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CRITERIA FOR PROJECTING TOOL-ELECTRODES APPLIED IN THE FORMATION OF SURFACE LAYERS WITH ELECTRIC DISCHARGES IN PULSE

BY

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Abstract: The article contains an analysis of the functional conditions of the tool-electrodes applyed in the formation of deposited layers by means of electric discharges in pulse. During the analysis it is demonstrated that the next criteria will be considered to produce the tool-electrode: the form of the processed surface; the material used to produce the tool-electrode; the relative shifting speed between electrode – piece; the conditions of cooling the tool-electrodes; the compatibility of the electrode and piece material in the formation of deposited layers.

1. Introduction

One of the modern methods of material processing is that of electro-erosion [1]. It allows the realization of small size pieces with a complicated form by drawing the material from the semi-finished product [1,2], or the formation of deposited layers by applying electrodes [4, 6] made of compact materials or by introducing powder [6, 9] or mixtures of powder [4, 8, 9] in the working space.

This processing method has some advantages compared to the classical ones; it can realize the processing of all materials able to conduct electricity irrespective of their physical and mechanical properties [1,2, 9]; it is easily applied in practice by adjusting the existing tool machines to new conditions and by supplying them with sources of current and the needed tools and devices [5, 7]; it does not require specially prepared surfaces before the processing [8, 9]; it ensures a high level processing of low roughness surfaces [10], etc.

In spite of the above enumerated advantages of this method its implementation in the machine and tool building industry has not achieved the required level because of the relatively low productivity of drawing the material (of about mm3/min [9, 12, 13]) in the dimensional processing of pieces and respectively due to the relatively low mass growth intensity of pieces (of about

1,2 g/min [9, 11, 12, 13, 14]) in the deposited layer formation. Even though the application of supplementary energy sources against the interstice [9, 10], the growth of the electric discharge frequency in pulse and their energy [7], the application of electric and magnetic fields against the interstice [9], the laser radiation [2, 6] etc allowed to a certain degree to increase the feats of the above mentioned method of material processing, we cannot assert that a qualitative and quantitative leap has taken place in this domain.

The tool electrode projection and elaboration which must ensure a very high accuracy and high productivity of processing will play a special role in the further development of these technologies.

The total electrodes should possess a high resistance to electro-erosion and provide the formation of surfaces of complicated configuration. Because of this to project them it is necessary to determine the criteria for their projection. The ensuring of a high resistance against electro-erosion depends on the properties of the material used to produce the tool and on their cooling conditions throughout the processing.

2. Tool electrodes used today to form deposited layers

Tubular or cylindrical bar type tool electrodes (fig. 1, b) are used in the powder deposited layer formation using electric discharges in pulse with contact breaking (fig. 1, a). The formation of the deposits using tubular electrodes allows a more complete powder processing but this requires the tools to be made of the same material as the powder from which the deposit is formed.

This is necessary to avoid the influence of its material on the composition and properties of the newly formed layer. In the formation of deposits by means of introducing the powder in the interstice through the lateral or front part of the tool electrode, the latter is made in the form of a cylindrical bar of a material with certain properties that will confer the formed deposits prescribed properties and will ensure continuity and uniformity.

A more perfect variant of the powder deposit forming process is the one in which the contact between the tool electrode and the piece to be processed is avoided. In this case throughout the whole period of processing the interstice formed by the piece and tool has a constant size and constitutes about 0,3 …1,5 mm.

Strong electric fields or high voltage pulses are used to induce electric discharge in pulse against the interstice.

Previous investigations have demonstrated that powder particles are joined to the working surface of the tool-electrode in the process of deposit layer formation. This leads to the violation of the processing regime.

The influence of the tool material and dimensions on these effects has been highlighted. The process of deposit formation on the anode is caused by the warming which happens due to its interaction with the plasma canal of electric discharges in pulse and by the Joule- Lentz effect determined by the average value of the current intensity which traverses the interstice formed by the tool and piece.

