Monitoring of dynamic processes in the machining of parts with vibrations

Elena Levchenko* and Nikolay Pokintelitsa
Sevastopol State University, Department of Mechanical Engineering, Sevastopol, Russia
*ealev1978@mail.ru

Abstract. There are the results of theoretical researches for the control of dynamics of the part motion in machining of parts with vibrations, based on the use of a group of magnetic modulation sensors, allowing to measure the nature of changes and motion of the part, as well as the amplitude, frequency and acceleration of motion during machining.

1. Introduction
As far as one can judge about the quality and productivity of the vibration machining process by material removal, surface roughness, and the residual stresses arising in the result of microhardness strengthening, removal and stabilization. It is necessary to make one important clarification in terminology here. Strictly speaking, these quantities do not characterize the productivity, but the intensity of the processes. Productivity is a complex characteristic, depending on the number of loaded parts, the required degree of roughness reduction, the duration of loading and separation of parts [1-6]. In some cases, it is required to complete unloading of the medium and its replacement on another, with smaller graininess, backwashing of medium, fixing and detaching parts, installing special protective plugs in the holes of the parts and removing them after machining, etc.

Productivity of vibroabrasive machining shall be understood as the amount of material removed per unit of time and of vibration-strengthening as the time to achieve the required physical and mechanical properties of the machined surface of the part.

2. Main text
The basis of the functioning of machines with vibrations is the process of mechanical vibrations. The oscillation process has to correspond to the required parameters, i.e. amplitude, oscillation frequency. The specific feature of vibro -machining is that it is very difficult to measure the parameters of oscillations of the working medium inside the machine and monitoring of the vibro-machining process at best is reduced to measuring the parameters of oscillations of the body [7].

The motion of the machining part has a complex nature and can be represented by the correspondence:

\[ f(x, y, z, t) = A_m \sin(\omega t + \psi) + \sum_{n=2}^{\infty} A_m \sin(n \omega t + \psi_n) + R(x, y, z, t), \]

where \( A_m \sin(\omega t + \psi) \) – fundamental oscillation of vibration generator;
\[ \sum_{n=2}^{\infty} A_n \sin(n \omega t + \psi_n) \] – oscillation, caused by the bottom of the system;

\[ R(x, y, z, t) \] – translation motion of the part.

The monitoring of the motion of the vibrating machine, the working medium and the part has two objectives: the first is to determine the parameters of the vibrating machining mode; the second is control of the technical condition of the mechanisms. Diagnostic systems for controlling mechanical vibrations can be divided into four groups according to the degree of complexity, instrumentation and software.

The simple system for monitoring of mechanical oscillations is implemented in the form of a combination of a simple small-sized vibrometer and a stroboscope. The vibrometer measures the general parameters of vibrations: vibration displacement, vibration speeds and vibration accelerations in the standard frequency ranges and also measures vibration parameters in other frequency ranges. It may have low pass and high pass bands.

The stroboscope is used to determine the shaft speed of the machine and the relative motion of its details and also for identification of nonstationarity of speed details rotation.

The comparison of the overall vibration levels with the established standards can be made for each machine [8, 9].

Operative monitoring system for mechanical vibrations can be implemented using portable analyzers. It allows undertaking the analysis of the vibration spectrum and its temporary implementations at the place of operation of the test object, to immediately assess the technical condition of the bearings and determine their defects.

The analyzer has the ability to view and analyze the vibration spectrums among themselves and identify their differences. For solving the problems of diagnostics, it is necessary to control the phase of oscillations, so, the analyzer should have a shaft speed sensor. A dual-channel analyzer allows using for diagnostic the corrective analysis, mutual spectra and functions for concreteness. The system requires qualified personnel to service.

The semi-permanent monitoring and diagnostics system is implemented on the basis of a computer. It collects a huge amount of data, from which an analysis of the technical condition of the machine is made on the basis of the analysis. There are used the analyzers – data collectors. The regulatory analyzer is used for such purposes. It is recommended to analyze the changes in the vibration spectra of the machine after 200-1200 hours of work.

The on-line monitoring systems are used for the most demanding machines, the failure of which leads to the expensive repairs. Various domestic and foreign software is offered on the market these days [10-12].

The software allows creating the database of the results of vibration control of the machine.

The set of threshold levels in the form of “masks” for each object is used for finding faults of vibration spectrums in the system. The set of “masks” covers the entire frequency range of machine vibrations.

The highest level of monitoring and diagnostics are expert systems. The software of such systems has different levels which depend on a type of monitoring. The quality of monitoring depends on the characteristic technical means of collecting information, i.e. from sensors of mechanical values.

The peculiarity of vibration monitoring is that their operating mode is vibration and the detection of mode violations, which is necessary to detect the background of quite intense vibrations. The features of the control are as follows:

- it is necessary to control the movement dynamics of the whole vibrating machine and also a working medium;
- it is necessary to control the movement of the processed details.

Development of technical means of obtaining primary information (sensors) of a special type which are currently absent is necessary for this purpose. The question of information processing is less relevant as it is standard, theoretically well developed and realized in the form of programs.
As the vibromachine has two or several synchronously working vibration generators, in the case of synchronization failure, the motions of the container will not be identical longwise a container and the process of vibro-processing will be disturbed. Therefore, it is necessary to control the motion dynamics of individual parts of the vibrating machine along its length. Besides, the control system should provide information about the amplitude and frequency of the container oscillation and also to monitor a status of bearing blocks.

