INSTALLATION AND TECHNOLOGY OF ELECTROSPARK ALLOYING OF METAL SURFACES

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Abstract

Electrospark alloying (ESA) is a micro-bonding process capable of depositing wear-corrosion-resistant coatings to repair, improve, and extend the service life of the components and tools. During coating, short-duration electrical pulses ranging from a few microseconds to a few hundreds of microseconds are used to deposit the electrode (anode) material on the component surface (cathode) to produce a protective layer. One of the main components of installations for ESA is the current pulse source, which is responsible for technological parameters of the metal surface modification process. The data represent novel approaches to the formation of current pulses, which, in our opinion, will essentially expand the process capabilities.

1. Introduction

The TOPAZ factory started the development and production of advanced equipment for surface modification of machines and mechanism parts in order to expand the market for the factory's products. One of the fields of the realized products is manual and mechanized systems for electrospark alloying (ESA) of metal surfaces. This modification method is based on the phenomenon of erosion and polar transferring of the anode material (applied material) to the cathode (processed workpiece surface) during an electric discharge between them in a gaseous medium.

The pioneers of this method of modification of metal surfaces (elaborated simultaneously with the method of electrospark dimensional processing of metals) were Soviet scientists, married couple, USSR State Prize winners Boris Romanovich Lazarenko and Nataliya Iosaafovna Lazarenko. Academician of the Academy of Sciences of Moldova B.R. Lazarenko was the organizer of the Institute of Applied Physics and the Experimental Factory of the Academy of Sciences in Chisinau. His scientific interests ranged between theoretical and applied aspects of electrophysicochemical methods of impacting on the material. The "Moldovan school" of physicochemical methods of metal processing founded by B.R. Lazarenko allows the Topaz factory to produce machines and introduces the world-class physicochemical methods of metal processing, in particular, for ESA.

It is known that the pulse current parameters and the physicochemical properties of the electrodes and interelectrode materials of the gaseous medium determine the following technological features and the properties of the resulting coatings: mass loss of the anode, mass received by the cathode, gradient depth values of hardening effects in the near-surface coating area, residual stress level, coating thickness, etc.

An indispensable feature of the ESA method is the implementation of sparks between the electrodes. A spark must accompany each current pulse at any given time. Analysis of the current state in the field of the manufactured equipment for ESA revealed a number of shortcomings in the capabilities of the existing current generators; some of them are as follows [1, 2]:

—Reduction in the integrated electrical power applied to the interelectrode spark gap per unit time upon switch to a precision ESA mode due to the lack of possibility to compensate for its decrease by a corresponding increase in the pulse repetition frequency (its frequency is hardly set by limit characteristics of electromagnetic vibrators).

—Reduction in the amount of energy passing through the spark discharge in the case of using current pulses of long duration in connection with the short-circuiting of the spark channel by colliding electrodes (only a portion of the current pulse is accompanied by a spark discharge).

—Reduction in the amount of sparks in the total number of pulses upon switch to a precision mode because of the inability to provide an explosion of volume of contact microroughnesses under conditions of colliding electrodes (typically, the switch to precision modes is achieved through a decrease in the spark pulse energy by reducing the discharge voltage of the capacitor).

The foregoing had defined features of the ideology of construction of the current pulse generator developed by TOPAZ which were aimed at excluding the above-described disadvantages in the implementation of the ESA method. Simultaneously, activities focused on imparting new capabilities to the current pulse generator, and hence the technological process, were conducted. Let us explain some of the approaches in achieving these aims.

2. Results and discussion

One of the main objectives of the organization of high-performance process of coating modification by the described method (including new technological capabilities) is the possibility to organize a spark channel at any given time. Therefore, in the design of systems for ESA, it was necessary to reject the idea of formation of a spark channel by collision of the tool-electrode and the workpieces using an electromagnetic vibrator. Hence, there were limitations in the implementation of the electrospark coating formation, especially using high-precision alloying modes (high-frequency regimes of alloying at low pulse energies). The limitations are attributed to the impossibility of organizing the high-frequency operation of electromagnetic vibrators. Moreover, there was no possibility of using pulse groups with different parameters of current pulses and pauses between them to implement additional properties of the process (e.g., a group of six to eight 1-ms pulses).

