TOOL AND WORKPIECE QUALITY PROTECTION IN ELECTROCHEMICAL MACHINING

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Abstract During electrochemical machining process (ECM) random disturbances – electrical discharges - often occur, what is usually the reason of stopping the process. This fact limits the ECM process automation and make it difficult to introduce for mass production. In practice the two main ways of problem solution are possible: the first one is connected with process parameters optimisation and designing special units which protect electrode and workpiece against short circuits. The second way is connected with universal electrodes application. In the paper these two ways are presented and discussed.

Keywords*:* ECM, ECM - CNC, PECM, short circuit

1. INTRODUCTION

The characteristic feature of electrochemical machining (ECM) is the absence of mechanical contact between the electrode and workpiece and the fact that material excess is removed as a result of electrochemical dissolution process. The electrochemical dissolution process is accompanied by intricate processes of mass, energy and electric charge transportation. Especially important for the machining process stabilisation is the process of hydrogen and heat transportation (by electrolyte flow) out of interelectrode gap (Fig. 1) [5, 10, 11]

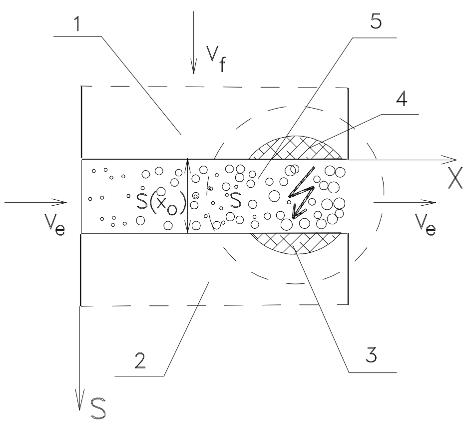

Figure1: Scheme of electrochemical machining process: 1 - electrode-tool, 2 – workpiece; 3, 4 - areas where the electric discharge can occur because of high hydrogen concentration or high electrolyte temperature (electrolyte boiling), 5 - interelectrode gap, v_e - velocity of electrolyte flow.

Because of inertia of this process an uneven and random distribution of electrolyte temperature, hydrogen concentration and dissolution process conditions occur. When in some area of machined surface electrolyte velocity is too low or electrolyte temperature and hydrogen concentration is too high the electrolyte conductivity decreases what is a reason of temperature and hydrogen concentration increase and interelectrode gap thickness decrease. When interelectrode gap becomes smaller the intensity of electrical field increase and the probability of electrical discharge (short circuits) increase. Electrical discharges in machining area are in many cases a reason of machining process interruption and electrode and workpiece damage. So, it is necessary to do the best to avoid electrical discharges (short circuits) during machining process.

2. PROCESS PARAMETERS OPTYMIZATION

In many cases the efficient way to avoid short circuits is process parameters stabilization, especially: velocity of electrode tool displacement, interelectrode voltage, electrolyte pressure and discharge, electrolyte temperature, pH and sludge concentration. Very important is distribution of electrolyte flow and pressure on machined surface, because in areas with low velocity of electrolyte flow and pressure probability of shot circuit rapidly increases. This way of process control is not fully satisfying. In order to improve protection against short circuits the investigations have been carried out and special units have been designed [1, 2, 3, 4,]. Thank to this units it is possible to control course of interelectrode voltage and electrical current and foresee the electrical discharge occurrence. When danger of electrical discharge is find out the power supplier is automatically putting off.

The investigations carried out at the Institute of Metal Cutting have been concentrated on monitoring the interelectrode voltage and current course during stable and just before short-circuit stages of the electrochemical machining process [11]. Some results of monitoring are presented in Fig. 2.

