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BOUNDARY CONDITIONS ANALYSIS OF ECM MACHINING FOR CURVILINEAR SURFACES

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Abstract

Electrochemical machining of curvilinear surfaces is one of the most basic and widely spread among electrochemical technology procedures for machine and tool parts. Constant parameters for preset machining time are hard to determine in this technology. This article presents a method of boundary conditions analysis based on computer simulation of the process. Resulting from calculation controlling code for ECM processing for which machining parameters changing over time are determined in a computer simulation of the process. An example of carrying out calculations leading to determining process controlling code for preset electrode surfaces is also presented.

***Keywords**: computer simulation, electrochemical machining, boundary conditions analysis*

1. Introduction

Among very important issues stimulating further development of technology we can distinguish: learning and increasing its ability to achieve the desired geometry of the machined surfaces, minimizing the distribution of workpiece shape deviations, and increasing the rate of machining performance indicators repeatability. Issues of the surface machining using ECM process are directly linked to its researches field.

Machined surface development issues include [3]:

- shape change in time analysis,
- determining the final shape and its variation when changing machining conditions,
- determining the geometry of the tool electrode to obtain the desired machined shape,
- process conditions optimization with respect to minimization of machined shape deviations,
- searching for new ways to increase machining accuracy.

Conventional methods of machining have reached the current stage of development thanks to the introduction of: numerical control, optimization of the process structure and machining parameters, control by using microcontrollers or computers. Multidimensional, dynamic process of ECM requires a computer based design system and sophisticated control of machining. The condition for the development of modern ECM technology, is a good understanding of the nature of physical phenomena that occur during machining and the process of electrochemical dissolution inherent limitations. Precise quantification of these constraints will enable selection of optimal value of parameters at any given time of machining. This will ensure both high quality and economic rates, and at the same time will not lead ECM process to the so-called critical state, in which the machining is interrupted and electrodes are damaged [5].

2. Modeling of the electrochemical process shaping

Modeling ECM machining means designation the changes of the inter-electrode gap (IEG) width, evolution of the machined surface shape in time and distribution of the physical-chemical conditions occurring in the machining area, like: static pressure distribution, the electrolyte flow speed, temperature and volume concentration of the gas phase. Determination of these distributions for each time step during the simulation process allows the adaptive control of the process. This is particularly important when machining curvilinear surfaces.

2.1. Mathematic and numeric modeling

A two-dimensional, two-phase vesicular electrolyte flow in IEG is assumed. At the same time, triggering a complex tool electrode (TE) vibrating movement in mutually perpendicular directions, that is TE progressive and electrolyte flow. Detailed assumptions and mathematical model of electrochemical machining with vibrating TE for curvilinear shaped surfaces is presented in works [1,8,9].

Determination of the machined surface (anode) shape evolution in time is described by equation of evolution [2,3,8,9] showing the real shape change of the machined surface.

The initial shape of the machined surface and the TE was defined in the modeler 3D as free surfaces of the type NURBS. For numerical calculations digitization work piece (WP) and TE was performed by an approximation of the surface with curves. Detailed algorithms developed for the numerical model were presented in the works [9,10].

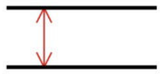
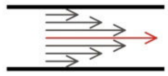
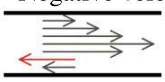
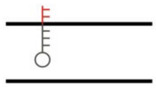
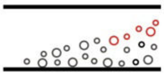
2.2. Boundary conditions analysis

Both theoretical and empirical studies have proved that in case of complex curvilinear surfaces for which the electrolyte flow route differs for different inter-electrode gap intersections it is very hard to select constant machining parameters for a preset process time. This is a reason why boundary conditions analysis (BCA) was developed. Assumed values considered machining parameters, for which ability to reach boundary values (critical state) will be examined, where in practice, interruption of the process will take a place. Table 1 shows the examined process parameters, considered for boundary conditions occurrence and ways to modify them.

Then interconnections between considered parameters and ways to modify them were developed. Considered parameters with possible system reactions were associated in a way to have a control on the strength of their impact. Fig.1 shows an diagram of boundary conditions analysis.

In the case of critical states CS of controlled parameters CP machining simulation will back in time to pre-determined in time control points t_k, where an appropriate modification of parameters will take a place. It should be emphasized that the modified machining parameters are reset to the output parameters value *Pw* in the case of no occurrence of boundary conditions within a specified simulation time.

