INVESTIGATION OF THE REMOVAL OF THE DIAMOND LAYER OF A WHEEL DURING ED GRINDING WITH CHANGING POLARITY OF ELECTRODES

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Abstract: The article investigates the features of the formation of holes on the surface of a bond of grinding wheels. The impact of electrical discharges on the bonds of groups 2 and 4 causes the formation of altered surface layers with increased mechanical properties, which contribute to more durable retention of grains. The main factors affecting the thickness of the modified layer are the pulse energy, wheel rotation speed, and the amount of fluid supplied to the cutting zone. In bonds of group 1, due to the low value of the Palatnik's criterion, the electroerosive effect shapes a very developed relief, the protrusions of which have more grains. In bonds of group 3, including non-conductive components, discharges with the energy of more than 0.05J cause the appearance of cracks. Therefore, an instrument with bonds of groups 1 and 3 should be operated with pulse energy not exceeding 0.05J.

Keywords: ED grinding, diamondiferous tool layer, unit pulse, metal removal.

Introduction

To reveal the physical essence of the ED diamond grinding process, in which the overall effect of exposure consists of individual phenomena, occurring in microvolumes in fractions of a second (diamond grinding, electroerosive editing), it is necessary to study these microprocesses. In the case of diamond grinding, it should be explored microcutting with a single grain to study the cutting process. Then transferring the results obtained during these studies to the real process of mass microcutting-scratching, it is possible to obtain a general picture of the phenomena that occur during diamond grinding. Similar methods also exist in the study of electroerosive processes. Studying the phenomena, accompanying single electrical discharges, it is possible to describe the integral process of electroerosive straightening, provided that the additivity of the process is preserved.

Many works are devoted to the study of the phenomena, accompanying single electric discharges [1-5]. For this purpose, most of them used devices that generate separate acute-angled pulses. The advantage of these devices is the simplicity of their design. The disadvantages include the long duration of the generated pulse, the difficulty of adjusting its parameters, and the sawtooth shape. The results obtained when working with such devices do not correspond to the real conditions of grinding, since most modern generators generate pulses that are close to rectangular. Therefore, it was necessary to study exactly rectangular pulses for real conditions of ED diamond grinding.

Research Methodology

Under laboratory conditions, it is rather difficult to manufacture an oscillator that forms individual pulses close to rectangular.

Therefore, a device was developed for ShGI 40-440 (ШГИ 40-440) transistor oscillator. It is easy to manufacture, reliable in operation and it has small dimensions (70×70×20mm). By switching a conventional six terminal toggle switch, the oscillator is switched from the continuous generation mode to the mode of generating unit pulses (single electrical discharges).

The device diagram (Fig. 1) works as follows. In the initial state ($П_1$ in position 0), the diagram is disconnected from the oscillator. By switching $П_1$ in position 1, we turn off the voltage amplifier, since the transistor T_3 is open. When the K_1 button is pressed, the C_1-C_5 diagram is discharged through the diode D_1, supported by the resistance R_1.

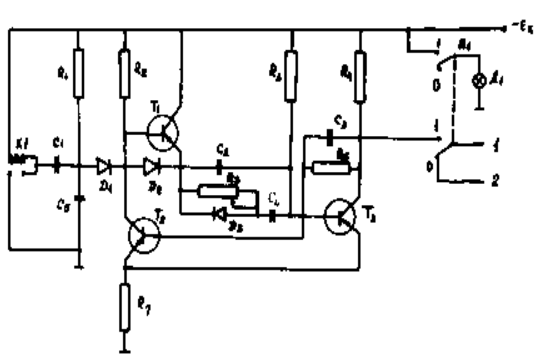

Fig. 1. Schematic diagram of the device for ShGI 40-440 (ШГИ 40-440) transistor oscillator to form a unit pulses

In this case, an acute-angled pulse is formed based on the transistor T_1. Transistor T_1 opens and changes the state of the one-shot multivibrator (T_2T_3). The voltage at the collector of the transistor T_3 is rectangular. Simultaneously with the closing of the transistor T_3, the C_4R_5 circuit begins to charge. Its time constant determines the pulse duration. After charging C_4, the triode T_3 opens, T_2 closes, closing T_1. Thus, the diagram is restored to its original state. As a result, rectangular pulses are obtained at the output of the oscillator (Fig. 2).

To study the effect of unit pulses on the diamondiferous layer of circles on metal bonds, a plant, which consisted of ShGI 40-440 (ШГИ 40-440) transistor oscillator, a device for the formation of unit pulses, C1-29 oscilloscope, a device for fixing the electrode and the sample under study, has been used.

