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MACHINABILITY BY ELECTRICAL DISCHARGE MACHINING OF SOME MATERIALS FOR CUTTING TOOLS

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Abstract: *The necessity to ensure greater service lives for the cutting tools led to the using of materials characterized by a diminished machinability by classical machining methods. In such conditions, one of the machining methods able to allow the efficient obtaining of the cutting tools active surfaces was the electrical discharge machining. Usually, the cutting tools materials include elements with high melting and vaporizing temperatures and this fact could negatively affect their machinability by electrical discharge machining. To evaluate the machinability by electrical discharge machining of the electroconductive materials, a device which use a single electrical discharge was designed and built. The experimental researches aiming the evaluation of the machinability of some cutting tool materials by electrical discharge machining proved their reduced size of the machinability index based on the quantity of material removed by a single electrical discharge.*

Key words: *electrical discharge machining, machinability, cutting tools materials, single electrical discharge experimental research, empirical models.*

1. INTRODUCTION

The cutting is a physical mechanical complex process by which the machining allowance is removed from the workpiece by a shearing deformation and which ensures the required accuracy and surface roughness.

The cutting tools are the components of the technological systems which directly contribute to the material removal from the workpiece, by pressing the workpiece material until the shearing phenomenon develops. Due to their important role in the cutting process, the materials used for making the active parts of the cutting must correspond to high strength conditions; such a condition requires that the cutting tool material hardness must exceed the workpiece material hardness with at least some HRC units. If the high hardness is essential for the functional role of the cutting tool, the same property generates important difficulties when the active part of a cutting tool must be finished ore re-sharpened.

The high hardness of the active part of the cutting tool determines the using only of the abrasive processes for the material removal when the active surfaces of the tool are finished or they are affected by a re-sharpening process.

Other actual solution able to ensure acceptable conditions for the material removal from the active part of a cutting tool is offered by the so-called *non conventional machining methods.* It is known that these methods are based essentially on increasing the energy available in the work zone, by different ways, so that either a traditional machining process develops under better conditions, or the machining process develops on new principles, fundamentally different in comparison with the basic principle of the traditional machining process (the principle of the plastic deformation) [6].

As non-conventional machining methods which are applied for finishing the active parts of the cutting tools made from hard materials, one can consider the electrochemical machining, the electrical discharge machining, the hybrid machining by electrochemical dissolution and electrical discharges etc.

The electrical discharge machining is a non conventional machining method which applies the effects of the electrical discharges initiated between the electrode tool and the workpiece, when adequate machining equipment is used.

Among different machining techniques based on the electrical discharge machining, in the case of the cutting tools especially the wire electrical discharge machining and the electrical discharge machining with rotative disc electrode tool are applied.

Because within the plasma channel specific to the electrical discharge machining temperature exceeds the melting and vaporizing temperatures of any existing material, the hardness of the workpiece material does not influence usually the characteristics of the machining method and this means that the cutting tool materials could be machined by electrical discharge machining even they have a high hardness, obtained by an eventual previously applied quenching treatment.

2. MACHINABILITY BY ELECTRICAL DISCHARGE MACH

The machinability is the technological property of a certain material to be machined in the most convenient conditions for the manufacturer: by using high speed of machining, but with small wears of the tools, with a minimum mechanical or energetic solicitation, with obtaining a reduced surface roughness, easy-to-be- removed chips, etc. As this definition shows, there are different