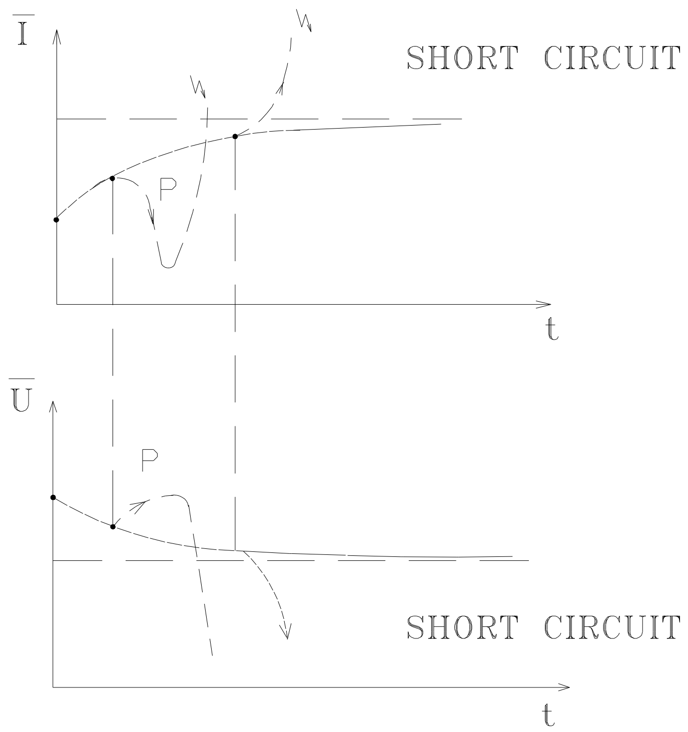

Figure 2: Current intensity and interelectrode voltage courses during stable (full line) and unstable (just before short-circuit - dashed line) stages.

The results of investigations made it possible to determine more precisely the parameters of set unit against short-circuit. It should include:

- sensor responding for the sharp interelectrode voltage drops, which are caused by short-circuits,
- sensor responded for the interelectrode voltage vibrations when their frequency is in the range of 8 - 40 kHz; these are vibrations caused by electrolyte flow hydrodynamic (turbulence),
- sensor responding for the interelectrode voltage vibrations when their frequency is in the range of 72 - 90 kHz; these are vibrations caused by arc discharges which occur in the area where dissolution process was stopped. The reason of dissolution process inhibition can be the lack of electrolyte or the fact that wholly interelectrode space is filled with hydrogen or water vapour (steam).

When the stage before short-circuit is identified the most important task is quick decrease of interelectrode voltage. The set against short-circuit has been successfully applied in worked out at the Institute of Metal Cutting ECM machine tools [11]. The highest reliability of this unit can be reached when electrochemical machining is carried out for optimal process parameters. However, random shorts circuits occur from time to time.

3. PULSE ELECTROCHEMICAL MACHINING

From above presented considerations results that high concentration of hydrogen and high electrolyte temperature increase probability of electrical discharge occurrence. In order to decrease hydrogen concentration and electrolyte temperature Pulse Electrochemical Machining (PECM) has been applied [9, 10]. The most advanced scheme of PECM is presented in Fig. 3. During this process interelectrode voltage has pulse character and pause time between successive voltage pulses or pack of pulses (t_p) should be long enough to remove from interelectrode gap heat, dissolution process products and evaluate electrode position in relation to workpiece (A, B,…, S_o) and thickness of material removed (a). Then, dissolution process is continued during time $t = t - t_p$ and cycle is repeated again and again. In this way of machining distance between electrode and workpiece, concentrations of electrochemical reaction product and electrolyte temperature are controlled. The same machining accuracy and workpiece surface quality increase and probability of short circuits and electrodes damage decreases.

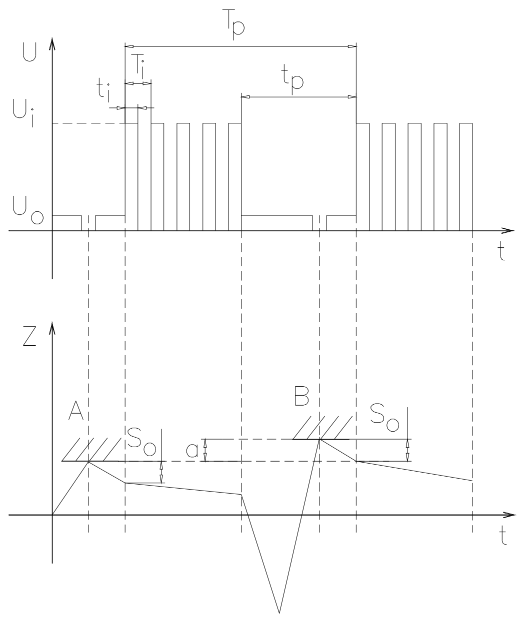

Figure 3. Scheme of PECM with periodical control of electrode – tool position in relation to workpiece; U interelectrode voltage during machining, U_o – interelectrode voltage when dissolution process is stopped, Z – electrode displacement, t – time of the process; A, B, - points of successive contact between electrode and workpiece when machining process is stopped, a – thickness of allowance removed during one machining cycle, S_o – thickness of interelectrode gap at the beginning of voltage pulse or pack of pulses.

The advantages of PECM are higher accuracy and lower probability of short circuits in comparison to classical ECM. The main disadvantage is lower metal removal rate.

4. ELECTROCHEMICAL MACHINING WITH UNIVERSAL ELECTRODE – TOOL

In order to increase machining accuracy and limit short circuits during process the investigations of electrochemical machining with universal electrode (ECM-CNC) have been carried out [6, 7].

