Application of ultrasonic vibration to improve technological factors in electrochemical machining of titanium alloys

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Abstract

One of the ways to improve technological factors in electrochemical machining is introduction of electrode tool ultrasonic vibrations. Ultrasonic vibrations change condition of electrochemical dissolution and gives possibility to decrease the electrode polarisation, therefore it can be promisingly applied in case of titanium alloys machining. In the paper research on Ti-6Al-4V alloy PECM supported by ultrasonic vibrations has been presented.

1 Introduction

Electrochemical machining is an important technology in machining difficult-to-cut materials and to shape complicated contours and profiles without tool wear and without inducing residual stresses. One of the ways to improve technological factors in electrochemical machining (ECM) is introduction of electrode tool ultrasonic vibration (USECM).

Generally, application of ultrasound to fluid causes a chaotic, turbulent flow. Propagation of the sound wave through the ultrasonically irradiated media creates pressure drop, which can breaks forces holding the liquid molecules together and produce cavitation micro bubbles. Bubble grows extensively and then undergoes an energetic collapse, which usually occurring in less then one microsecond and leads to the local generation of extreme conditions of temperature and pressure [1].

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In case of ultrasonically assisted electrochemical machining ultrasonic gives possibility for creating cavitation micro-bubbles near the workpiece and electrode surface. Process of micro-bubbles collapse in area adjacent to electrode gives possibility for increasing the intensification of mass and electric charge transportation. Taking into account results of investigation presented in [2] [3] it is right to state that ultrasonic vibrations have a significant influence on the conditions of electrode processes.

2 Problem formulation

One of the main problems with electrochemical machining of titanium alloys is surface pitting connected with surface oxidation. The low conductivity oxide film on the machined surface, prevents the workpiece from a direct contact with the electrolyte and normal electrochemical dissolution process can not proceed without breaking down the film. Dissolution is possible only in high current density areas with concurrent film regeneration. In low current density regions, where dissolution can not completely remove the oxide film, surface with pitting and high roughness is obtained. Usually, to avoid this problem active electrolytes are applied (i.e. NaCl) but its application is connected with decrease of machine and tooling live.

As was presented in previous works carried out in the Institute of Advanced Manufacturing Technology [3], cavitation phenomena occurring in the gap during USECM is responsible for depasivation and depolarization of machined surface. Therefore, this king of hybrid ECM - based machining can be promisingly applied in case of titanium alloys machining.

Below the experimental research of Ti-6Al-4V alloy Ultrasonically Assisted Pulse Electrochemical Machining (USPECM) has been presented. Analysis of obtained results have given possibility to evaluate the influence of machining parameters on removed material thickness and surface roughness.

3 Experimental test

The range of PECM application depends on accuracy, surface quality and metal removal rate which can be achieved during machining. Because of this fact it has been decided that experiments will be carried out with constant but as high as possible electrode tool feed rate (no gap adjustment between the pulses). The same interelectrode gap is small what gives possibility to obtain high current density. During dissolution of titanium alloy competing concurrent activation and passivation process determines the anodic dissolution rates and localization and therefore the removal rate distribution and surface roughness. Factors such as electrolyte type, flow condition, pulse parameters and voltage amplitudes may have significant influence on the machining results.

Taking into account results of analysis of phenomena occurring into interelectrode gap during one voltage pulse the following factors have been taken into account:

- **input factors:** interelectrode voltage: U = 20 – 30 V, electrode – tool feed rate: v_f = 0.1 – 0.5 mm/min, pulse time t_i = 1 – 5 ms, pause time t_p = 1 – 5 ms,
- **output factors:** thickness of the machined allowance a [mm] surface roughness parameter Ra and Rz [μm], interelectrode gap thickness S_k [mm], pulse current density I_{imp} [A].
- **constant factors:** shape and dimensions of electrode-tool (R = 10.5 mm) and machined surface – see Figure 2, machined material: Ti-6Al-4V alloy, electrode-tool material: copper, electrolyte: 15% water solution of $NaNO_3$, electrolyte temperature: 25^oC, initial interelectrode gap thickness: S = 0.2 mm, electrode – tool displacement: h = 2 mm, amplitude of ultrasonic vibrations A = 4 μm.

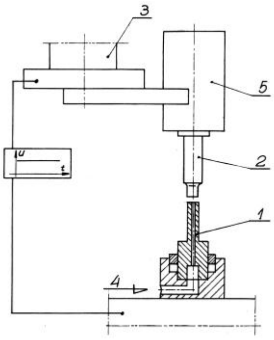

Figure 1: *Scheme of test stand for investigations of PECM and USPECM process supported by electrode ultrasonic vibrations; 1 – workpiece, 2 – electrode-tool, 3 – tool plate of machine - tool EOCA 40, 4 – hole for electrolyte supplying, 5 – ultrasonic head.*

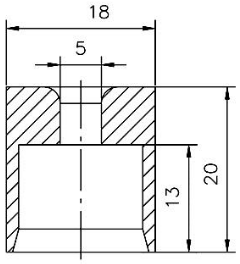

Figure 2: *Shape and dimensions of the machined sample.*

During tests electrode - tool is displaced in direction of machined surface with velocity v_f (Figure 1). Electrolyte flows into interelectrode space through the hole in the sample (Figure 2). Between electrodes the voltage pulses occur with appropriate pulse and interval time duration. As a function of investigated object the neural net has been applied.

