3) same with oscillations of the cathodic section; 4) change in the amplitude of the oscillations of the arc with simultaneous deflection of its anodic and cathodic sections.

sections of arc and in the voltage on it in the corresponding frequency characteristics, i.e., within the indicated ranges of variation of the parameters determining the burning of the electric arc in a two-jet plasmatron its frequency characteristics remain practically constant and independent of them.

The foregoing discussion leads to the conclusion that the freely burning electric arc in a two-jet plasmatron can be described, aside from other parameters, by the characteristic frequency of the oscillations, whose existence must be taken into account in constructing physical and mathematical models of the electric arc and in developing the corresponding technological processes. The observed dependence of the properties of the electric arc on the frequency of the external magnetic field must apparently be manifested, appearing in a more veiled form, not only in freely burning but also in compressed arcs, determining to a large extent their behavior and geometrical form.

NOTATION

I and U, current in and voltage on the electric arc; ΔU_m and ΔU, maximum and instantaneous values of the magnitude of the change in the voltage on the arc during one period of oscillations; A_m and A, maximum and instantaneous values of the magnitude of the amplitude of the oscillations of the arc in an external magnetic field; f, frequency of the external magnetic field; and B, induction of the magnetic field.

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SELECTION OF THE OPTIMAL DISTRIBUTION OF HEAT-TRANSFER AGENT FLOWS IN A VENTILATED CASSETTE RADIOELECTRONIC APPARATUS

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An algorithm for determining the optical distribution of heat-transfer agent flows is proposed, and recommendations regarding the solution of the optimization problem are given.

As the analysis of different structures shows, combined cooling systems are increasingly more often used in radioelectronic apparatus (REA). The most efficient, economical, and simple cooling systems are those based on conductive outflow through heat sinks. However, the higher density of the assembly and the higher power of the electronic equipment make it necessary to use specific methods for removing heat. In many cases the amount of heat removed is increased by natural or forced ventilation [1, 2].

In this work we study electronic apparatus with a cassette construction with forced ventilation. The REA block is assembled from identical boards with modules arranged on them or integrated circuits. The metallic frames and heat sinks play the role of structural elements and raise the effective thermal conductivity of the heated zone. In the general case, the heat sources in such REA are distributed nonuniformly, and each source occupies an arbitrary region and has an arbitrary capacity. In REA of the cassettetype, however, the problem of modeling the heat sources is simplified by the fact that the cassettes or groups of cassettes occupy volumes in the form of steps with a rectangular cross section, the power in which may be assumed to be uniformly distributed.

Experience in constructing REA shows that the volume of stored air or other heat-transfer agent is limited, and this does not permit efficient cooling of the entire volume of the apparatus [3]. In the case of a stepped distribution of heat sources, some zones do not require special cooling, so that it is desirable to ventilate the heated zone only in the regions with the highest thermal loads.

Channels in REA of a cassette form have a rectangular profile, so that the regions of convection, just as the sources of heat, will have the form of rectangular steps.

There arises the problem of selecting the thermal and mathematical model of the apparatus described for the analysis of the temperature field as well as for the formulation and solution of the question of optimal distribution of heat-transfer agent flows between the channels of the apparatus in order to achieve the best, with respect to a definite criterion thermal state.

Thermal Model. The thermal model of the object studied is a particular case of the generalized model studied in [4]. The heated zone of the REA is represented in the form of a uniform anisotropic parallelepiped with effective coefficients of thermal conductivity λ_x, λ_y, λ_z along the corresponding axes (Fig. 1). The heat flux from the surfaces of the parallelepiped escapes into the surrounding medium, and is also carried away by convective air flows, blown through the apparatus. Thus the thermal model can be viewed as a system of two bodies: a uniform anisotropic parallelepiped with a step distribution of heat sources and regions of convection and a moving medium in the channels of the heated zone.

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