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CONTROL OF METAL CUTTING PROCESS BASED ON VIBROACOUSTIC SIGNAL

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КОНТРОЛЬ ПРОЦЕССА РЕЗАНИЯ МЕТАЛЛОВ НА ОСНОВЕ ВИБРОАКУСТИЧЕСКОГО СИГНАЛА

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ABSTRACT

The article deals with the use of a vibroacoustic signal generated by the cutting zone as an informative parameter for controlling the process of cutting metals when creating high-performance technologies in automated production.

АННОТАЦИЯ

В статье рассмотрены вопросы использования виброакустического сигнала генерируемого зоной резания в качестве информативного параметра для контроля процесса резания металлов при создании высокопроизводительных технологий в условиях автоматизированного производства.

Keywords: cutting tool, vibroacoustic signal, material, informative parameters, cutting process, control, contact loads, automated system, sensor, deformation, measurement range, high-frequency radiation, amplitude, experiment.

Ключевые слова: режущий инструмент, виброакустический сигнал, материал, информативные параметры, процесс резания, контроль, контактные нагрузки, автоматизированная система, датчик, деформация, диапазон измерения, высокочастотные излучения, амплитуда, эксперимент.

Studies show the high information content of the cutting process parameters, such as cutting force, power and temperature. Let's pay attention to the vibroacoustic signal (VAS) generated by the cutting zone. The choice of this signal as an informative parameter was made on the basis of the fundamental provisions of the theory of metal cutting.

The wear process of an cutting tool a process of friction, plastic deformation, gluing, diffusion, running smoothly on contact damage to the tool and workpiece. In this case, the values of the main elements change and a part of the excess energy is released. Energy transformations in the cutting tools are due to the termination of the elasticity of wave oscillations, the consequence of the movement of dislocations and the transformation of structural-structural transformations, transformation at the contact areas of the tool. The wear resistance of the material depends on the intensity of these processes [1,3].

The informative value of the signals identifying processes in cutting control is necessary taking into account side effects and surface perception of the material. Therefore, the informative parameters of the cutting process are regularities of use depending on the geometric position of the subjects of cutting.

Contact surfaces when cutting metals at the micro level are a set of individual points that are the first to undergo energy transformations and are the oscillators of the VAS. To measure VAS parameters, standard industrial sensors are used, which are installed under the cutting plate in the tool holder. Qualitative control of the processing process is possible only in the case of a sufficiently clear information signal obtained using sensors [2,4].

Each of the above sources of information is inherently associated with the affected process and receives important information about this particular process. The cutting or contact zone, where the basic physical phenomena are observed, is very small and difficult to achieve with conventional hardware.

The characteristic signal perceived by the sensors allow only a slight perception of sensations in the observed machining. So the cutting force integrally affects the contact loads, which determine the evolution of the range of physical properties that accompany the cutting process. A significant part of such cases causes the destruction of the material of the workpiece and occurs with some delay, as a result of which the cutting process is a complex technological integral type. Its comprehen-

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sive control, especially in industry, was difficult until recently due to the impossibility of a qualitative determination, the occurrence of contact in a tool with a part [10].

Based on the foregoing, the technical means of the control system should be an automated system that controls the following physical parameters of the metal cutting process, such as VAS, cutting force, main drive power and electromagnetic contact emission of the cutting zone.

In modern practice, a large number of sensors have been developed to measure the vibroacoustic signal, based either on the ability of an inertial body mass to its state in space (inertial sensors), or on the ability of some materials to generate a wide range of signals under the influence of mechanical deformation (piezoelectric effect) [5,8].

Among the variety of VAS sensors, the most widely used are sensors that work on the piezoelectric effect. First of all, this is due to the simplicity of design, high reliability, high sensitivity and a wide frequency band of the recorded vibroacoustic signal. If we consider the requirements for the sensor in metalworking conditions, then the sensor must have increased sensitivity, take into account the perception of the measurement range and measure frequencies in the range. Therefore, a piezo sensor is quite suitable for measuring VAS [6,9].

The output power of piezoelectric transducers is very small, so the output of the transducer must be turned on with a gain with as high an input impedance as possible.