Tab. 1. Examined ECM process parameters

Examined parametr	Modification way for ECM parameter
IG height 	Reduce feed rate V_f Temporary stop of TE Retract TE
Velocity of IG electrolyte flow 	Reduce feed rate V_f Temporary stop of TE Retract TE
Negative velocity of the electrolyte 	Reducing the frequency ω_w Reducing the frequency ω_p
Temperature of electrolyte 	Reduce feed rate V_f Temporary stop of TE Retract TE
Gas phase concentration 	Reduce feed rate V_f Temporary stop of TE Retract TE

The consequence of such analysis are time-varying machining parameters. This forces the need to generate control code to run machining process.

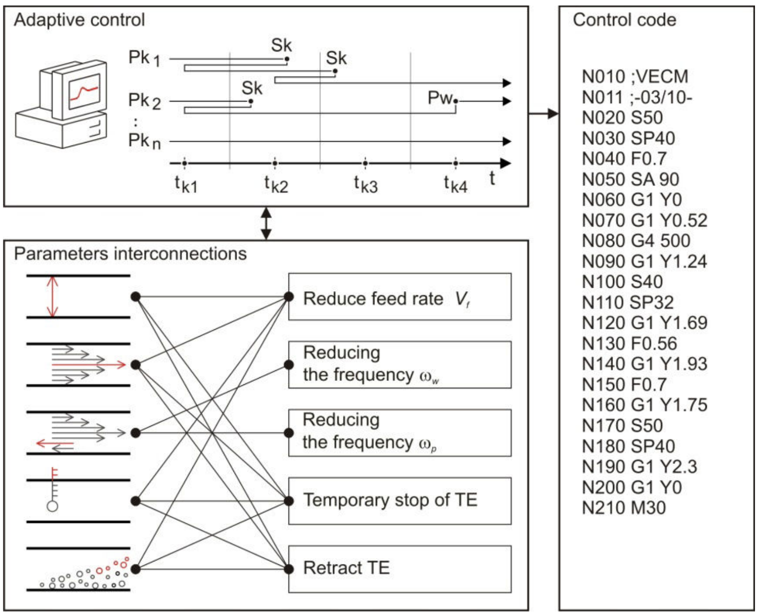


Fig. 1. Boundary conditions analysis diagram

A fragment of such a control code is shown on Fig.1. In the code for the given location of the TE in the direction of Z axis, new machining parameters are defined based on the BCA analysis. For example:

```
N020 S50        - longitudinal vibrations,
N030 SP40       - transverse vibrations,
N040 F0.7       - feed rate mm/min,
N050 SA 90      - oscillation phase shift by 90 degrees,
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```
N060 G1 Y0        - move to the starting point,
N070 G1 Y0.52     - machining endpoint,
N080 G4 500       - Temporary stop 500 ms,
N090 G1 Y1.24     - parameters update,
N100 S40          - longitudinal vibrations,
N110 SP32         - transverse vibrations,
N120 G1 Y1.69     - parameters update,
N130 F0.56        - feed rate mm/min
N140 G1 Y1.93     - parameters update
N150 F0.7         - initial - feed rate mm/min
N160 G1 Y1.75     - parameters update
```

3. Machining simulation program

This assumption allowed new algorithms to be developed for numeric models, in order to accomplish boundary conditions analysis (Fig. 2) Consequently, this allowed to expand the ECM simulation program with another module.

