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CONTENTS

SCIENTIFIC AND TECHNICAL

<i>Krivtsun I.V., Demchenko V.F. and Krikent I.V.</i> Model of the processes of heat, mass and charge transfer in the anode region and column of the welding arc with refractory cathode	2
<i>Makhnenko V.I., Markashova L.I., Berdnikova E.N., Shekera V.M. and Onoprienko E.M.</i> Kinetics of corrosion crack growth in 17G1S pipe steel	10
<i>Som A.I. and Zelnichenko A.T.</i> Numerical calculation of thermal processes in centrifugal plasma powder cladding	13
<i>Dmitrik V.V. and Bartash S.N.</i> Features of damageability of steam pipeline welded joints by the creep mechanism	19
<i>Kravchuk L.A.</i> Elimination of undercuts in EBW with complete and incomplete penetration	22
<i>Bely A.I.</i> Influence of main technological parameters of the plasma cladding process on properties of composite deposited metal	25

INDUSTRIAL

<i>Kuchuk-Yatsenko S.I., Kachinsky V.S., Ignatenko V.Yu., Goncharenko E.I. and Koval M.P.</i> Magnetically-impelled arc butt welding of parts of automobile range of products	28
<i>Kah P., Salminen A. and Martikainen J.</i> Laser-arc hybrid welding processes (Review)	32
<i>Khorunov V.F., Maksymova S.V. and Stefaniv B.V.</i> Manufacture of drill bits for production of dispersed methane in mine working	41

BRIEF INFORMATION

<i>Sidorenko P.Yu. and Ryzhov R.N.</i> Application of pulse electromagnetic effects to control the process of electrode metal transfer in arc welding	44
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NEWS

Solemn Meeting dedicated to the Jubilee of Victory in the Great Patriotic War	46
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INFORMATION

Automatic machines ADTs 625, ADTs 626 and ADTs 627 for orbital welding of pipelines	47
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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.

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 is 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

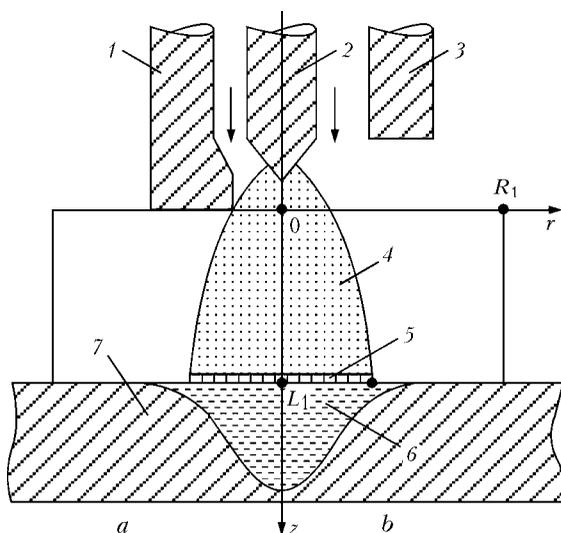


Figure 1. Schematics of plasma (a) and TIG (b) welding: 1 – plasma-shaping nozzle; 2 – refractory electrode (cathode); 3 – shielding gas nozzle; 4 – arc column; 5 – anode region of the arc; 6 – weld pool; 7 – workpiece (anode)