

PRIMARY RESEARCH ON HYBRID EROSION MACHINING PROCESSES

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Abstract

Electrodischarge and electrochemical machining are modified for special application in Micromachining and Microfinishing operations. In the paper the test stands for electrochemical micromachining supported by laser beam (ECLMM), electrodischarge machining in mixture of dielectric and powder (AEDM) and electrodischarge machining supported by electrode-tool ultrasonic vibrations (USEDM) are presented. Using these test-stands the primary experimental test have been carried out. Results of these test for USEDMM have been described in the paper. The discussed idea of test-stands for ECLMM, AEDM and USEDMM will be applied in electrochemical and electrodischarge special machine-tools designed and produced at the Institute of Metal Cutting.

1 INTRODUCTION

The electrochemical and electrodischarge machining processes are widely applied in industry. These processes are applied for machining details made of difficult for cutting metals, alloys and composites [Rajurkar et al. 1999]. However in many cases electrodischarge and electrochemical machining are not enough efficient and accurate. In order to solve this problem one can introduce additional factors, which can support the main electrochemical or electrodischarge processes. In practice one can distinguished the following processes [McGeough, De Silva 1996]: electrodischarge process supported by electrochemical dissolution, electrodischarge process supported by ultrasonic vibration, electrodischarge process carried out in mixture of dielectric and powder (for instance silicon), electrochemical or electrodischarge grinding, electrochemical machining supported by ultrasonic vibration or local laser beam heating. One of very important directions of development in manufacturing is small part machining (*Micromachining*) and surface smoothing (*Microfinishing*). Below the equipment

for electrochemical machining assisted by laser beam, electrodischarge machining assisted by ultrasonic vibrations and electrodischarge machining in mixture of dielectric and powder will be presented. The first two processes can be applied efficiently for micromachining operations. The last one is mainly applied for microfinishing operations.

2 ELECTROCHEMICAL MACHINING ASSISTED BY LASER BEAM (ECLMM)

One of the main problems in electrochemical small surfaces machining is localisation of dissolution process. The efficient way of solving this problem is local heating by laser beam the area of material allowance, which should be removed. As it has been proved the local heating by laser beam makes it possible [Davydov 1994]:

- to increase (10 – 100 times) the velocity of dissolution or deposition coating processes,
- to localise the dissolution process on the small area,
- to carry out the dissolution or deposition processes in areas difficult to reach and machine with cutting tools,
- to machine materials difficult for electrochemical machining (for instance semiconductors).

In order to receive the satisfactory dissolution or deposition process, localisation the influence of laser beam should be concentrated only in the machined area. It is possible when process parameters are optimal. In process parameters optimisation it should be taken into account, that as a result of laser beam influence the potential of deposition or dissolution, velocity of electrochemical reactions, rate of diffusion processes in boundary layer, current efficiency, level of material passivation, are changed. During electrochemical machining assisted with laser beam, the dependence of interelectrode voltage, electrolyte and machined material chemical composition and physical properties on rate of dissolution process is different than in classical case.

From above presented considerations it results that universal test stand should have possibility of changing the following process parameters:

- interelectrode voltage (pulse or constant),
- power of laser beam,
- time of pulse and pause between pulses,
- dimensions of laser beam spot on machined surface,
- relative displacement of laser beam and machined surface (in x, y and z axis),
- electrolyte discharge,
- electrolyte properties,

- distance between cathode and anode.

The scheme of test stand for ECLMM process realisation is presented in Fig. 1.

