EDM – analyses of current and voltage waveforms

Obróbka elektroerozyjna – badanie impulsów elektrycznych napięcia i natężenia prądu

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The article presents results of monitoring current and voltage waveforms in EDM process. The relations between process parameters and stability of electrical erosion have been determined.

KEYWORDS: electrical discharge machining (EDM), current, voltage waveforms

Development of electro-discharge machining is directly related to the development of construction technology of machine generators and their control systems. In the process of electrical discharge, the most important factor influencing on the state of the surface layer, accuracy and efficiency of the material removal and the electrode wear is the type of current and voltage waveforms (pulse shape, voltage and current amplitude, time interval) [4, 5]. During electro-discharge machining, not all pulses are effective, resulting from various types of conditions in the gap between electrodes. Accumulation of the eroded material in the gap between electrodes may lead to serial arc discharge and thereby reduce the efficiency of the material removal process. Process monitoring is therefore important for optimizing the process parameters. Recent publications [1-3, 6] point to the need for further development of both current and voltage monitoring systems to ensure proper processing stability and productivity. Work on the construction of new power supplies and circuits to achieve the best pulse characteristics, are being carried out.

Experimental research

The purpose of the study was to monitor voltages and currents waveforms during electro-discharge machining and to determine areas of erosion stability.

A measuring circuit was developed, which allowed to determine the characteristics of the machine tool generator. Currents and voltages waveforms during EDM process were recorded. The current measurement was done by the indirect method - based on the voltage drop on the current shunt. The maximum value of the voltage drop for set currents does not exceed 3 V, so the signal is fed directly to the oscilloscope card. Measurement of electrical discharge voltage was made by insertion into the 10-fold decreasing probe system. The individual connections between components are made from shielded coaxial cables terminated with BNC connectors or terminals. The application was developed in a LabView environment that enabled the operation of the oscilloscope card. Recorded data was transferred directly to the hard disk of the computer. The processing and analysis of the measured results was carried out in National instruments DIAdem software. Determining the actual current and voltage waveforms required the use of appropriate converters (0.187 V / 1 A for current measurement, 10X amplitude for voltage measurement).

Electro-discharge machining occurs when the supply voltage U_z is lowered to the discharge voltage U_c and the discharge current I_c increases (fig. 1). The electrical voltage supplied from the generator to the electrodes immersed in the dielectric generates an uneven and time-varying electric field (110 V/m). With sufficient magnitude of the electric field and specified voltage U_g, called the boundary voltage, the emission of electrons from the cathode occurs. Electrons collide with the atoms of the medium and cause their avalanche impact ionization, resulting in a plasma channel. The current flowing through the plasma channel melts and evaporates the workpiece and working electrode, resulting in cavities, called craters.

The end of the generator's work cycle, voltage and current drop causes the plasma channel and gas bladder to close. The material thrown out of the craters solidify in the dielectric, creating processing products. Some of the material that has not been removed from the crater solidifies again in the surface. Stabilization of the conditions occurs in the gap in time interval, after which the process is repeated cyclically. The amount of eroded material during a single impulse significantly influences the material removal rate, which is one of the basic parameters associated with the economics of EDM use in production processes.

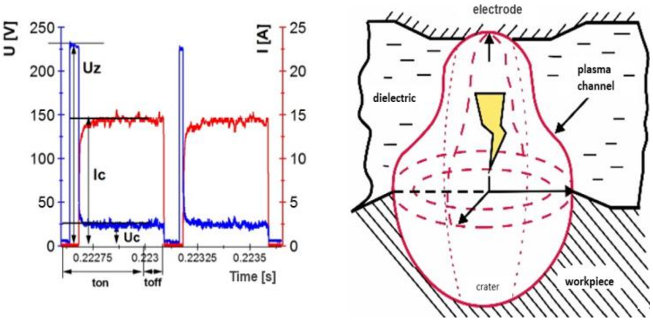

Fig. 1. Voltages and currents waveforms and erosion process diagram

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The discharge voltage U_c has a decisive influence on the ionization of the channel, through which the current flows. For a higher discharge voltage, it is possible to set a higher value for the inter-electrode gap and thus to facilitate its rinsing and product dissipation by the dielectric. Increasing the discharge voltage results in an increase in both surface roughness and removal efficiency.

Discharge current I_c directly affects the amount of eroded material. Maximum current values are used in roughing to ensure proper process performance. Depending on the type of working electrode material, the maximum current density should not exceed 15 A/cm^2 for copper and 25 A/cm^2 for graphite electrodes.

The pulse duration t_{on} associated with the discharge current I_c determines the amount of thermal energy delivered to the workpiece. With the increase in pulse duration and discharge current, both the diameter and the depth of craters generated by the electric discharge increase. Time interval t_{off} is responsible for stabilizing the inter-electrode gap (remove products of the process, deionization of the discharge channel).

