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FORMATION OF LIQUID METAL FILM AT THE TIP OF WIRE-ANODE IN PLASMA-ARC SPRAYING

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A mathematical model is proposed, describing formation of a molten metal film at the tip of sprayed anode-wire under the conditions of plasma-arc spraying of coatings. Numerical analysis of the influence of spraying mode parameters on the position of molten wire tip relative to plasma jet axis, thickness of liquid interlayer contained on the wire tip, temperature and velocity of metal flow in it was performed.

Keywords: *plasma-arc spraying, coatings, wire-anode, spraying modes, thermal condition, molten metal film, mathematical model*

Stability of the process of plasma-arc wire spraying, as well as formation of specified quality characteristics of coatings, are largely determined by the conditions, under which the concentrated flow of spraying material particles is formed. Parameters of the formed dispersed particles depend chiefly on the intensity of the processes of thermal and gas-dynamic interaction of melting wire-anode with arc plasma flow moving around it. Therefore, detailed study of the above processes, including development of the appropriate mathematical models, is highly important for further progress of plasma-arc spraying technology.

Spraying of wire consumables is not given enough attention in scientific-technical publications, the available work being devoted, mainly to the process of electric-arc metallizing [1–3]. Results obtained in the above studies are not applicable to the process of plasma-arc spraying, as it differs by the location of sprayed wire relative to the arc (the latter form an angle of 70–90°), as well as high values of temperature (up to 30,000 K) and velocity (up to 4000 m/s) of plasma, flowing around the wire [4].

For the conditions of plasma-arc spraying a model was earlier proposed for thermal processes in solid metal wire-anode, fed into the plasma arc behind the plasmatron nozzle tip [5]. This model allows forecasting the temperature field and calculating the molten metal volume depending on the parameters of plasmatron operation mode, wire feed rate and diameter, as well as its position in space relative to the tip of plasma-shaping nozzle and distance from molten wire tip to plasma jet axis. However, the melt zone thickness obtained within this model can differ considerably from that observed in the experiments. The reason for that is the molten metal at the wire tip being under a considerable dynamic impact of the plasma flow that results in just part of the melt being contained at the wire tip, forming a liquid interlayer, and part being carried off into a thin jet — so-called tongue [1]. Here, the molten wire tip takes up such a position relative to plasma jet axis that corresponds to the thickness of liquid interlayer, ensuring a balance of thermal and dynamic impact of plasma on the molten metal. In other words, for a correct determination of the parameters of liquid metal interlayer contained on the sprayed wire tip, as well as distance from the molten wire tip to the plasma jet axis, it is necessary to coordinate the calculations within the thermal model [5] with calculations of gas-dynamic impact of the transverse plasma flow on the molten metal. Development of such a self-consistent model is exactly the objective of this study.

When plotting a mathematical model of formation of molten metal film at the tip of sprayed wire-anode under the conditions of plasma-arc spraying, let us assume that solid metal wire of round cross-section of radius R_w is fed into the plasma arc at constant rate v_w normal to the axis of symmetry of the plasma flow (Figure 1). The arc closes on the wire right end which is the anode. Let us also assume that the melting front is flat (plane $z_b = 0$) and is located normal to the plasma flow axis at distance L_p from it, and the rate of wire melting is equal to its feed rate. Under the impact of the arc anode spot and high-temperature plasma flow moving around the arc, it is heated, and molten metal volume of thickness L_{liq} forms at its tip, that is carried off into a thin jet by plasma flow moving around the arc. Let us assume that the upper part of liquid interlayer contained at the wire tip takes the form of a spherical segment under the impact of the arriving plasma flow, the spherical segment having height L_b and radius R_b of a sphere forming the segment with the center in a point located at distance L_0 from the melting front ($R_b = L_0 + L_b$; $R_b^2 = L_0^2 + R_w^2$) (see Figure 1).

As a result of removal of part of the melt from the wire tip, the conditions of heat balance in it are violated. Tending to an equilibrium condition, the wire will take up such a position relative to plasma jet axis, defined, for instance, by distance $L_p - L_b$, at which the volume of liquid interlayer contained at the