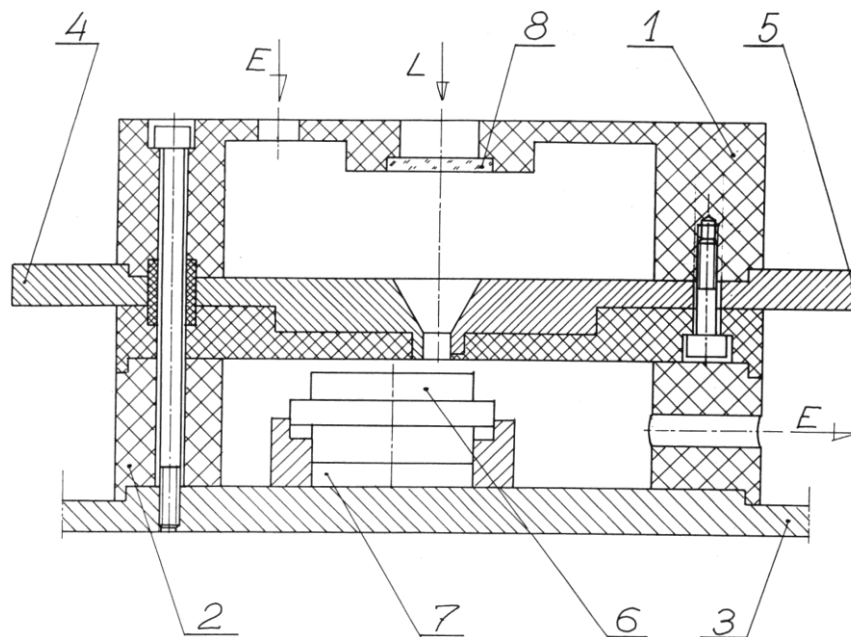


Fig. 1 Scheme of chamber for carrying out electrochemical machining assisted with laser beam, where:

- L - Nd-YAG laser beam,
- E - electrolyte inlet and outlet,
- 1 - upper housing,
- 2 - lower housing,
- 3 - base plate,
- 4, 5 - electrode with insulation (version I and II),
- 6 - workpiece,
- 7 - mechanism for setting of the gap thickness,
- 8 - special optical glass for transmission laser beam

In presented construction the laser beam can be displaced along x, y axis on the area 20x20 mm. It is also possible to apply stable laser beam and displaced along x, y axis work table.

The idea of equipment for ECLMM process realisation presented in Fig 1 can be applied for manufacturing in industrial conditions.

3. ELECTRODISCHARGE MACHINING IN THE MIXTURE OF DIELECTRIC AND POWDER (AEDM)

Technological indicators of electrodischarge machining process, metal removal rate, surface quality, surface roughness and number of cracks, depend mainly on power and energy of electrical discharges. The efficient way of decreasing number of cracks and surface roughness and generally improve surface quality is electrodischarge machining using the mixture of dielectric and powder of silicon, graphite, aluminium or other materials [Naruniya et al. 1989; Mohri 1991; Uno, Okada 1997].

The improvement of surface quality results from the better electrical discharge distribution on machined surface. Characteristic of this distribution depends on interelectrode gap thickness, which is higher in case of machining in dielectric with powder. Higher value of interelectrode gap thickness is the reason of the fact that discharges are more stable and influence larger area of machined surface. The comparison of surface roughness received in dielectric and its mixture with silicon powder is presented in Fig. 2.

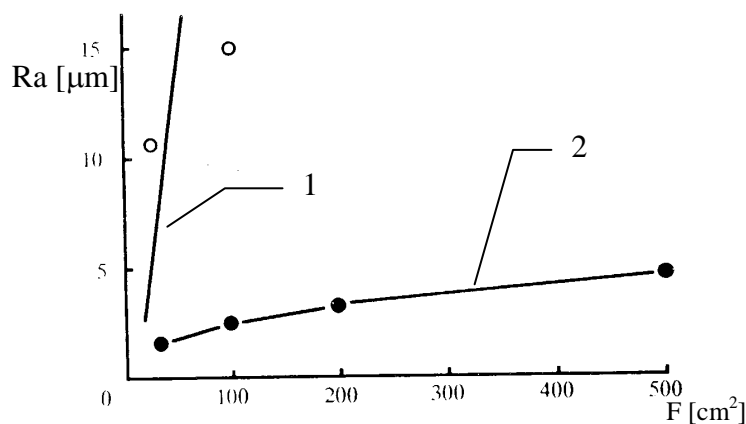


Fig. 2 Relationship between surface roughness parameter and surface of machined detail [Kobayashi 1995]; where: 1 – case of machining in clear dielectric, 2 – case of machining in mixture of dielectric and silicon powder

