OBTAINING BY ELECTROCHEMICAL AND ABRASIVE MACHINING OF THE POLISHED SURFACES FOR WORK PIECES FROM TITANIUM

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ABSTRACT. Electrochemical and abrasive machining is a combined method between anodic dissolution and the metal removing from the work piece by abrasive disks.

This method is applied for obtaining of some surfaces with a small roughness for work pieces from different material: steel, titan, aluminium. Titanium has a great resistance to the corrosion process. At the machining of the work pieces from titanium alloys appear many difficulties because of the low thermic conductivity and high hardness. A process with good results is electrochemical erosion together with machining with abrasive disks.

KEYWORDS: anodic dissolution, electrochemical erosion, abrasive disks, current efficiency, inorganic solutions.

1. INTRODUCTION

Machining by electrochemical and abrasive erosion is a method that involves the anodic dissolution as well as material removing from the work piece surface with abrasive discs.

This process of machining is applied for obtaining of some surfaces with small roughness for work pieces from titanium, steel and aluminum. Electrochemical machining generates not burr and no stress, and provides a long tool life, with a damage free machined surface, a high material removal rate and a good surfaces quality [1], [7].

In electrochemical and abrasive machining of titanium alloy, defects such as pitting and poor surface roughness often appear. The electrolytic product forms an insoluble pellicle which adheres to the surface of anode, resulting in differences in dissolution behavior between the substrate and anode surface.

In this process, machining is affected both by the grinding action of the abrasive disk and by electrochemical erosion. Hence, it may be also called mechanically assisted electrochemical machining (figure 1):

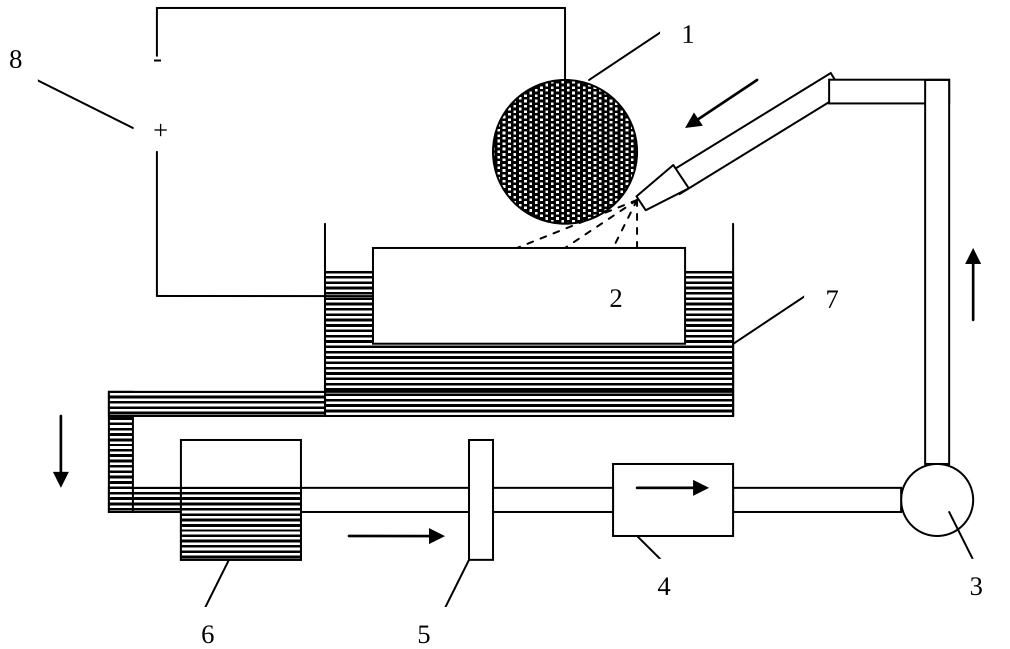


Fig.1 Schematic of a typical electrochemical and abrasive machining

1-Grinding wheel, 2-workpiece, 3- pump, 4- heat exchanger, 5- filter, 6- electrolyte tank, 7- electrolyte, 8-power supply

The work- piece and the wheel do not make contact with each other because they are kept apart by the insulating abrasive particles which protrude from the face of grinding wheel.

The electrolyte is carried past the work-piece surface at high speed by the rotary action of the grinding wheel, metal is removed from the work-piece by the simultaneous and electrochemical and abrasive action.

