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PROCCEDINGS

10 - 13 September 2007

FACULTY OF
COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME I

Session 1 - Systems Engineering and Intelligent Systems
Session 2 - Advances in Control Theory and Control Engineering
Session 3 - Optimisation and Management of Complex Systems and Networked Systems
Session 4 - Intelligent Vehicles and Mobile Systems
Session 5 - Robotics and Motion Systems

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Ch. Ament

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

Table of Contents

CONTENTS

Page

1 Systems Engineering and Intelligent Systems

2 Advances in Control Theory and Control Engineering

3 Optimisation and Management of Complex Systems and Networked Systems

4 Intelligent Vehicles and Mobile Systems

5 Robotics and Motion Systems

Paper submitted after copy deadline

2 Advances in Control Theory and Control Engineering

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V. Borikov

Linear Parameter-Oriented Model of Microplasma Process in Electrolyte Solutions

PROCESS IDENTIFICATION AND MODELLING

Abstract: This paper presents the model of microplasma process in electrolyte solution based on linear electric circuit. Elements of the parameter-oriented model were defined. Its electrical parameters and example of the modeling are given. Modeling was carried out in MATLAB with Simulink.

Keywords: microplasma process, linear model, electrical parameters, equivalent circuit of microplasma process.

1. INTRODUCTION

The microplasma method of the metal surface processing is the most perspective method among traditional electrochemical process [1]. The method consists of processing of details in electrolytes by large density currents. During covering the local plasma sparks are observed that is the basic characteristic of process.

Modeling of coating process allows defining the most informative parameters for control and operating of the technological microplasma process of oxide, composite oxide-polymeric and oxide-metal coverings on aluminium, titan and their alloys of various structures.

Simulation is one kind of computer modeling. It is designing of system model and investigations of this model with the purpose either understand behavior of system or estimate (within the framework of restrictions by some criterion or its series) the various modes of the given system functioning [2]. For simulation, the structurally functional model is supplemented by parameters or data describing details of process functioning. Thus, the received model can be considered as algorithm of functioning of object, realized as the computer software complex.

The given researches are directed to construction the equivalent circuit, allowed to establish interrelation of received properties of oxide-ceramic coverings and registered electric parameters of system during microplasma oxidation process. As consequence, it is an opportunity of analysis of these properties at a stage of coverings formation. As a result, there is opportunity of control of microplasma oxidation process on the received cyclic volt-ampere curves with the purpose of creation of the covering with necessary quality.

Besides, the equivalent model will allow to observe change of process parameters without real experiments and will form a theoretical basis for creation of new microplasma technologies and definition of optimum modes, and structures of the process equipment.

2. PARAMETER-ORIENTED MODEL

As a model of the microplasma process, the parametrical model based on linear circuits has been offered.

The choice of linear circuits is caused by two reasons. The first reason is that electrochemical processes in electrolytes are submitted in the literature by the elementary equivalent circuits very frequently, representing combinations of capacity and resistor. In the general case the equivalent circuit for the metal-oxide electrode may be depicted by the parallel connected capacity *C* and the active resistance *R*. Full complex resistance of such circuit is:

$$Z = R/(1 + jwRC)\,. \tag{1}$$

The separately active and reactive parts of the complete resistance are usually measured in experiment. Therefore, the equation is convenient as following:

$$Z = \frac{R}{1+(wRC)^2} - j\frac{wR^2C}{1+(wRC)^2}\,. \tag{2}$$

The second reason is the proof of opportunity of the microplasma process control with the information of active and capacity parts of process’ volt-ampere characteristics, recommendations for development of new methods of measurement of covering properties, and new methods of the technological processes control.

It was shown from experiment that during process time the active and capacity part of microplasma current was changed. It is connected with changing of active resistance and capacity of the equivalent circuit.

For electrochemical measurements the three-electrode electrochemical cell was used that representing a ceramic glass in diameter of 110 mm, height of 110 mm. The stainless steel electrode by thickness of 2 mm served as auxiliary electrode having the half ring form on internal glass diameter. The surface of the auxiliary electrode exceeded a surface of the working electrode. Standard platinum spherical electrode EPL-02 was chosen as comparison electrode.

In a microplasma mode the sample 40x40 mm size was exposed to processing made of the aluminium alloy 2021, preliminary smoothed out and skim. Experiment was carried out in 4 componential electrolyte of the following structure, g/l: $Na_2HPO_4 \times 12\, H_2O$ – 30; $Na_2B_4O_7 \times 10\, H_2O$ – 30; H_3BO_3 – 20; NaF – 10.