The results of machining depend on classical electrodischarge process parameters (pulse energy and power, time of pulse and time of pause) as well as on

properties of mixture of dielectric and powder. The properties of above mentioned mixture depend on:

- sort of dielectric (water based or hydrocarbon based dielectric)
- sort of material powder,
- dimensions and shape of powder grains,
- powder grain concentration,
- uniformity of powder grain concentration.

In order to check this process in practice the electrodischarge machine tools produced at the Institute of Metal Cutting have been equipped with a special portable unit for dielectric mixture with powder preparing and putting it into machined area.

The scheme of this unit is presented in Fig. 3. It can co-operate with any electrodischarge machine - tool, especially with electrodischarge machine tool type EDEA 16.

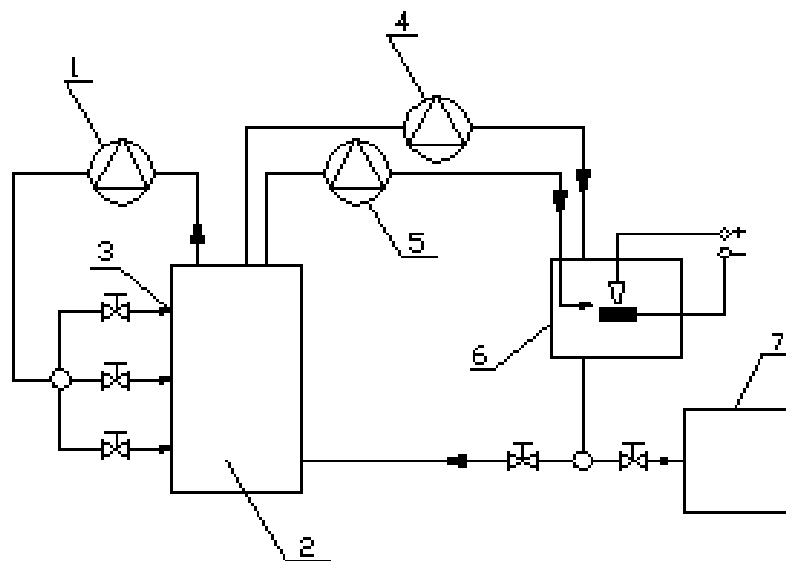


Fig. 3 Scheme of portable unit of dielectric and powder mixture circulation; where: 1 – pump for dielectric and powder mixing, 2 – tank of dielectric and powder mixture, 3 – working fluid inlets, 4 – working fluid outlet, pump for supplying the machining area with dielectric and powder mixture, 5 – pump for supplying fluid into the interelectrode gap, 6 - working chamber, 7 – tank for waste working fluid

It has been assumed that as a working fluid can be applied:

- deionised water,
- hydrocarbon based dielectric,
- mixture of above mentioned liquids with different powders.

As a powder can be applied grains of graphite, Al, Si and SiC with sizes from 5 to 70 μm . In order to prepare the mixture, the some amount of powder and dielectric liquid is put into a tank. Then, pump (1) force liquid circulation (see Fig. 3) what helps to have a uniform mixture of fluid and powder, which is then pump to machining area.

The primary tests with silicon powder and hydrocarbon based dielectric have proved that it is possible to decrease surface roughness parameter about 20 – 30 % in comparison to machining in clean dielectric. The idea of equipment for providing the EDM process in the mixture of dielectric with powder can be applied in industrial conditions.

