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MODEL OF THE PROCESSES OF HEAT, MASS AND CHARGE TRANSFER IN THE ANODE REGION AND COLUMN OF THE WELDING ARC WITH REFRACTORY CATHODE

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The main difference of the proposed mathematical model of the welding arc from the known ones describing the atmospheric-pressure arcs is allowance for the multi-component composition of the arc plasma, which is caused by evaporation of the anode metal and convective diffusion of metal vapours in the arc column. The model can be used for numerical analysis of thermal, gas-dynamic and electromagnetic characteristics of the arc plasma in inert-gas tungsten-electrode and plasma welding, as well as for modelling of thermal and dynamic effects of the arc on the weld pool surface.

Keywords: *tungsten-electrode welding, plasma welding, electric arc, arc column, multi-component plasma, anode region, anode potential drop, mathematical model*

Many models are available for numerical investigation of the processes of energy, impulse, mass and charge transfer in plasma of the electric arc, as well as of the processes of its interaction with electrodes using different arc welding methods [1–14]. However, most of them assume that the arc plasma is one-component, i.e. containing atoms and ions of a shielding or plasma gas, which is the inert one in the majority of cases. As a rule, plasma of the real welding arcs is multi-component, as along with gas particles it also contains atoms and ions of an evaporating material of electrodes, and anode in the first turn. Therefore, it is necessary to allow for the multi-component nature of the arc plasma in development of an adequate mathematical model.

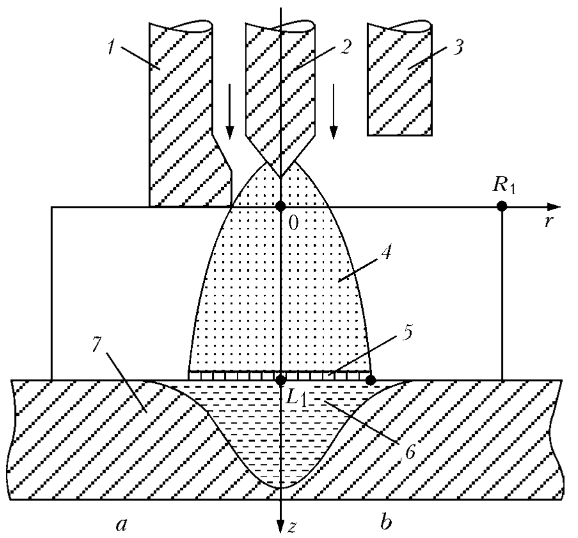

Figure 1. Schematics of plasma (*a*) and TIG (*b*) welding: *1* — plasma-shaping nozzle; *2* — refractory electrode (cathode); *3* — shielding gas nozzle; *4* — arc column; *5* — anode region of the arc; *6* — weld pool; *7* — workpiece (anode)

Such a model must have another important characteristic — self-consistency, which makes it possible to allow for relationship between the physical processes occurring at electrodes and in near-electrode plasma regions and processes occurring in the arc column. It should be noted that the majority of studies dedicated to integrated modelling of the electric (including welding) arc use fairly simplified models of the near-electrode regions [4, 6, 9–12], whereas studies dedicated to investigation of the near-electrode phenomena (e.g. [15] and references given in it) pay an insufficient attention to the processes occurring in the arc column.

As theories of the cathode phenomena, as well as processes occurring in the near-cathode plasma of the electric arc with a refractory (non-evaporating) cathode are adequately elaborated [16–19], the purpose of the present study consists in development of the self-consistent mathematical model of physical processes taking place in the anode region and welding arc column (electric arc with the evaporating anode) in inert-gas tungsten-electrode and plasma welding (Figure 1).

Processes occurring in the arc plasma adjoining the surface of the evaporating anode are described by using the approach suggested in studies [20–22], according to which the near-anode plasma is conditionally subdivided into three zones (Figure 2).

The first zone directly adjoining the anode surface is a layer of the space charge, wherein the condition of quasi-neutrality of the plasma in violated and the main potential drop takes place between the plasma and anode. This layer can be considered collisionless, as under a pressure close to the atmospheric one and at electron temperature $T_e \sim 1$ eV characteristic of the conditions under investigation [23, 24], thickness of