TECHNOLOGICAL CAPABILITIES OF ELECTRIC DISCHARGE CUTTING BY THE END OF A ROTATING NON-PROFILED ELECTRODE-TOOL

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Abstract: One of the promising and little-studied areas is electrical discharge machining with rotating non-profiled electrodes in the form of rods or wires, which has developed only in recent years with the advent of CNC equipment adapted for these purposes. The main target of this work is actual research of the features of electrical discharge machining with non-profiled electrodes when performing work related to cutting out the end of a wire electrode, in particular, to obtain holes in tubular parts, made on specially developed equipment. The studies were carried out on a part made of X165CrMoV12 tool steel with a wall thickness of 1.5 mm. The most optimal cutting modes have been selected. The performance, quality and accuracy of the processed surface were evaluated in comparison with ED (electrical discharge) duplication. General recommendations for the implementation of the processes of electrical discharge cutting by the end of a non-profiled electrode are given.

Key words: electrical discharge machining, technology, performance, electrode, tubular part, tool steel.

1. INTRODUCTION

Wide use in mechanical engineering of materials with special strong physical and mechanical characteristics that determine their poor machinability with traditional cutting methods, building of parts with complex shapes, increased requirements to the quality of the surface layer and manufacturing accuracy, as well as the need to reduce the cost of processing and increase labor productivity led to the emergence and widespread wandering in the production of electrophysical processing methods and based on these methods of technological processes [1-3].

This group of processing methods includes those technological methods of processing workpieces, in the implementation of which the energy impact on the workpiece is carried out by non-traditional cutting methods, processing by plastic deformation, heat treatment, and other types of exposure or a combination of several of their types [4-8]. To such innovational types of energy impact include electric field, electrochemical effects and exposure to flows of microparticles [9].

Electrical discharge machining (EDM) is the destruction of metal under the influence of electric discharges causing heating, melting, ejection of molten particles of local surfaces working fluid, ionization, and decomposition of working fluid [10-15]. EDM process changes the shape, size, roughness surface properties of the workpiece [16-18].

The EDM method has found the greatest application in performing operations such as stitching simple holes in cavities, volumetric copying of shaped surfaces, cutting wire tool, electroerosive cut, electrical discharge milling. Electrical discharge machining methods for sizing conductive materials significantly expand the capabilities of modern technologies, allowing to successfully process any conductive materials, regardless of their hardness and toughness [19, 20].

The most commonly used types of EDM are wire EDM, ED duplication, ED deep hole drilling of small diameter and EDM with rotating non-profiled electrodes in the form of rods or wires [20]. The technological capabilities of the last type type of processing have not been fully investigated. Specialized complexes for electrical discharge machining with non-profiled electrodes have been developed so far only for micro-discharge machining, and information on the technical parameters of this type of machining is presented in insufficient quantities [21, 22].

However, this is a rather urgent task for research, since using this method it is possible to cut out holes in tubular parts. In the details of hydraulic units of engines (valves, spools, liners), holes of various shapes are often found (Figure 1), the processing of which by milling presents certain difficulties associated with the need to turn the workpiece and small radii of rounding of corners [23-25].

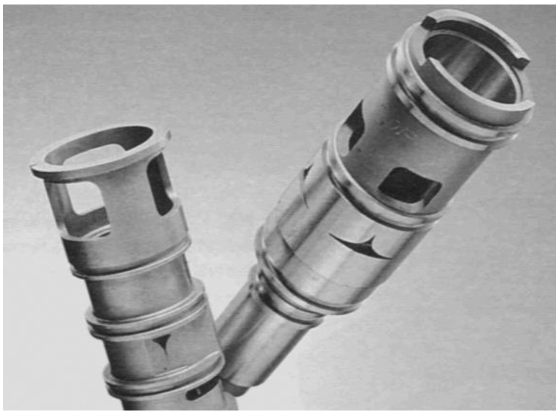


Fig. 1. Valve sleeves with holes

Such holes are usually obtained by ED duplication requiring the manufacture of graphite or copper electrode-tool, which increases the processing cost (especially, in the case of complex surfaces) [21, 22]. Compared to duplication technology, the cycle of technological preparation of production during EDM with rotating non-profiled electrodes in the form of rods or wires is significantly reduced due to the elimination of labor-intensive design and manufacture of the electrode-tool [24, 25].

2. MATERIALS AND METHODS

The object of the study is the tubular part made of X165CrMoV12 tool steel with a thickness of the wall of 1.5 mm. Chemical composition of the steel is presented in Table 1.