4. ELECTRODISCHARGE MACHINING SUPPORTED BY ULTRASONIC VIBRATIONS (USEDM)

In electrodischarge process the material allowance is removed as result of melting and evaporating machined material during electrical discharges. The mean temperature in electrical discharge channel is about 8 000 – 12 000 K [Albiński et al. 1995]. The heat is transported from electrical discharge channel to machined material and in a lesser extended to the electrode – tool. The products of this process should be removed during pause between successive pulses from interelectrode area. One of the efficient ways of improving the process of erosion products transportation from interelectrode area is to apply the ultrasonic vibration of electrode or workpiece [Lju Inczun, Du Sonjan 1986; Kremer et al. 1991; Zhixin et al. 1997; Egashira, Masuzawa 1999]. In order to modernise one of electrodischarge machine-tool worked out at the Institute of Metal Cutting, the necessary investigations have been undertaken. Their results will be presented below.

At first the special ultrasonic head has been designed and manufactured. The amplitude of ultrasonic vibrations is changed together with power of vibrations from 2 to 11 μm . The scheme of test stand for ultrasonically assisted electrodischarge machining is presented in Fig. 4.

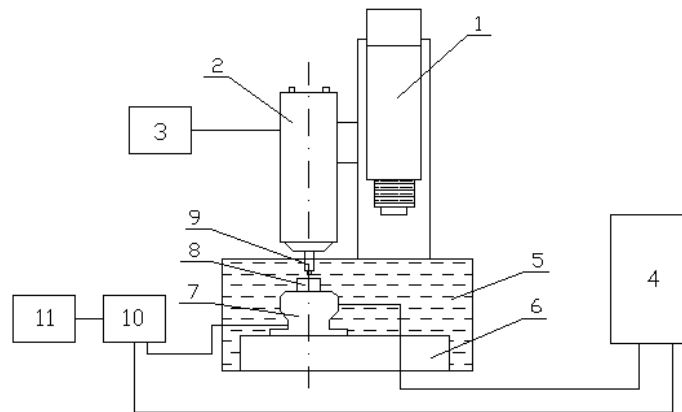


Fig. 4 Scheme of test-stand for ultrasonically assisted electrodischarge process; where: 1 – head of machine – tool EDEA 16, 2 – ultrasonic head, 3 – ultrasonic generator, 4 – generator of electric pulses UZSD 40Z, 5 – working chamber, 6 – workpiece table, 7 – workpiece handle, 8 – workpiece, 9 – electrode tool, 10 – oscilloscope, 11 – computer for voltage and current registration.

Using above presented equipment the primary tests have been carried out. Their results are presented below.

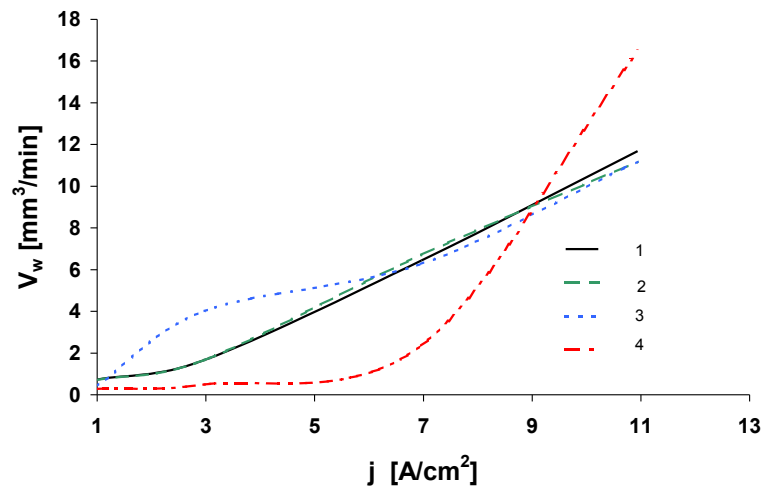


Fig. 5 Relations $V_w = f(j)$ for classical EDM without electrode vibration (4) and different amplitude A of electrode vibrations (1, 2, and 3): 1 - $A = 9.7 \mu\text{m}$, 2 - $A = 6.2 \mu\text{m}$, 3 - $A = 3.8 \mu\text{m}$, machining surface 0.5 cm^2