With sinusoidal force $f=F_m \sin\omega t$ instantaneous current $i=dq/dt= d(d_{11}F_m \sin\omega)/dt$. The concentration output voltage with the measuring circuit attached to it is

$$\bar{U} = \dot{I}\left[\frac{R/(j\omega C)}{R+1/(j\omega C)}\right], \quad \dot{I} = j\omega d_{11}F;\ \bar{U} = d_{11}F\left[j\omega R/(1+j\omega RC)\right]. \tag{1}$$

When cutting, the piezoelectric transducer is affected by vibrational forces $P_B(t)$ and acoustic emission forces $P_{AЭ}(0)$. There are significant differences between them. So $P_B(t)$ has a pronounced low-frequency character, which is caused by its nature, i.e., fluctuations of large mechanical masses involved in the metalworking process. Usually the frequency of these oscillations rarely exceeds 10 ... 15 kHz. $P_{AЭ}(t)$ is high-frequency, its frequency usually ranges from 20 kHz to hundreds of MHz. Such high-frequency radiation is associated with micro destruction in the cutting zone.

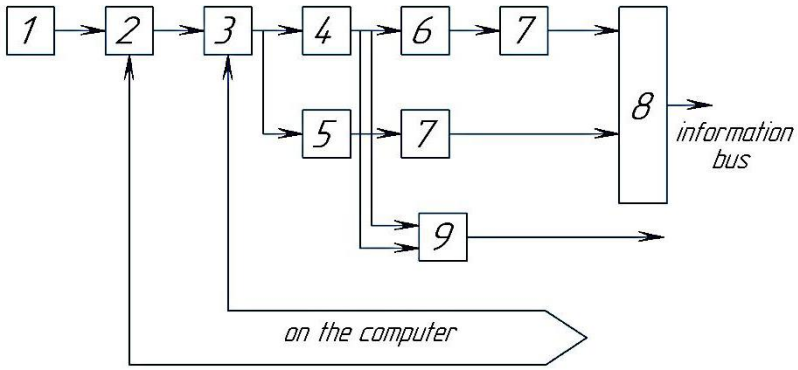

Figure 1. Block diagram of the measurement and processing of VAS indicators. 1-sensor, 2-switcher, 3-line amplifier, 4-low pass filter, 5-high pass filter, 6-power amplifier, 7- integrating amplifier, 8- converter

The constituents of P_B and $P_{AЭ}$ VAS are relatively easily separated by a filter system, after which they can be processed in appropriate ways. In addition, studies show that it is necessary to measure the power characteristics $P_B(t)$ and $P_{AЭ}(t)$, i.e., the power of vibrations and the power of acoustic emission. For this it is necessary to quadrature the signal amplitude. The block diagram of the module for measuring and processing VAS parameters is shown in fig. 1.

The operation of the device is as follows. The signal from the VAS 1 sensor is fed to the switch 2, controlled from the computer. After that, the signal is fed to the normalizing multiplier 3, the parameters of which are set by the computer, based on information about the expected cutting mode. The signal is divided into two channels: vibrational and emission. In the vibration channel, a high-frequency trap filter 5 (cutoff frequency 20 kHz) passes the frequency components of the mechanical vibration of the cutting tool (that is, up to 20 kHz), is integrated in the integrator 7 and is fed from it to the converting-coupling device 8. In the acoustic emission channel, the signal passes through the low-pass filter 4 and is subjected to squaring in the quadrature 6 and through the integrator 7 enters the conversion and interface device 8. To generate the touch signal, the registrar 9 is used, which receives information from filters 4 and 5. The touch signal is fed to the information bus [7].

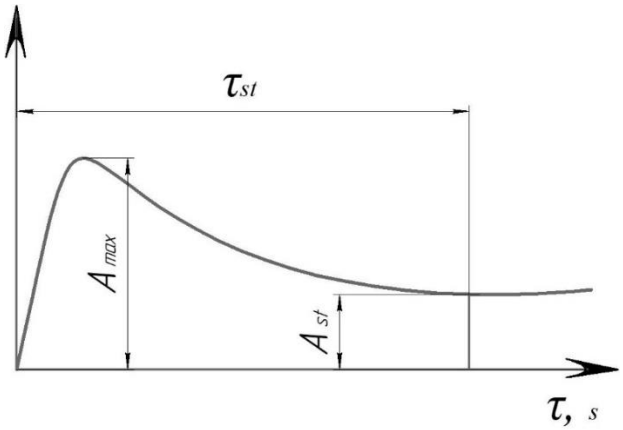

Figure. 2. Curves of vibroacoustic signal changes in time

The main measurements are linear amplifier, frequency filter, integrator amplifier and power gain. During the measurement, control was carried out using an oscilloscope. Registration of informative parameters, such as the components of the cutting force P_Z, P_X, P_Y, the effective power N of the cut, the value of VAS A, the EMF of the cut E, the level of electromagnetic emission of the EEME of the cutting zone was carried out on a computer using an ADC.

