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V. Borikov

Industrial Power Supply for Plasma Electrolytic Oxidation

NANO MATERIALS AND PROCESSING

Abstract: This paper presents the industrial power supply for surface modification of metals and alloys at plasma electrolytic oxidation. Structure, operation description, and technical parameters of power supply are given.

Keywords: plasma electrolytic oxidation, power supply, structure, technical parameters.

1. INTRODUCTION

Electric current through a boundary "electrode-solution" in anodization causes formation of metal oxides on the electrode surface that result in increase of the boundary resistance. Under high polarization voltage, an oxide breakdown occurs accompanied by luminescence. The processes are called the anodic spark electrolyze also known as plasma electrolytic oxidation (PEO).

This process is one of electrochemical methods of coating and becomes popular for use in surface modification of alloys and metals providing their necessary wear-resistant, anticorrosion, electric, and decorative properties. In Fig. 1 the work piece in the electrolyte bath at plasma electrolytic oxidation is given. And in Fig. 2 one can see spark mode of the process.

Fig. 1. Plasma electrolytic oxidation process

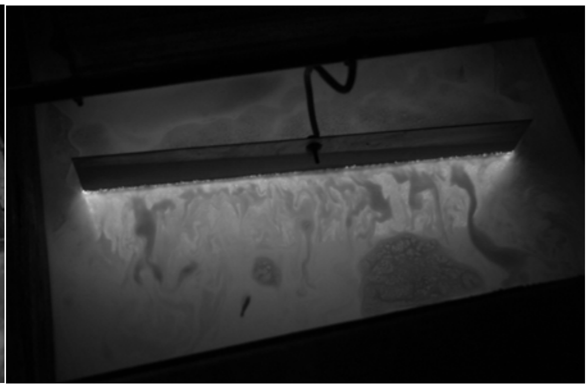

Fig. 2. Spark mode

Application of the PEO technologies depends on the technological equipment developed basic element of which is the industrial power supply (Fig. 3). The coating properties achieved at plasma electrolytic oxidation are characterized many factors:

electrolyte, work piece being processed, its dimensions, equipment, technological modes of plasma oxidation etc. The choice of plasma electrolyte oxidation technology frequently depends on available power supplies (PS) for PEO. And the results of investigations in the field of plasma coating make it possible to develop power supplies with definite characteristics. At industrial application of PEO the basic problem is an effective energy use during plasma oxide coating formation. Optimization problems should be solved as to work piece area and quality of coating.

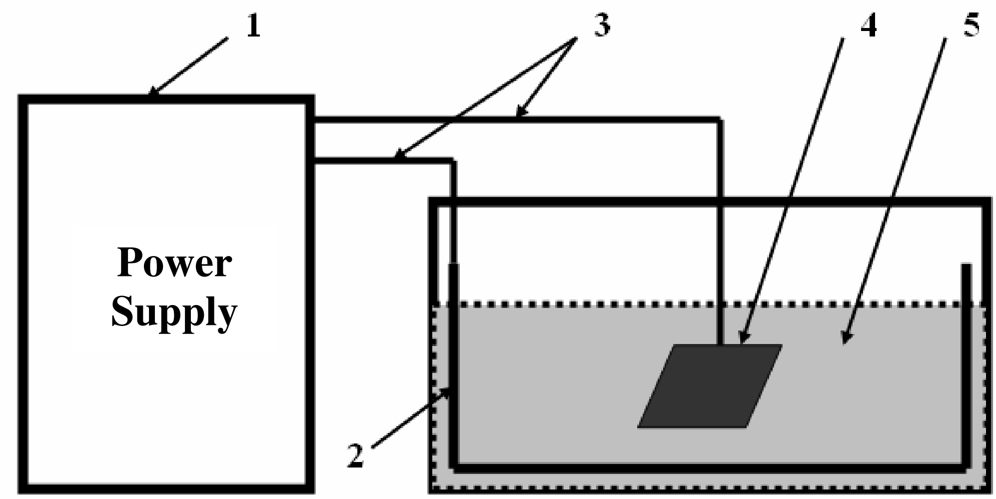

Fig. 3. Connection of the power supply in PEO technological process:
1 – PEO power supply; 2 – cathode; 3 – feed bar;
4 – work piece (anode); 5 – bath with electrolyte

