1.8.25. ON-LINE VIBRATION-BASED DIAGNOSTICS OF THE PRODUCTION PROCESS

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The automatic working capacity maintaining of the machine-tool equipment by minimal manual intervention ("untended manufacturing") cannot be done without wide use of the built-in diagnostic tools, which are collecting data about the quality of the production process. The functions of the on-line diagnostics are not only evaluation of the mechanisms and working process condition, detection of the faulty operation's place and its causes, but also the decision-making function to eliminate the failure effect. To the problems solving by the on-line diagnostics can be refered: 1) diagnostics of the cutting tool condition; 2) diagnostics of the cutting process and its optimization; 3) control of the functioning and condition diagnostics of the machine tool units; 4) size control; 5) additional problems appearing under certain circumstances, for example operation mode adaptation to the changeable situation in the cutting area, correction of the actuating elements position to compensate the temperature deformation. The tool (sensors) selection for the on-line diagnostics of the cutting process is generally determined by two factors: the informativity, which is adequate to the investigated situation appearing in the cutting area, and the simplicity and reliability of the integration into the machine tool. Following this criterion the selection will generally depend on the force parameters and vibration parameters control in the wide frequency range. It seems that the control of the cutting force, torque moment or cutting power solves the problem. But it is so at first sight. In the production conditions the cutting force monitoring requires such built-in diagnostic tools, which are not reducing the machine tool omnitude by conditions of the gang-tooled machining by the automatic tool change. By these conditions the most universal diagnostic parameter remains the control of the drive cutting power. This the most widespread method is not void of essential defects. Point is that the automation industry, where are needed the built-in tools of the on-line diagnostics, is mainly based on the multifunction machine tool, which make possible to become a finished piece by the one set-in. That is at one machine tool is used the cutting tool for the primary machining, cutting tool for finishing process inclusive the small end-cutting tool. By its working the consumed power is significantly lower than the variation of no-load power even of the modern drive. The failures of this cutting tool make the basic part of the common quantity of the cutting tool failure. The experience shows that the failure of such cutting tool by means of the control of the drive power either cannot be detected, or are identified but with a significant delay, while the further broken tool advance leads to significant plastic deformations of the work piece and tool.

The vibrations in the range of 30 – 40 kHz are measured by serially manufactured accelerometers, which can be safely installed on the elastic system of the machine tool at a considerable distance from the cutting area, where the sensor is protected from chips and accidental damage. This setup does usually not require the machine-tool retrofit, although it should be given attention to protect the sensor cable against damage. The problems appear by having swing joints between the accelerometer and the cutting area, i.e. when are rotating both the cutting tool and the work piece. However, at high cutting speeds, for example, at the circular grinding machines, it does not cause difficulties. But if machine tables are periodically rotating the machine tool must be additionally tooled up by the mechanism, which extracts and presses the accelerometer during rotation of the table. This makes relevant to equip the measuring channel by the wireless signal transmission system, which would help to install accelerometers onto the rotating elements freely and would make unnecessary the cable laying through the machine tool to the sensor. Sometimes the accelerometer can be replaced by a microphone. In the published articles can be seen such solutions, although in this case the correlation of the useful signal and the interference becomes much worse.

By cutting and friction the nature of the vibroacoustic signal has a complicated structure in a wide frequency range, which does not coincide with the nature of the forces during cutting. For example, by increasing the contact area during friction the oscillation amplitude may increase sharply by some stages and at some stages it can fall or doesn't change at all. The complex nature of the vibroacoustic signal is compensated by its sensitivity to changes of the contact processes during cutting and friction, but also by "long-range action" of the vibroacoustic signals. For example, the sensitivity shows by the fact, that when the cutting tool approaches with the rotating work piece, the moment of their contact significantly changes the vibroacoustic signal as early as at the stage of elastic interaction of the cutting tool with the microrelief of the work piece. The "long-range action" of the signal becomes apparent in the fact, that the signal representing the processes in the cutting area communicates this information to the remote locations of the elastic system. The variety of manufacturing operations and cutting conditions have an impact on the parameters of the vibroacoustic signals. If you are currently interested in information, for example, on the wear of the cutting tool, the influence of other factors will be the source of interference, which reduces the reliability of the diagnostic procedures. Conversely, by finishing operations the information about the parameters of vibrations in the cutting area affecting the condition of the surface and the surface layer may become a priority.

The proper assessment of the cutting process condition finds difficulty because of the complexity of the process itself, which hasn't so far any unified theory, as well as because of the complex structure of its dynamics. The dynamics of the contact interaction during cutting is determined, on the one hand, by the impact interaction of the microrelief, on the other and – by the intense formation of adhesive bonds, seeking to turn the cutting tool and the work piece into a coherent whole. There are grounds for the allegations, that the process of plastic materials cutting is, in principle, self-oscillating. Thus, the vibroacoustic signal is generated by the complex nonlinear system and its self-oscillating process adjusts to the processing conditions. In this situation the search of the parameters of the vibroacoustic signals, which give reliable information about the tool wear and the surface quality is a complex and multivariate problem. It is further complicated by the fact that the update of the tool and construction materials takes place much faster than the research in the area of the cutting process diagnostics.

The problems of the cutting process diagnostics are more difficult because of the additional problems of the diagnostics of the most important units of technological equipment, which are responsible for the processing accuracy or able to cause an emergency situation or a failure in the process cycle. First of all we need to consider the work of spindles, which in modern machine tools are mechatronic modules having high accuracy and speed. The slight deviations in the stage of assembling of these units or disturbance of their operation conditions cause unexpected failures during the processing, which are leading to costly repairs and downtime. The traditional areas of diagnostics, including vibroacoustic methods at the stage of the run-in test of these units do not always reveal inconspicuous faults, which at the stage of the intensive use lead to their rapid development and the instantaneous destruction of the bearing. In this regard, such units must be equipped not only with temperature sensors, but also with the accelerometers, which are tracking the vibration anomaly under conditions of the multiple interference, among which the process of cutting has the leading role. For a detailed assessment of the readiness of spindle units for use in multifunction machine tools we have to search for new diagnostic algorithms, including an analysis of the spatial distribution of vibration speed vectors and the vibration acceleration vectors, as well as to do the dynamic testing of spindles with variable directions of the dynamic force and loading variations in the spindle run-in. Despite the fact that a number of methods of the vibroacoustic diagnostics is sensitive to changes in the state, the cutting process and spindles, the development of criteria, which we need to make a decision, requires the accumulation of statistical material. Such material can appear only with the broad introduction of the methods of the pre-operational and operational diagnostics by the manufacturers and consumers of the machine-tool equipment.