

A LASER ANALYZER FOR DIAGNOSTICS CNC-MACHINE TOOL

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Abstract: The work states the progressive method and a laser intelligent analyzer of emergencies control of the technological equipment and processing materials. A laser analyzer of the acoustooptical interactions the optical and electrical on based. The multiparametrical spectrums' analyse of the dynamical signals from the technological equipment allows to register of the current changes condition of the cutting tool and process in whole. This series of the optoelectronical analyzers with the CNC-machine tools are coordinated and its carries out automatic control of the breakage, the cutting tool wear, the moment of cutting tool jamming in the workpiece. This intelligent analyzers, functional algorithms and mathematical control models for the turning, milling and drilling technological automatic processing are created. The application of this laser control system allows to increase the productivity and the efficiency of the automation precision processing materials.

Keywords : emergenciens diagnostics, technological automatic processing, laser analyzer.

1 INTRODUCTION

The problem of increase of quality of the automated production process of materials is urgent at a modern condition of an industry, when there is a constant reduction of workplaces at preservation of the equipment. Danger of occurrence of infringement production processing in this case grows. The quality of technological process is determined by conformity of the current condition of the equipment, tool and detail to the given parameters in the engineering specifications, and the quality management of technological process is carried out by diagnostics the arising instabilities. For a case of machining to the instability concern: the critical deterioration cutting tool, breakage, constraint of the tool in a body of processable preparation (for the drilling process), emergencies of the equipment, when is broken a normal course of the production processing. Discrepancy of parameters the given sizes in this case is observed. The achievement of stable quality of machining is possible only at use of systems of the analysis of the current condition of the cutting tool. The systems of threshold regulation only for quantity manufacture are most distributed. Therefore the development of such analyzer of a condition of the production process for the automated individual manufacture is expedient.

The functions of quality surveillance of process carry out control and measuring of a sensor's subsystem, the principle of which action is based on definition of a condition of the cutting tool. One of the basic requirements to quality of such subsystems is the opportunity of their coordination with system of the CNC-machine tool for creation of the automated monitoring systems of the production process.

2 A DIAGNOSTICS METHOD OF THE CUTTING TOOL EMERGENCIES

Most sensitive to the instability of the process of machining are the physical phenomena natural image arising at cutting materials (the acoustic emission (AE), the vibration, the electromotive force (EMF) of the cutting process. The changes of parameters of signals identifying these phenomena, characterize changes occurring in a zone of cutting, condition of CNC-machine tools, the edge of the cutting tool, the roughness of a work detail [1, 2].

Processing the information about process of cutting acting from primary converters, is usually carried out through electronic means. So, for example, definition of connection frequency of dependences of the acoustic and power (force) factors allows to supervise quality of a processable

surface during deep drilling on depth of the deformed layer at production process. The analysis of spectral structure of AE - signals of the cutting process allows to supervise quality of process on the form parameter at the turning processing. The electronic monitoring systems and diagnostics of a condition of the cutting process are known which carry out the analysis of a condition of the cutting process on the basis of the device of the Fourier transform. Realization of such systems however is hardware - technical is rather difficult.

For measurement of precision quality parameters of usually use the noncontact methods of definition of deterioration the cutting edge, roughnesses, form of a surface of a work detail by photo-electric devices. The action principle of such devices, for example, on the reflectometrical methods of measurements in industrial quality surveillance, on use of effect of dispersion of a light flow by a controllable surface, which the angular distribution depends of a roughness parameters, is based. The devices of a such optical method of measurement allow to achieve the errors by 1 - 5 microns. One of the exactest methods of measurement is a diffractational method of measurement of the cutting tool wear. An error of measurements of the gauge no more than 1 micron. The errors up to $0,6\mu\text{m}$ provide of the laser interferometrical system. However all listed systems have restrictions only for fair processing without application of cooling liquids.

Thus, on the basis of the carried out analysis it is possible to conclude, that the known monitoring systems of a condition of the production process have restrictions, and in conditions of the automated manufacture allow to supervise quality of process of processing of details only for quantity manufacture.