Bonding materials such as copper, brass, nickel or copper impregnated resin are commonly used for the manufacture of metal-bonded grinding wheels. The main function of the abrasive particles in the electrochemical and abrasive machining is as follows:

1) to maintain the electrolyte insulation between anode work-piece and cathode grinding wheel and to maintain the electrolyte flowing between them;
2) to continuously remove any passive layer that may be formed on the work-piece surface by chemical reaction;
3) to determine work-piece shape and size.

The main function of the electrolyte used in electrochemical and abrasive machining is to produce the desired finish by electrochemical dissolution, to conduct heat away from the inter-electrode gap, to flush reaction products away from the inter-electrode gap, to minimize chemical wear of the conducting grinding wheel by maintaining its chemical inertness. In this case of machining was used sodium nitrate ($NaNO_3$).

Ti 60 (Ti-5, Al.-4, Sn-2., Zr.-1, Mo-0, 35Si-0,7Nd) is a high temperature titanium alloy that now is used for important component of aircraft engines [3]. Electrochemical and abrasive machining is a non –traditional machining method that allows applications to all kinds of metallic materials in regardless of their mechanical properties. It is widely applied to machining of titanium alloys components. The experimental results suggest that with appropriate process parameters, high quality holes can be obtained in a $NaNO_3$ solution [5].

Electrolyte properties affect the dissolution of the material being machined. The electrolytes in an electrochemical and abrasive machining not only transfer currents during machining, but also carry away the by-products and heat that are produced in the machining process [2]. The applied electrolytes can greatly influence the processing quality. Different electrolytes can produce different machining effects when applied to the same material and a particular electrolyte’s machining effects varies with the type of material that is machined [5].

Titanium alloys have multiple applications in automobile industry, mechanical machining, medical equipment and other industries. The diversity of functionality is because of titanium’s low density, high strength and corrosion resistance [3], [5].

At the machining of titanium alloys appear some difficulties because of the low thermic conductivity and high viscosity. Good results were obtained by applying electrochemical erosion and abrasive disks.

In this paper was studied the machining of work pieces form titanium by electrochemical erosion in an electrolyte solution of $NaNO_3$ and for increasing the process efficiency at the metal removing were applied abrasive disks.

Machining by electrochemical erosion could be improved by applying the abrasive disks [6]. When the two methods are combined results the following effects:

a) the protective pellicle is removed due to the action of abrasive disks;

b) increasing the flowing rate of the electrolyte solution in the working space;
c) the electrical resistance in the working space is modified.
The metallic surface of the work piece can present scratches because of the abrasive disk. The roughness of the work piece from titanium, obtained at the machining by electrochemical and abrasive erosion is correlated with the voltage from the working space and the abrasive grains from the disk.

2. EXPERIMENTAL METHOD

The material used for this work is titanium (Ti 60) and the electrolyte for the electrochemical machining was $NaNO_3$ 10%.
The voltage from the working space was between 10 and 60 V and the current intensity between 0,5 and 6 A. At first, the machining was achieved only by electrochemical erosion in a solution of $NaNO_3$ electrolyte 10% concentration. The current intensity was measured at different values of the voltage from the working space.
The obtained values are given in table 1:

Table 1 Current intensity for titanium dissolution in $NaNO_3$ electrolyte

$NaNO_3$ conc. [%]	Current voltage values for titanium dissolution U[V]	Current intensity I [A]]
10	10	0,3
10	20	0,5
10	25	0,6
10	30	0,8
10	40	0,95
10	50	1,2
10	60	1,5

To improve the electrochemical machining was applied also the metal removing with abrasive disk, and after that both process were applied in the same time.
By applying of electrochemical and abrasive machining was removed the protective pellicle from the work piece surface, increases the flowing rate of the electrolyte in the working space and the quantity of removed metal [6].
In table 2 are presented the obtained values at the machining by electrochemical and abrasive erosion at different voltages:

Table 2 Current voltages for titanium dissolution in by electrochemical and abrasive erosion in $NaNO_3$ electrolyte

$NaNO_3$ conc. [%]	Current voltage U [V]	Quantity of removed metal by [g/l]		
		Electroch. erosion	Abrasive erosion	Electrochemical and abrasive erosion
10	5	0	0.3	0.6
10	10	0	0.3	0.9
10	15	0.1	0.3	1.3
10	20	0.1	0.3	1.5
10	25	0.1	0.3	1.6
10	27	0.3	0.3	1.8
10	30	0.8	0.3	2

It is found that using suitably optimized parameters for electrochemical grinding can greatly decrease the surface roughness of a work piece.
In table 3 is presented the influence of the current intensity and the quantity of removed metal:

Table 3 Current intensity I [A] influence on the metal removed by electrochemical and abrasive erosion

Current intensity I [A]	Metal removed by electrochemical erosion [g/l]	Metal removed by electrochemical and abrasive erosion [g/l]
0,5	0	0.5
1	0	0.6
1.5	0.2	0.8
2	0.25	0.85
2,5	0,3	1,2
3	0,32	1,4
3,5	0,35	1,5
4	0,37	1,6
4,5	0,4	1,68
5	0,42	1,72

The surfaces roughness at the electrochemical-abrasive machining of the work piece from titanium depends on the voltage from the working space as well as the grains size from the abrasive disk [4].

