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EXPERIMENTAL STUDIES OF VIBRATION OF THE TECHNOLOGICAL DEVICE FOR ELECTROCHEMICAL MACHINING OF CURVILINEAR SURFACES

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Abstract: *The paper provides the results of dynamic experiments of the technological device facilitating electrochemical machining of any shaped curvilinear surfaces and rotary shaping surfaces with curvilinear profile. With the experimental analysis of vibration, in selected points of the technological device the vibration was identified.*

Keywords: Technological device, ECM, Vibration analysis.

1. Introduction

Designing the technological device (research stand) providing the function of the machine tool or mini machine tool, one shall note the necessity of solving the problems immediately connected with the dynamics of the phenomena accompanying the operation of the device (Marchelek, 1991). The key job is to ensure a stable motion of the tool and the object being machined. The deviations from the assumed motion of the tool and the machined object are usually a result of external effects on mass-spring system, OUPN (machine tool-holder-object machined-tool), as well as mass-spring properties of the OUPN system. The mass-spring properties of the OUPN system have a crucial effect on the nature of oscillating motions (Cannon, 1973 and Gutowski et al., 1986). The real dynamic OUPN system is a nonlinear continuous system. Very often, investigating dynamic phenomena in machine tools, due to poor mass-spring nonlinearity of the OUPN system and vibration for analysis, one uses the linear approximation. The technological device will, in fact, meet the input functions if the OUPN system is stable and, on top of that, it will demonstrate specific dynamic properties. Most frequently, to evaluate those properties, the so-called dynamic quality indices are applied (Cannon, 1973 and Piszczek et al., 1982).

This paper has been an attempt at evaluating the technological device meeting the function of the research stand (machine tool) for ECM for selected excitations generating vibration, based on the analysis of time and amplitude-frequency characteristics.

2. Technological device

2.1. Characteristics of the technological device

Designing the technological device for examining the ECM with shaping electrodes, it was assumed that the size of the surface machined will not exceed 40 cm^2. The values of the machined surface assumed provide mostly the parameters of DC power supply, the mass of the electrodes and the forces acting on them, which determines the mechanical load of the stand. It has an essential effect mostly on the stiffness of the elements of the body, their shape and the size (Paczkowski, 2010, Osiński, 2013). The technological device facilitates performing ECM with a fixed shaping electrode, vibrating across the gap (Fig. 1).

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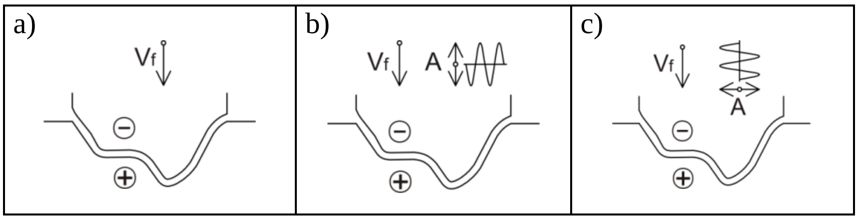


Fig. 1: Kinematics of the working electrode motion.

2.2. Components of the technological device

The basic component of the stand is its body. It is made up of two basic plates *1* and *2*, as well as two mobile plates *4* and *5* (Fig. 2a) connected with each other with four guide-posts *3* together with closed linear bearings type LM20UU. Electrodes are connected with mobile plates.

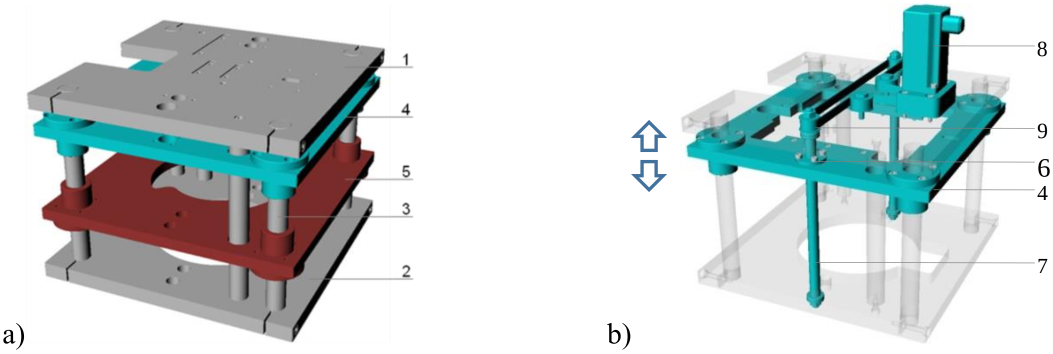


Fig. 2: a) Research stand body; b) Main feed of the working electrode.

The stand body, depending on the type of machining, is mounted with adequate drive systems of electrodes producing motions: feed motion and velocity V_f and circular motion with velocity and drive systems causing vibration of electrodes in directions normal and perpendicular to in-feeding motion.

The drive system of the main feed Fig. 2b of the working electrode consists of mobile plate *4* mounted on guide-posts with rolling sleeves and connected with nuts *6* with guide screws *7*. Guide screws are driven with servomotor *8* with the toothed belt drive *9*.