The information-measuring complex (Fig. 1) was used for measurement of currents impacted and polarized voltage with the purpose of construction cyclic volt-ampere curves. The information-measuring complex includes the power supply, three-electrode electrochemical system and the measuring equipment for registration and processing of the information (computer measurement system).

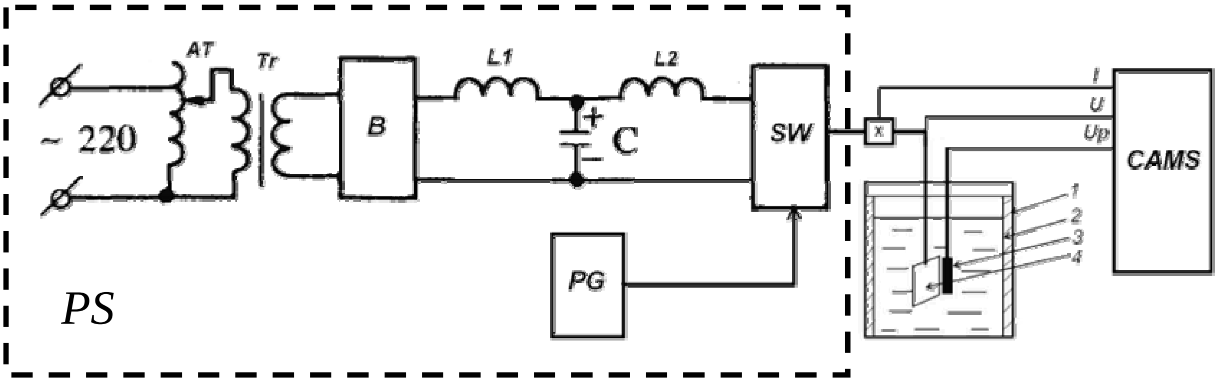

Fig. 1. The information-measuring complex: 1 is ceramic glass; 2 is auxiliary electrode; 3 is comparison electrode; 4 is working electrode, AT – autotransformer, SW – electric switch, B – electric bridge, PG – pulse generator, PS – power supply CAMS - Computer-Aided Measurement System

The pulse voltage (E) from the power supply to microplasma system is allocated between a working electrode (U) solution $(I * R_S)$:

$$E = U + I * R_S \tag{3}$$

The computer measurement system allows to receive a volt-ampere dependences of microplasma processes in the pulse mode at voltage up to 300 V, voltage rise-time of 10^8 V/sec, currents up to 100 A and to registration of the voltage and current signals with discrete 25 mV and 1 mA accordingly (Fig. 2).

As a result the time-coordinated data appropriate to input signal of voltage *U*, to voltage on the comparison electrode *Up* and data of the current proceeding through sample *I* are formed in the computer. Measurement of all electric parameters (*I*, *U*, *Up*) is carried out simultaneously during one pulse (200–250 usec). Representation of the information or as current and voltage diagrams or as tabulated values is carried out automatically.

Influence of microplasma processing time independent on alloy kind has the follow effect: cyclic volt-ampere curves are shifted in area of the large voltage and smaller values of current (Fig. 3).

