Evaluation of plasma parameters during the explosive electron emission pulse of vacuum arc cathode spot cell

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A simple complete model of the explosive emission pulse of the cathode spot cell has been proposed that involves both – the ignition and the decay of the explosive plasma. The ignition is due to the hydrodynamic tearing of the liquid metal jet, propagating into the plasma generated by the preceding explosive cell. The decay is due to the plasma expansion and the density decrease down to the initiation one. The explosion per se is treated as the transition of the jet material over the critical state.

The average parameters of the plasma have been evaluated. In particular, the plasma basic parameters – the density and temperature are about 10^{20} cm^{-3} and 1 eV respectively.

The ratio of the average pressure to the average current density has been evaluated

$$\langle p\rangle/\langle j\rangle \approx n_0\, T_{cr} / j_{\max},$$

where n_0 is the initial (liquid-metal) density, T_{cr} is the critical temperature, and $j_{\max}$ is the maximal current density during the tearing that is about few GA/cm^2. This ratio gives a specific plasma acceleration force, and the obtained value that is about tens of g cm / C s agrees with the measured recoil force and with the product of measured ion velocity and erosion rate, $v_i \times \gamma_i$.

The average ohmic electric field $\langle E\rangle = \langle j/\sigma\rangle$ has been found to be several tens of kV/cm. This field is responsible for the current transfer through the explosive plasma and, hence, the cathode potential fall formation. For the known cathode potential fall, the corresponding specific plasma size is several micrometers. Such a plasma is formed after the explosion of the entire liquid-metal jet. In addition, the total current flowing through an exploding liquid-metal jet has been estimated to be some amperes.

Finally, a general estimate of the plasma-to-magnetic pressure ratio $\beta = 8\pi p/B^2$, for a current-carrying plasma column has been derived

$$\beta\, \kappa^2\, n\, R^2 = 4 m_e c^2/e^2 = 1.41{*}10^{13}\ \mathrm{cm}^{-1}$$

(where $\kappa = j\sqrt{\frac{2\pi m_e}{T_e}}\,/\,en < 1$ is the current fraction) that indicates that the column compression by a magnetic field ($\beta < 1$) takes place only for large-scale low-density plasmas ($n\, R^2 > 10^{14}$ cm^{-1}), such that occurs far from explosive cells.

Recall that we have considered likely lowest plasma density – near the initiation threshold (10^{18} cm^{-3}) and have derived nearly the maximal current density (exceeding 1 GA/cm^2). One should stress that there is no issues of the space charge emission limitation as the current of this density flows inside a tearing liquid-metal jet.

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