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SOME CONSIDERATIONS CONCERNING THE ELECTROCHEMICAL DISCHARGE DRILLING

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Abstract: *One of the solutions used to increase the machining performances is to combine two or many different known machining processes; this is the case of the so-called hybrid processes. Nowadays, the electrochemical discharge drilling (included in the group of the hybrid machining methods) is used preferentially to achieve holes in workpieces made of insulating materials. Some aspects concerning the electrochemical discharge drilling method based on the using of the semidielectric fluid were studied in the laboratory for non-traditional technologies from the Technical University "Gh. Asachi" of Iaşi. A device adaptable on the workshop milling machine was built and experimented; the experimental results proved the possibilities to achieve holes of small diameter in workpieces made of difficult-to-machine metallic materials.*

Key words: *electrochemical discharge drilling, semidielectric work liquid, device, electrode tool wears.*

1. INTRODUCTION

The combination of different machining methods is one of the ways used nowadays to obtain new solutions for improving the machining performances. Generally, the researches directed to such a combinations were following to obtain the advantages specific to two or many different machining methods (increasing of the material removal rate, reducing of the surface roughness, diminishing of the tool wear etc.).

There are researches concerning both the combination of the so-called classical machining methods with non-traditional machining methods and the combination of two or many non-traditional machining methods. The electrochemical discharge machining methods can be included in the last group of machining methods able to generate the material removal from the workpiece.

The electrochemical discharge machining method is considered as being based on the simultaneous development of two different processes in different working zone: the electrochemical dissolution and the electrical discharges [13].

The analysis of the electrochemical discharge machining methods existing at present emphasizes the usage of two work liquids categories:

a) Work liquids type electrolytes; such liquid were used especially for the machining of the workpieces made of insulating materials;

b) Work liquids type semidielectric, applied in the case of the machining of the metallic workpieces.

Researches concerning the first group of electrochemical discharge machining methods was developed especially in Japan, in some countries of Western Europe or in United State of America, in India [6, 7, 8, 10, 12] etc., while the second group of methods (based on the using of the semidielectric fluids) was studied by the researches from the former Soviet Union [4], Eastern Germany, Czechoslovakia, Romania etc.

Thus, K. Kurafuji and K. Suda published in 1968 [8] some experimental results concerning the drilling of some glass workpieces.

In 1984, J. McGeough referred to some electrochemical discharge drilling and trepanning methods, by the using of an electrolyte work liquid.

The mechanisms and the phases of the electrochemical discharge processes which use work liquids type electrolytes were studied by A. Khayry and H. A. El-Hofy [6].

The first researches concerning the use of the semidielectric liquids in the case of the electrochemical discharge machining methods were made by the Soviet researcher V. N. Gusev, in 1928. Afterwards, V.N. Gusev, but also other researchers (E. A. Drozd, I.I. Bogorod et al.) investigated the phenomena specific to the above mentioned machining process or developed new machining techniques based on the electrochemical discharges processes. Specific aspects to the using of the electrochemical discharge machining process led to the using of the name of anodic – mechanical machining method [4, 12].

In Romania, the first known research in the field of the electrochemical discharge machining methods seems to be made by M. Singer, who elaborated a doctoral thesis at Braşov, in 1954. After 1954, a group of researches working at the Polytechnic Institute of Timişoara or in connection with this group developed an ample research program concerning especially the electrochemical discharge cutting [3, 5, 9, 14].

Thus, ample researches concerning the anodic – mechanical cutting were made by G. Savii [11], Z. Lăncrăngean [9], T. M. Karnyaszky [5] et al.

Other group of researches achieved in Romania was directed to the study of the electrical discharge grinding profiling etc.

In 1998, R. Herman published a monograph intended to present different theoretical and practical aspects specific to the anodic-mechanical machining method [3]. Detailed aspects concerning the complex electrical machining are also included in one [14] of the volumes of the treatise of non-conventional technologies.

Some global analyses of the electrochemical discharge machining techniques were elaborated by J. Kozak, and K. Rajurkar [7].

