ELECTROCHEMICAL FINISHING SURFACES AFTER ROUGH MILLING

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Summary In the paper experiments of the electrochemical smoothing process has been presented. The smoothing has been carried out on the whole surface after rough milling. This way of smoothing, in comparison to smoothing with universal electrodes, gives possibility of decreasing time of machining. However, as it had been proved in the paper, the final results of machining are limited by shape errors created in electrochemical process.

1. INTRODUCTION

One of the main advantages of electrochemical machining is good quality of surface layer created in the process. It results from the fact that in electrochemical machining allowance is removed by electrochemical dissolution process, which does not introduce any changes in surface layer of machined product. Another advantage of electrochemical machining in finishing operations can be high metal removal rate. In other machining processes, for instance electrodischarge machining or milling with ball ended tool, in finishing operations metal removal rate is rather small. So, it will be very efficient if it would be possible to apply in finishing operations electrochemical machining. In presented case the problem of electrochemical finishing surfaces after milling with ball ended tool has been analysed and investigated. In former investigations the electrochemical smoothing had been carried out with ball ended universal electrode [1,2,3]. The results were very encouraging; however because of small efficiency of the process (time consuming) below presented investigations have been undertaken. The electrochemical smoothing process has been carried out on the whole surface as in classical drilling. This way of machining offers high efficiency but its application depends on final surface geometrical structure.

2. PROBLEM FORMULATION

Considerations have been carried out for case of finishing flat cylindrical surface (Fig.1). Electrolyte has been transported to machining area through the central hole in workpiece. Workpiece surface has been primary milled with ball ended tool. During electrochemical finishing flat cylindrical electrode has been displaced in direction of workpiece.

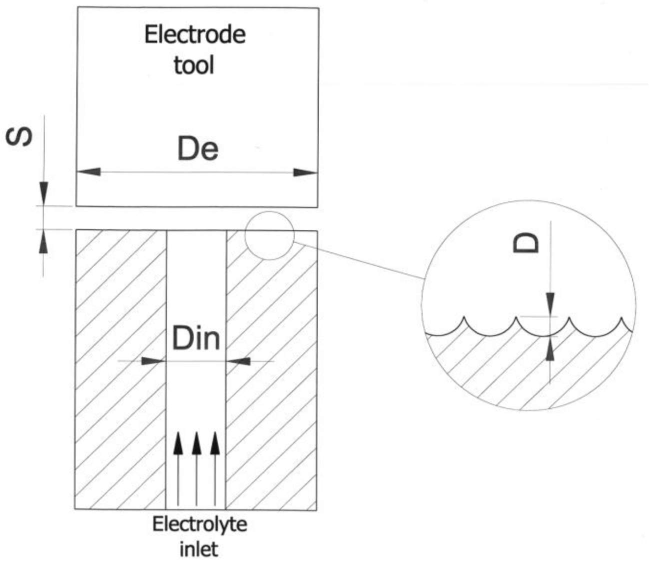

Fig. 1. Scheme of electrochemical machining surface after rough milling.

Local rate of machining can be evaluated from relationship (1)

$$V_n = \eta k_v (U - \Phi) \frac{\kappa}{S(t,P)} \quad (1)$$

Where:

V_n – velocity of dissolution process,
η - dissolution process current efficiency,
ηk_v – coefficient of electrochemical machinability,
U – interelectrode voltage,
Φ- electrode polarisation,
κ - electrolyte electrical conductivity,
S(t, P) – interelectrode gap thickness depended on time “t”and point “P” position on machined surface

From relationship (1) results that in places where interelectode gap thickness is small velocity of dissolution process is high. So, it is right to assume that velocity of dissolution process is significantly higher on waviness created in milling tops in comparison to their bottoms. This effect can be increased by anode polarisation increase on the waviness bottom. On the other hand velocity of dissolution process depends also on electrolyte electrical conductivity, which value changes together with electrolyte temperature and hydrogen concentration according to relation (2).

$$\kappa = \kappa_0 [1 + \varpi \Delta T(t,P)][1 - C_H(t,P)]^{1,5} \quad (2)$$

Where: κ_0 – inlet value of electrolyte electrical conductivity.