The drive system of transverse vibration of the working electrode Fig. 3a consists of the support *10* embedded through sliding elements *11* and guides *12* on plate *4*. Support *10* is driven with servomotor *13* through toothed belt drive *14* and eccentric cam *15*. A constant pressure of the support to cam is ensured by a spring *16*.

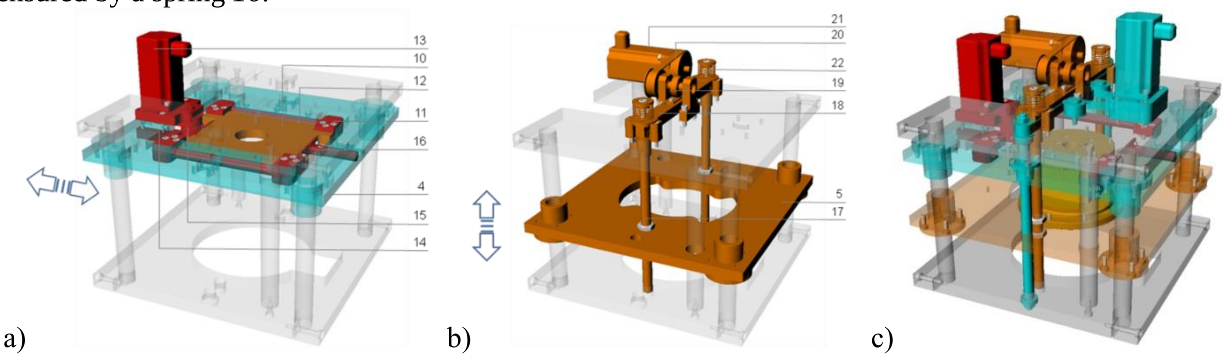


Fig. 3: a) Drive of transverse vibration of the working electrode; b) Drive of longitudinal vibration of the electrode; c) Technological device – configuration with shaping electrode.

The drive system of longitudinal vibration of the electrode Fig. 3b consists of the mobile plate *5*, mounted on guide-posts with rolling sleeves and connected through tappets *17* with beam *18*. The beam *18* cooperates with eccentric cam *19* driven with the toothed belt drive *20* with servomotor *21*. The constant pressure of beam *18* with cam is ensured by springs *22*. Fig. 3c demonstrates the configuration of the research stand for drilling with shaping.

For the right operation, the technological device is supplemented with the following components: DC power supply, the system of feeding with electrolyte, process parameters control system.

2.3. Machining cells

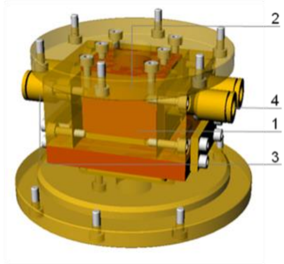


Fig. 4: Machining cells with shaping curvilinear electrode.

The key component of the stand is the machining cell. Depending on the ECM type, two different design forms of the machining cell were considered for drilling with curvilinear shaping electrode (Fig. 4).

Irrespective of the type of machining, in the machining cell one will find the object machined 1 and working electrode *2* (Fig. 4). Depending on the type of erosion machining, the electrodes are mounted adequately to mobile plates *10* and *11* (Fig. 2).

3. Technological device experiments

The experiments of the technological device included the measurement of vibration:

– the component performing horizontal translational motion,
– the component performing vertical translational motion,
– a rigid plate merging the structure of the research stand (namely the entire research stand).

The experiments were performed under working conditions (regular operation) of the research stand, namely for the assumed conditions of ECM shaping machining of shaping surfaces with curvilinear profile. Tab**.** 1 presents possible configurations of excitations of translational vibration, horizontal and vertical, the measurements were taken for.

Tab. 1: Possible configurations of excitations of horizontal and vertical vibration.

Measurement No.	1	2	Flow rate electrolyte
Horizontal forced vibration (sensor 1 - Hz)	0	50	
Vertical forced vibration (sensor 2 - Hz)	75	0	Q = 2 l/min

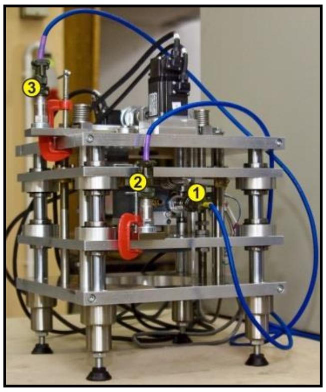


Fig. 5: Vibration sensors distribution.

The distribution of measurement points and privileged directions of measurements are shown in photograph (Fig. 5). Sensor 1 is mounted to the working component, performing horizontal translational motions produced by the circular motion of the eccentric mechanism the drive of which was executed using the toothed belt drive and the stepper motor. The theoretical amplitude of vibration comes from the eccentric mechanism applied and it is ± 0.05 mm. Sensor 2 is mounted on a mobile plate the vertical translational motion of which is also produced by the eccentric mechanism. Similarly, the eccentric mechanism is driven by the toothed belt drive and the stepper motor. The theoretical amplitude if vibration is ± 0.1 mm.