The electrical erosion of M1, MC1, MC2, MC3, MC6, MC8, MC15, MB1, MO4, MO13, M50 bonds has been investigated in a working medium—an aqueous solution of sodium nitrite and soda ash of various concentrations. The working medium was introduced into the gap between the tool and the sample from the bond by drops. The size of the gap between the electrodes was set using a micron indicator from the position of the short circuit, which was determined using a low-voltage ohmmeter.

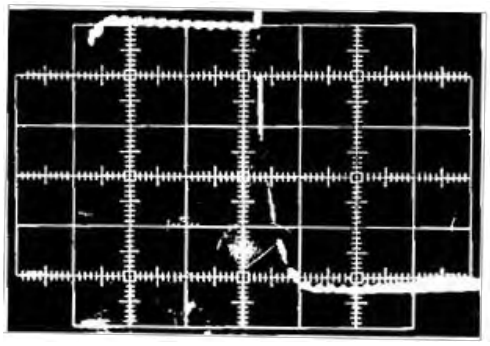

Fig. 2. Unit pulses of rectangular shape (1 mark corresponds to 10µs, 1 scale division of the oscilloscope corresponds to 1.5V)

For the values characterizing the hole obtained in the bond, the values of its diameter, depth, and volume have been taken. The diameter and depth of the hole have been determined by profilograms recorded in two perpendicular sections on a Surtronic 25 profilograph-profilometer. The volume of the hole has been calculated using the well-known formula [6]:

$$V_л = \frac{\pi}{6} D_л^2 h_л, \qquad (1)$$

where $D_л$ – hole diameter, mm,

$h_л$ – hole depth, mm.

ShGI 40-440 (ШГИ 40-440) transistor oscillator has been used as a power source. The speed of rotation of the circle has been changed through pulleys on the shaft of the electric motor. As the test, we have used circles made of M1, MC1, MC2, MC3, MC6, MC8, MC15, MB1, MO4, MO13, M50 cup-shaped bonds. The bond layer has been polished to Ra 0.04µm; a steel ball served as an electrode, which was set at a distance of 10–15mm from the surface of the circle before the experiment. Simultaneously with the rotation of the circle, the ball was given a traverse $S_{пр}$ of 10–15m/min. The working fluid has been fed into the gap, as in straightening. As a result of the combination of the two movements of the circle and the electrode, a series of spiral holes has been formed on the bond surface. By changing the polarity, the dependence of the parameters of the holes on the anode and the cathode on the rotation speed has been established. The pulse energy has been varied in the range from 0.0J1 to 0.3J by connecting additional resistances to the working gap. The calculation of the pulse energy has been carried out, according to the formula:

$$W_u = \int_0^{\tau_u} UId\tau , \qquad (2)$$

where U – discharge voltage, V,
I – discharge current, A,
τ_u – pulse duration, s.

Results

The volume of the hole formed as a result of a single discharge on the tool diamondiferous layer is the main characteristic that ultimately determines the productivity of the dressing process. Therefore, determining the degree of influence of various factors on the hole volume is of great importance.

Experiments carried out for all the investigated bonds have shown that the hole volume non-linearly depends on the pulse energy. The authors of [7,8] came to similar conclusions. As a result of the research, it was found that with an increase in the pulse energy from 0.01J to 0.3J, the hole volume in the bond increases from $(1-6)\cdot 10^{-5}$mm to $(25-347)\cdot 10^{-4}$mm.

It should be noted that for all bonds the nature of the dependence of the dimple volume on the pulse energy does not change, i.e. the character of the $V_л = f(W_u)$ curve remains constant. However, components with different thermophysical and electrical properties in bonds have a noticeable effect on the amount of material removed by a single discharge.

As a first approximation, the erosion resistance of a bond, as is known, can be determined using the Palatnik's criterion:

$$\Pi = c\gamma\lambda T^2 , \qquad (3)$$

where c – heat capacity, cal/g*°C,
γ – density, g/cm^3,
λ – thermal conductivity, cal/cm s*°C,
T – melting temperature, °C.

Analysis of the electrical and thermophysical properties of the bonds made it possible to arrange them in a row, according to the increasing electrical discharge resistance: MO4, MO13, MB1, M1, MC6, MC15, MC2, MC3, MC1, MC8, M50 (Fig. 3). This arrangement of the ligaments is explained as follows. Bonds MO4, MO13, MB1 (group 1) are made on a copper-aluminum-tin base with small additions of other elements.

