SHEATH VS. QUASI-NEUTRAL PLASMA VOLTAGES IN HIGH-PRESSURE ARC DISCHARGES*

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Two very different approaches to theoretical description of interaction of high-pressure arc plasmas with refractory cathodes exist in the literature. One group of researchers believes that space-charge effects on refractory cathodes are small and contribute to the arc voltage no more than one or two volts. Accordingly, these researchers use simulation models which are based on the assumption of quasi-neutrality, or even stronger assumption of local thermodynamic equilibrium (LTE), in the whole arc volume. Other researchers believe that the voltage drop in the near-cathode space-charge sheath is no less than 10V and rely on models where the near-cathode sheath plays a central role.

Extensive experimental data on near-cathode voltage obtained during the last decade for low-current arcs ($I \leq 10$A), which are in the range 10-50V, indicate that the first above-described (no-sheath) approach is not justified and the second (sheath-accounted) approach should be used for such arcs, and this is a common knowledge now. Unfortunately, reliable experimental data are difficult to obtain for high-current arcs. The status quo is as follows: the sheath-accounted approach is used in virtually all works on modelling of low-current arcs; the no-sheath approach is used in most works on high-current arcs. Amazingly, there has been little interaction between research in these two fields, in spite of the physics of near-cathode plasma layers in high- and low-current arcs being similar, and the question as to what physical reasons could justify the use of so strongly different approaches has not even been asked.

In this work, both a sheath-accounted model and an LTE model are used for modelling of electrical characteristics of a short atmospheric-pressure argon arc. It is found that the LTE model substantially overestimates the resistance of the part of the arc column adjacent to the cathode sheath. Furthermore, it is shown that if this resistance is evaluated in the framework of the LTE model in an accurate way, than the calculated arc voltages are significantly higher than those observed in the experiment. However, conventional numerical algorithms like SIMPLE perform this evaluation in an inaccurate way and the use of these algorithms amounts to a cut-off, which is why it is possible to obtain in the modelling arc voltages comparable to the experimental values.

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