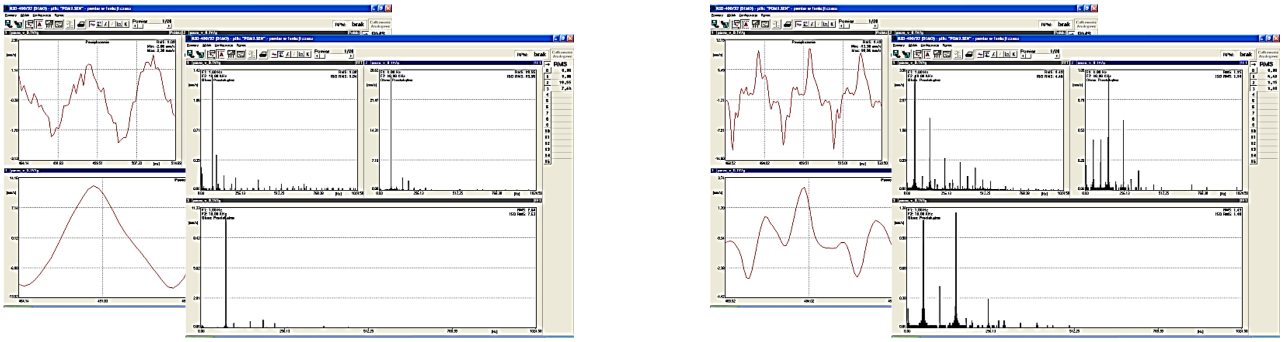
Sensor 3 has been mounted on a fixed plate of the research stand. The results of the measurements have been presented graphically in a form of time characteristics and frequencies characteristics for respective sequences of measurements have been plotted (Fig. 6). The dynamic identification of the kinematic system of the technological device, equipped with machining cell to ECM digestion of axisymmetric surfaces, similarly as in point 4.2, was performed to identify the nature of real vibration of the working electrode forced with cams driven with belt drives with an additional source of vibration generated by servomotor, producing the circular motion of the object machined.

4. Conclusions

The results of the experiments in terms of the research stand vibration as well as the presented plots of time characteristics and amplitude-frequency characteristics facilitate drawing the following conclusions:

– the FTT analysis shows that the dominant ones are the components with frequencies equal to the frequency of the input excitation (e.g. 37.5 Hz, 75 Hz),

– components of vibration with frequencies lower than the frequency of excitation come from self-vibration of the system resulting from the hydrodynamics of electrolyte flow (pressure of feeding, volumetric flow rate of electrolyte) in the interelectrode gap of the machining cell,
– components of vibration with frequencies higher than the frequency of excitation of the motion system of the stand are caused by the effect of rotating elements of the stand (belt drives, toothed wheels, stepper motors),
– the velocities of vibration of the component forcing vertical vibration are similar to the theoretical values specified for harmonic signal with known frequency and amplitude (Fig. 7a),
– velocities of vibration of the component forcing horizontal vibration differ from the theoretical values specified for harmonic signal with known frequency and amplitude (Fig. 7b).



a) Measurement 1 *b) Measurement 2*

Fig. 6: Time patterns for the velocity of vibration for selected measurement points FTT analysis for selected measurement points for: a) vertical vibration f = 75 Hz and horizontal vibration f = 0 Hz; b) vertical vibration f = 0 Hz, horizontal vibration f = 50 Hz.

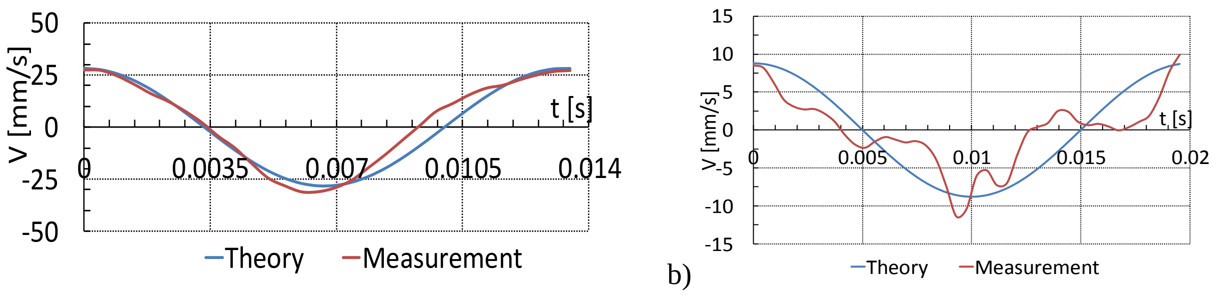


Fig. 7: Time patterns for the velocity of vibration: a) vertical vibration f = 75 Hz, horizontal vibration f = 0 Hz; b) vertical vibration f = 0 Hz, horizontal vibration f = 50 Hz.

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