Development of power supply for high-current plasma processes in solutions is connected with choosing the kind of actuating voltage (sine wave, asymmetric, trapezoidal pulse etc.), calculating voltage values on electrode-solution boundary and voltage values in solution, and also calculating current values (total, active and capacity), necessary for the optimum surface modification [1].

2. ALGHORITHM OF SELECTING POWER SUPPLY PARAMETERS

Despite significant amount of papers in the field of power supply for technological processes, only few works concerning development and generalization of such devices in the plasma electrolyte oxidation field are found. It is especially applied to the devices with adjustable charge process and pulse discharge. Now, the majority of industrial power supplies for PEO can be classified as follows:

power supply without energy accumulation forming output signals from the AC half wave or a part of AC half wave;

power supply without energy accumulation forming output signals with rectifier or inverter control [2];

power supply with energy accumulation [3].

The methodology mentioned below for designing the structure and parameters of power supply for plasma electrolyte oxidation can be used. The algorithm given represents a set of steps, making it possible to choose the validated structure of power supply.

Step 1. Setting the current density for the plasma electrolyte oxidation.

Step 2. Setting the area of work pieces being processed.

Step 3. Evaluating the equivalent circuit parameters of PEO process load.

Step 4. Calculating the PEO process voltage.

Step 5. Definition of the pulse duration of the plasma process voltage.

Step 6. Definition of the pulse frequency of the plasma process voltage.

Step 7. Definition of the electric charge quantity for plasma process.

Step 8. Choosing energy store (electromechanical, capacitor etc.).

Step 9. Choosing the mains (three-phase network, one-phase network etc.).

Step 10. Definition of the energy accumulation technique.

Step 11. Choosing discharge technique.

Step 12. Setting power supply efficiency.

Step 13. Setting power supply cost.

Step 14. Setting mass, dimension parameters.

Step 15. Safety of the power supply.

Finally, all 15 steps make it possible to form PS structure and to determine its electric and economic parameters. Each step and PS parameters is connected with optimization problems solving. These problems can be divided into two groups. First group (steps 1-7) is related to the problem of choosing the PS electric parameters. For example, substantial growth of the pulse duration of the plasma process voltage at the given voltage results in irrational use of input energy with increasing the impoverished layer at work piece-electrolyte boundary and decreasing the coating speed and heating up electrolyte.

The problems of PS structure optimization may be placed to the second group where the source efficiency is more often taken into account. Application of traditional means for charging capacitor as energy storage with the charge current-base elements results in the problems of the current-limited elements choice. Introducing reactive elements in PS structure makes it possible to increase its output voltage that in turn results to the charge current increase.

Note that only a part of current through electrochemical system is used for formation of the ceramic covering. It results in decreasing profitability and productivity. In this connection the systems with rectangular or trapezoid voltage pulse are of interest. Thus, oxide covering with definite properties depends not only on current density, but also pulse duration.

3. POWER SUPPLY DESCRIPTION

In Tomsk Polytechnic University the power supply with energy accumulation in battery condensers and trapezoidal voltage pulse for functional and decorative ceramic coverings at the plasma electrolytic oxidation was developed.

The power supply is composed of three sections: power section, control section and section of measurement and protection. The block diagram of the power section is presented in Fig. 4. It consists of the decoupling power transformer, controlled rectifier, energy accumulator, and electronic switch.

