Computer Modeling of the Electrochemical Machining by Electrode-Tool with Isolated Rear Part

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Abstract[1]

We consider a spherical electrode-tool, whose working (equipotential) surface is the part of whole surface. Another part of the electrode-tool surface is insulated, having a constant stream function. The problem is solved by using of integral transformations of analytical function of complex variable into potential and stream function of axisymmetrical field, taking into account the singularities of solution.

1. Introduction

Unlike problem, considered in [1], a spherical electrode-tool (ET) of radius r_t, whose working (equipotential) surface is the part *FCE* of surface only, is considered here (fig. 1). The other part of ET surface *FDE* is isolated, and the stream function is constant and equal to its value on the axis portions $y>y_D$ in this part. The center of ET is at the distance h from the workpiece plane surface. The gap between ET and surface is equal to $S = h - r_t$.

The problem is solved by reducing to an auxiliary plane problem by the same method as problems, considered in [1], but with regard to singularities of the function $w(\zeta)$ (the complex potential of auxiliary plane field). For this purpose an analytical function of parametric complex variable ζ is considered. The domain on the ζ plane is the ring.

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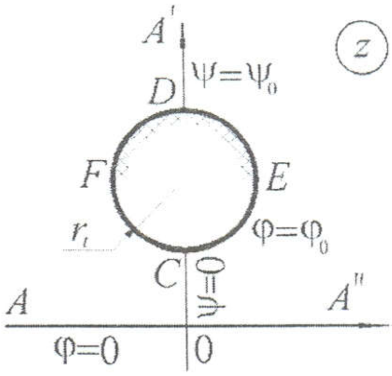

Figure 1. The Scheme of the Electrodes Position

2. Problem Solution Method

The function $z(\zeta)$ is determined by the formula

$$z(\zeta) = z_0(\zeta) + z_1(\zeta) = \sqrt{h^2 - r_t^2}\,\frac{1+\zeta}{1-\zeta}, \qquad (1)$$

and potential and stream function are found as the sums

$$\Phi(x_0, r) = \Phi_0(x_0, r) + \Phi_1(x_0, r) =$$

$$= i\alpha\left[\nu\varphi(x_0, r, S + r_t + ir_t) - \bar{\nu}\varphi(x_0, r, S + r_t - ir_t) - \right.$$

$$\left. - \bar{\nu}\varphi(x_0, r, -S - R + iR) + \nu\varphi(x_0, r, -S - R - iR)\right] -$$

$$-\frac{\alpha}{\pi}\mathrm{Im}\int_{x_A}^{z_0}\frac{dw}{dz}\frac{dz}{\sqrt{(z - z_0)(z - \bar{z}_0)}};$$

$$\Psi(x_0, r) = \Psi_0(x_0, r) + \Psi_1(x_0, r) =$$

$$= i\alpha\left[\nu\psi(x_0, r, S + r_t + ir_t) - \bar{\nu}\psi(x_0, r, S + r_t - ir_t) - \right.$$

$$\left. - \bar{\nu}\psi(x_0, r, -S - r_t + ir_t) + \nu\psi(x_0, r, -S - r_t - ir_t)\right] +$$

$$+\frac{\alpha}{\pi}\mathrm{Im}\int_{x_A}^{z_0}\frac{dw}{dz}\frac{(z - z_0)dz}{\sqrt{(z - z_0)(z - \bar{z}_0)}},$$

where w is defined according to (3.3.51), and $\varphi(x_0, r, z_1)$ and $\psi(x_0, r, z_1)$, according to [2, table 3.1], represent in the form

$$\varphi(x_0, r, z_1) = \ln \frac{x_0 - z_1 + \sqrt{(z_1 - z_0)(z_1 - \bar{z}_0)}}{x_0 - x_1 + \sqrt{(x_1 - x_0)^2 + r^2}}$$

$$\psi(x_0, r, z_1) = z_1 + \sqrt{(z_1 - z_0)(z_1 - \bar{z}_0)} - x_1 - \sqrt{(x_1 - x_0)^2 + r^2}$$

