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The Use of Discontinuous Functions for Modeling the Dissolution Process of Steady-State Electrochemical Shaping

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Abstract—We consider a modified statement for the electrochemical shaping problem. In modeling the process of the anodic dissolution we use a jump-like current efficiency function that defines the rate of the movement of the anode border. The anode surface is divided into three parts, namely, that of the active dissolution, that of no dissolution (with a small current density), and a transient part, where the current density equals the critical value.

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The study of electrochemical shaping is of great practical interest, because the technologies of electrochemical machining (ECM) are widely used in various branches of industry. Works [1–4] are devoted to the mathematical modeling of ideal ECM processes by means of the theory of functions of complex variables.

The dissolution rate V_{ecm} is defined by Faraday's law

$$V_{ecm} = k\eta j, \quad k = \varepsilon/\rho,$$

where ε and ρ are the electrochemical equivalent and the density of the dissolved material; j is the current density on the anodic boundary; $\eta = \eta(j)$ is the current efficiency (a portion of the current that takes part in the reaction of the metal dissolution).

Earlier in solving the ECM problems the dependence $\eta\,(j)$ of the current efficiency on the current density either was assumed to be constant [1, 4] or was approximated by hyperbolic [2, 3] or homographic functions [4]. As follows from the experiment [4], in the case of intensive ECM by the pulse current the current efficiency drops abruptly in passive electrolytes as the current density j decreases and j is large enough. This leads to the idea of approximating the dependence $\eta\,(j)$ by functions that have a discontinuity of the first kind. In this paper we approximate $\eta\,(j)$ by the step function

$$\eta\,(j) = \begin{cases} \eta_0, & j > j_1; \\ 0, & j < j_1. \end{cases} \qquad (1)$$

We consider the problem of machining by the flat semi-infinite electrode tool (ET) that moves vertically downward with a constant speed V_{et} (Fig. 1, a). This problem has been solved in [2] under the assumption that the current efficiency is a square-fractional function.

With the step function $\eta(j)$ three zones with three types of boundary conditions are formed on the workpiece surface AC. The first zone AE, where the intensity of the electric field exceeds $E_1 = j_1/\varkappa$ ($\varkappa$ is the electrical conductivity of the electrolyte), is characterized by the steady-state condition [4] $|E| = -E_0 \sin\theta$, where θ is the angle of the inclination of the intensity vector to the X-axis and E_0 is

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