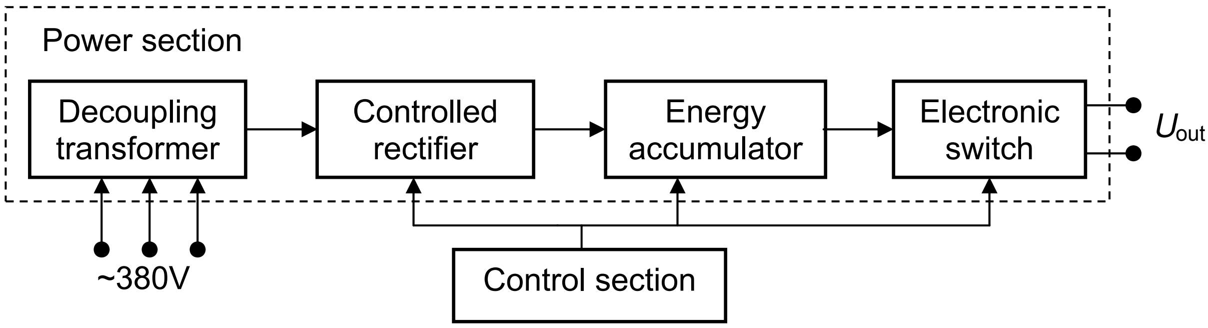

Fig. 4. Simplified block diagram of power section

The controlled rectifier and electronic switch make it possible to synchronize processes of electric energy accumulation necessary for formation of plasma coverings and transfer of the electric energy saved to loading.

The control section provides the algorithm of interaction of all PS blocks and forms pulses the parameters of which determine quantity of energy in the output loading. The power supply is remote controlled. Operating time may be set by operator or with timer. The control circuit is housed in the sliding block and galvanically decoupled from the power section of PS that provides additional safety to personnel. The indication block shows the modes of source operation.

The power supply is equipped with the consumed energy measurement device and device of target parameters measurement of plasma process. There are five measurement parameters: the bath voltage, work piece current, electrolyte temperature, power supply voltage and current. Using three-electrode system of measurement, we have an opportunity of connecting the reference electrode to the device of target parameters measurement.

The PS protection circuit prevents from the development of emergency processes at troublesome situations: output overload, input overload, loading switch off, faults in the control circuit, parameters deviation of the mains, power elements failure.

The operation begins after setting necessary technological process parameters. Technological parameters are set at mounting and estimated taking into account the work piece.

Photos of the power supply are presented in Fig. 5 and Fig. 6.