In view of the above, we proposed to use an electromagnetic vibrator to provide continuous sliding of the tool-electrode over the workpiece surface, i.e., maintain an electrical contact between them throughout the entire alloying process, rather than to implement periodic mutual collisions of the electrodes [2, 3].

The experimental results confirmed the possibility of the designed equipment to increase the productivity, while traversing the area subjected to alloying, especially for alloying with small quantities of electrical energy pulses. Enhancement of the performance was not only due to an increase in the pulse repetition frequency by using ESA with the tool-electrode sliding along the workpiece surface, but also by reducing the proportion of pulses with a full short circuit caused by the collision of the counter electrodes. At the same time, the implementation of the tool-electrode oscillations on the workpiece surface also opens an ample possibility of rapidly exposing to the ESA process using bursts of pulses with different electrical parameters and with controllable duration pauses between the pulses in group. It was found that this approach to implementing the process significantly changes the patterns of electrode erosion and polar transfer of the material of the tool-electrode to the workpiece and thus the surface properties of the workpieces.

To organize the ESA process using groups of pulses with different parameters, a special current generator has been developed at the Topaz factory. It is based on the idea of formation of parameters of an individual pulse (as well as their sets in groups) by the parallel–serial superposition of individual pulses from several independent discharge contours. In the developed generator, the number of these contours (in which current switching is carried out by powerful transistors) can be six and more (depending on production engineering demands). Figure 1 shows current oscillograms to illustrate some possibilities of energy release in the spark gap for both an individual current pulse (one contour) and a group of pulses from different contours with different capabilities in the technological circuit design.

With the parallel–serial addition of current pulses (using the example of three contours), it is possible to obtain varied parameters of duration and amplitude of the total current pulses (Figs. 1a–1d). In the case of the parallel simultaneous addition of pulsed currents, for example, three contours, it is possible to obtain the total momentum of a half sinuous current with a 1300-A current amplitude at a pulse duration at the base of 85 μs (Fig. 1e).

Application of pulse-width modulation can significantly enhance the capacity of each generator circuit in terms of the energy parameters per pulse, including its form.

It is also possible to organize modes with an increased mass erosion transfer from the anode to the cathode as a result of aggregate discharges collected in a burst for a given program. Research of the mechanism of mass transfer caused by exposure to sparks under these conditions revealed the possibility of increasing the mass transfer by a factor of 1.5 and more with unchangeable parameters of total energy spark discharges (e.g., alloying of steel 35–40 samples using a high-strength tungsten–cobalt tool-electrode). Investigation of the laws of formation of the coating surface under high mass transfer conditions revealed the necessity to implement electroerosion smoothing in one process step. This objective was accomplished by introducing additional pulses per burst. Figure 2 shows an oscillogram of pulse bursts consisting of a current pulse responsible for the organization of mass transfer and two pulses for the implementation of spark erosion grinding.

The average current of the pulse generator remains the same for all technological regimes of ESA. Its value was based on the conditions of restrictions on the thermal regime of the tool-electrode (the absence of the contact zone overheating). Thus, the cross-sectional area size of the tool-electrode was selected on the basis of convenience of the alloying process visualization. For example, for the processing of a BK8 alloy electrode on an area of 8 mm^2, the average current is 3 A. In the case of necessity of changing the processing area of the electrode in the lower side, regimes of the generator work at an average current of 2 and 1 A are provided without changing the energy release in a pulse mode or in their totality (bursts). The possibility of delivery of a single pulse (or single burst) in the interelectrode gap is also implemented to study the spatial resolution of erosive spots, which are necessary to generate sweep programs for effects from discharges in the case of a mechanized deposition process.