2. SPECIFIC ASPECTS TO AN ELECTROCHEMICAL DISCHARGE DRILLING

As above mentioned, there are many researches concerning the electrochemical discharge drilling applied in the case of the insulating material workpieces and when the electrolyte is used as work liquid.

If the semidielectric work liquid is used (aqueous solutions of sodium silicate), one can notice that when the electrodes are connected in the direct current circuit, on the workpiece surface the thin insulating film appears, as the result of the chemical reactions between the work liquid and the workpiece material (fig. 1). The insulating film has a bigger thickness in the zone where the intensity of the electric field is bigger; if there are not actions of insulating film removal, the intensity of the chemical reactions diminishes and the machining process stops. It is necessary to mention that the insulating film could be adherent to the workpiece surface and hard enough.

To remove the insulating film, the relative motion and the pressure are necessary between the electrode tool and the workpiece electrode. In the case of the electrochemical discharge machining, this means that the electrode tool should have a rotation motion and, simultaneously, it can be pressed on the workpiece surface. In this manner, the thickness of the insulating film could diminish until electrical discharges are initiated.

Among the closest peaks of the asperities existing on the electrode surfaces, the electric field could be intense enough that the electric rigidity of the substance existing in the gap is breakdown and plasma channel corresponding to the electrical discharges are generated (fig. 2). At the contact of the plasma channel with the electrodes materials, the high temperatures determine the developing of melting and vaporizing phenomena and

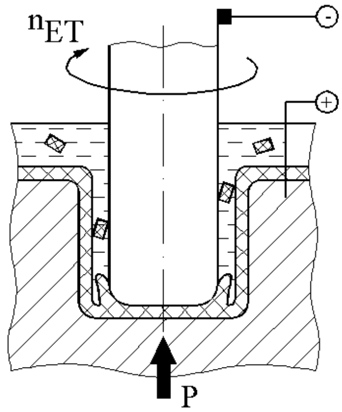

Fig. 1. Insulating film appeared on the workpiece surface as consequence of the chemical reactions.

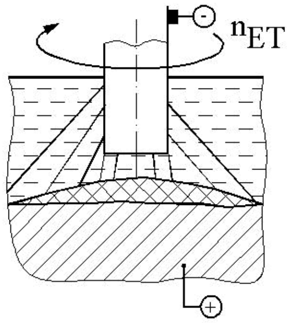

Fig. 2. The insulating film removal as consequence of the pressure and relative motion between the electrodes.

small quantities of the electrodes materials are ejected in the gap.

Other consequence of the electrical discharges is the removal of the insulating film in those workpiece zones affected by the discharges; in the subsequent stages, the electrochemical process develops once again and the new insulating film develops. The removal of the insulting film and penetration of the non used work liquid in the gap can be achieved in different ways. Such a way could be based on the electrode tool periodical removal of the workpiece surface; this means that the electrode tool has to achieve a rectilinear alternative motion along his longitudinal axis.

In the laboratory of non-conventional technologies from the Technical University "Gh. Asachi" of Iaşi, there were developed researches aiming to find a simple solution to achieve small diameter holes in workpieces having small thickness, but made of difficult-to- machine materials.

One of the ways found to solve the above mentioned problem was to build a device able to materialize the electrochemical discharge process on the workshop milling machine. It is known that this machine tool has a slotter ram able to achieve the rectilinear alternative motion with a controlled stroke length.

On the slide of the slotter ram, the adequate device was assembled; practically, an electric motor was used to obtain the rotation motion transmitted afterwards to the electrode shaft by means of the belt drive. The proper electrode tool is fixed in a chuck with spring collet existing at the other end of the electrode shaft (fig. 3).

As electrode tool, the cylindrical bars with diameter smaller than 1 mm were used. A subsystem slip ring – brush permits the connection of the electrode shaft in the direct electric circuit.

The distance between the electrodes can be controlled by means of the vertical displacement of the machine tool table.