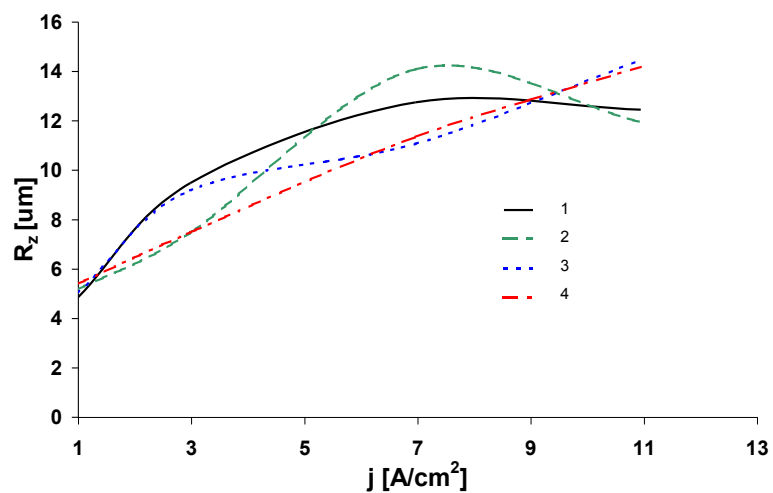


Fig. 6 Relations $R_z = f(j)$ for classical EDM without electrode vibration (4 and different amplitude A of electrode vibrations (1, 2 and 3): 1 - $A = 9.7 \mu\text{m}$, 2 - $A = 6.2 \mu\text{m}$, 3 - $A = 3.8 \mu\text{m}$, machining surface 0.5 cm^2

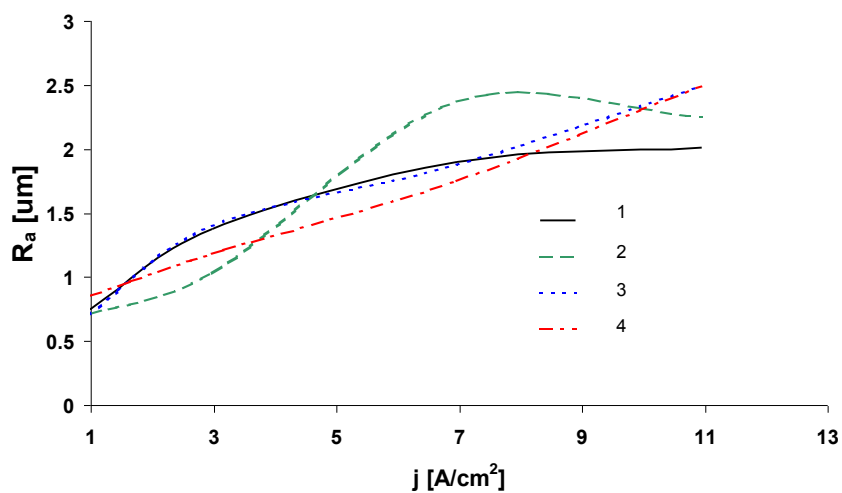


Fig. 7 Relation $R_a = f(j)$ for classical EDM without electrode vibration (4) and different amplitude A of electrode vibrations (1, 2 and 3); where: 1 - $A = 9.7 \mu\text{m}$, 2 - $A = 6.2 \mu\text{m}$, 3 - $A = 3.8 \mu\text{m}$, machining surface 0.5 cm^2