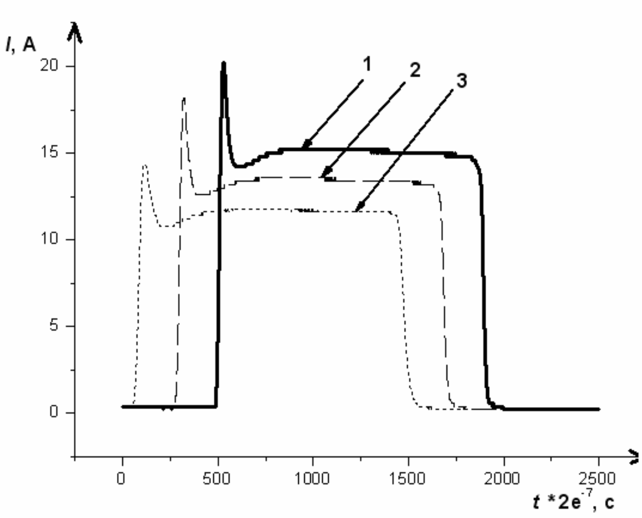

Fig. 2. The curves of current from oscilloscope: 1 - 3 min, 2 - 4 min, 3 - 5 min

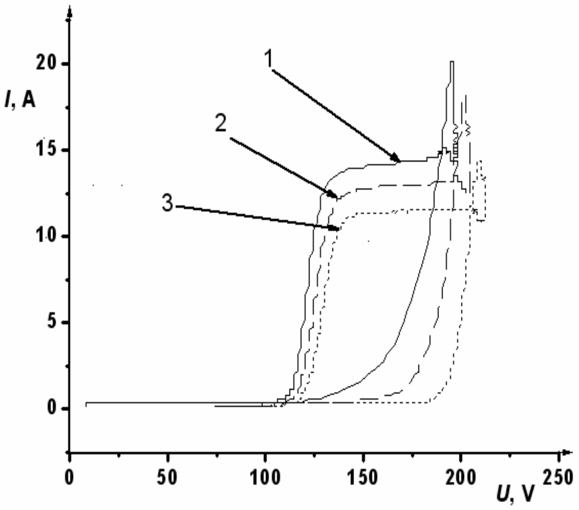

Fig. 3. Volt-ampere characteristics of aluminium alloy 2021 from time of covering process: 1 - 3 min; 2 - 4 min; 3 - 5 min

In this case the equivalent circuit of measurement is shown in Fig. 4, where *Rw Ra* is resistance of the spark stages on working and auxiliary electrodes, *Cw* and *Ca* is capacity of working and auxiliary electrodes, *Rs* is resistance of electrolyte solution, *Rc* and *Cc* is resistance and capacity of the comparison electrode (platinum electrode), *Rg* is resistance of the voltage source.

3. COMPUTER MODELING OF THE MICROPLASMA PROCESS

Modeling was carried out in MATLAB environment with Simulink toolbox.

The equivalent circuit of the microplasma system in Fig. 5 [3] was used for simulation.

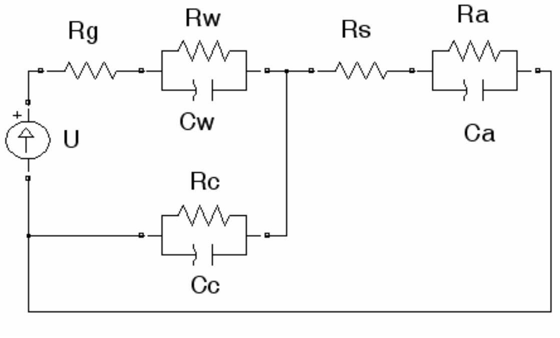

Fig. 4. Equivalent circuit for current from the three-electrode electro-chemistry cell

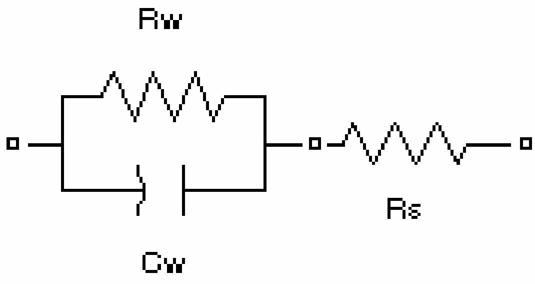

Fig. 5. The equivalent circuit of the microplasma system: Cw – the capacity part of electrode reactance, Rw – the active resistance of electrode, Rs – the solution resistance

In MATLAB environment the simulation model of coating system (Fig. 6) was designed. Elements of the circuit appropriate to experimental data for the current and voltage forms.