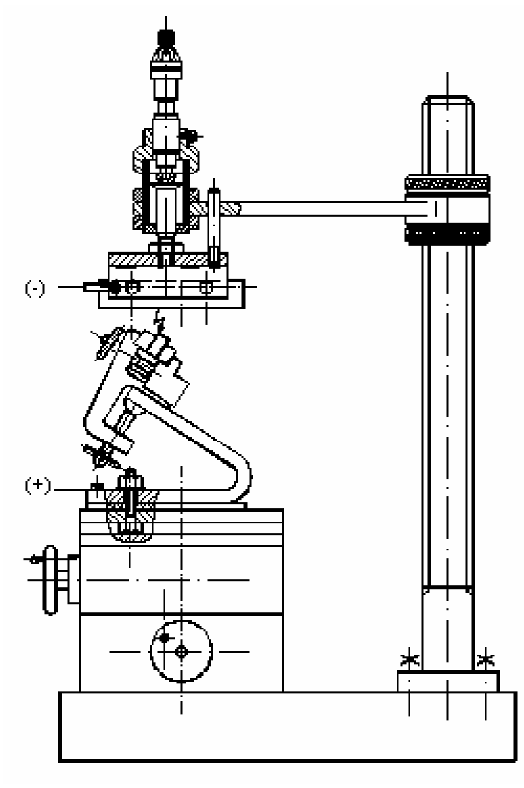

Fig. 1. Device for the study of the machinability by electrical discharge machining based on the using of a single electrical discharge.

criteria and indexes to evaluate the machinability; such criteria could be the tool wear, the machining forces, the energy necessary for removing a certain quantity of the workpiece material, the surface roughness, the volume of the a certain quantity of chips etc.

On the other hand, there are many factors able to affect the machinability; even the chemical, physical and mechanical properties of the machined material are the main group of factors able to affect the sizes of the machinability indexes, there are also factors which characterize the conditions of the machinability testing and which can affect the sizes of the machinability indexes. For example, the type of the machining, the size of the testing parameters, the tool materials, the presence and the type of the eventual work liquid, the characteristiques of the testing equipment (rigidity, vibrations etc.) etc. could be considered as factors which can modify the sizes of the machinability indexes.

In the case of the by electrical discharge machining, the main criteria which can be used for the evaluation of the machinability could be the material removal rate, the electrode tool wear, the roughness of the machined surface etc. If the material removal rate is considered as criterion for the machinability evaluation, some machinability indexes could be the machining speed (the speed of the electrode tool penetration or motion in the workpiece material), the volume, the mass or the weight of the workpiece material removed in a certain time unit, the time necessary to removed a certain quantity of the workpiece material etc.

On the other hand, the methods for the machinability evaluation could be classified in methods of long duration, which develops in proper machining conditions and methods of short duration; in the last case, some changes in the testing conditions allow the diminishing of the test duration, to obtain the information about the material machinability in short time. Of course, even the machining principle applied in the case of the short duration tests are the same as in the long duration tests, sometimes researches aiming to prove the correspondence between the results obtained by the above mentioned two categories of testing methods could be necessary.

A short duration test valid in the case of the evaluation of the machinability by electrical discharge machining is based on the measuring of the quantitative effects of a single electrical discharge, of course in defined testing conditions. For example, as such quantitative effects generated by a single electrical discharge, one can consider the dimensions of the cavity generated on the test piece surface by the electrical discharge, the volume or the masse of the quantity of material removed by the electrical discharge etc.

The main group of factors able to affect the sizes of the machinability indexes determined by using the above mentioned criterion for the evaluation of the machinability by electrical discharge machining is in connection with the chemical composition of the test piece; it is expected that due to the presence of elements characterized by high melting and vaporizing temperatures, the materials used for making the active parts of the cutting tools to have a low machinability by electrical discharge machining.

Thus, if the material for active parts of the cutting tool has a high content in tungsten, titanium etc. (materials having high melting and vaporizing temperatures), its machinability by electrical discharge machining could be reduced.

Along the last decades, the researchers tried to evaluate the machinability of different materials by electrical discharge machining.

Thus, Sing et al. showed [5] that in the case of electrical discharge machining of hardened AISI 6150 tool steel using different electrode materials, the performances of EDM increase with the increase in pulsed current and the best machining rates are achieved by copper-tungsten electrode.

C.H. Che Haron et al. [2] noticed that in electrical discharge machining of XW42 tool steel, the material removal rate is higher and the relative electrode wear ratio is lower with copper electrode than graphite electrode. They found also that the increase in the current and electrode diameter reduced tool wear rate as well as the material removal rate.

In the case of in electrical discharge machining of tungsten carbide, S. H. Lee and X. P. Li [4] established that material removal rate and the surface roughness of the workpiece are directly proportional to the discharge current intensity.