These lacks are eliminated by the new universal laser analyzer of a condition of process of machining on the basis of the optical analysis of the Fourier spectrum of the dynamics signals in a cutting zone. The operations of the Fourier transform are carried out in a mode of real time and consequently are most applied for the automated monitoring systems of quality by production process, in particular, for group management of CNC-machine tools.

For mathematical modeling of the developed analyzer in work the dependences of hardware function of the processor on entrance signals of of the dynamics process of cutting, parameters of optical system are analysed. The dependences are considered which define physical transformations of an electrical signal to optical analogue for the subsequent processing at the Raman-Nath diffraction.

In work [3] the method of the resolution increase of the analyzer by differentiation of a Fourier - image of an input signal is stated. The differentiation is carried out at illumination of the modulator aperture by Gaussian beams, the intensity distribution of which to the first transverse Hermite-Gaussian modes.

In work the new mathematical determining model of functioning at the approximation of stationary casual processes are received. It is caused by that on a background the slowly current technological process of cutting suffices the registration of separate realizations of an electrical non-stationary casual signal is carried out. The mathematical models are constructed in view of the statistical characteristics of the dynamics cutting signals. It allows to apply them to definition of a condition of the cutting tool during machining.

3 PRINCIPLE OF THE SHEETS CREATION OF THE LASER ANALYZERS

The creation methods of the laser acoustooptical analyzers optical systems of a condition of the process of machining materials on CNC-machine tools are developed:

1. Registration of vibrations on the cutting tool surface by a reflectometrical method with the subsequent processing amplitude-frequency-phase distributions of the light fields in a output plane of the optical system. These methods are used basically for turning processing.
2. Formation and analysis of a mutual power spectrum of vibration, acoustical emission and electromotive force signals of cutting process. They are used at different kinds of machining.
3. The construction of analyzers, which is based on the Mach-Cender modified interferometer, allows to supervise jamming of the tool during drilling, milling on the basis of definition of the mutual spectral characteristics of vibrating signals of a cutting tool and detail dynamic subsystem.
4. Analysis of a mutual spectrum of superficial and volume acoustic fluctuations of the tool by Mach-Cender modified interferometer.
5. Creation the multichannel acoustooptical systems of the spectral and correlation analysis of the dynamical signals for the monitoring of the group CNC-machine tools, the processing CNC-centres.

The circuit of the analyzer of a condition of turning processing is based on application of the developed combined method of the resolution increase of the system by a combination of the balance modulation of an electrical signal and illumination of the input modulator by laser radiation containing maximum transverse Hermite-Gaussian modes for the reliability increase of the results.

The dynamic signals describing the current condition of production process, act in the optical and electronic system of processing as electrical signals from primary converters established in system CNC-machine tools on minimal distance from of a cutting zone.

The transformation of electrical signals in optical system of the analyzer of a spectrum is carried out by the acoustooptical modulator (AOM) of light fields working in a mode the Raman-Nath diffraction or Bragg diffraction, which allows to the form of an output optical system a Fourier spectrum of a researched electrical signal. So, the device [5, 6] contains optical system, in which is established diffractive AOM, on which input through electronic system of registration and transformation consisting of the filters, amplifier, the researched signal acts. As changes of the amplitude-frequency-phase distributions parameters of the light fields on an output of the analyzer optical system of a spectrum will correspond to changes diffraction of an input electrical signal parameters, the application of such optical and electronic systems for the analysis of dynamic signals of the cutting process is quite expedient.

Advantages of systems in comparison with electronic systems are speed at processing signals with application of the Fourier device in the real time scale. It raises productivity of the quality surveillance process, thus reducing the cost price of the diagnostics system and quality surveillance.