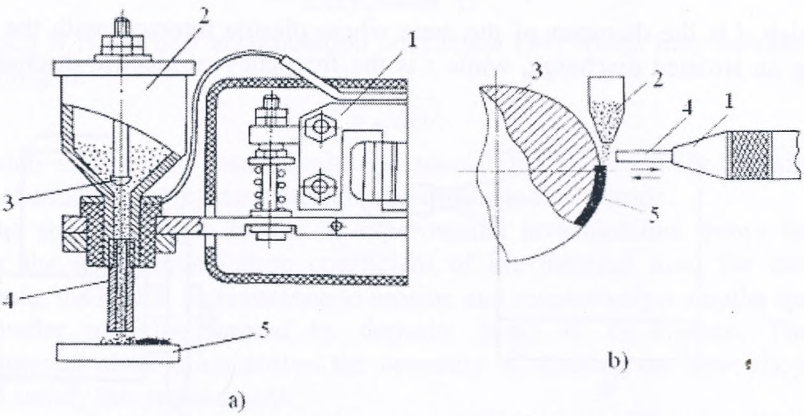

Fig. 1 Tool electrodes used in the formation of powder deposits by contact breaking [9]:
a) 1-vibrator; 2-bunker; 3-dosing element; 4- tool electrode; 5-the piece to be processed;
b) 1-vibrator; 2-bunker; 3-cathode piece; 4-bar tool electrode; 5-processed piece.

The copper cylindrical electrode adjusted under an angle of 15…20° degrees referred to the piece axis proved to be more durable for this variant of deposit formation.

Later it became necessary to transmit it a rotation movement, thus the cone-shaped tool electrode subjected to the rotation movement was recommended for the first experimental equipment. The long standing use of such equipment revealed essential drawbacks of total electrodes.

The erosion of the cone tip takes place under the influence of electric discharges. As a result the value of the interstice and the anode electric field are changed. A thorough investigation of electro-erosion phenomena has shown that they constitute a component of the deposit formation process for the interstice. S=0,1…0,5 mm.

Second, it is stated that when working with relatively high frequencies and energies (f=15…20Hz, W>1…2 J) the tool electrode is heated under the influence of the "warm" electrode spots and this leads to its melting, oxidation and destruction through drawing the material in solid, liquid or vapor state. These factors do not allow a long lasting processing to get the layers.

The total or partial omission of these factors can evidently be realized by devising a tool whose working surface is constantly renewed. This idea was practically realized by devising, designing and producing the tool-anode shaped as a rotating disc (fig. 2. b).

The advantages of this electrode compared to the cone-shaped one are evident because it allows the development of the process so that each discharge may begin on a new portion of the surface which has advanced in the working zone of the interstice. This requires calculating the linear speed of a certain point on the tool-electrode surface, according to [6, 9]:

$$v = 60 \cdot d_z \cdot f \;\; \text{m/min} \tag{1}$$

in which d is the diameter of the zone where plasma interacts with the anode during an isolated discharge, while f is the frequency of electric discharges in pulse.

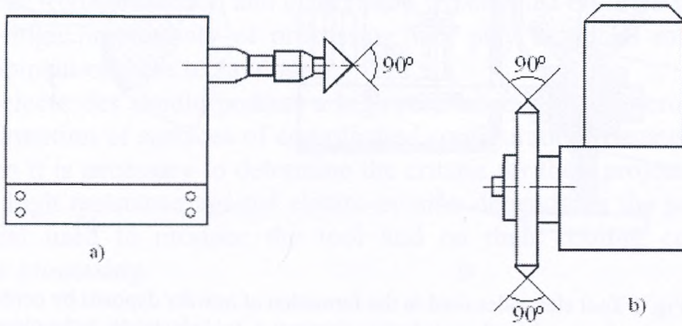

Fig. 2 The tool- electrode for powder deposit layer formation:
a- cone-shaped tool- electrode (anode); b- disc tool- electrode (anode) [6, 9]

Experimental investigations were done aiming at determining the erosion intensity for the electric discharges in pulse under a regime of under excitation which takes place in the air at an ordinary pressure.

The aim of these investigations was to determine the resistance to electric erosion of tool-electrodes depending on the heat accumulation coefficient of the material used for their production (fig. 3).