During ECM – CNC process electrode in shape of spherical cup (or other) is displaced over machined surface as in Fig. 4. Machined area is small and also small are electrochemical reaction product concentration and electrolyte temperature. In addition universal electrode trajectory is design to have distance between electrode and workpiece in the range of ~ 0,05 – 0,1 mm. Thank to this fact the direct mechanical contact between electrode and workpiece is impossible. The advantage of ECM – CNC process is high accuracy and very low probability of electrical short circuit. The main disadvantage is very low metal removal rate. However, in this way of machining using simple electrode it is possible to machine large sculptured surfaces.

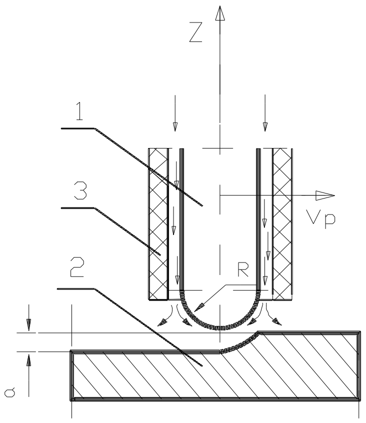

Figure 4: Scheme of ECM – CNC; 1 – electrode, 2 – workpiece, 3 – nozzle for electrolyte supplying, a – material excess removed during one electrode pass.

5. ABRASIVE ELECTROCHEMICAL MACHINING WITH UNIVERSAL TOOL

From above presented considerations results that machining accuracy and surface quality usually increase when the probability of short circuits decreased. Here is presented way of electrochemical machining - electrochemical grinding (ECG –CNC) with spherical abrasive tools [6, 8]. The material allowance is removed as a result of electrochemical dissolution process and mechanical grinding. It is worth to underline that the main advantage of this way of machining are: high flexibility, pretty – good surface layer properties and high reliability in material removal, even when in machined surface there are non-metallic inclusions or when on machined surface passivation occurs. In electrochemical grinding electrical discharges usually occur during machining but their influence on workpiece surface quality is very low. The main disadvantage of this process is the abrasive electrode – toll wear because of its mechanical contact with workpiece.

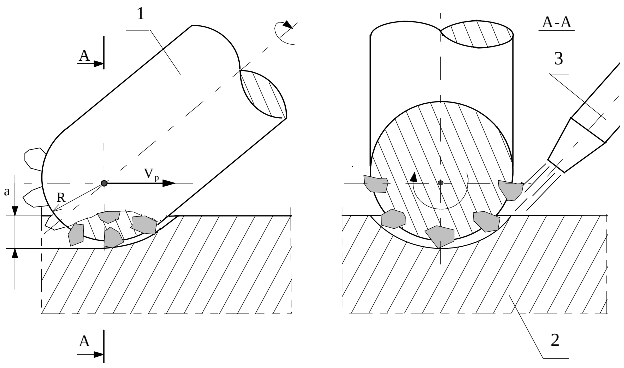

Figure 5: Scheme of electrochemical grinding with spherical tool (ECG – CNC), 1 – rotating abrasive tool, 2 - workpiece, 3-nozzle for electrolyte supplying, a – thickness of material removed during one tool pass.

6. SUMMARY

In each machining process exists a very direct relation between tool and workpiece quality. So, it is essential to take care about tool quality. In metal cutting processes the systems of monitoring state (quality) of the tool have been worked out. As indicators of the state of the process (and the same the state of the tool) power consumption or mechanical cutting forces usually are applied. In electrochemical machining (ECM) there is no mechanical contact between tool and workpiece (exception is electrochemical grinding – AECM) and the only possibility is monitoring of interelectrode voltage and current.

Tool and workpiece quality protection in electrochemical machining is very important and very difficult problem. The most efficient way of ECM practical application is sinking operation. Dissolution process is carried out here on the whole surface. The final workpiece shape is obtained as a result of reproduction of electrode – tool shape in machined material. The surface quality and metal removal rate are usually satisfactory on condition that machining process is carried out without short circuit. In order to decrease probability of short circuits it is necessary to stabilise the basic process parameters. Very efficient is application of special anti-short circuits units, which can foresee short circuit and put off electrical supplier and the same protect electrode - tool quality. The reliability of anti-short circuit system is lower than100%. The reliability of this protection system can be increased by:

- process parameters optimisation and stabilization in all ECM ways of machining,
- application of PECM and ECM – CNC with universal electrodes.

The exception here is ECM grinding process but it is not clear ECM process; it is a hybrid ECM – CNC process.

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