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Electrical discharge machining with the application of the conductive laser channels

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Abstract

The method of the electrical discharge machining (EDM) with the application of the solid metal wire electrode-tools (WET) is known. The wear of the WET and limits of the values of the current and the tension force are the disadvantages of the EDM method.
The EDM with the application of the conductive laser channel (CLC) as an electrode-tool is offered. The equivalent electric scheme of the electroerosive cell with two plasma channels: CLC and electrical discharge, is considered.
The distribution of the heat in the workpiece after the current pulse passing through electroerosive cell is studied.
The experimental research of the EDM process with the use of the CLC as an electrode-tool are carried out.

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Keywords: The conductive laser channel; electrical discharge machining; the schemes of the machining

1. Introduction

Electrical discharge machining (EDM) is one of the most effective methods of processing of the hardly machined materials and technological objects of a complex form. By means of this method the high accuracy of the machining (to 1 μm) and a low surface roughness is reached (Ra up to 0,04 μm).

The main lack of the method is the wear of the electrode-tool leading to the decrease in accuracy of the machining and current limits and the force of a tension at the implementation of wire electrical discharge machining (WEDM) using metal electrode-tools in the form of wire with a diameter of 0,08…0,03 mm.

The restrictions imposed on WEDM with the use of metal (solid-state) electrode-tools essentially are not removable. Only their partial compensation for the account of deterioration of other parameters of the machining is possible (accuracy, surface roughness).

The plasma channels received as a result of the optical breakdown of different environments by laser radiation are known [1 - 4].

In the works [5 - 7] the use of plasma channels as electrode-tools at the electrophysical and electrochemical methods of machining is proposed.

In this work the processes of thermal destruction of the workpiece as a result of WEDM with the use the plasma laser channel (PLC) of the electrode-tool are considered. Electrical discharge machining with the use of the conductive laser channels has essential differences from the traditional processing because PLC has a variable resistance and diameters at the place of processing since there are different types of power influence (heat energy and radiation energy of PLC plasma, energy of the shock wave which is formed at the optical breakdown). In this regard it is advisable to conduct the investigations on the process of electrical discharge machining with the use of the conducting laser channels (CLC).

2. The theoretical research of the electrical discharge machining with the use of the conductive laser channels

The electrical discharge machining with the use of PLC represents a difficult process including the different physical

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phenomena. In the real work the phenomena taking place in the machined zone during the action of the electric discharge are considered. In Fig. 1 the scheme of the processing is represented.

The conductive laser channel is created at a distance of the interelectrode gap of *s(t)* from the workpiece. Between PLC and the workpiece there is an electric discharge. Diameter of $d_k(t)$ and electrical resistance of PLC $R_k(t)$ are not constant in time.

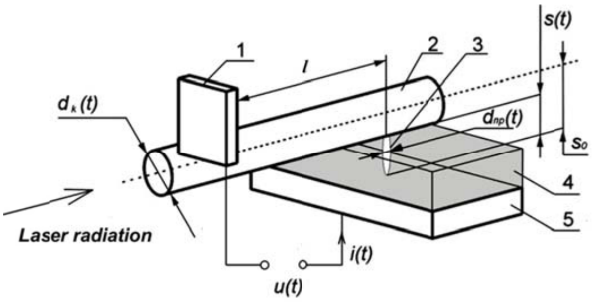

Fig. 1. Scheme of the electrical discharge machining with the use of PLC: 1 - current lead, 2 - PLC, 3 - electric discharge, 4 - working liquid, 5 - workpiece; $d_k(t)$ - PLC diameter, *l* - distance between the current lead and the place of the electric discharge, *s(t)* - interelectrode gap (IEG), *i(t)* -current, *u(t)* - voltage, $d_{pr}(t)$ - diameter of the channel of the electric discharge, s_0 - distance between the optical axis and the workpiece

The change of the diameter of PLC $d_k(t)$ leads to the change of the interelectrode gap size *s(t)* at an invariable distance between the optical axis of the focusing system and the workpiece. At the electroerosive processing the destruction of the workpiece material is the result of the thermal influence. Between PLC and the workpiece the channel of discharge (fig. 2) is formed.

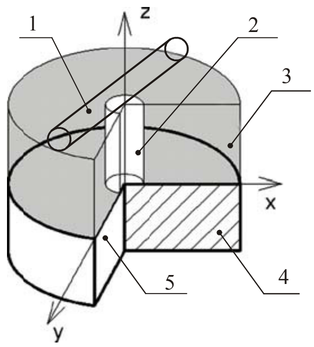

Fig. 2. Scheme of the heat transfer at the electrical discharge machining: 1 - PLC; 2 - channel of discharge, 3 - working liquid, 4 - modeling plane, 5 - workpiece

The distribution of the power which is allocated on the workpiece allows to determine the size of the heat flux coming to its surface:

$$q(r,t) = W_a(t)/(\pi R^2(t)\exp(-r^2/R(t)^2)),$$

where *r* - the coordinate describing the distance from the center of the channel of the electric discharge (fig. 6). In the place of the contact of the channel of discharge with the workpiece the surface source of heat is created. The axial symmetry to an axis *z* of the intensity of the heat flux created by the channel of discharge is supposed, and the parameters of the workpiece do not change in all volume. From the three-dimensional problem of the heat conductivity it is possible to pass to the two-dimensional, having considered the heat transport in the plane of the section of the workpiece (fig. 3).

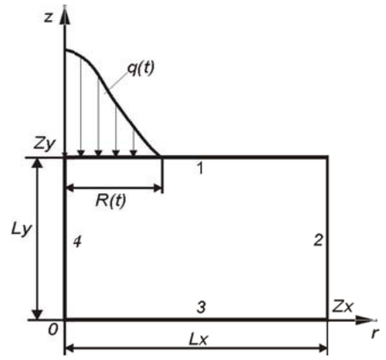

Fig. 3. The scheme of modeling of the heat transfer in the volume of the workpiece

The non-stationary equation of the heat conductivity in the Cartesian coordinate system:

$$\rho C \frac{\partial T(r,z,t)}{\partial t} = \lambda\left(\frac{\partial^2 T(r,z,t)}{\partial r^2} + \frac{\partial^2 T(r,z,t)}{\partial z^2}\right),$$

where ρ is the material density, C is the specific heat capacity, λ is the thermal conductivity, T is the temperature, t is the time, r and z are the coordinates.

The two-dimensional problem of the heat conductivity was solved by the finite elements method with the following initial and boundary conditions:

Initial conditions:

At $t = 0$:

$T(r, z) = T_0$; $T_0 = 300$ K

At $t > 0$:

Boundary conditions:

Border 1

In the place of the contact of the channel of the electric discharge with the workpiece surface the heat flux is set:

$0 \le r \le R(t)$, $z = Z_y$: $\lambda \frac{\partial T(r,z,t)}{\partial z} = q(r,t)$

On the rest of the surface of the workpiece there is a heat exchange with the working liquid:

$R(t) \le r \le Z_x$, $z = Z_y$: $\lambda \frac{\partial T(r,z,t)}{\partial z} = a(T_g - T(r,z,t))$,

where *a* - the heat exchange coefficient of the workpiece material with the working liquid.

Border 2

The heat exchange with the air on the side surface:

$r = Z_x$, $0 < z < Z_y$: $\lambda \frac{\partial T(r,z,t)}{\partial r} = k(T_v - T(r,z,t))$.

where k - the heat exchange coefficient of the workpiece material with the air.