In table 4 is presented the values obtained at different voltages for the surface roughness:

Table 4 Surface roughness dependence on the voltage from the working space

Voltage from the working space U [A]	Surface roughness [μm]
0	1,4
3	0,6
5	0,45
10	0,40
15	0,35
20	0,32
25	0,34
30	0,4

At voltages smaller than 5V the obtained results are not good because the metallic surface is broken and when the voltage is greater than 25 V the processed surface has a great roughness with pitting process because of the electrochemical erosion. The best machining is obtained between 5 and 25 V.

The surface roughness depends also on the moving rate of the abrasive disk. The obtained values for the surfaces roughness at different moving rate of the abrasive disk are presented in table 5:

Table 5 Surface roughness at different rate of the abrasive disk

Moving rate of the abrasive disk [m/s]	Surface roughness [μm]
100	0,09
200	0,15
400	0,16
500	0,19
1000	0,20
1500	0,21
2000	0,22

In the machining by electrochemical and abrasive erosion takes place also the achieving of the protective pellicle on the work piece surface and the periodical removing of this pellicle that has an important influence on the metal dissolution from the processed surface.

The roughness of the processed surface depends on the moving rate of the abrasive disk. In table 6 are presented the results obtained for the surfaces roughness at different moving rate of the disk.

Table 6 Surface roughness at different rate of the abrasive disk

Moving rate of the disk[m/s]	Surface roughness [μm]
0	0,05
100	0,38
300	0,4
500	0,4
1000	0,42
1500	0,43
2000	0,45

In table 7 are presented the obtained results for surface roughness at different size of the abrasive grains:

Table 7 Surface roughness for different size of the abrasive grains

Size of the abrasive grains [mm]	Surface roughness [μm]
200	10
500	7
1000	0,8
2000	0,4
5000	0,2

3. RESULTS AND DISCUSSIONS

From the presented values it can be concluded that the current intensity increase until a voltage U=25V and after that the increasing takes place rapidly. The anodic dissolution appears only after a voltage > 25V. In aqueous solution titanium has the tendency to achieve a protective pellicle. In figure 2 is presented the dependence between the current intensity and the current voltage at the processing of titanium alloys by electrochemical and abrasive machining.

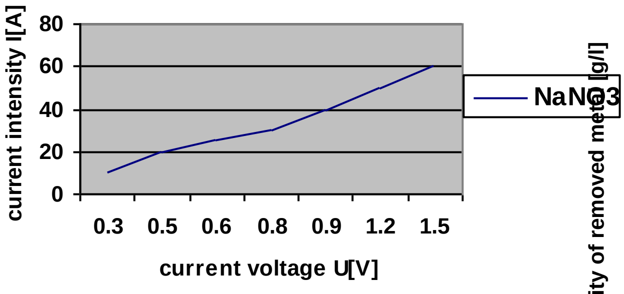


Figure 2 Dependence of the current intensity I [A] on the current voltage U [A] at the machining by electrochemical-abrasive erosion

At the machining by electrochemical and abrasive method increases the quantity of removed metal from the titanium work piece. By abrasive erosion the quantity of removed is constant and at the electrochemical machining the increasing is not significant.

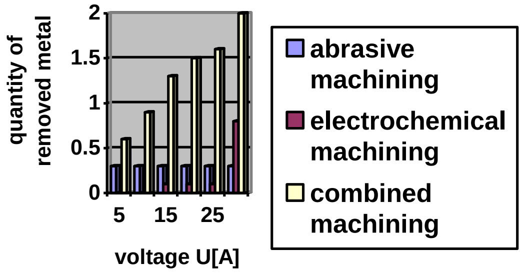


Figure 3. Dependence of the quantity of the removed metal on the voltage from the working space

From this figure it can be observed that the metal dissolution takes place by electrochemical machining at voltage values greater than 25V in the same time increasing the intensity of the electrical current.

The removed metal quantity increases with the increasing of the current intensity.