3. DEVICE FOR THE STUDY OF THE MACHINABILITY BY ELECTRICAL DISCHARGE MACHINING

In the laboratory of non-conventional manufacturing technologies from the Technical University "Gheorghe Asachi" of Iaşi, some researches concerning the study or the electrical discharge machining process led to the design and building a device for the evaluation of the machinability by this machining method [1].

As above mentioned, the device uses the effect of a single electrical discharge. As known, if the electrical discharge appears between the closest asperities existing on the plane surfaces of electrode tool and the test piece, the result is a crater (a cavity) appeared as a consequence of the microexplosion produced by the material evaporation after the strong heating in a very short time. This crater has an approximately cylindrical or conical shape and the entering orifice shape could be approximately circular. A difficult problem could be the measuring of the dimensions characterizing this craters; because a simple measuring of the crater depth can not offer a measuring high accuracy (the bottom of the crater can have a not regulated shape), the sectioning of the test piece along the axis of the crater is necessary, but this operations (the test piece sectioning) could need more time and the machinability testing could be not efficient (in this case, it is not a short duration test).

To diminish this disadvantage, other testing scheme was considered. Thus, one knows that if the discharge is produced between the sharpened edges of two parallelepiped bars, the cavity generated by the single electrical discharge is nod closed; the material removal generates an open cavity, whose dimensions (width and depth) can be easier measured by optical means.

This testing scheme was used in the case of the device schematically presented in figure 1.

The electrode tool is a parallelepiped bar made of copper; it is clamped in a U-shaped piece assembled to the end of the rod specific to a micrometric gauge. If the micrometric screw is acted, the electrode tool is moved in the vertical direction, to decrease or to increase the distance between the electrode tool and the test piece.

This last component – the test piece – must have also a parallelepiped shape with square section and sharpened edges. The test piece is placed so that its rectilinear edge is in a horizontal position, but in a vertical plane perpendicular on the vertical plane corresponding to the active edge of the electrode tool.

The two electrodes are connected in a relaxation circuit including a direct current supply.

When the electrode tool moves to the test piece, there is a moment when the distance *s* between the electrodes becomes smaller than the distance favorable for the initiating of an electrical discharge:

$$s < \frac{U}{E}, \qquad (1)$$

where U is the voltage applied to the electrodes and E is the electric rigidity of the medium existing between the electrodes.

4. RESULTS OF THE EXPERIMENTAL RESEARCHES CONCERNING THE MACHINABILITY BY ELECTRICAL DISCHARGE MACHINING OF SOME CUTTING TOOLS MATERIALS

By means of the above mentioned device, some experimental researches were made.

The experiments were performed in accordance with the requirements specific to a factorial experiment with two variables (capacity C and voltage U) at two levels.

The sizes of the electric capacity were $C_{min} = 1000$ µF and $C_{max} = 10000$ µF, while the sizes of the voltages were $U_{min} = 40$ V and $U_{max} = 80$ V.

The limits of the capacity and voltage were selected so that the usual sizes of the voltage and capacity applied in the proper electrical discharge machining are included between these limits.

For each set of experimental conditions, three experiments were made; for the mathematical processing of the results, the arithmetic media of the experimental researches were taken into consideration.

The mathematical processing of the experimental research was performed by the use of a specialized software [3] based on the method of least squares. Even the software offers the possibility to select the best function from the point of view of its adequacy to the experimental results, firstly a function type power was preferred, due to capacity of this function to immediately emphasize the influence exerted by different factors on the output parameter. Of course, the power type function can be applied only in the case of monotonous variation of the experimental results, as the results of the experiments performed by means of the device for the study of the machinability by electrical discharge machining were.

As result of the mathematical processing of the experimental results, the following empirical relations were established [1] for the crater width:

$$B = 0.0148\, C^{0.340} D^{0.464}, \qquad (2)$$

in the case of the test piece made of high-speed steel and:

$$B = 0.00368\, C^{0.405} D^{0.560}, \qquad (3)$$

in the case of the test pieces made of sintered carbide type ISO - P35.