In case presented in Fig.1. Electrolyte velocity decrease along machined surface radius (r) increase, what support electrolyte temperature (T) and hydrogen volumetric concentration (C_H) increase. Velocity of electrolyte also depends on direction of flow. It is easier for electrolyte to flow along than across waviness created in milling operation. After some time ECM process reach steady state with constant distribution of interelectrode gap thickness and constant value of electrochemical dissolution velocity.

$$S(P) = \frac{\eta k_v (U - \Phi)\kappa}{V_f} \qquad (3)$$

Because of above mentioned reasons electrochemical machining can introduce its own shape errors resulted from electrolyte properties, electrode polarisation and current efficiency changes.

The general aim of below presented investigations is to find out if electrochemical sinking can be applied in finishing operations.

3. RESULTS OF EXPERIMENTS

Experiments have been carried out for different:

- workpiece initial waviness D = 0,042 – 0,52 mm,
- velocity of electrode displacement – V_f =0.1 – 0.6 mm/min.
- g/D = 0,25 – 1.75; where: g – thickness of allowance removed during electrochemical machining.

As a main technological process indicator the waviness height (P_t)measured in direction perpendicular to direction of milling with ball ended tool has been taken. Scheme of measurements are presented in Fig.2. Measurement have been carry out using TOPO 01P profilometer designed and built at IOS Kraków.

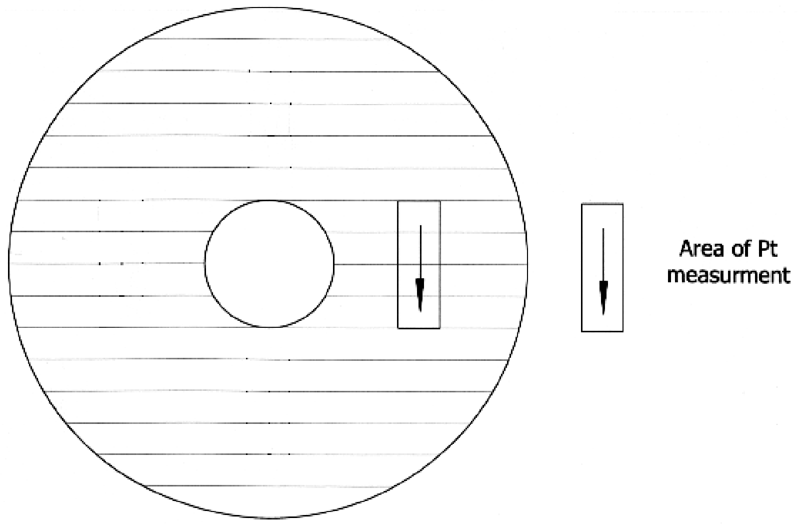

Fig.2. Scheme of surface waviness after ECM smoothing measurements.

In smoothing operations thickness of material removed should be as small as possible. Its minimal value could be not lesser than surface waviness after milling (D). It results from experiments presented in Figs.3 - 9.

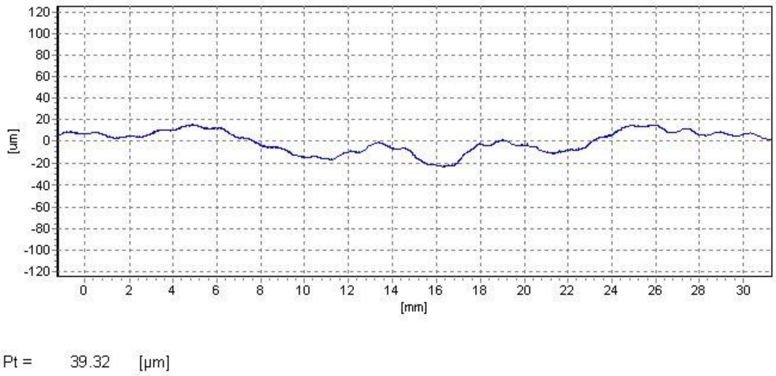

Fig. 3. Surface geometrical structure after electrochemical smoothing; D = 0,042 mm, V_f = 0.35 mm/min, g ~D, P_t = 39.32 µm

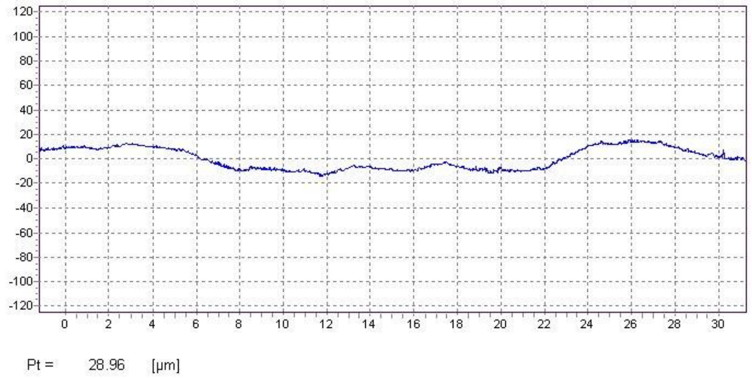

Fig. 4. Surface geometrical structure after electrochemical smoothing; D = 0,280 mm, V_f = 0.35 mm/min, g ~D, P_t = 26.98 µm.