In conditions of development of flexible industrial systems, of the productivity productions there is a necessity of group management of the CNC-machine tools. The decision of a task of management of group of metalcutting machine tools is difficult for carrying out with the help of multichannel electronic control systems, as the systems of the signals processing are extremely difficult in manufacture, are expensive and do not provide high efficiencies at realization of process of the spectral analysis of signals. Use of multichannel acoustooptical devices will supply parallel processing of dynamics signals of the cutting process registration, acting through separate electronic channels, from each machine tool separately. It will allow to lift productivity of quality surveillance in conditions of deserted technology. The generalized circuit of the laser device for the control of dynamic processes of the production processing (Fig. 1) contains the diffractive AOM as devices of the input and transformation electrical signals.

The calculation of correlation dependences of signals with application of recording optical environments (for example, the photochromium materials) allows to abstract from concrete conditions of processing connected to modes of cutting, geometry of the tool and preparation, physical and chemical parameters of the pair "tool - detail" materials, rigidity of the equipment.

The simultaneous analysis of the mutual spectrum and correlation characteristics of signals describing the current quality of processing, for example, of the AE and EMF of the cutting process, allows to increase reliability of definition of limiting condition of the tool and, as a consequence, quality of a processable detail. Thus in a target plane of optical system of the device the mutual power spectrum of signals reflecting a picture of dynamic processes in a cutting zone is formed. It will raise reliability of formation of managing teams on change in modes of cutting, entering of correction into process of the production processing, or on stop of the CNC-machine tools in case of revealed emergency situations. To preliminary of a emergency situation, computing device of the processor connected to the working head of the CNC-machine tool. It will allow to expand functionalities of monitoring systems of the quality processing of the precision details with use of various kinds tool, processable materials, types of metalcutting machine tools.

As the redistribution of fields of a pressure in a material of preparation is entailed by the waves distributions of the elastic deformation on a surface of the cutting tool, the spectral characteristics of superficial acoustic waves it is possible as to determine through the optical and electronic hybrid processors. So, the effective measurement system of a roughness of a detail surface at the acoustooptical interactions phenomenon of the laser radiation at a running acoustic pulse can be constructed.

The analysis of the spectral making signals in a range of frequencies more than 1 GHz is carried out. However the fluctuations of the laser radiation power can negatively influence at the optical system characteristics and as a whole on reliability of the control, therefore is necessary stabilization of the radiation power. Thus it is possible to combine a method of the analysis of superficial waves with the simultaneous analysis of volumetric acoustic waves. It raises productivity of controllable processes,

as the condition of the cutting tool on macro- and micro-levels is estimated, but has restrictions, characteristic for direct optical methods of measurement.

The check of serviceability of the new analyzer was carried out by preliminary realization of the tests of the cutting tool on the turning CNC-machine tool. The durability characteristic of a casual signal of vibrations are determined.