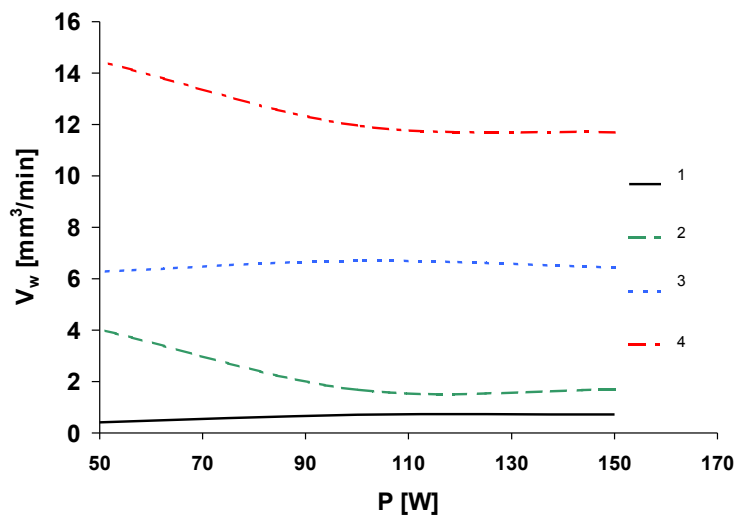


Fig. 8 Relation $V_w = f(P)$ for different mean current density; 1 - $j = 1 \text{ A/cm}^2$, 2 - $j = 3 \text{ A/cm}^2$, 3 - $j = 7 \text{ A/cm}^2$, 4 - $j = 11 \text{ A/cm}^2$, P – power of ultrasonic vibrations

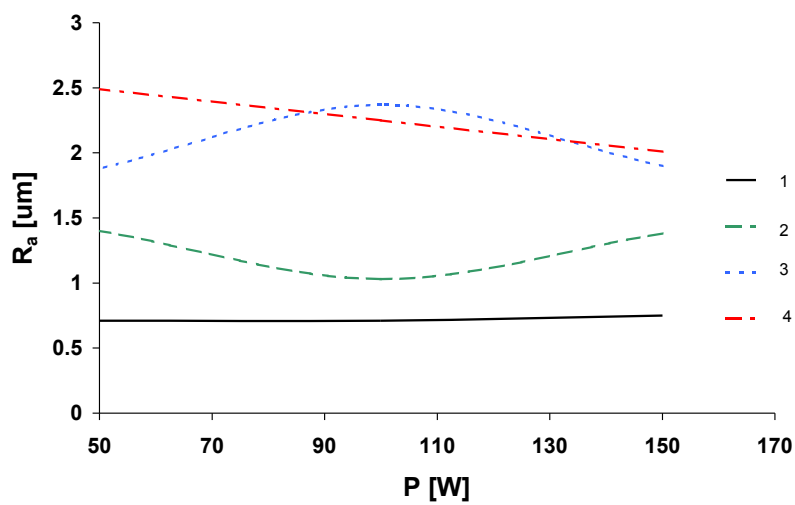


Fig. 9 Relation $R_a = f(P)$ for different mean current density: 1 - $j = 1 \text{ A/cm}^2$, 2 - $j = 3 \text{ A/cm}^2$, 3 - $j = 7 \text{ A/cm}^2$, 4 - $j = 11 \text{ A/cm}^2$, P – power of ultrasonic vibrations