Table 1. Chemical composition of X165CrMoV12 tool steel (in weight %)

C	Si	Mn	Cr	V	Mo	W
1.65	0.33	0.30	11.50	0.30	0.60	0.50

In the part it is necessary to obtain a hole with dimensions of 5-8 mm with a tolerance of 0.015 mm per side. To obtain such a hole in a material that is difficult to machine by cutting, one can use electrical discharge cutting by the end of a rotating non-profiled electrode-tool in the form of a wire.

Investigations related to electrical discharge cutting by the end of a rotating wire electrode were carried out on a modernized equipment ELFA-731.

To solve the problems put in this work, a number of upgrades were carried out on the equipment, with the goal of adapting the installation, originally intended for performing electric-spark alloying operations, which are economically profitable and technologically promising in solving the problems of increasing the operational characteristics of various parts of machine and cutting tools subject to intense wear [26-30], for dimensional EDM using a thin wire or special hollow rods as an electrode.

A dielectric fluid bath, filtration and pumping systems were installed. Also, a special electrode-tool module was designed and manufactured, which allows to perform operations of cutting with the electrode-tool end, marking, engraving, processing of through slots and small-diameter holes. The module is equipped with a special carriage, on which a conductor sleeve is installed and a system for supplying a working fluid under pressure through an electrode. The carriage allows you to manually adjust the height of the conductor sleeve.

The diagram of installation after modernization is shown in Figure 2.

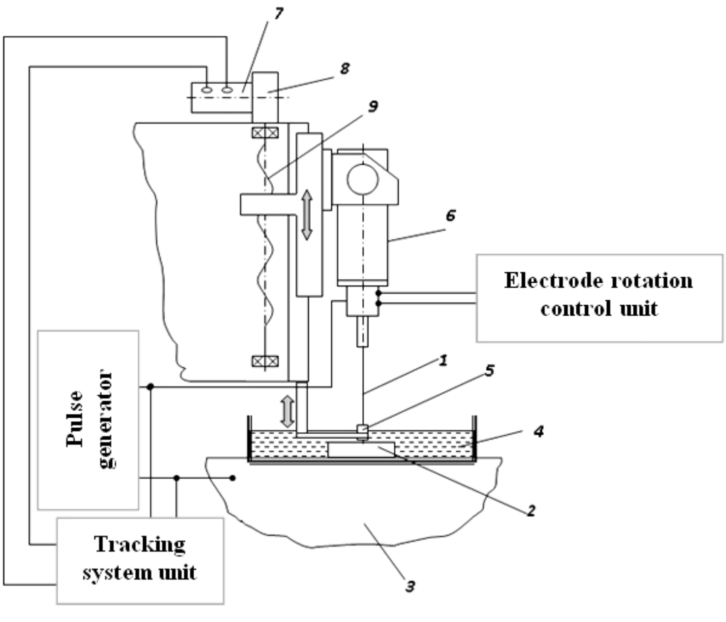


Fig. 2. Diagram of a module for electrical discharge machining with a rotating non-profiled electrode tool: 1 – wire electrode tool; 2 – processed product; 3 – table; 4 – bath; 5 – conductor sleeve; 6 – head; 7 – electric motor of the tracking system; 8 – reducer; 9 – lead screw

The electrode-tool (1) of the required diameter is installed in the collet, and the workpiece (2) is installed on the working table (3) in the bath (4) with a dielectric liquid.
The required value of the gap between electrodes is maintained by an electromechanical tracking system, by moving the tracking head (6) in the vertical direction by means of an executive motor (7), a worm gear (8) and a lead screw (9). The engine (7) is controlled by a tracking system unit.
In order to improve the processing conditions, the electrode-tool is given rotation from the electric motor (7). A tubular part made of hardened tool steel X165CrMoV12 was mounted on a mandrel. During processing, the electrode was moved along the X-axis, and the part was rotated (Z-axis). The hole processing scheme is shown in Figure 3. After cutting out the part, several additional passes were made to eliminate the taper and ensure the required hole dimensions. The processing time for a 5-8 mm hole in a part with a wall 1.5 mm thick was 6.5 min.