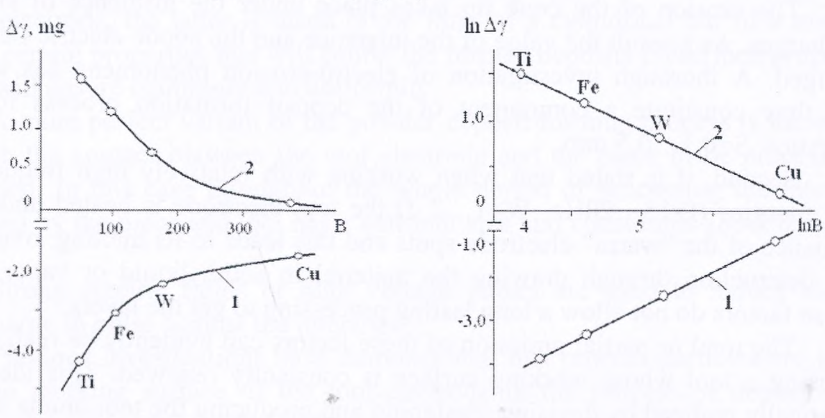

Fig. 3 The dependence of deposited powder quantity on the tool-electrode (anode)- 2 and its masserosion-1, depending on the heat accumulation coefficient, b [9].

Both curve 1, which describes the mass reduction of the tool-electrode (anode) because of erosion, and curve 2, which points to its growth due to powder particle deposits, may be described as:

$$\pm \Delta \gamma_E = m \cdot B^n , \qquad (2)$$

in which B is the heat accumulation coefficient [94] which may be calculated according to:

$$B = \sqrt{c\rho\lambda} \qquad (3)$$

in which *c, p,* λ are respectively the special thermal capacity, density and thermal conductivity of the material used for the tool-electrode.

The analysis of the results of experimental investigations shows that the higher the heat accumulation coefficient of the material used for the tool-electrode, the higher its resistance to erosion and respectively a smaller quantity of powder particles formed by deposits sticks to its surface. The last experimental observation proves the necessity of working out new alloys that would satisfy this requirement.

Lately superficial processing using electric discharges in pulse (EDP) has found a new domain of usage: the formation of oxide layers. In this type of processing the tool-electrode is shaped according to the form of the surface head.

There is no relative movement between the components of this technological system as the processing is realized through the migration of the plasma canal on the processed surface of the piece and the oxide pellicle is formed. The formation of the oxide pellicles takes place as a result of the oxygen ions interaction in the plasma canal of electric discharges in pulse with the processed surface of the piece.

The surface cementation is done with the help of tool-electrodes made of technical graphite. The latter helps to introduce effect energy in the interstice and to saturate the processed surface with carbon due to which it is necessary to keep the size of the interstice constant. To provide this the tool-electrode is produced in the form of a bar or rotating disc.

3. Criteria for designing tool-electrodes

Taking into account the above said concerning the influence of different factors on the erosive process and their intensity, the destination of tool-electrodes for dimensional processing, those used to form deposited layers and for thermal treatment and for -thermal treatment of surfaces using electric discharges in pulse in order to design tool-electrodes the following criteria may be put forward:

– the form which is determined by the character of processed surface (usually during the formation of deposited layers and superficial thermal treatment the interstice should be kept constant). In this case this desideratum may be realized in two ways:

– first, through permanent renewal of the working surface and second by producing the tool and the rotating disc form ensuring the development of each precursory discharge from a new portion of the surface;

– the material for production (this means using a material with a high heat accumulation coefficient that will ensure a much longer time of melting under the same conditions – that will exceed the duration of the electric discharge in pulse;

– the speed of shifting the working surface (it will be greater that the speed of shifting the “cold” electrode spots in conformity with [9,10] about $10 \ldots 10^2$ cm/s);

– cooling in the working process (usually during the working process the tool-electrode is heated due to heat accumulation when electric discharges are repeated, and this may cause erosive processes or thermal dilation which may lead to changes in both the processing regime and in the interstice that may be realized by organizing the cooling with a liquid that will circulate within the body of the tool or by producing a disc of massive dimensions; the cooling may be also obtained by means of a system of insufflating the processed surface;

– compatibility of the tool material with that of powder when deposited layers are formed; joining the tool surface and that of the processed piece when the processing is performed under a static regime and the canal of discharge migrates both on the surface of the piece and on that of the tool.

4. Conclusions concerning the elaboration of criteria for designing tool-electrodes

The analysis of the effects that take place in the material of electrodes during the dimensional processing, the formation of deposited layers and the superficial treatment allow us to conclude that when designing tool-electrodes it is necessary to take into account the following:

1. the form of the processed surface;
2. the material used to produce the tool-electrode;
3. the relative shifting speed between electrode – piece;
4. the conditions of cooling the tool-electrodes;
5. the compatibility of the electrode and piece material in the formation of deposited layers.

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