LOW-FREQUENCY OSCILLATIONS OF PLASMA ROTATING IN A MAGNETIC FIELD

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The interest in arcs in a magnetic field displacing relative to a gas stream has been rekindled in recent years [1-4]. Although such arcs find application in experimental practice, the phenomena taking place therein have received very little study.

A convenient subject for study of the processes in a moving plasma are arcs rotating in stationary magnetic fields. Separate measurements were made in [3, 4] of the ionization front propagation velocity and the frequencies of the oscillations which develop in the plasma. Unfortunately, the experimental conditions were not comparable. The present paper is devoted to simultaneous study of these interrelated phenomena.

The experimental setup is shown in Fig. 1. The parameters of the oscillations in the arc column and its rate of rotation were determined from the fluctuations of the radial and azimuthal components of the electric field and the oscillation of the brightness of the arc self-radiation in the 6328 ± 40 Å range. The diameter of the luminous area from which the light was gathered was 1.5-2 mm, the pressure varied from 5 to 20 Torr, the discharge current varied from 0.05 to 0.40 A. Argon was used as the working medium.

When the magnetic field was imposed the arc began to rotate. Figure 2a shows an oscillogram of the self-radiation, from which we determined the arc rotation period. Similar oscillograms were obtained with the aid of dual probes. The rotation frequency ω and the linear velocity V of the arc motion as a function of magnetic field intensity are shown in Fig. 3a. In these experiments the gas pressure was 10 Torr, the arc current was 0.11 A, and the voltage drop across the arc was 50-60 V.

The linear velocity of the arc rotation is close to the ionization front velocity (Fig. 3b) measured under similar conditions [3], although it does exceed the latter somewhat. This may be explained by entrainment of gas by the rotating motion of the arc.

Since the gas pressure and current density in the arc are low, it follows from [3] that the arc must be scavenged with a stream of neutral gas. Such an arc is best described by the so-called porous cylinder model.

The dependence of the arc rotation rate on the magnetic field intensity, calculated from the relation

$$\frac{1}{c}\,\mathbf{j}\times\mathbf{H}=n_i\sum_k m_k\nu_{ka}(\mathbf{V}-\mathbf{V}_a),$$

was close to that shown in Fig. 3a.

Here $\mathbf{j}$ is the arc current density, H is the magnetic field intensity, c is the speed of light, n_i is the charged particle concentration, m_k is the reduced mass, ν_{ka} is the charged particle-neutral collision frequency, V_a is the neutral gas velocity increase owing to rotational motion of the arc.

In studying the individual luminous pulses, we detected the structure (Fig. 2b and c) corresponding to internal, comparatively low-frequency (1-10 kHz) oscillations of the plasma inside the arc column. The

Moscow. Translated from Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, Vol. 10, No. 5, pp. 141-143, September-October, 1969. Original article submitted April 23, 1969.

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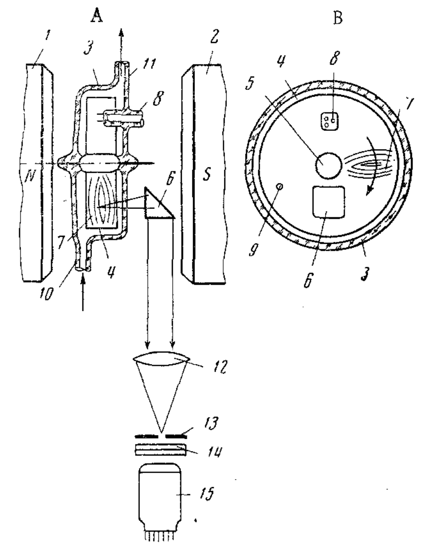

Fig. 1. Experimental setup: 1,2) electromagnet poles; 3) glass vessel; 4) hollow cylindrical anode with inside diameter 80 mm; 5) heated cathode with outer diameter 25 mm; 6) rotating prism for bringing out arc self-radiation; 7) arc; 8) triple-electrode probe with 2.5-mm distances between electrodes; 9) thermocouple; 10,11) fittings for argon in and out; 12) converging lens; 13) visual field diaphragm; 14) interference filter; 15) photomultiplier.

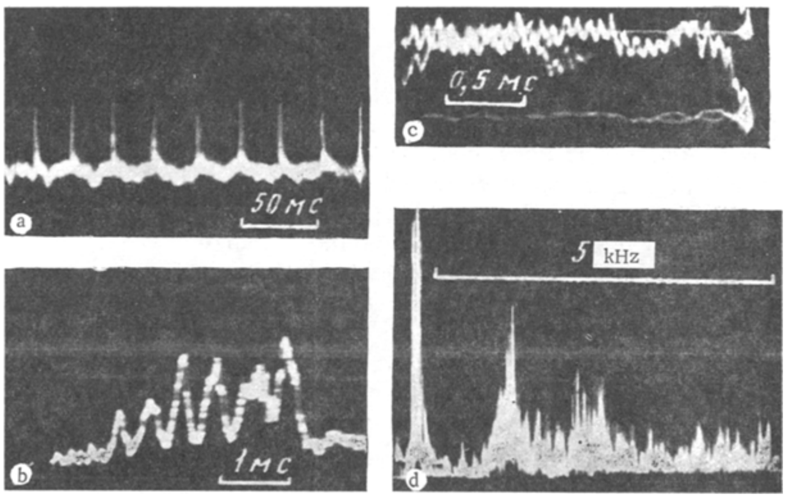

Fig. 2. Oscillograms: a) arc self-radiation pulses; b) self-radiation pulse structure; c) high-frequency oscillations of plasma luminosity; d) frequency spectrum of luminosity oscillations.

characteristic spectrum of these oscillations, obtained using a spectrum analyzer, is shown in Fig. 2d. The oscillation frequency ω is linearly related with the magnetic field intensity (Fig. 3c). In the probe measurements these oscillations were observed only at frequencies close to 10 kHz. Similar oscillations observed previously using the probe method were interpreted as oscillations of the drift type [4].

In our experiments both drift and magnetoacoustic oscillations could arise [5-7]. Measurements of the amplitude of the arc plasma density gradient oscillations by the schlieren method using a He – Ne laser were undertaken in order to clarify the nature of the oscillations. In view of the small degree of ionization the effect of the electronic component could be neglected. The sensitivity of the setup with respect to argon was 10^{16} cm^{-4} atoms. The amplitude of the oscillations was below this magnitude and reliable amplitude measurements could not be made.

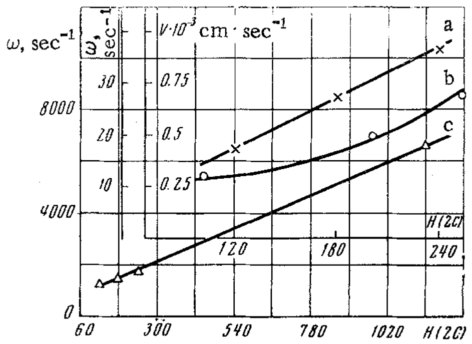

Fig. 3. Curves: a) arc rotation frequency; b) ionization front velocity; c) frequency of internal oscillations of arc plasma as a function of the magnetic field intensity.

Thus, the study showed the following: 1) the arc rotation velocity is very close to the ionization front propagation velocity; 2) both the arc rotation velocity and self-oscillation frequencies are linearly connected with the intensity of the external magnetic field; 3) the density oscillation amplitudes are very small and for the neutral component amount to less than 10% of the average value.

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