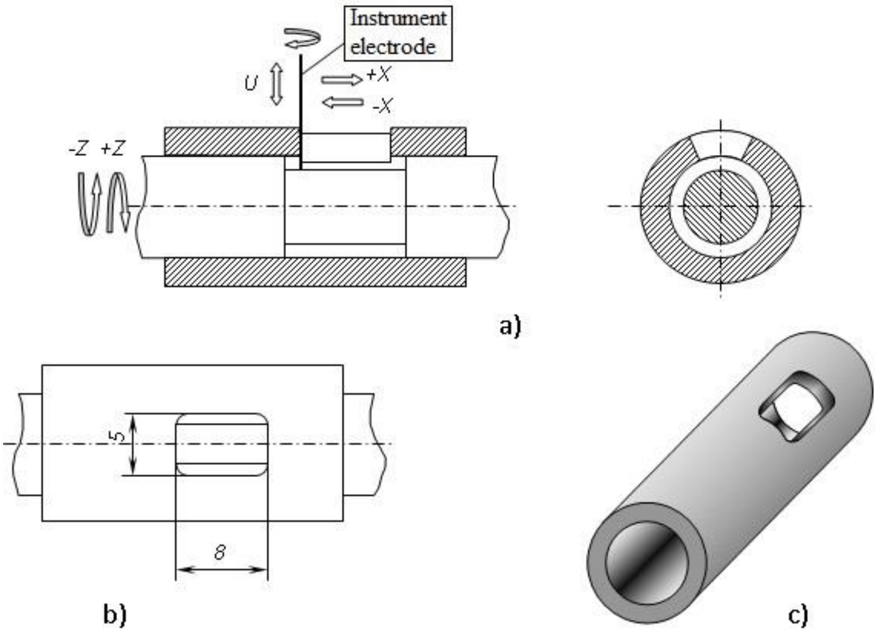


Fig. 3. Cutting out a hole in a tubular part: (a) processing scheme; (b) sketch of the treated surface; (c) tubular part with cut out hole

3. RESULTS AND DISCUSSION

As a result of the modernization of the equipment, the electrical discharge cutting of the wire electrode end was carried out and the technological capabilities of this type of processing were investigated.
The optimal processing mode to obtain a hole in the tubular part was established experimentally:
Short-circuit current I_{SC} = 6.4 A;
No-load voltage U_{out} = 90 V;
Duty cycle q = 5;
Pulse duration t_{on} = 12000 ms;
The capacity of the discharge capacitor connected in parallel with the gap between electrodes C = 1 μF;
Electrode – copper;
The working fluid – oil;
Diameter of electrode – 0.75 mm;
Electrode rotation frequency – 2000 rpm.
A hole was obtained with dimensions of 5-8 mm with a tolerance of 0.015 mm per side in a tubular part made of X165CrMoV12 tool steel with a wall thickness of 1.5 mm. Due to the wear of the electrode, the walls of the resulting hole had a slope. The slope angle depends on the ratio of the rates of erosion of the processed material and the electrode. Complete surface treatment was performed in several passes with the achievement of surface roughness R_a = 0.32...0.67 μm. The time taken to process one hole is the basis for calculating performance. The productivity under optimal processing mode was approximately 8 mm^2 / min at a short-circuit current of 6.4 A (Figure 4).

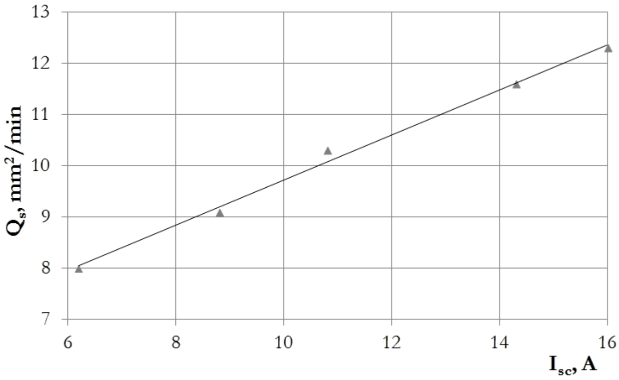
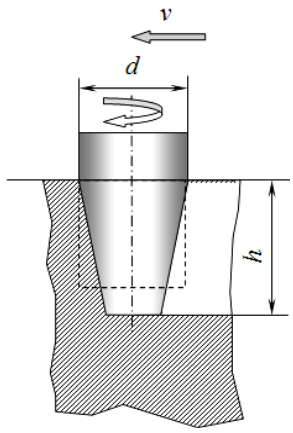
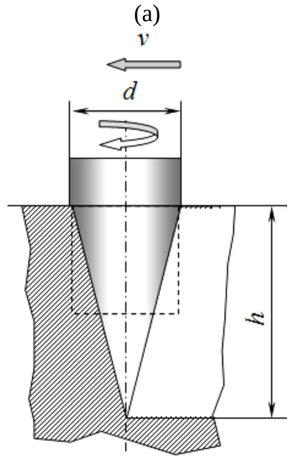