4 Discussion of results

The main parameters of the process are interelectrode voltage U and pulse time t_i. Thickness of the material allowance a increases with the U and t_i increases. For this same parameters of machining, introduction of the ultrasonic vibration, cause only little increase (about 5%) of machined allowance thickness (Figure 3).

One can notice, that significant difference between investigated processes are in surface roughness (Figure 4). Ultrasonic vibrations are the main reason of Ra decrease, especially for U < 25 V.

For the smallest value of pulse time (1 ms) and the biggest value of interval time (5 ms) the smallest value of interelectrode gap thickness and the highest value of pulse current have been reached (Figure 5). For these conditions it has been possible to achieve the smallest value of surface roughness parameter Ra (Figure 6). Though the principle: the highest current density the smallest surface roughness parameter is true in analysed case, however one can state, that minimal value of Ra for USECM process is similar as in case of normal ECM of titanium alloys.

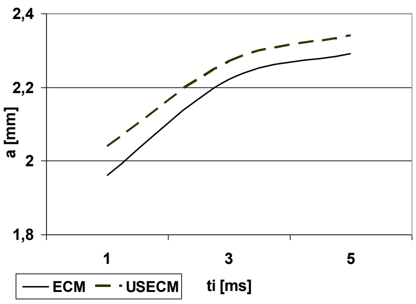

Figure 3. *Relationships between removed allowance thickness a and pulse time t_i for ECM and USECM; parameters of machining: t_i = 3 ms, t_p = 3 ms, v_p = 0.3 mm/min.*

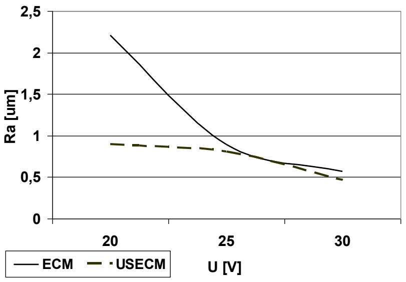

Figure 4: *Relationships between surface roughness Ra and interelectrode voltage U for ECM and USECM; parameters of machining:; t_i = 3 ms, t_p = 3 ms, v_p = 0.3 mm/min.*

5 Summary

From above presented experimental tests results that electrode ultrasonic vibrations change the course of the dissolution process and values of technological indicators of the PECM process.

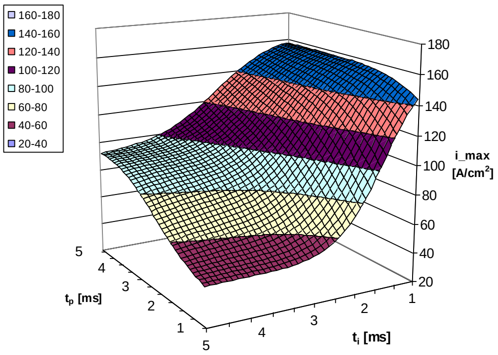

Figure 5: *Relationship between pulse current density and pulse t_i and pause t_p time for following parameters of machining: U = 25 V, v_p = 0.3 mm/min.*

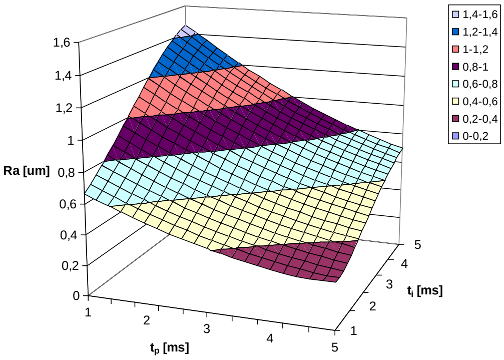

Figure 6: *Relationship between surface roughness and pulse t_i and pause t_p time for following parameters of machining: U = 25 V, v_p = 0.3 mm/min.*

Introduction of electrode ultrasonic vibrations can be a reason of:

- creating shock wave and cavitation phenomena which are accompanied by micro jets and pulse pressure in boundary layer, what is a reason of changing hydrodynamic conditions in machining area,

- generating some amount of heat what can increase temperature in machining area,

As a result of above mentioned phenomena it is possible for optimal process parameters to:

- improve the heat and reactions products removal out of machining area,
- support diffusion and decrease the rate of passivation processes,
- decrease the potential drops in the layers adjacent to electrodes,
- increase coefficient of machinability,
- create the optimal hydrodynamic conditions from surface roughness parameter Ra point of view,
- decrease the surface roughness parameter Ra in comparison to classical and pulse electrochemical machining without electrode-tool ultrasonic vibrations, however, it needs further optimisation research.

The electrode ultrasonic vibrations complicate the course of phenomena occurring into interelectrode gap by creating the occurrence of the new phenomena (cavitation).

Literature

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