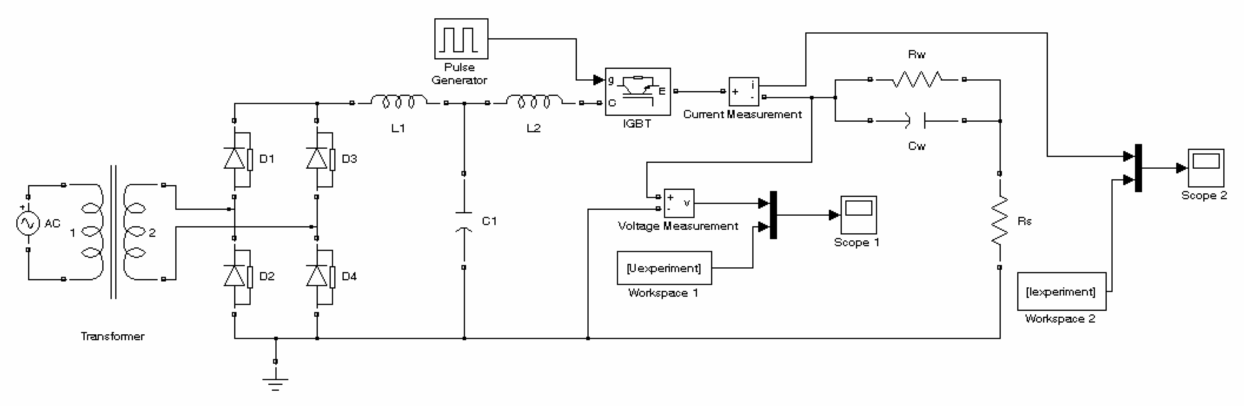

Fig. 6. The coating model in MATLAB

The data of current and voltage measured on experimental device [4] at the various points of time were used for modeling: a pulse voltage from the power source, the polarizing voltage (between the comparison electrode and the working electrode) and current in circuit.

Definition of resistance and capacities was made based on experimental data from the formula:

$$E_{PS}=U_C*(\frac{R_W}{R_S}+1)+L*C*\frac{\partial^2U_C}{\partial t^2}+(\frac{L}{Rw}+C*R_S)*\frac{\partial U_C}{\partial t}, \qquad (4)$$

recognizing that the *RLC* resonance is presented in system.

As a result of modeling the voltage pulse (Fig. 7) and the current pulse (Fig. 8) is received appropriate to form and size of the experimental data.

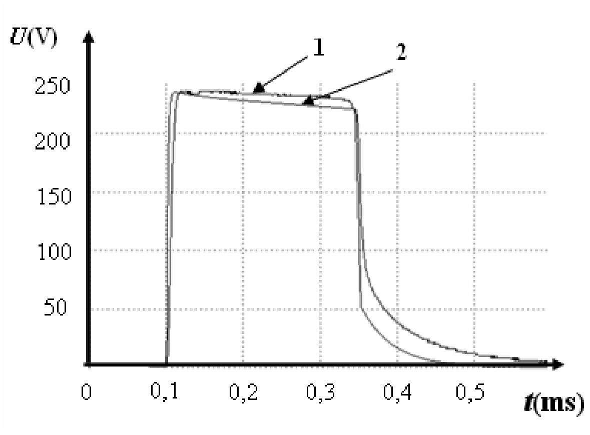

Fig. 7. The voltage pulse: 1 – from experiment, 2 – from model

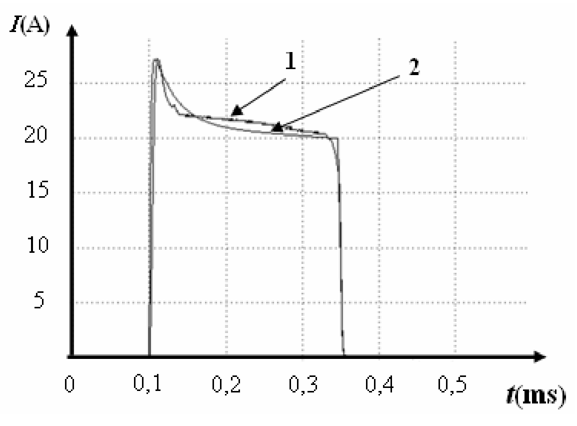

Fig. 8. The current pulse: 1 – from experiment, 2 – from model

4. CONCLUSION

As a result it is possible to present the microplasma process for pulse influences model with use of the certain restriction linear circuits. The given restriction is division of microplasma process into 3 phases: formation of a barrier layer, microplasma breakdown and relaxation of system.

The received results give initial approximation of the microplasma system model characteristics in two stages. Values of elements of system are received for the simulating model: *Rs* =8.2 Ohm, *Rw*=2.8 Ohm, *Cw* = 15 uF for covering surface area *S* = 16 cm^2, *t*= 20 min. The third phase will differ of the oxide layer resistance which is not subject to breakdown, in the given phase resistance is *Rw*=30 Ohm.

The simulated signal retains approximately 95 % of the original signal energy. The estimation on energy mismatch was made on square-law norm:

$$\delta = \frac{\int_{t0}^{t} \left[x(\tau) - y(\tau)\right]^2 d\tau}{\int_{t0}^{t} x(\tau)^2 d\tau}, \tag{5}$$

where $x(\tau)$ is signal received from experiment, $y(\tau)$ – during simulation.

Models describing behavior of electrochemical system will allow to create power supplies for micro-arc oxidation equipment, plasma processing in electrolytes as well as to define parameters for coating control. Researches in the given field are carrying out. The modeling of the microplasma process with use of the nonlinear circuits, in particular, introduction of Zener diode is planned.

5. ACKNOWLEDGMENT

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