Fig. 4. Effect of short-circuit current (I_{sc}) on cutting performance (Q_s)

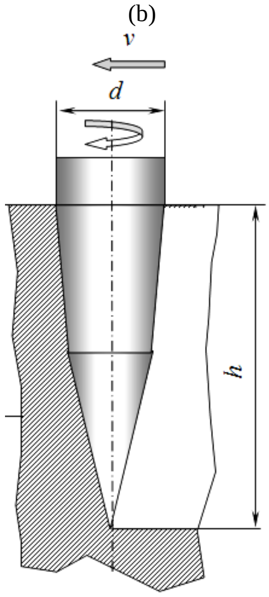
A linear increase in cutting performance is observed with an increase in short-circuit current. It was found that the cutting performance is affected by the speed of movement of the electrode-tool (*v*), and with a decrease in the latter, productivity (Q_s) increases, due to an increase in the processing area due to the greater deepening of the electrode-tool (*h*) (Figure 5).



(a)



(b)

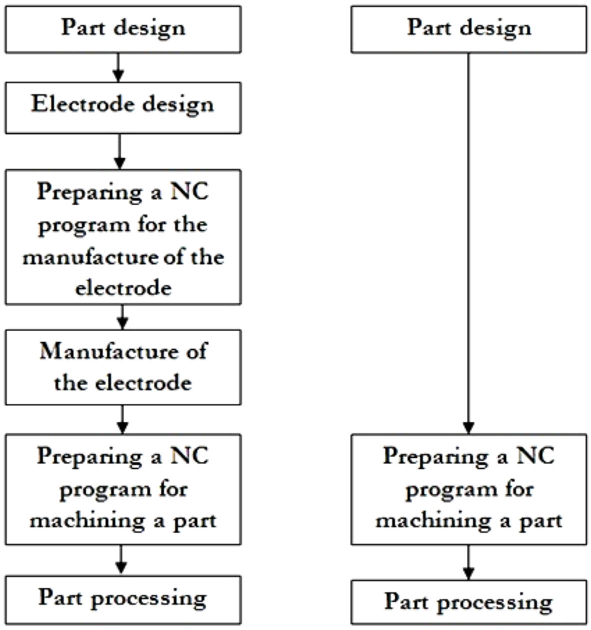


(c)

Fig. 5. The nature of the recess being formed and the change in the shape of the electrode depending on the speed of movement of the tool electrode:
(a) high speed of movement; (b) average speed of movement; (c) low speed of movement

With an increase in the electrode-tool diameter (*d*), the processing productivity also increases, and with different short-circuit current strengths, the productivity is directly proportional to the electrode-tool end area.

When processing a similar surface using electrical discharge duplication, it is required to design and manufacture special electrodes of tools made of copper or brass, which causes an increase in the total labor intensity of production by two or more times, and also increases the cost of processing in comparison with the electrical discharge cutting by the end of a rotating non-profiled electrode-tool (Figure 6).



(a) (b)

Fig. 6. The structure of the preparation cycle for EDM of a part during volumetric duplication (a) and during EDM with a rotating non-profiled electrode-tool (b)

As a rule, for the manufacture of one part using ED duplication it's necessary to have a set of 3 or more electrode-tools. In addition to this, difficulties arise with the withdrawal of destruction products from the treatment zone. For this purpose, special systems for forced pumping of the working fluid are created.

It is noted that ED cutting with the end face of a rotating tool has a number of features that affect the processing performance. These include the relatively small area of the working surface of electrode, the rotation of the tool electrode, and improved conditions for the output of erosion products.

The design of the developed module for cutting with the end part of a rotating non-profiled electrode-tool can be used for other equipment equipped with positional-contour CNC systems. Processing can be carried out both with a wire (rod) and a tubular electrode with the supply of a working fluid through the electrode-tool body or a conductor sleeve.

4. CONCLUSIONS

The investigated technological possibilities of electrical discharge cutting by the end of a rotating non-profiled electrode-tool showed the efficiency of cutting out holes in tubular parts.

The dependence of the cutting performance on the speed of movement of the electrode was established: there is an increase in processing productivity with an increase in the area of the treated surface due to a greater deepening of the tool and with a decrease in the speed of movement of the electrode.

With an increase in the electrode-tool diameter, the processing productivity also increases as well as with increasing short-circuit current.

It has been found that, in comparison with ED duplication, the considered technology gives an economic effect from reducing the cost of materials and manufacturing of electrode-tools, and also provides flexibility and easy adaptability for the production of other products.

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