PLASMA JET DEVIATION IN A TRANSVERSE MAGNETIC FIELD

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Study of the plasma jet ejected from the anode orifice of a hydrogen arc plasma source [1-3] has shown that the jet protons have a relatively large longitudinal energy (40-90 eV) [4]. The present study will offer a new method of determining the longitudinal energy from the rotation of a plasma jet in a transverse magnetic field. We will consider the motion of a plasma jet with total current I and ion current I_p in a transverse magnetic field H. The mass per unit length M is related to I_p and the longitudinal proton velocity V by the expression $M \simeq m_p I_p/eV$. When a magnetic force $F = IH/c$ acts on a unit length of such a jet it forms an arc of radius $R = MV^2/F$. When the jet detector is located in a plane removed from the beginning of the jet by a distance L (Fig. 1), the radius R can be defined by the jet deviation Y: $R = (L^2 + Y^2)/2Y$. Therefore the energy of longitudinal proton motion can be determined from the three measured quantities I, I_p, and Y:

$$\frac{1}{2} m_p V^2 \simeq \frac{1}{2} m_p \left(\frac{ReHI}{m_p I_p c}\right)^2 = \frac{1}{8} m_p \left(\frac{eH}{m_p c}\right)^2 \left(\frac{I}{I_p}\right)^2 \left(\frac{L^2+Y^2}{Y}\right)^2. \qquad (1)$$

The jet deviation Y is determined from current signals from 15 independent parallel probes, constructed of gold-coated tungsten wires 30 μm in diameter and 40 mm long, connected to a beam analyzer system [5]. These probes are located 7 mm apart from each other in a plane which is removed from the anode orifice by a distance L = 80 mm. The deviation can only be determined when the jet profile can be sufficiently determined from the probe signals. Such narrow profiles will be found only at low gas pressures in the valve [6], pulsed injection of gas into the arc channel, or at low delay times for arc firing relative to gas injection, i.e., when the plasma jet is weakly scattered through the gas flowing out of the anode orifice. The degree to which scattering expands the jet is shown in Fig. 2, which presents two plasma jet profiles generated by a 270-A arc at a flow rate of $2 \cdot 10^{17}$ gas molecules/pulse (narrow profile) and at a flow rate of $6 \cdot 10^{17}$ gas molecules/pulse (wide profile). Therefore, profile measurements were performed at a flow rate of $2 \cdot 10^{17}$ molecules/pulse with an arc firing delay of 500 μsec, when the profile was sufficiently narrow. Figure 3 shows two profiles of a jet with proton current of 0.6 A and total current of −1 A, deviated by magnetic fields of +38 and −38 G. These profiles permit an accurate determination of the zero point

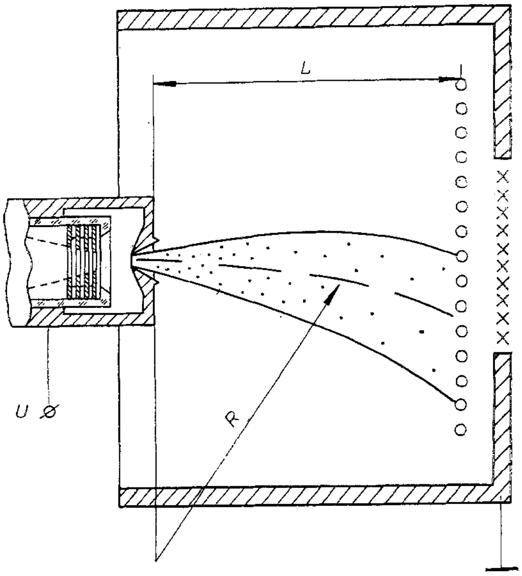

Fig. 1

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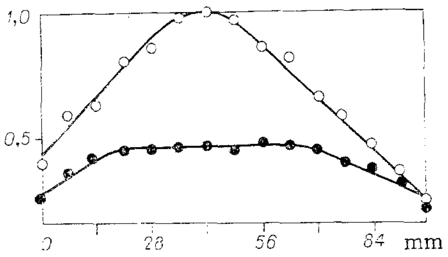

Fig. 2

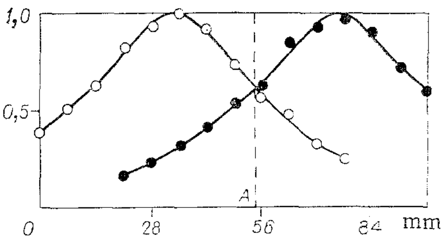

Fig. 3

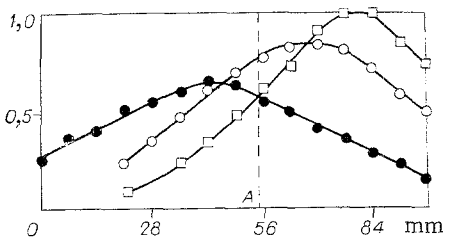

Fig. 4

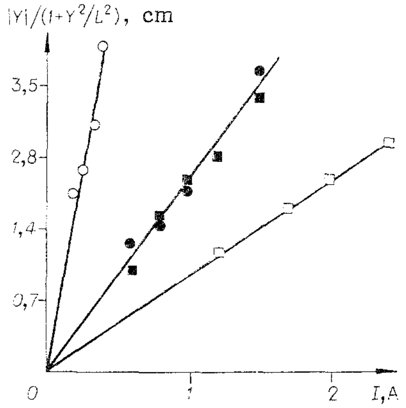

Fig. 5

(point A, Fig. 3) relative to which the deviations of the centers of the beam profiles were then measured. Figure 4 also shows several profiles of the same jet with different total currents (−1.3 A, □ ; −0.8 A ○ ; +0.6 A, ●) in a field of +38 G. It is evident from Fig. 4 that change in the total current from positive to negative shifts the profile to the right-hand side of the zero point A. Increase in negative current leads to a narrowing of the profile, which significantly improves the accuracy with which its center can be determined. Similar profiles were also taken for a field of −38 G. Jet deviations as functions of total current in various magnetic fields and at various proton currents in the jet are shown in Fig. 5 (0.6 A, ±38 G, ●, ■; 0.7 A, 22 G, □ ; 0.03 A, 132 G, ○). For the plasma jet with 0.03-A proton current the total current scale is an order of magnitude smaller than depicted. It is evident from Fig. 5 that the quantity $|Y|/(1+Y^2/L^2)$ depends linearly on total current I, which is controlled by the anode potential U (see Fig. 1). The slopes of the lines of Fig. 5 increase with increase in magnetic field and with decrease in proton current. The effects noted agree with Eq. (1). This means that the plasma jet moves in a transverse magnetic field as it does in a conductive liquid. The observed slopes of the lines in Fig. 5 gives longitudinal proton energies as follows: 55 ± 5 eV, □ ; 60 ± 5 eV, ● , ■; 100 ± 20 eV, ○). These energies are close to those determined from the radial divergences of plasma jets with similar proton currents [4], and several times greater than the energies determined by proton rotation in a transverse magnetic field within a plasma jet with proton current of several tens of amperes [7].

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