More than 100 EDM experiments were performed, in which voltages and currents waveforms were recorded in the range: I_c - 1.7 to 36 A, t_{on} - 6 to 1200 μs, t_{off} - 6 to 600 μs. The studies included a deviation analysis of the values of these parameters adjusted to actual measured values. Analysis of the voltage waveforms has shown that for the highest set discharge current and pulse duration values as well as minimum time interval, in most cases, arc or short circuit occurs. For short time interval, the plasma channel may not be completely deionized, thus increasing the likelihood of a subsequent discharge in the same place. Unremoved process products resulting from material erosion reduce the resistance of the medium (dielectric) and destabilize the conditions in the gap. There is a high probability of a short-circuit. The control system of the machine counteracts the described phenomena by increasing the gap between electrodes (momentarily raising the electrode) and at the same time extends the break time (fig. 2).

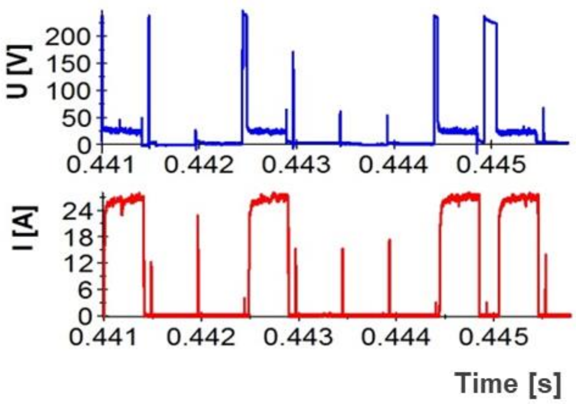

Fig. 2. Recorded currents and voltages

The correct operation of the generator control system ensures the energy repetition of the discharge. As a result, the presented disturbances have no significant effect on the quality of treated surfaces. However, poorly adjusted ranges of set parameters can have a significant impact on the process performance. Experimental results confirm the Gaussian density distribution of discharge power, depending on the type of electrical pulses. For short impulse times and the smallest discharge current values, the surface texture is characterized by a high density of tops. As a result of the heat flux, changes occur in the microstructure of the material - melted layer, heat-affected zone or tempered layer appear (fig. 3). The increase in discharge current and pulse duration increases the diameter and power of the discharge channel, resulting in a much higher height and spacing between the vertices. The duration of the heat source has a decisive influence on the thickness of the heat-affected zone layer. As the pulse duration increases, the amount of heat supplied to the workpiece increases (through conduction), resulting in phase changes.

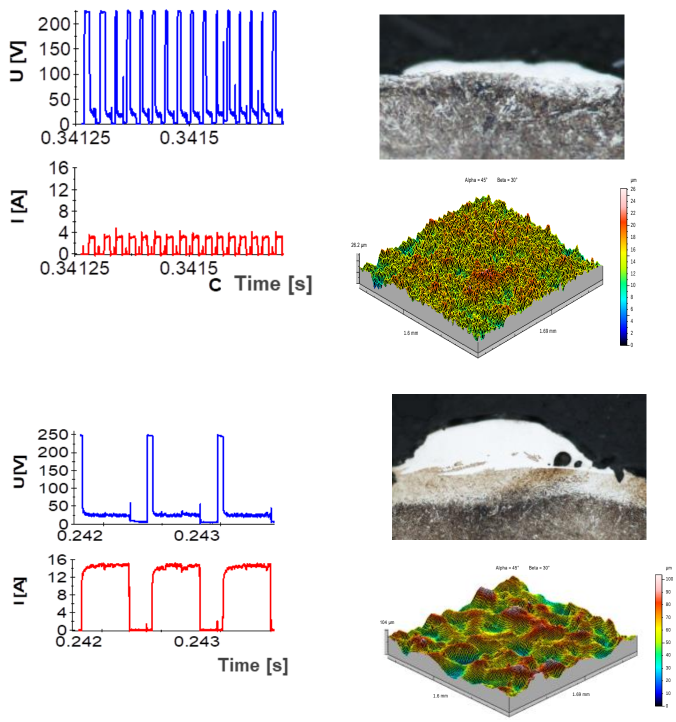

Fig. 3. Current-voltage waveforms along with stereographic images of the surface after electro-discharge machining and photographs of metallographic surface finishes of WNL 60 HRC steel: a) U_c = 25 V, I_c = 3.2 A, t_{on} = 13 μs, t_{off} = 11 μs; b) U_c = 25 V, I_c = 14.3 A, t_{on} = 400 μs, t_{off} = 150 μs

Conclusions

The EDM erosion process mainly depends on the type of electrical impulses, i.e. discharge current, pulse duration, discharge voltage. These parameters define the energy delivered to the workpiece and the size and shape of the discharge channel.

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