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MODELLING OF PROCESSES OF HEAT-, MASS- AND ELECTRIC TRANSFER IN COLUMN AND ANODE REGION OF ARC WITH REFRACTORY CATHODE

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Numerical analysis of thermal, electromagnetic and gas-dynamic characteristics of plasma of free-burning arc in argon at atmospheric pressure with tungsten cathode and copper water-cooled anode was performed in the anode region and column of welding arc based on self-consistent mathematic model of processes of heat-, mass- and electric transfer. Results of calculation of current density on the anode and heat flow in the anode are compared with the available experimental data. It is shown that considering of the anode potential drop in the model provides more accurate predictions of the characteristics of heat and electric interaction of arc plasma with anode surface.

Keywords: *fusion welding, electric arc, refractory cathode, arc characteristics, modelling of heat-, mass- and electric transfer*

Information about thermal, electric and dynamic effects of arc on welded metal is necessary for efficient application of the electric arc as a heat source in fusion welding. Investigation of welding arcs using the mathematic modelling methods [1–8] seems to be relevant since experimental determination of characteristics of the welding arc important from technological point of view such as density of electric current and heat flow over the surface of welded part is complicated due to high values of temperature of arc plasma and metal surface temperature, small geometry of region of arc fixation and series of other factors.

Let us consider the electric arc with refractory cathode burning in inert gas at atmospheric pressure. The main attention will be given to the processes taking place in a column and anode region of the arc since theory and mathematic models of cathode phenomena, including processes in a near-cathode plasma, were developed in sufficient details for such an arc [9–12]. Study [13] proposed a self-consistent mathematic model of indicated processes for conditions of nonconsumable electrode welding and plasma welding. The aim of the present work is a verification of given model by means of numerical investigation of distributed characteristics of plasma of column and anode region of a free-burning arc with tungsten cathode and copper water-cooled anode and comparison of obtained results with available experimental data.

Two interconnected models are included in the self-consistent mathematic model of the processes of energy-, mass- and electric transfer in the column and anode region of the welding arc with refractory cathode in accordance with approach applied in [13]:

- model of arc column describing interaction of thermal, electromagnetic, gas-dynamic and diffusion processes in multicomponent plasma of the arc column;
- model of anode region which allows determining characteristics of thermal and electric interaction of arc with anode surface (part), necessary for analysis of thermal, electromagnetic and hydro-dynamic processes in welded metal.

Model of the anode region of arc with evaporating anode proposed in study [13] allows calculating distribution of anode potential drop $U_a = -\Delta\varphi$ along the anode surface and density of heat flow q_a, being entered in the anode by arc, depending on current density on the anode j_a, temperature of electrons of plasma near the anode T_{ea} as well as temperature of its surface T_s. Distribution of j_a and T_{ea} along the anode surface can be determined with sufficient accuracy in modelling of the arc with refractory cathode based on the model of arc column with self-consistent boundary conditions on the anode.

Comparison of calculation value $\Delta\varphi$ with one experimentally measured for the case of application of the arc with tungsten cathode and copper water-cooled anode burning in argon at atmospheric pressure (arc current 200 A, 10 mm length) was carried out for verification of conformity of selected model of anode processes. The following experimental data [14, 15] were used in calculations: $j_a = 3.5\cdot10^6$ A/m^2, $T_{ea} = 9840$ K, $T_s = 720$ K, that provides $\Delta\varphi = 4.04$ V. Obtained calculation value complies with experimentally measured $\Delta\varphi = 4.01$ V [15] with high accuracy. Figures 1 and 2 show applied in further calculation dependencies of $\Delta\varphi$ and q_a on temperature of electrons in the near-anode plasma and density of electric current on the anode for the free-burning argon arc with refractory cathode and copper water-cooled anode.