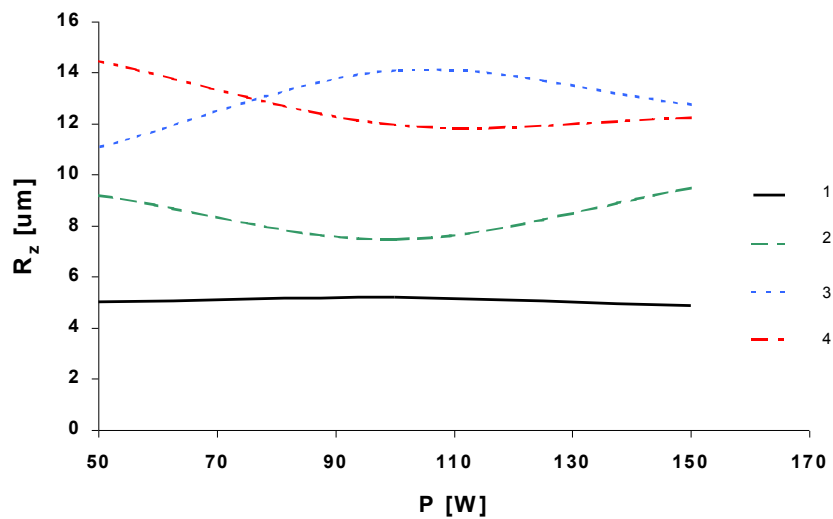


Fig. 10 Relations $R_z = f(P)$ for different mean current density: 1 - $j = 1 \text{ A/cm}^2$, 2 - $j = 3 \text{ A/cm}^2$, 3 - $j = 7 \text{ A/cm}^2$, 4 - $j = 11 \text{ A/cm}^2$, P – power of ultrasonic vibrations

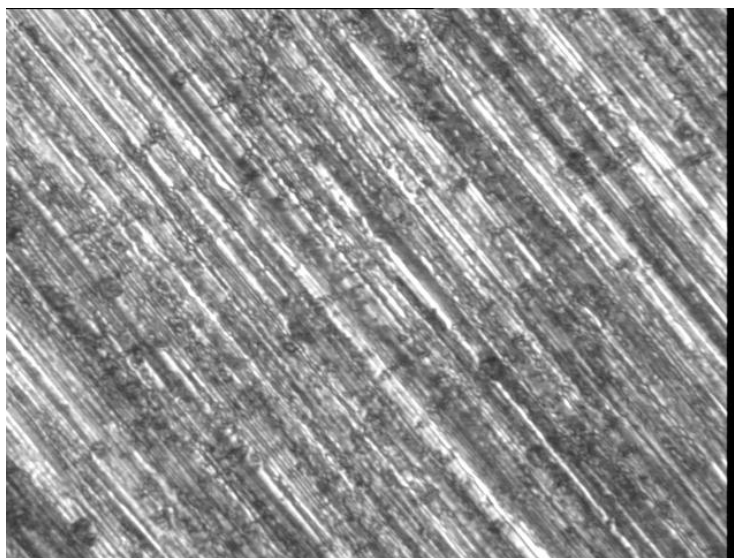


Fig. 11 Photograph of initial sample surface after grinding machining (Magnification 300 times)

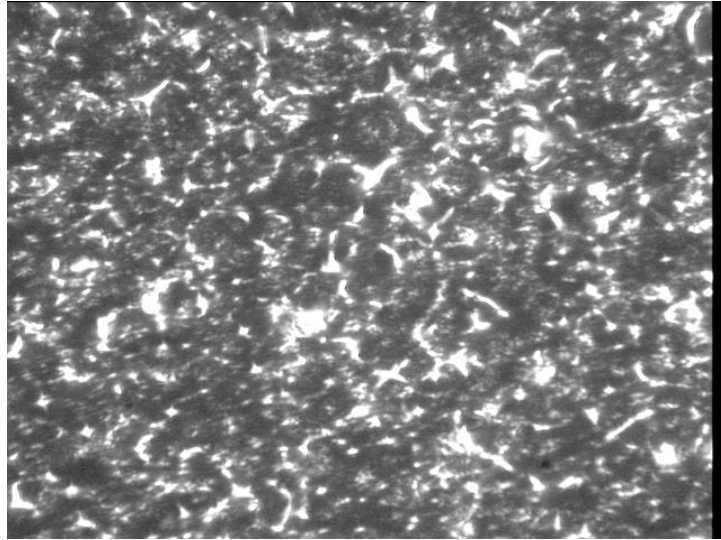


Fig. 12 Photograph of machined surface after USED M; $A = 6.15 \mu\text{m}$, $j = 1 \text{ A/cm}^2$
(Magnification 300 times)