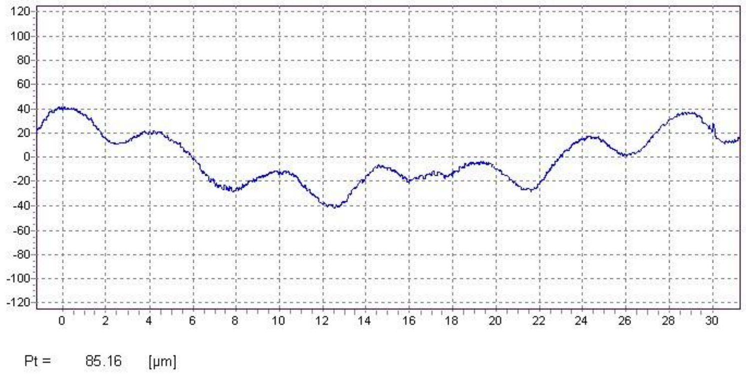

Fig. 5. Surface geometrical structure after electrochemical smoothing; D = 0,517 mm, V_f = 0.35 mm/min, g ~D, P_t = 85.16 µm.

When D is small (Fig.3) time of smoothing is short and because of that surface initial waviness only slightly decreased. For bigger initial waviness (Fig.4) time of smoothing also is bigger and initial surface waviness decreased about 10 times. The shape of the surface line presented in Fig.4 indicate that waviness created in milling operation was removed and new surface shape errors resulting from ECM process were created. When D was increased to D =0.517 mm (Fig. 4), even long lasting of electrochemical machining cannot removed initial surface waviness.

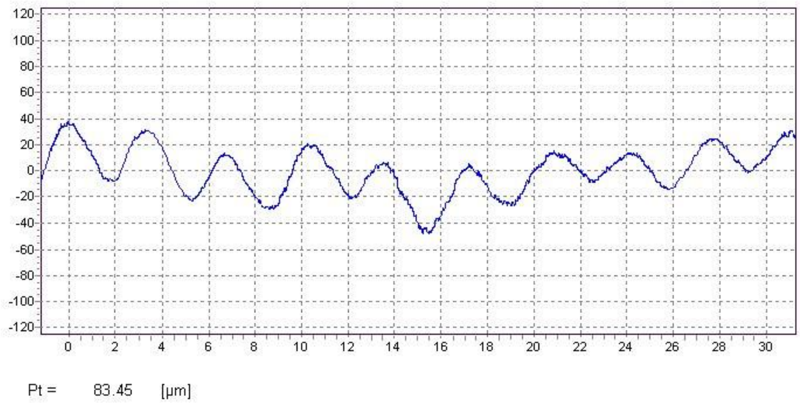

Fig. 6 Surface geometrical structure after electrochemical smoothing; D = 0,280 mm, V_f = 0.35 mm/min, g ~ 0,25 D, P_t = 83.45 μm.

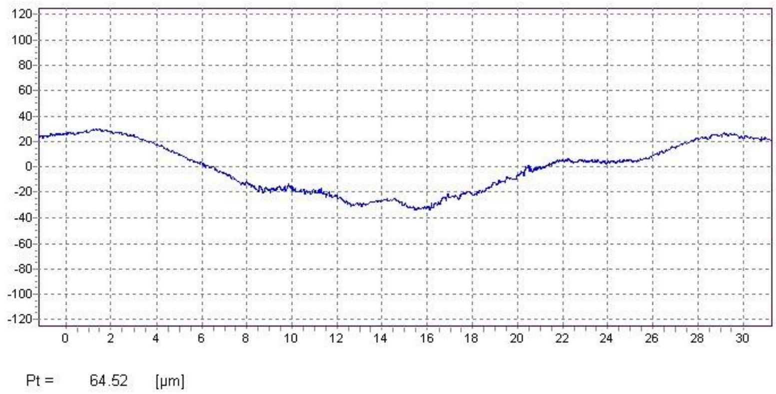

Fig. 7. Surface geometrical structure after electrochemical smoothing; D = 0,280 mm, V_f = 0.35 mm/min, g ~1.75 D, P_t = 64.52 μm.