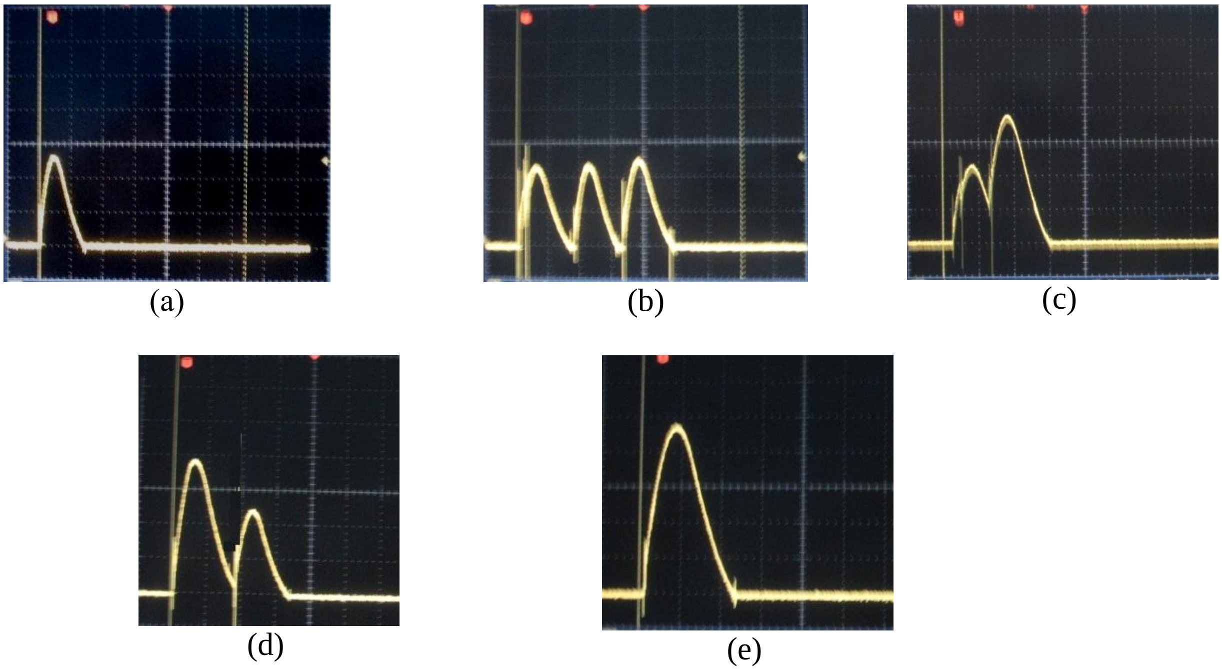

Fig. 1. Current oscillogram illustrating the possibilities of the superposition of sine-wave current of the individual circuit pulse generator: (a) one contour; (b) three contours, the currents of which are connected sequentially in time; (c) three contours, the first two currents are stacked sequentially in time, the third current is set parallel to the second folded and simultaneously with it in time; (d) three contours, the two first currents are set simultaneously, the third current is connected in series and in time after the end of the sum current of the first two contours; and (e) three contours, the currents of which are connected simultaneously. The scale interval is 265 A/Cage (C) along the vertical axis (current) and 40 μs/C along the horizontal axis (time).

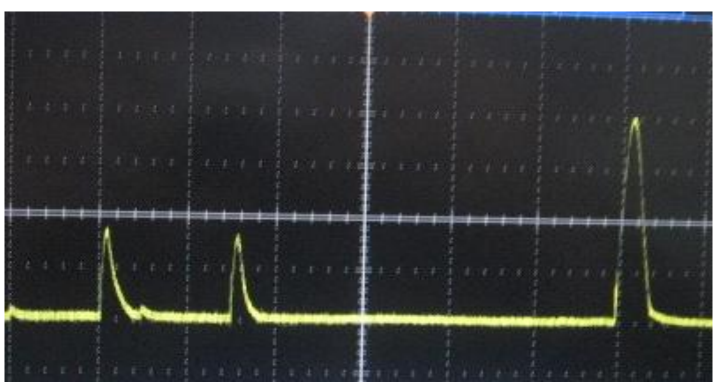

Fig. 2. Current oscillogram illustrating possibilities of transferring bursts of three sine-wave pulses in which the first two perform the electroerosion smoothing, the third provides the base layer coating. The scale interval is 265 A/C along the vertical axis (current) and 40–200 μs/C along the horizontal axis (time).

The generator is governed by a special programming device controlled by a human-machine interface imparting the above specified individual features to the technological process of electrospark modification of metal surfaces. These features are imparted by a change in pulse durations and pauses between each contour and the necessary time delays at various current superpositions of different contours.

References

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