On fig. 2. shows the curve of the change in the integral level of the VAS amplitude in the frequency range above 5 kHz with the suppression of low-frequency mechanical oscillations of the technological processing system.

The amplitude of the vibroacoustic signal when the cutting tool plunges into the workpiece reaches the maximum value Amax, and then changes its value. It is characteristic that the change in the amplitude of the VAS in the initial period of the cutting process occurs intensively. After reaching the Ast level, there is a slight increase in amplitude, signal stabilization.

The results of experiments carried out on various tool and machined metals show that the stabilization time of the VAS coincides with the end of the running-in of cutting tools. In addition, the VAS parameters change depending on the cutting conditions, which once again shows the information content of this signal. To identify the relationship between the stabilization time of the VAS and the period of running-in of the cutting tool, the stabilization time τst of the amplitude of the VAS was initially determined. This period of time was divided into certain intervals.

The methodology of the experiments was that for each workpiece and the proper selection of tools, cutting is used in various processing modes. When cutting to critical wear (h=0.6 mm for carbide cutters) with non-regrindable carbide inserts, the grades of the recorded integral level of the vibroacoustic signal differ according to the wear measurement results of the wear perception tool in different parts of the curve $b_3 = f(\tau)$. The methodology for conducting experimental studies for a given pair of "workpiece-tool use" is specially designed to achieve the goal of perceiving metals, when in order to obtain the dependence $V = f(\tau)$ or $T = f(v, s, t)$, it is necessary to conduct experiments with a constant pair .

On fig. 3. estimated wear of the tool on the back surface from the cutting time, respectively, for steel 45 and tool material T5K10, and in fig. 4. dependence of the VAS amplitude on the cutting time.

The next stage of the research was to determine the relationship between the intensity of the change in the VAS in the initial period of the cutting process, and the intensity of tool wear in the area of the normal wear period.

A joint analysis of the curves of wear and change in the amplitude of the VAS over time shows that the period of running-in corresponds to a high value of the signal amplitude; normal wear area - slight change; catastrophic wear area - a significant increase in the measurement of the measured signal.

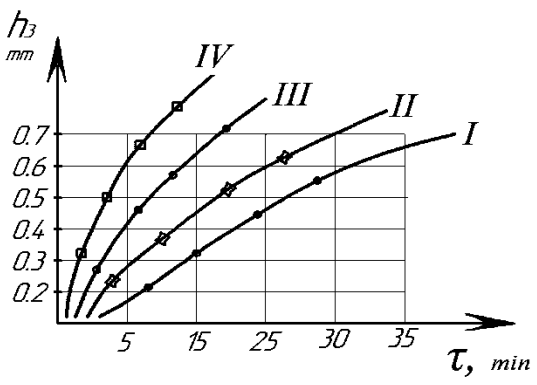

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Figure. 3. Wear of the cutting tool from the cutting time when processing steel 45 with a cutter from T5K10; S=0.1mm/rev, t=0.5mm, I - V=2 m/s, II - V=2.7 m/s, III - V=3.6 m/s, IV - V=4.9 m/s

The reason for the intense change in the signal amplitude during the period running-in is the desire of the technological processing system, in particular the cutting tool, to a balanced state. In this case, the cutting tool gradually changes its geometry and the physical and mechanical properties of the surface layers, adapting to the specified cutting conditions. This is accompanied by the formation of a rational geometry of the tool due to intense wear, as well as a structure in accordance with the temperatures and loads that occur in the contact areas of its front and rear surfaces.