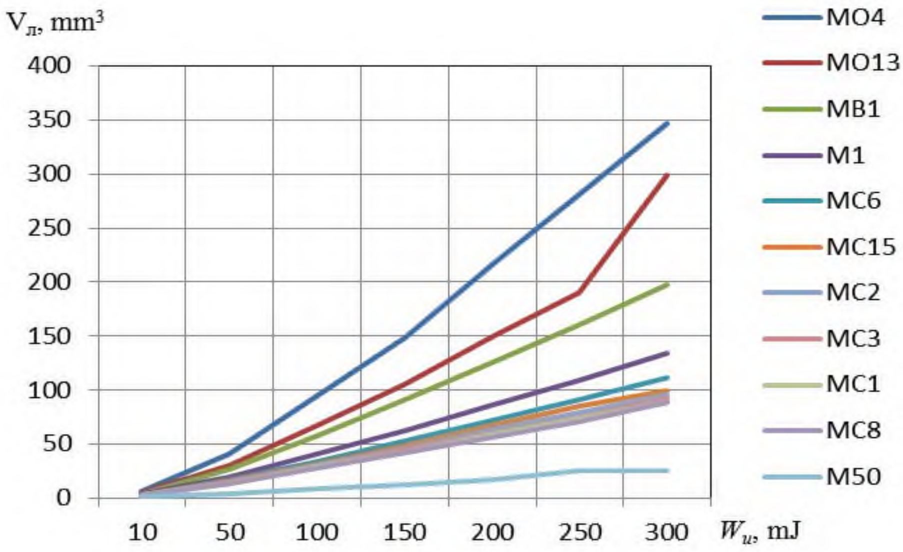

Fig. 3. Impact of pulse energy on a hole volume

Since aluminum and tin have small values of Palatnik's criterion, the electroerosive resistance of these bonds is low; therefore, while other things being equal, the volumes of the holes in the bonds of group 1 are maximum.

Bonds of group 2 (M1, MC6, MC15) have a copper-tin base. The absence of aluminum in them and the addition of conductive alloying elements increase Palatnik's criterion and, accordingly, reduce the hole volume under the action of the discharge. The addition of components that do not conduct electric current into the bonds of group 3 (MC2, MC3, MC1, MC8) further increases their electroerosion resistance, reducing the hole volume when exposed to single discharges. The bond of group 4 (M50) is a copper-impregnated VK10 hard alloy.

From the point of view of EDM, this is the composition of an ideal tool with a high value of Palatnik's criterion. Good thermal conductivity and current conductivity due to the presence of copper in the bond, high density and melting point of tungsten carbides provide a high electrical discharge resistance of the bond, as a result of which, while all other things being equal, the volumes of single holes in this bond were minimal. The processing of the experimental results has been carried out by the methods of mathematical statistics. In each sample, 50 holes have been measured obtained by exposure to pulses with the same energy. The volume of each hole has been calculated. Then the law of distribution of hole volumes has been determined, its characteristics and the deviation of the empirical distribution curve from the theoretical one have been calculated. The arithmetic mean and variance have been determined for each pulse energy. Based on these calculations, a regression analysis has been performed, as a result of which the following formula has been obtained:

$$V_л = aW_u^b, \quad (4)$$

where $V_л$ – hole volume, mm^3,

a,b – coefficient and exponent, taking into account the bond composition,

W_u – pulse energy, mJ.

The values of the coefficient a and the exponent b, the volumes of the holes $V_л$ calculated by the formula (4) are given in Table 1.

Table 1. Values of coefficients

Bond	*a*	*b*
MO4	0.387	1.194

MO13	0.345	1.145
MB1	0.327	1.123
M1	0.282	1.081
MC6	0.267	1.057
MC15	0.259	1.046
MC2	0.252	1.042
MC3	0.247	1.038
MC1	0.244	1.035
MC8	0.242	1.031
M50	0.088	1.008

The analysis shows that deviations from the linear dependence for all bonds are natural and, depending on the bond components, these deviations appear to a greater or lesser extent. This character of deviations from the linear dependence cannot be attributed to measurement errors.

Conclusion

Analysis of the research results shows that with an increase in the pulse energy, the volume of a single one increases. This relationship has a non-linear nature. The effect of electrical discharges on the bonds of groups 2 and 4 causes the formation of altered surface layers with increased mechanical properties, which contribute to more durable retention of grains. The main factors affecting the thickness of the modified layer are the pulse energy, the speed of the tool, and the amount of fluid supplied to the cutting zone.

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