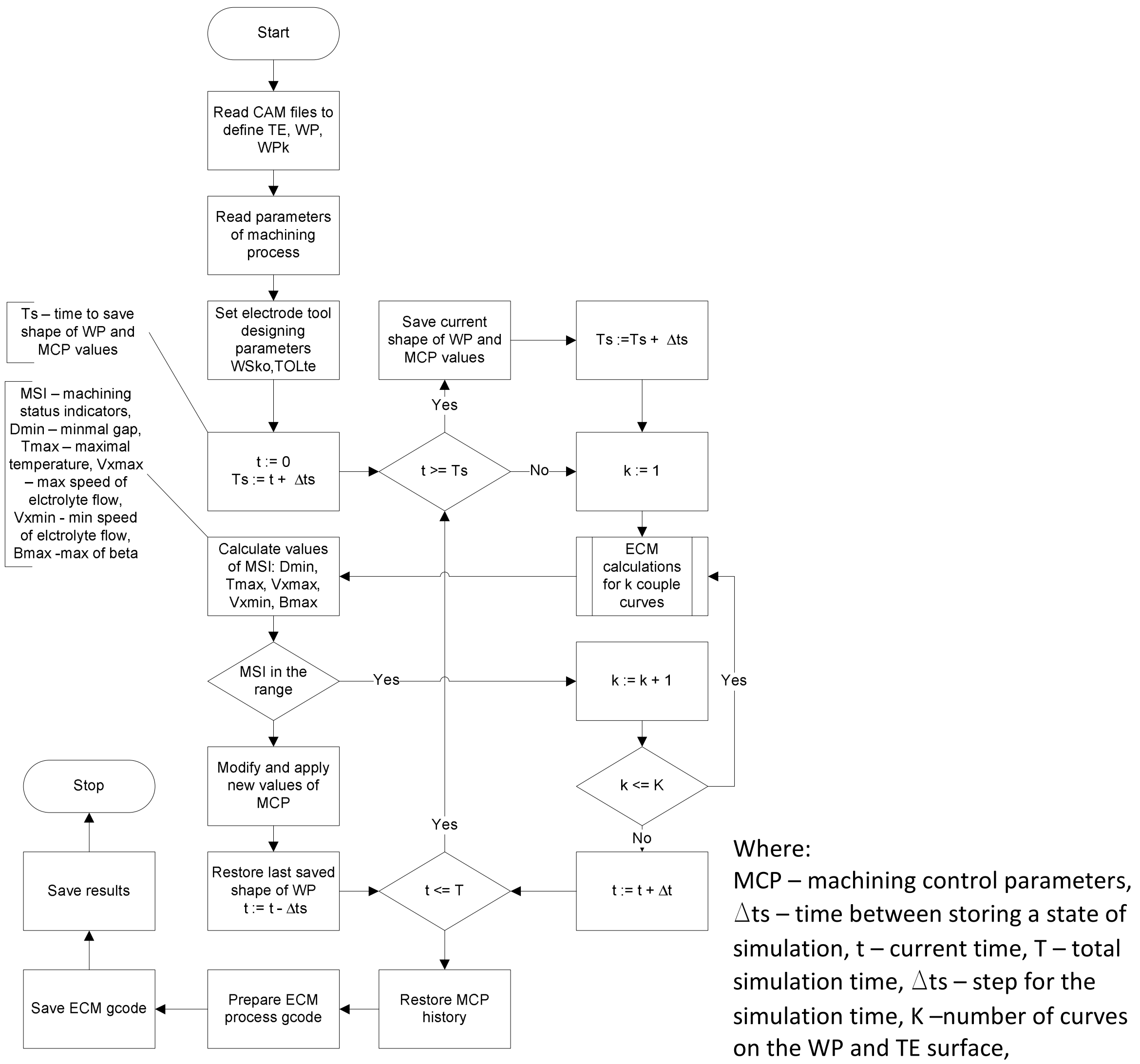

Fig. 2. Boundary conditions analysis flowchart

Fig. 3 shows a modified machining simulation program. In the first tab of this program initial process parameters are entered. They are at the same time reference parameters for boundary conditions analysis. In a new program module a choice of mutual interrelationships between parameters and system reaction can be made, with a given level of interaction.

a) b)