A fixing tape with screw was used for the workpiece clamping in the cylindrical recipient with transparent wall; this transparence permitted the direct following of the process development.

To ensure the pressure necessary between the electrodes, the device table was placed on a cylindrical bar which moves within a sleeve fixed, at its turn, on the machine tool table. The motion of the cylindrical bar in the sleeve is limited by a screwed pin assembled in the bar and having the possibility to move in a channel executed in the sleeve.

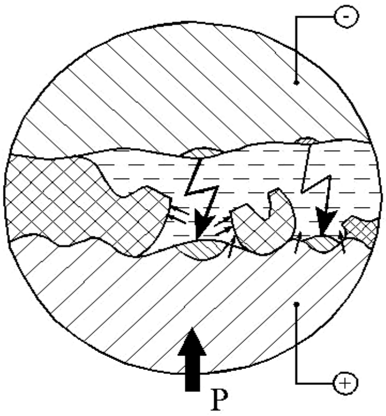

Fig. 3. Phenomena occurring within the gap existing between the electrode tool and the workpiece.

A nut placed on the screwed external surface of the sleeve allows the pressing of the spring used to ensure a certain size of the pressure between the electrode tool and the workpiece.

3. EXPERIMENTAL RESEARCH

By the using of the device adaptable on the workshop milling machine, some experimental researches were developed. A factorial orthogonal experimental plane with four variables at two levels was elaborated. As independent variables, there were selected the electrode tool diameter d (d_{min}=0.5 mm and d_{max}=0.9 mm), the potential difference U between the electrodes (U_{min}=35 V and U_{max}=45 V), the capacity C of the capacitors included in the relaxation circuit (C_{min}=33 μF and

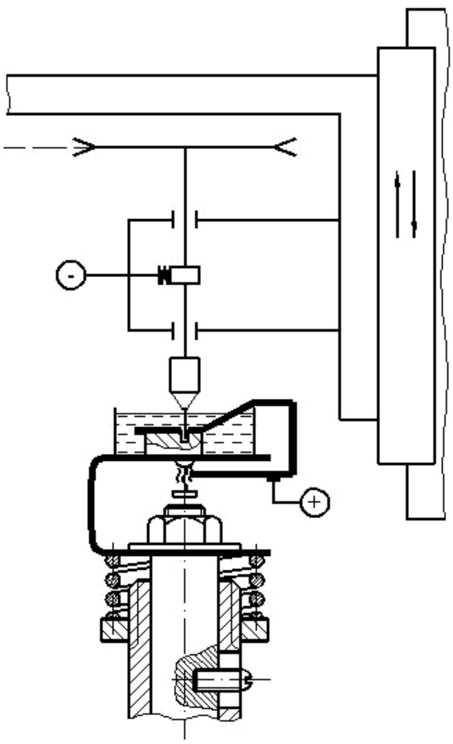

Fig. 4. Schematical representation of the device used for electrochemical discharge drilling.

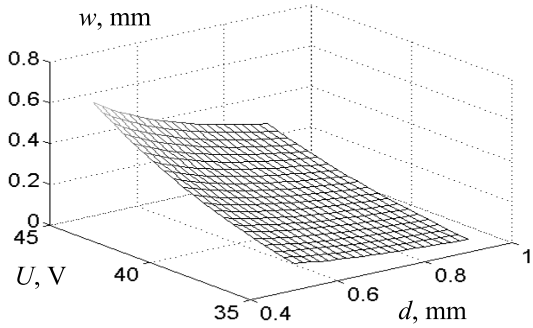

Fig. 5. Influence exerted by the electrode diameter d and by the potential difference U on the electrode tool wear w (C=33 μF, δ=1.05 g/cm[3]).

C_{max}=840 μF) and the work liquid density δ (δ_{min}= 1.05 g/cm3, δ_{max}= 1.20 g/cm3).