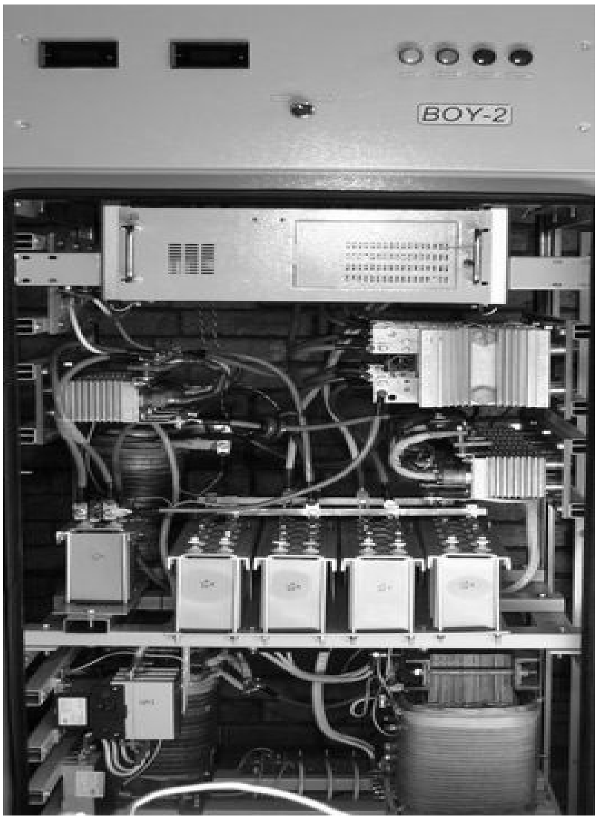

Fig. 5. Power supply

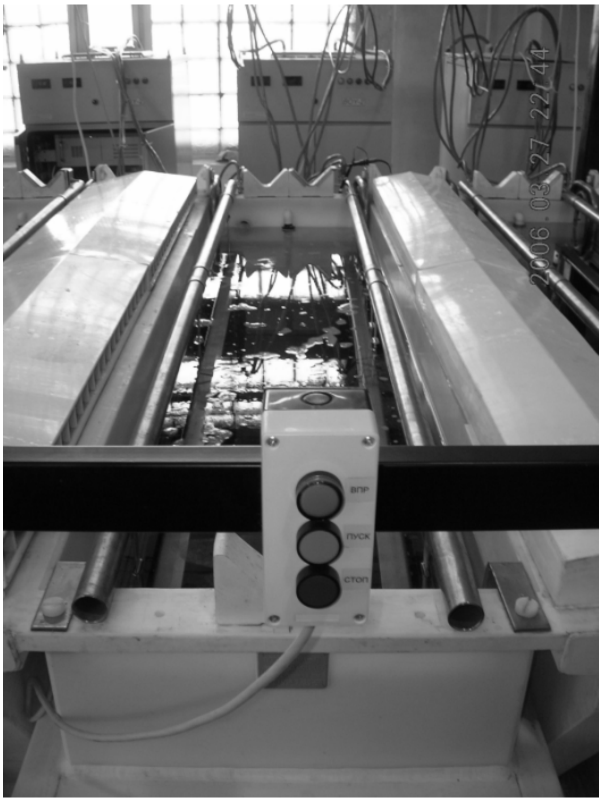

Fig. 6. Practical application in industry

The basic technical parameters of the power supply for plasma electrolytic oxidation are:

power source – 380 V ±10 %, 50 Hz three-phase mains;

power consumption – no more 35 kW;

maximum pulse voltage on condensers – 800 V;

maximum pulse current in all operation modes – 10 kA;

pulse duration – up to 1 ms;

frequency of current pulses – no more 40 Hz;

readiness time – 10 min;

duration of technological operation - 16 hrs.;

power supply is protected from overload and idle.

4. CONCLUSION

This power supply is used in processing line for formation of protective-decorative ceramic coatings in Krasnoyarsk city, Russian Federation.

The surface up to 1 m^2 is treated by this equipment and coverage rates is up to 1 μm per minute [4].

The decorative ceramic coatings achieved at processing with power supply developed is presented in the Fig 7.

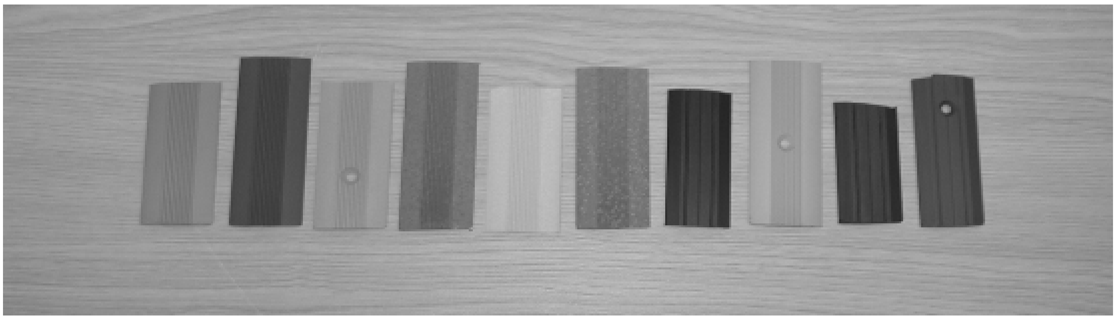

Fig. 7. Decorative ceramic coatings

5. ACKNOWLEDGMENTS

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Author:

Dr., Assoc. Professor Valery Borikov

Tomsk Polytechnic University, 30 Lenin Avenue

Tomsk, 634006, Russia

Phone/Fax: +7 3822 420449 / E-mail: borikov@camsam.tpu.ru