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CONTENTS

SCIENTIFIC AND TECHNICAL

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CHARACTERISTICS OF NON-EQUILIBRIUM ARC PLASMA IN PLASMATRON NOZZLE CHANNEL

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A mathematical model was developed for processes of energy, pulse, mass and discharge transfer in non-equilibrium plasma of electric arc, burning in cylindrical channel with water-cooled walls being blown out by laminar flow of plasma inert gas. The model is based on multi-fluid equations for nonisothermal, ionization non-equilibrium arc plasma, considering double ionization of atoms of the plasma gas written in a drift-diffusion approximation. Such an approach allows uniform description of the processes taking place in central region of the channel (in arc column plasma) as well as near-wall region (in plasma ionization layer) up to interface of space charge layer directly adjacent to channel wall. Consideration of the processes taking place in collisionless layer of space discharge and determination of characteristics of thermal and electric interaction of arc plasma with channel wall is carried out using corresponding boundary conditions on interface of the indicated layer. Besides, if presence of doubly charged ions in arc plasma is taken into account, it is possible to calculate its characteristics in a wide range of values of arc current and channel radius. Numerical solution of equations of the proposed model is carried out by finite volume method. Corresponding software is developed for computer realization. Detailed numerical analysis is given to radial distribution of characteristics of argon arc plasma in the cylindrical channels of direct plasmatron nozzle as well as intensity of longitudinal electric field in arc plasma and heat flow from plasma to channel wall at different values of arc current, channel radius and consumption of plasma gas. It is shown that in contrast to the central regions of the channel, where arc plasma is virtually equilibrium, a significant thermal and ionization non-equilibrium of plasma is realized in the near-wall region. It is also shown that increase of arc current and reduction of channel radius requires consideration of the doubly charge ions present in arc plasma. Comparison of results of modelling of characteristics of the non-equilibrium argon arc plasma in the plasmatron nozzle channel with available experimental data was carried out. 11 Ref., 1 Table, 9 Figures.

Keywords: *arc plasmatron, plasma-shaping channel, electric arc in channel, non-equilibrium plasma, mathematical modelling*

Development of new and improvement of existing plasma technologies, such, for example, as plasma welding, cutting, powder surfacing and coating deposition require reliable information on integral and distributed characteristics of plasma, generated by direct and indirect arc plasmatrons depending on type and structural peculiarities of the plasmatron, mode of its operation and composition of plasma gas. Thermal, gas-dynamic and electromagnetic characteristics of arc plasma flow, generated by such devices, are mainly determined by its interaction with a wall of plasmatron plasma-shaping channel. Besides, specified interaction determines the characteristics of heat and electric effect of arc plasma on the channel wall. They allow optimizing plasmatron design and increase its operation life. Experimental determination of the characteristics of arc plasma in the plasmatron channel as well as characteristics of its interaction with the channel wall is complicated due to small geometrical dimensions of the channel, high values of plasma and wall temperature.

Therefore, aim of the present work is a development of mathematical model and accurate numerical research of the processes of energy, pulse, mass and discharge transfer in non-equilibrium plasma of electric arc, burning in plasmatron cylindrical channel, as well as determination of heat and electric characteristics of its interaction with the channel wall.

The model based on multi-fluid equations for thermal and ionization non-equilibrium plasma [1] can be used for theoretical description of the processes of energy, mass and electric transfer in arc plasma volume, containing electrons, ions and neutral atoms. An approach, similar to one proposed in works [2–6] for investigation of cathode and anode processes in the electric arc, including with doubly and triply charged ions, can be used for consideration of the processes of interaction of such a plasma with the channel wall.

Corresponding approaches were earlier used for numerical analysis of distributed characteristics of