Fig. 8. Surface geometrical structure after electrochemical smoothing; D = 0,280 mm, V_f = 0.1 mm/min, g ~D, P_t = 141.34 μm.

For constant initial surface waviness very important is thickness of allowance removed during electrochemical machining (g). When “g” is too small (Fig. 6) initial surface waviness is only decreased but not removed. Increasing thickness of removed material (g) it is possible to remove initial waviness D and waviness resulting from ECM process is created (Fig. 4).

Further increase of thickness “g” didn’t improve machined surface quality (Fig. 7) because surface error created during ECM process increased.
Very important smoothing process parameter is electrode displacement velocity V_f (Figs 3, 8 and 9). For small V_f time of machining is very long and initial surface waviness is removed, however significant shape errors resulting from electrochemical smoothing process are created (Fig.8).

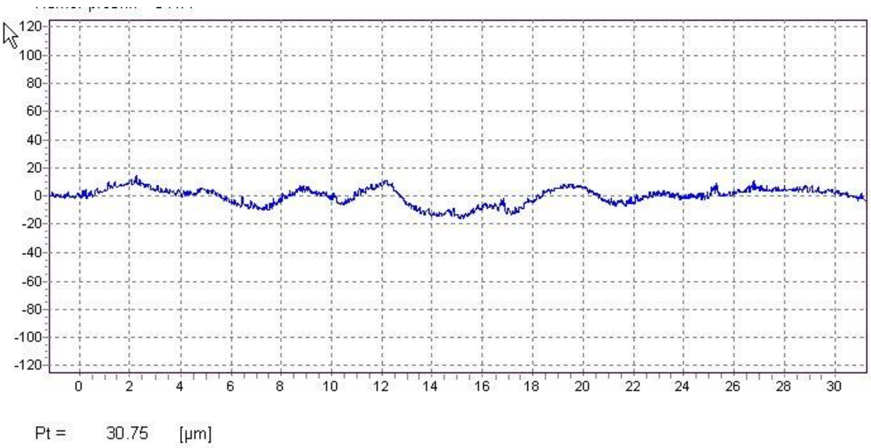

Fig. 9. Surface geometrical structure after electrochemical smoothing; D = 0,280 mm, V_f = 0.6 mm/min, g ~ D, P_t = 30.75 µm.

When velocity of electrode displacement was increased, shape errors significantly decreased (Fig.4 and 9). Initial surface waviness has been removed and shape errors resulting from ECM process were created.

From presented above primary investigations results that:

- in order to remove initial surface shape errors in electrochemical drilling process thickness of allowance removed should be at least as big as initial errors are,
- during electrochemical smoothing initial shape errors are decreased however at the same time errors connected with electrochemical machining process are created; so the smoothing process should be finished when shape errors are minimal,
- electrochemical smoothing process is more efficient for higher velocity of electrode displacement V_f.

In investigated case shape errors created in ECM process result from not uniform distribution on machined surface conditions of dissolution process. So, in order to obtain high surface accuracy it is necessary to find out optimal dissolution process parameters for both stages: removal initial errors after milling and ECM process in steady state. In investigated case the shape errors created as a result of ECM process one can see in Fig. 10, 11 and 12 where spatial view of machined surface is presented.

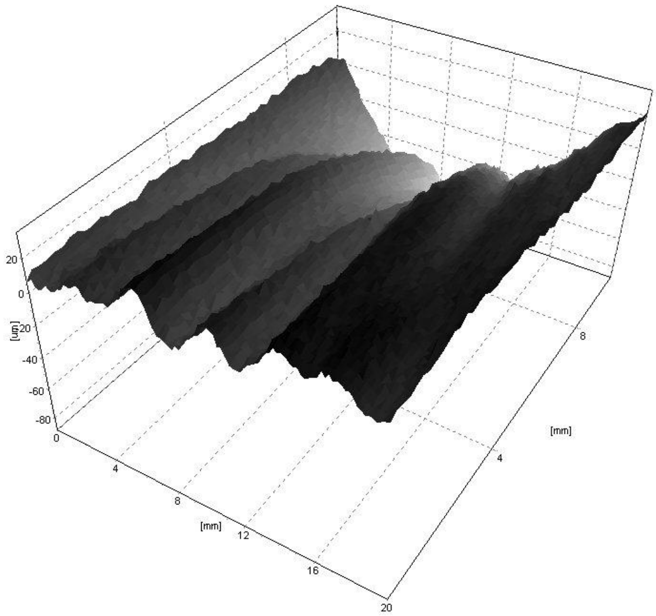

Fig. 10. Spatial surface geometrical structure after electrochemical smoothing; D = 0,280 mm, V_f = 0.6 mm/min, g ~ D.

