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Cavitation flow of an ideal incompressible fluid in the electrochemical machining of metals☆

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ABSTRACT

The limiting simplest model of the non-linear two-dimensional problem of the electrochemical machining of metals taking account of the attached cavitation is constructed on the basis of a model of an ideal electrochemical shaping process and the theory of ideal incompressible fluid jets. A solution is obtained related to the determination of the steady shape of the surface of the component (anode) taking account of the cavity formed in the machining on the cathode tool boundary. The results of the calculations show that the model reflects the qualitative effects related to the effect of the added cavity on the shape of the machined component.

Reviews of the literature on problems of the theory and technology of the electrochemical processing of metals are available.[1,2]

In view of the fact that electrochemical reactions products, including gaseous products, are formed in electrochemical processing, the flow of electrolyte in the interelectrode gap becomes a multiphase flow. A scheme for the possible flow processes in the interelectrode gap has been described [1] and the special importance of the attached cavitation process has been noted.[3]

The following are the main factors promoting the initiation of attached cavity:

A high electrolyte flow rate, the initial gas content of the electrolyte and the liberation of gaseous electrochemical reaction products. An attached cavity, filled with gas and fluid vapours can form on the cathode tool at sites with a reduced pressure, for example, in the flow around the sharp edges of the cathode tool. A model of an ideal incompressible fluid [3] is used to describe the cavitation flow. The low electrical conductivity of the gas-vapour medium filling the cavity gives rise to local screening of the machined surface that leads to instability in the anodic dissolution process[1].

1. Model of the electrochemical treatment process

A diagram of a section of the interelectrode gap is shown in Fig. 1: the part AD is the boundary of the cathode tool; DC is the boundary of the attached cavity and the line ABC corresponds to the steady anode boundary. We introduce the Cartesian coordinate system (x_1, y_1) associated with the cathode that moves in a direction opposite to the ordinate axis at a constant speed V_c. The origin of the coordinates was chosen to be at the point D. The points A and C are infinitely distant. The electrolyte flow is directed from point A to point C. At point D, the flow is detached from the cathode surface AD with the formation of a cavity, the boundary DC of which extends to infinity. The model of a cavitation flow with an infinitely long cavity is identical to the model of a jet flowing around a body according to the Kirchhoff scheme.[3] During machining, the cathode tool goes deeper into the body of the blank and, as a consequence of the cavity screening a part of the surface being machined, an unmachined zone is formed on the anode boundary which, in the model, corresponds to the linear part BC.

According to the model of the ideal electrochemical machining process,[1] the electric field with a potential u in the interelectrode gap is described by the Laplace equation, and the function $u(x_1, x_2)$ is the imaginary part of the complex electric field potential

$$W_1(z_1) = \upsilon(x_1, y_1) + i\,u(x_1, y_1), \quad z_1 = x_1 + iy_1$$

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