Role of the Diffusion Current in Nonequilibrium Modeling of Welding Arcs

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Abstract

It has been recognized that self-consistent models of the arc and the electrodes could give the required realistic predictions of the arc voltage over a wide range of arc currents provide that they account for nonequilibrium effects in the near-electrode regions. Models based on the assumption of local thermodynamic equilibrium (LTE), on the other side, predict arc voltages which do not differ much from experimental values only for high arc currents, where the main contribution to the total arc voltage results from the arc column. Therefore, a physically justified arc model has to consider deviations from both thermal and ionization equilibrium. Another hot topic in the arc modelling is the usage of the Ohm's law in its general form, i.e. accounting for the diffusive transport of electrons and ions. In the near-cathode region of the arc, the diffusion current of the electrons is reaching values competing with the conductive current and hence the total electron current is significantly reduced. In the near-anode region, the diffusion current provokes a negative voltage.

In the present work, a 2D self-consistent nonequilibrium model of an arc in argon will be presented. The model is based on the COMSOL Multiphysics® platform and describes the fluid dynamics, the heat transfer, the magnetoelectrodynamics, and species conservation. The corresponding equations are strongly coupled and a special attention has to be paid to the initial and solver conditions. The governing equations are solved applying the COMSOL Multiphysics® interfaces of Laminar Flow, Electric Currents, and Magnetic Fields, which are complemented by Weak Form PDE for the temperatures of electrons and heavy particles, and species conservation for the ions.

Results obtained with the nonequilibrium model demonstrate beside the typical arc plasma characteristics (e.g. temperatures of electrons and heavy particles, particle densities, electric current density, electric potential, flow velocity) the role of the diffusion current in the near electrode regions.