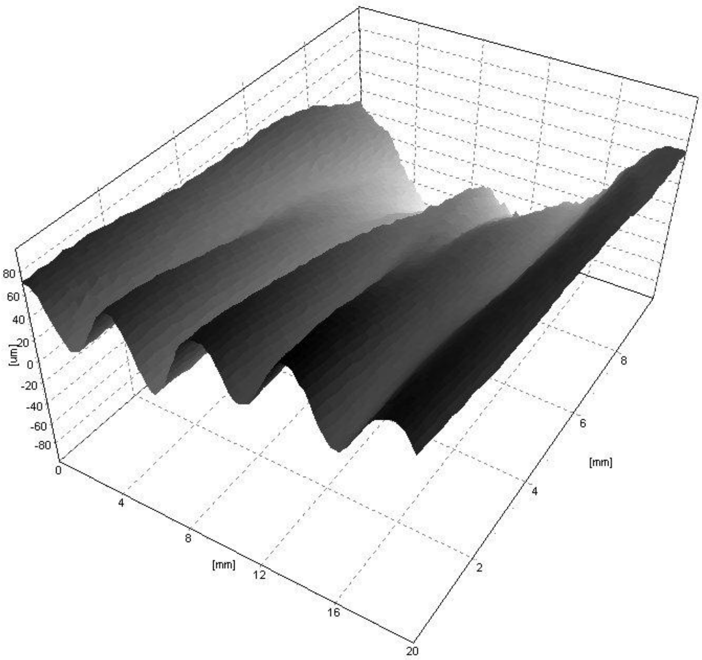

Fig. 11. Spatial surface geometrical structure after electrochemical smoothing; D = 0,517 mm, V_f = 0.35 mm/min, g ~D.

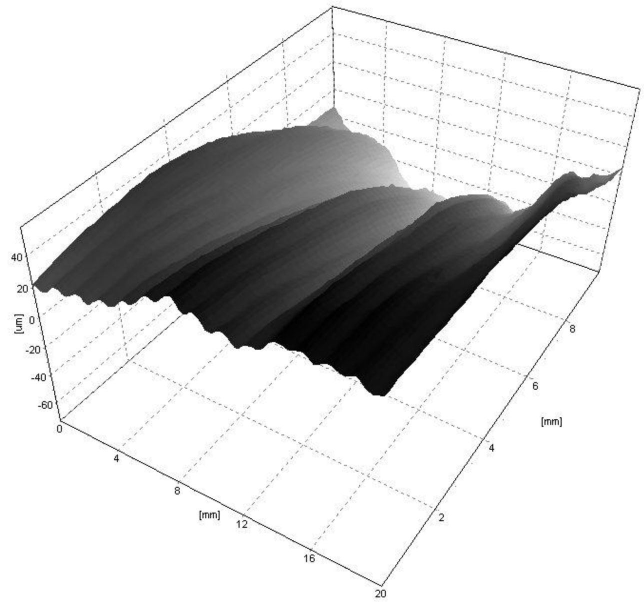

Fig. 12. Surface geometrical structure after electrochemical smoothing; D = 0,042 mm, V_f = 0.35 mm/min, g ~D.

Surface after rough milling had some regular waviness with constant height. The final geometrical structure after ECM smoothing is not uniform and very difficult to define.

4. SUMMARISING

Results of experiments indicate that in investigated case it is possible to decrease surface initial shape errors in shorter time but with lower accuracy than in case of smoothing with universal ball ended electrode. In ECM smoothing it is possible to distinguish two main processes. In the first process the initial shape errors are decreased. In the second one the shape errors typical for electrochemical machining are created and usually the final surface geometrical structure (errors) is a result of this process. So, electrochemical smoothing can be very efficient but on conditions that ECM smoothing is carried out in optimal conditions, from surface errors point of view.

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