If the height H of the crater was taken into consideration, the following empirical relations were established:

$$H = 0.00502\, C^{0.404} D^{0.427}, \qquad (4)$$

in the case of the test piece made of high-speed steel and:

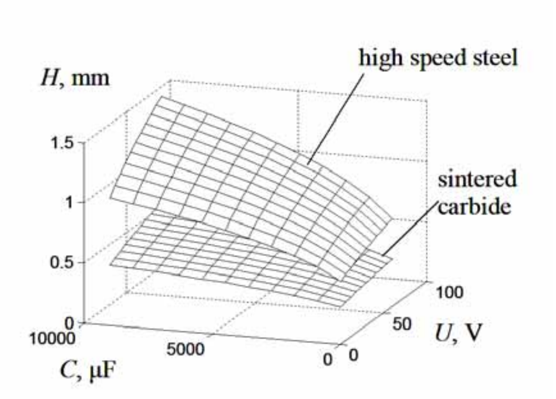

Fig. 2. Influence exerted by the voltage U and capacity C on the height H of the cavity generated by a single electrical discharge.

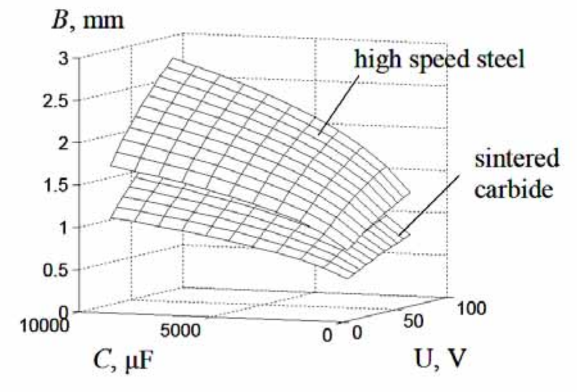

Fig. 3. Influence exerted by the voltage *U* and capacity *C* on the width *B* of the cavity generated by a single electrical discharge.

$$H = 0.00211\,C^{0.382}D^{0.449}\,, \qquad (5)$$

in the case of the test piece made of sintered carbide type ISO - P35.

The analysis of these empirical model shows that the capacity *C* and the voltage *U* exert a similar influence on the width *B* and height *H* of the gap generated on the test pieces in the cases of the both materials studied (high speed steel and sintered carbide type ISO – P35, the coefficients and the exponents of the empirical models having the same signs (plus or minus) and sometimes close sizes. As expected, the gaps generated on the test pieces made of cemented carbides are smaller than the gaps generated in similar conditions on the test pieces made of sintered carbides; the fact is emphasized by the sizes of the coefficients, which are smaller in the cases of the gaps generated on the test pieces made of sintered carbides. On the other hand, one can notice that the voltage *U* exerts an influence greater than the same influence exerted by the capacity *C* both on the width and on the height of the gap (the sizes of the coefficients affecting the capacity *C* being smaller in the case of the same empirical mathematical relations).

Two graphical representations elaborated on the basis of the empirical relations (2), (3), (4) and (5) are presented in figures 2 and 3.

5. CONCLUSIONS

Due to their height hardness specific to the materials used for the active parts of the cutting tools, one of the machining methods of the cutting tools active parts is the electrical discharge machining. Just in the case of this machining method, the materials for the cutting tools are characterized by a diminished machinability, due essentially to their content in elements with high temperatures of melting and vaporizing. A faster method for the machinability evaluation by electrical discharge machining is based on the measuring the dimensions (width and height) of the gap generated by a single electrical discharge. In the laboratory for non conventional technologies from the Technical University “Gheorghe Asachi” of Iasi, a device able to ensure a single electrical discharge between the electrode tool and the test piece (both made as parallelepiped bars) was designed and built. The experimental results obtained in the case of two materials for cutting tools emphasized their different machinability evaluated by means of the width and height of the gap generated by a single electrical discharge. There was confirmed the assumption that the sintered carbides have machinability lower than the machinability of the high speed steels.

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