The duration of the machining test was established T=6 min, by taking into consideration the results of some preliminary experiments. Sheets of high-speed steel having a thickness of 1.5 mm were used as test pieces. The electrode tools were made of chisel steel. As output variable, the electrode tool wear was used; the lengths of the electrodes before and after the electrochemical discharge process were measured by the using of the digital slide gauge (measuring accuracy of 0.01 mm). One can consider the differences between the lengths of the electrodes before and after the machining process as indicator of the electrode tool wear as consequence of the electrochemical discharge drilling process.

The experimental results were processed by the using of the specialized software based on the method of the smallest squares [2]. The following empirical relation was thus established:

$$w = 1.329 \cdot 10^{-11} d^{-1.27} U^{5.739} C^{0.36} \delta^{9.655} \quad (1)$$

The relation emphasizes the important influence exerted by the work liquid density on the electrode tool wear, the absolute size of the exponent attached to the size δ having the biggest size in comparison with the sizes of the other exponents (9.655>5.739>1.27>0.36). The potential difference U between the electrodes can be considered as the second influence factor.

Some graphical representations corresponding to the influence exerted by the groups of two factors on the electrode tool wear are presented in figures 5, 6 and 7.

4. CONCLUSIONS

The electrochemical discharge drilling is a machining method based on the electrochemical dissolution process developed simultaneously with the electrical discharge erosion process. In the case of the electrochemical discharge drilling based on the using of the semidielectric work liquid, the process developing needs the existence of the relative motion and pressure between the active surfaces of the electrode tool and the workpiece. Within the laboratory of the non-conventional technologies from the Technical University “Gh. Asachi”

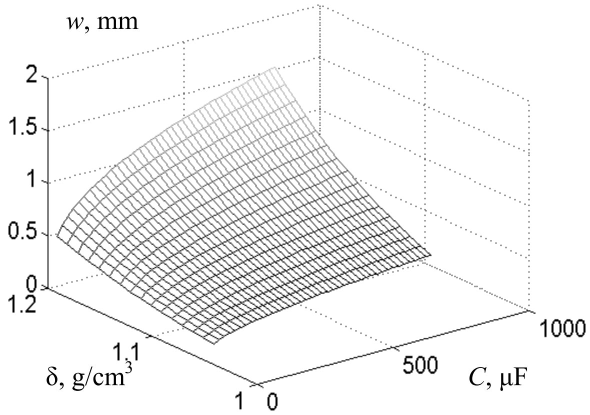

Fig. 6. Influence exerted by the capacity *C* of the relaxation circuit and by the work liquid density *δ* on electrode tool wear w (*d*= 0.5 mm, *U*=35 V).

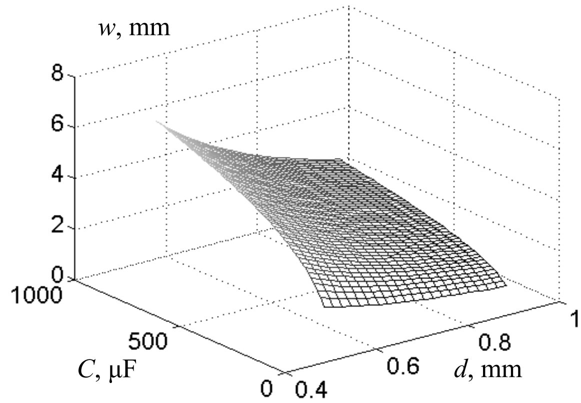

Fig. 7. Influence exerted by the diameter *d* of the electrode tool and of the capacity *C* of the relaxation circuit on electrode tool wear (*U*=45 V, *δ*= 1.20 g/cm^3).

of Iaşi, a device able to achieve the electrochemical discharge drilling was built; the device can be clamped on the slotter ram of the workshop milling machine. Some experimental researches proved the possibilities to use this device. The mathematical processing of the experimental results led to an empirical function type power; the relation emphasizes the influence exerted by the diameter of the electrode tool, the potential difference between the electrode tool and the workpiece electrode, the capacity of the relaxation electric circuit and by the work liquid density on the electrode tool wear (evaluated as the diminishing of the electrode tool length, as consequence of the electrochemical drilling process development).

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