The dependence between the quantity of removed metal and the current intensity I is given in figure 4:

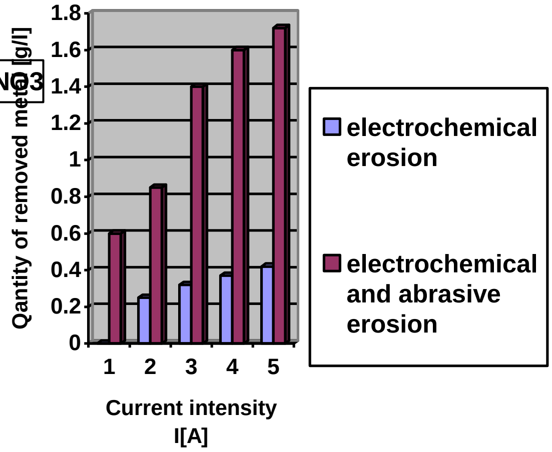


Figure 4 Dependence of the quantity of removed metal on the current intensity

The surface roughness at the machining by electrochemical and abrasive erosion of the titanium work piece is influenced by the voltage from the working space as well as the moving direction of the abrasive grains from the disk. In figure 5 is presented the influence of the voltage from the working space on the surface roughness:

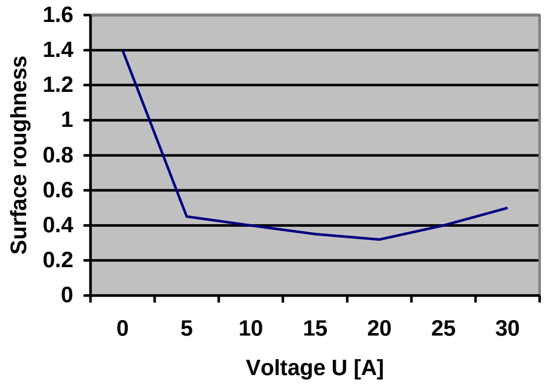
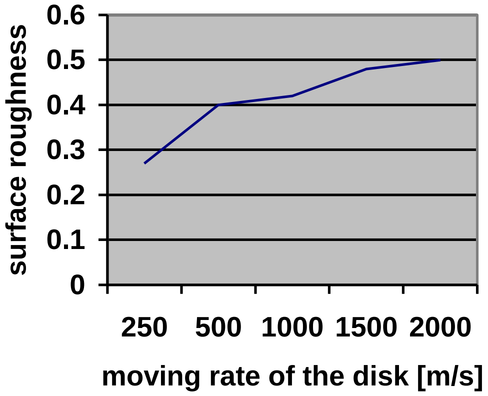


Figure 5 Dependence of the surface roughness on the voltage from the working space

When the voltage value is smaller than 5V the surface roughness is great and at voltages values greater than 25 V the roughness increases slowly appearing pits due to the electrochemical erosion. The best values are obtained between 5 and 25 V.

Surface roughness is influenced by the moving rate of the abrasive disk, from figure 6 it can be observed that it increases significantly at a disk rate of 500 m/s and after this value the increasing is low.



. **Figure 6** Dependence of the surface roughness on the moving rate of the disk

The influence of the abrasive grains on the surface roughness can be observed from figure 7:

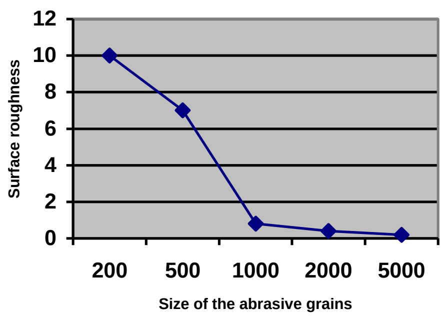


Figure 7 Dependence of the surface roughness on the size of abrasive grains

With the increasing of the size of abrasive grains the surface became more polished and also decreases the surface roughness.

4. CONCLUSIONS

At the machining of the work pieces from titanium have been obtained very good results by applying the electrochemical and abrasive machining. The obtained surface had a small roughness, well polished so were not be necessary additional methods for finishing.

Electrochemical and abrasive erosion applied together has many advantages:

- increases the quantity of removed metal from the work piece in a certain time of machining;
- the obtained surface has a small roughness;
- the protective pellicle is periodically removed so that the metal is removed from the desired surface;
- the electrolyte solution ($NaNO_3$ 10%) assures the obtaining of a proper efficiency of the process;
- the machining takes place independently on the type of the work piece;
- by metal erosion with abrasive disks, this method can be applied to different applications.

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