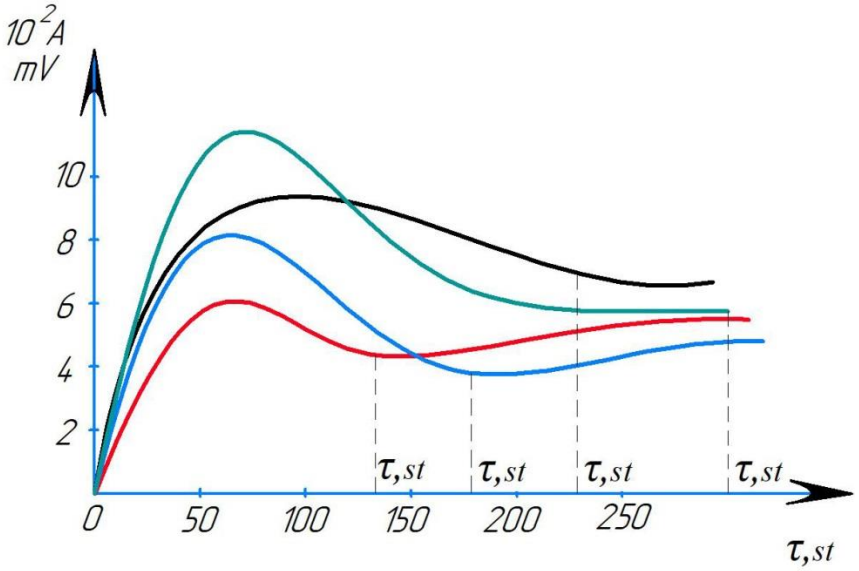

Figure. 4. The intensity of the change in the vibroacoustic signal in the initial period of the cutting process for conditional processing, shown in fig. 3

The reason for the slight change in the signal amplitude during the period of normal wear is the steady-state nature of the increase in wear over time and the decrease in wear intensity compared to the run-in period. A sharp increase in the signal amplitude in the area of catastrophic wear is associated with an excessively high wear rate due to the loss of fatigue strength of the tool material. A similar change in the signal amplitude is also observed in cases of processing at forced cutting conditions, when after a period of running-in, a period of catastrophic wear immediately sets in.

A feature of the results obtained is that with a change in cutting conditions, the following changes: amplitude during penetration Amax; signal stabilization time τst; amplitude of a stable level of Ast increase in amplitude over time after signal stabilization.

Thus, the totality of the obtained results of experimental studies shows that there is a close relationship between the intensity of the change in the VAS at the initial moment of the cutting process and the wear rate of the cutting tool in the steady process of its operation. Moreover, studies during processing at forced cutting conditions once again showed the informational capacity of the measured VAS, the expediency of its use in the creation of high-performance technologies in automated production.

References:

1. Aleshin N.P. Metody akusticheskogo kontrolya metallov. /N.P. Aleshin, V.Ye. Belyy, A.KH. Vanilkin. – M.: Mashinostroyeniye, 1989. – 456 s. [in Russian].
2. Mamurov E.T. Kontrol sostoyaniya rejushego instrumenta i vliyaniya parametrov protsessa rezaniya na parametry vibroakusticheskogo signala // Nauchno-texnicheskiy jurnal FerPI. – 2021. – T. 24. – spets. vyp. №. 2. – S. 28-33. [in Russian].
3. Mamurov E.T., Saydaxmedov R.X. Voprosy upravleniya protsessom rezaniya na osnove kontrolya i diagnostiki kachestva poverxnosti detali po vibroakusticheskomu signalu // Nauchno-texnicheskiy jurnal FerPI. – 2021. – T. 24. – spets. vyp. №. 2. – S. 53-57. [in Russian].
4. Mamurov E.T. Metalllarga kesib ishlov berishda kontakt jarayonlarning vibroakustik signalga ta'siri //Science and Education. – 2021. – T. 2. – №. 12. – S. 158-165. [in Uzbek].
5. Mamurov E.T. Kesuvchi asbob holatini va kesish jarayonini vibroakustik signal asosida tashxislash //Science and Education. – 2021. – T. 2. – №. 12. – S. 133-139. [in Uzbek].
6. Mamurov E.T., Kosimova Z.M., Djemilov D.I. Povyshenie proizvoditelnosti stankov s chislovym programmnym upravleniem v mashinostroenii //Science and Education. – 2021. – T. 2. – №. 5. – S. 454-458. [in Russian].

7. Mamurov E.T., Kosimova Z.M., Sobirov S.S. Razrabotka texnologicheskogo protsessa s ispolzovaniem cad-cam programm //Scientific progress. – 2021. – T. 2. – №. 1. – S. 574-578. [in Russian].

8. Medvedev D.D. Avtomatizirovannoye upravleniye protsessom obrabotki rezaniyem. – M.: Mashinostroyeniye, 1980. – 143 s. [in Russian].

9. Podurayev V.N., Barzov A.A. Tekhnologicheskaya diagnostika rezonansnym metodom akusticheskoy emissii. – M.: Mashinostroyeniye, 1988. –200 s. [in Russian].

10. Starkov V.K. Obrabotka rezaniyem. Upravleniye stabil'nost'yu i kachestvom v avtomatizirovannom proizvodstve. – M.: Mashinostroyeniye, 1989. – 296 s. [in Russian].