Complex coefficient argument $\nu = |\nu| e^{i(\pi/2 - \gamma)/2}$ is connected with an angle of inclination of the tangent to the ET surface at the point F to orient the singularity correctly ($\Psi = O\left(\sqrt{|s - s_0|}\right)$, $\Phi = \Phi_0 + O(s - s_0)$ on the portion of the tangent to the right of the point F, $\Psi = O(s - s_0)$, $\Phi = \Phi_0 + O\left(\sqrt{|s - s_0|}\right)$ to the left). Module $|\nu|$ is searched from the condition $E_x = \frac{\partial \Phi}{\partial x}(x_B) = 0$ at the point B. The coefficient α is defined from the equality of surface AF potential to described quantity, as above. The coefficients in the sum (3.3.51) are to satisfy the boundary conditions Φ=*const* on AF and Ψ=*const* on BF at collocation points.

3. Numerical Results

The results of calculation of stationary surface shape and diagrams of strength distribution, being necessary for definition of current density in the distinct workpiece portions, were calculated

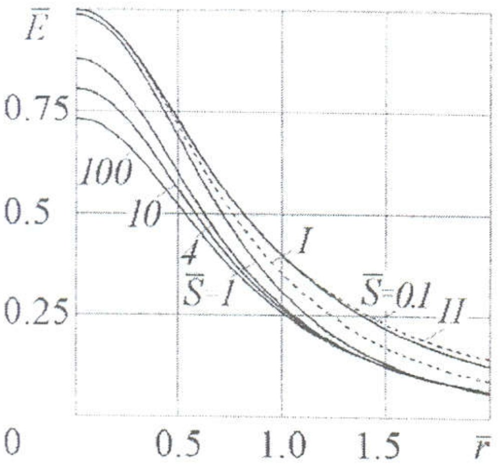

Figure 2. The Dependencies of Electrical Field Strength on Radial Coordinate

The curves of strength on the plane x=0 (workpiece surface) are shown in the fig. 2. The curve I corresponds to the machining by ET without isolation

$$\bar{E}(\bar{r}) = \frac{E_0}{\left(1 + \bar{r}^{-2}\right)^{3/2}},\ E_0 = \left[1 - \left(\frac{S}{a}\right)^2\right] \frac{\varphi_0}{S},\ \bar{E} = \frac{E}{E_0},\ \bar{r} = \frac{r}{a},$$

the curve II - to the linear approximation of this dependence

$$\bar{E}(\bar{r}) = \frac{E_0}{1 + \frac{3}{2}\bar{r}^{-2}},\ E_0 = \frac{\varphi_0}{S},\ \bar{r} = \frac{r}{a},$$

where S is the gap between ET and workpiece.

It appears, that in contrary to the field created by conducting spheres, the maximum of $\bar{E}(\bar{r})$ at the relative gap $\bar{S} = S/r_t > 1$ is considerably less than one, and at $\bar{S} \to \infty$ $\bar{E}(0) \to 0.76$. The ratio $\bar{E}_{hsp} / \bar{E}_{sp}$ ($\bar{E}_{hsp}$, $\bar{E}_{sp}$ are strengths of a hemisphere and a sphere) at $\bar{r} \to \infty$ is near to 0.76 as well at all $\bar{S} > 1$. If $\bar{S}$ decreases the workpiece strength values of the hemisphere and the sphere coincide. This form of the strength curves is explained by higher complexity of the model of electrode with insulation. As it was shown at the numerical experiment, a spherical electrode without insulation can be substituted within sufficiently high accuracy by a point current source located at the distance a

$$a^2 = 1.5 r_t S + S\sqrt{2.25 r_t^2 + S^2 + r_t S}$$

from the plane. The electrode with insulation is represented by a system of distributed charges, some part of them being stipulated by interacting with the equipotential plane, another part - by transition from the conductor to the insulation. The second part creates an additional inverse field that reduces the strength in comparison with the conducting sphere. The hemisphere being approaching to the half-plane, the first component increases, therefore a contribution of the second one decreases and the strength curves are equalized.

4. Conclusion

Thus, the series of plane and axisymmetric problems of ECM by electrodes with round cross-sections mainly, with isolation and without isolation are solved. The solutions are widely applied in practice by virtue of manufacturing simplicity, universality and convenience of using.

References

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2. Zhitnikov V.P. "Plane and axisymmetrical problems solution using the methods of complex variable functions". USATU, Ufa, Russia, 1996.