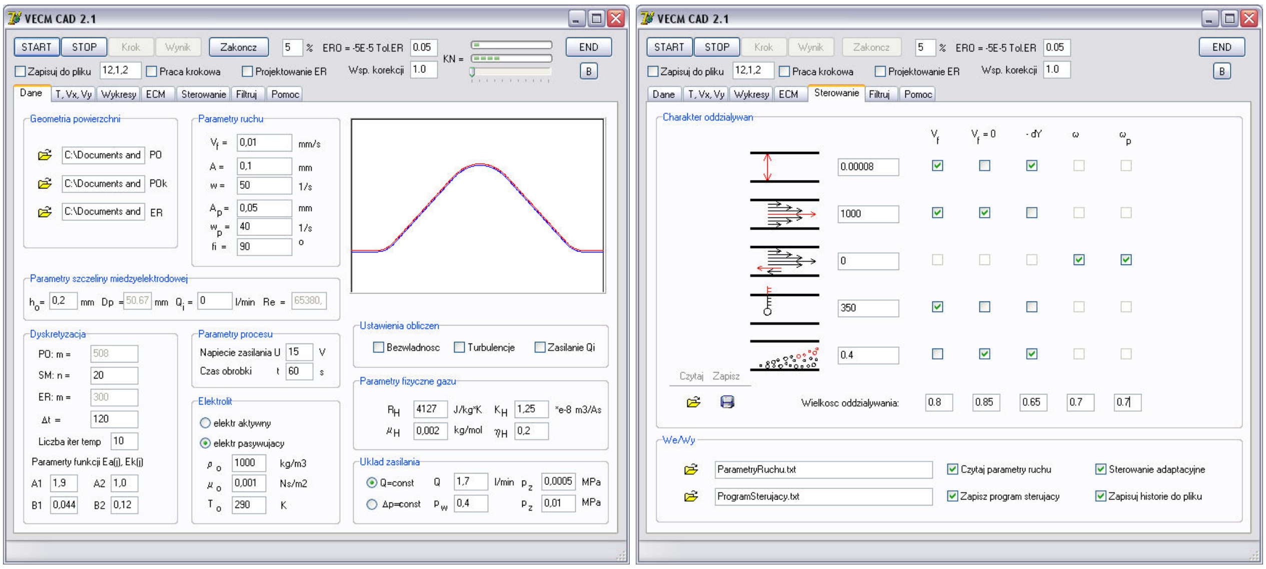

Fig. 3. Machining simulation program: a) initial machining parameters, b) boundary conditions analysis module

Additionally, the module enables loading and saving selected settings, modification of initial parameters for any machining moment (for example in the final part of the process, as optimal parameters for finishing machining), generating a code controlling hallowing.

Fig. 4 shows a process control diagram with regard to ECM machining simulation input parameters.

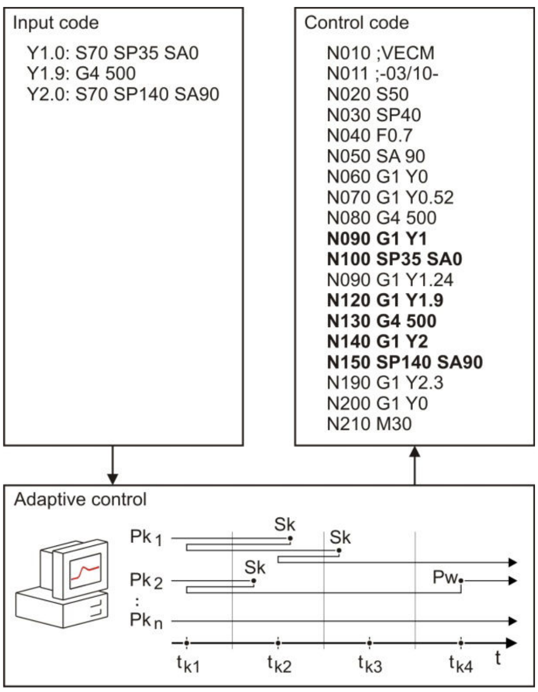

Fig. 4. Process control diagram with regard input parameters

In the body of control code (Fig. 4) input parameters are marked using bold capital letters.

6. Summary

In this work we presented a method boundary conditions analysis of ECM machining for complex electrode surfaces, as a result of which control code changing machining parameters in time was acquired.

Presented methods of modeling and controlling ECM process made possible an increase of machining stability and accuracy, especially for electrodes with complex shapes. Electrochemical drilling is a very complex process, therefore computer modeling of ECM machining process allows machining parameters to be chosen properly, and thus saving time and expenses.

It should be noted that the presented solution was obtained by analytical and numerical integration of complex systems of partial differential equations. This allowed to design complex numerical algorithms to simulate and analyze simultaneously an ECM machining for curvilinear surfaces when modifying machining parameters. IEG distribution, temperature, concentration of the gas phase and a flow rate of electrolyte, is analyzed for boundary conditions occurrence.

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