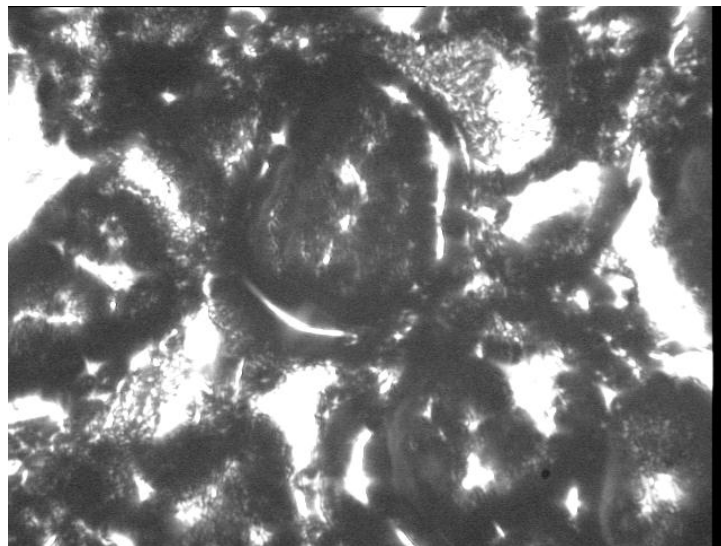


Fig. 13 Photograph of machined surface after USDEM; $A = 6.15 \mu\text{m}$, $j = 7 \text{ A/cm}^2$
(Magnification 300 times)

In experiments, the amplitude of electrode vibration was in the range $\sim 5 - 30$ % of interelectrode gap thickness. From Figs 5 to 10, it results that:

- Metal removal rate, especially for small values of mean current density, is significantly higher when ultrasonic vibrations support EDM process. It is because of more efficient machining product transportation (Fig. 5).
- Surface roughness parameters (in analysed case) don't depend significantly on electrode tool vibrations (Figs 6, 7). Their values are depended much on mean current density.
- Metal removal rate and surface roughness parameters don't depend significantly on ultrasonic vibration power (Figs 8 –10).

In Fig. 11 the photograph of initial surface of sample after conventional machining is presented. These samples have been used for the further investigations. In Figs 12 and 13 the photographs of machined surface after EDM assisted with ultrasonic vibrations are presented. In these photographs the white areas are the tops of surface roughness. The black ones are the bottoms of surface roughness. Surface presented in the photographs are similar as in case of EDM machining without ultrasonic vibrations. The further investigations will be realised for different conditions and for other parameters, which have not been taken here into account (pulse time, pause time).

These primary investigations have proved, that application of electrode ultrasonic vibrations can have positive influence on the EDM process.

Equipment built according to the idea presented in Fig. 6 can be applied for any electrodischarge machine – tools. The electrodischarge machine - tool modernisation can be made at the Institute of Metal Cutting.

5. RECAPITULATION

In many cases, the technological indicators of electrodischarge or electrochemical processes applications are not satisfactory. This problem is very important in Micromachining or Microfinishing operations. In order to improve technological indicators the electrodischarge or electrochemical machining processes are modified. In the paper the general idea of equipment for carrying out the following processes: electrochemical machining supported by laser beam, electrodischarge machining in mixture of dielectric and powder and electrodischarge process supported by electrode tool ultrasonic vibrations.

The equipment, which ideas are presented in the paper, can be applied in industrial conditions for micromachining (ECLMM, USEDMM) or microfinishing (AEDMF). This idea has been confirmed by primary investigations carrying out at

the Institute of Metal Cutting and will be applied in electrochemical and electrodischarge special machine – tools designed and produced at the Institute of Metal Cutting.

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