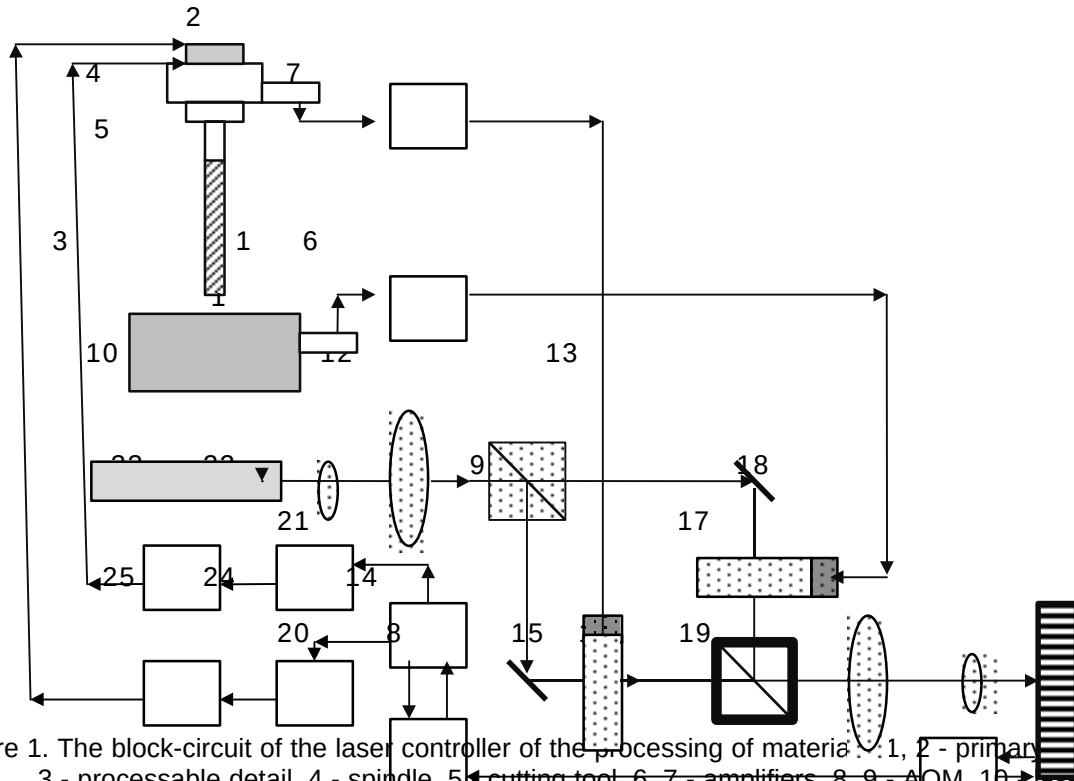


Figure 1. The block-circuit of the laser controller of the processing of material. 1, 2 - primary sensors, 3 - processable detail, 4 - spindle, 5 - cutting tool, 6, 7 - amplifiers, 8, 9 - AOM, 10 - laser, 11 - collimator, 12 - light-divide cuba, 13, 14 - mirror, 15 - light-divide cuba with a photochromium covering, 16 - Fourier-lens, 17 - lens, 18 - matrix CCD-element, 19 - feed block of the photoreceiver, 20, 22, 24 - interfaces, 21 - processors, 23, 25 - machine tool working heads

The histograms of distribution of relative density of probability show increase variance of the amplitude of a signal depending on a degree of process of the tool wear are constructed. The analysis of the approximation histograms of the density probability of amplitudes of an input signal of vibrations shows concurrence with the histograms, constructed as a result of statistical processing of meanings of the video signal amplitudes of the laser analyzer system.

On the basis of the carried out researches the algorithms of functioning of the analyzer are developed which allow to determine the current condition of process on an example of turning processing in view of the statistical characteristics of the dynamics signals of cutting, that is advantage in conditions of flexible manufacture in comparison with known methods, when diagnostics will be carried out on threshold meanings of the signals. The developed algorithms allow to determine stages of a conditions of the cutting tool: work, stable deterioration, critical deterioration, breakage of the tool.

The research of errors of definition of a degree of deterioration of the tool has shown reliability of the analysis of a condition of machining by the developed analyzer. As the size of a relative error does not fall outside the limits 3 % from rating value of deterioration at 10 series of experiments the suitability of use of the laser analyzer in conditions of the automated manufacture is proved.

4 CONCLUSION

On the basis of the adduced results of the research it is possible to make the following conclusion:

1. The construction methods of the laser acoustooptical hybrid analyzers schemes of the condition definition of machining process for the flexible without the work interruption of the automated equipment are created. That allows to increase the work productivity of the technological machining equipment.
2. The methods of the resolution increase of the laser acoustooptical analyzer of a condition of process of machining are developed, which allows to increase accuracy of the analysis of input electrical signals
3. The developed laser hybrid analyzer on a basis the acoustooptical interactions allows to carry out the multiparametrical analysis of the dynamic signals by application of the optical system of the spectral Fourier-analysis, methods of the statistical analysis for definition of limiting condition of the cutting technological process. In comparison with the electronic systems of processing of the information by the acoustooptical analyzer allows to reduce time of processing of the spectrum and correlation characteristics of analyzed signals, raises work reliability of the module.

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