The basis of the control system is the measuring device which consists of group of sensors and the processing device of the signals arriving from sensors. Sensors differ by the form of the measured value, on a frequency response, on sensitivity, on convenience of mounting. The convenience of installation plays an important role for assessment of quality of sensors. Than easier the installation of the sensor, that the greater the possibilities for its use.

The optimal condition of the measuring channel is the measurement of a large number of parameters of dynamics of the vibrating machine by the minimum number of measuring devices [12].

So, for example, measurement of such parameters as the container oscillation frequency, oscillations amplitude, displacement and vibration accelerations is possible by means of the displacement sensors of the vibromachine installed on its walls.

At the same time only the displacement is directly measured, the frequency and acceleration turn out after processing of the obtained primary information. The five parameters of the container movement can be measured using one type of sensors which function on the principle of measurement of constant magnetic field by transformers. The permanent magnets are used as the source of a constant magnetic field.

Such principle of sensor construction provides high temporary and temperature stability, reliability, high sensitivity, simplicity of installation, stability, and relatively low cost.

The most advanced magnet [5] WdFeB, on which magnetic field sensor moves is the basis of the sensor.

The construction of the container body displacement sensor is shown in (Fig. 1). The source of the permanent magnet field is a magnet 2 fixed on nonmagnetic spacer 3. The sensor has a П-shaped magnetic conductor 4, which has an air gap in which the modulator is placed. The magniflux, which is measured by means of the modulator, changes in the core during the moving of the sensor relatively to the permanent magnet.

The nature of change is illustrated by the graph provided in (Fig. 2). There is line section between points a and b.

![Figure 1. Construction of the sensor for moving the vibration container body: 1 – container body; 2 – permanent magnet; 3 – nonmagnetic spacer; 4 – magnetic conductor; 5 – modulator](image-url)

The magnetic potential on one plane of the permanent magnet created by the magnetic conductor with the winding located on it with current creating MDC – iw, is equal to:
\[ \varphi = \varphi_1 + \varphi_2 = \frac{1}{m_s} \int M'_n dS - \frac{1}{m_s} \int M'_h dS, \]  
\[ R_1 = \sqrt{(n-t-n')^2 + h^2((\omega-\omega')^2), \quad R_2 = \sqrt{(n+t-n')^2 + h^2((\omega-\omega')^2)} \]

The value of the quantities included in (2) are defined by the formula:
\[ \varphi_1 + \varphi_2 = \frac{M_n \cdot b}{2\pi} \left[ \ln \frac{n-t-a+\sqrt{(n-t-a)^2 + h^2((w-0,3b)^2)}}{n-t+a+\sqrt{(n-t+a)^2 + h^2((w-0,3b)^2)}} - \ln \frac{n+t-a+\sqrt{(n+t-a)^2 + h^2((w-0,3b)^2)}}{n+t+a+\sqrt{(n+t+a)^2 + h^2((w-0,3b)^2)}} \right] \]  

Figure 2. The dependence of the magnetic flux in the core from the movement of the sensor along the magnet on y coordinate

Conclusion
As is evident from the foregoing research on the monitoring of dynamic processes in the machining of parts with vibrations at incomplete loading of the vibromachine the oscillations are non-sinusoidal. The third and fifth harmonics appear. Thus signals from sensors oscillations of the machine and working medium allow determining the dynamic mode of the movement of the machine and a working medium. The magnetic flux in the core of the sensor increases with the enlarging of distance of a permanent magnet up to the vibrating machine wall.

References
[1] A.N. Reznikov, Thermal processes in technological systems (Mechanical Engineering, Moscow, 1990)
[2] R. Bridson, R. Fedkiw and J. Anderson, Robust treatment of collisions, contact and friction for cloth animation, ACM Transactions on Graphics, v. 21, pp. 594-603 (2002).
[3] J. Kopac, P. Krajnik, High-performance grinding – a review, J. Sci. Materials Processing Technology. 175, pp. 278–284 (2006)
[4] N.S. Penkin, A.N. Penkin, V.M. Serbin, Fundamentals of tribology and tribotechnology (Mashinostroenie, Moscow, 2008)
[5] V.B. Strutinskiy, V.M, Drozdenko, Dynamic processes in machine tools (Osnova-Print, Kiev, 2010)
[6] V.F. Terentyev, *Cyclic strength metallic materials* (Mashinostroenie, Moscow, 2001)

[7] T. Kuriyagawa, K. Syoji, H. Ohshita, *Grinding Temperature within contact arc between whell and workpiece in high-efficiency grinding of ultrahard cutting tool materials*, J. Sci. Materials Processing Technology. **136**, pp. 39–47. (2003)

[8] G. Gusanelli, A. Hessler-Wyser, F. Bobar, Microstructure at submicron scale of the white layer produced by EDM technique, J. Sci. Materials Processing Technology. **149** pp. 289–295 (2004)

[9] Y.C. Fu, H.J. Xu, J.H. Xu, *Optimization design of grinding wheel topography for high efficiency grinding*, J. Sci. Materials Processing Technology. **129**, pp. 118–122 (2002)

[10] Pokintelitsa N. *The Study of the Kinetics of the Protective Coating Formation in the Mechnochemical Vibrational /. N. Pokintelitsa, E. Levchenko/ Materials Today: Proceedings Volume 11, Part 1, 2019, Pages 543-547

[11] E. Levchenko *Theoretical Foundations of Vibration Processing Modeling / E. Levchenko, Yu. Deykun, Yu. Moroz Proceedings of the 4th International Conference on Industrial Engineering (ICIE-2018) 2018. – S. 1519-1526

[12] E. Levchenko *The study of dynamic characteristics during the vibration processing of parts*, MATEC Web of Conferences **224**, 01131 (2018)