Ways of automation and optimization of measuring instruments

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Abstract. The article deals with the problem that forms the basis of automation of measurements and control, and reduction of time for control operations. Completely new requirements that should be presented to modern systems of measuring instruments are identified and described. The generalized structural diagram of the measuring instrument, which is common to any measuring instrument, is analyzed and the main automation tasks are identified. Particular attention is paid to the main functional tasks that automated measuring instruments should perform. The relevance of systematic approach to the creation of the production process using automated measuring instruments is analyzed. At the end of the article, it is shown that when using a systematic approach to creating modern production processes, it is possible to solve the problem of high-quality manufacturing of products by increasing the number of measurements and obtaining more complete data on the properties of products.

1. Introduction
Currently, modern industrial facilities include a number of features. First of all, they are behavioral uncertainty and diversity, the hierarchical distribution of elements and subsystems, structural similarity and, directly, the excess of the main elements and subsystems, the structural relationship between them, the differentiation of the implementation of management and control powers at all levels of the hierarchy, the distribution of elements and subsystems territorially.

The worsening of these problems is a consequence of extraordinary events: the difference between the expected and real behavior of industrial facilities associated with external and internal factors. Since the process of monitoring the state of industrial facilities is not automated, the control is transferred to operators, which in turn includes the human factor in the activity of information-measuring systems. And as you know, the human factor has a number of inaccuracies and errors. In emergency situations, operators are not able to cope with the assessment and monitoring of the functional state of industrial facilities, which does not give a chance to obtain accurate characteristics and allow classical methods to fully realize all the functions of measuring, monitoring, diagnostics and identification of parameters of industrial facilities.

Measuring instruments - devices used to perform measurements, which include measuring instruments, sensors, systems. Such devices are used to determine the specific value of various parameters of the body with the subsequent display of the obtained data for the purpose of processing, analysis and transmission.
Most of the questions regarding this article relate to the problem of the complete absence of universal tools for synthesizing measuring systems in various subject areas, which would allow calculating the required amount of information (whether the measured value will take a certain value) that are contained in the measurement results. Despite the existing training manuals on intelligent measuring systems, and the state standard in this area, the problem posed cannot be solved, since these sources do not pose the task of solving it. It should be noted that intelligent measuring systems are systems that can be individually programmed to perform specific tasks, while using a programmable terminal to enter configuration parameters. Intelligent measuring tools, that is, devices that include intelligent sensors, automatic machines, automated installations. In other words, these are means for registering, transmitting, processing data operating using intelligent database-based algorithms. In the simplest version, the content of such systems is limited to a sensor and a processor for processing data according to the predetermined algorithm.

In the XIX - early XX centuries measuring instruments participated in the metalworking process, mainly in two capacities. This means measuring parts on the machine, which the worker used to adjust the technological process of processing according to the measurement results and control means in the Technical Inspection Department system to determine the readiness of the product. That is, essentially a non-automated control loop of accuracy machining control on the machine was closed constantly through the worker and occasionally through the channel "means of control - control of Technical Inspection Department - work - machine". Under these conditions, only accuracy was required from the measuring instruments, moreover, in the static operating mode, i.e. directly measuring the details of the part after removal from the machine.

2. Models and methods
A constant increase in the number of measurements, the high complexity of the parts under study, the need for a high degree of accuracy lead to an increase in labor costs and, ultimately, to an increase in the cost of measurements. Therefore, it is necessary to develop special automated systems.

Automation consists of the following items:

- The development of devices in which all operations are performed automatically.
- Replacing indirect measurements with direct ones.
- The creation of measuring tools with advanced functional capabilities.
- The use of processors and the development of devices with their use.
- Creation of a universal base of information measuring systems.

The goals of automation are:

- productivity increase;
- reduction of economic costs;
- improving the accuracy of measurements due to the absence of the subjective component of the error;
- simplified systematization of the received data;
- optimization of control of products.

The growth of requirements for processing accuracy and the level of automation of technological processes, which are driven by the need to improve product quality and reduce the time for control operations, resulted in the development of new metalworking equipment with built-in automated measuring and control instruments.

The use of computerization as part of an automated complex significantly increases the multifunctional capabilities of its use and increases the reliability of measurements and the authenticity of control. The quality of the system in this case is related to the quality of the software for the
functioning of the measuring equipment; moreover, with the improvement of the quality of the software, the optimization and accuracy of measurements are improved.

In this regard, the operation of devices in the automatic cycle puts forward a number of fundamentally new requirements:

- the need to ensure not only static but also dynamic measurement accuracy;
- the signal of the measuring information should be suitable for organizing automatic control of the machine.

Equally important is that simultaneously with the reaching of measuring instruments a qualitatively new level, a theory of active control metrology is being created, in which the elements of the accuracy analysis of the technological process take on particular importance.

Therefore, when creating the manufacturing process for manufacturing products, a systematic approach is important, which is, first of all, expressed in the fact that it is necessary to determine what and how much measurement information is needed to control the course of specific interrelated operations within the entire technological process, this is the expediency and sufficiency of the selected nomenclature measured parameters in terms of ensuring the reliability of quality control.

Depending on this, a measuring system should be built, optimized according to two criteria. A generalized block diagram is shown in figure 1 [1]:

- obtaining the necessary information with the required accuracy and in the required volume;
- cost-effectiveness of obtaining this information, it means taking into account all the costs necessary for the creation and use of measuring equipment.

Consequently, a systematic approach aimed at the final result - the production of products of a given quality should allow the most rational organization of the control by reducing redundant information.

For example, if the measuring tools of the machine can reliably carry out the operations of manufacturing the product with the required output parameters, then the amount of control outside the machine can be significantly reduced and, on the other hand, according to the results of measuring the product outside the machine, you can correct its operation and diagnose the possibility of malfunctions.
Thus, this essentially raises the question of integrating all the measuring tools into a single information measuring system (IMS), designed to provide the optimal control mode for both individual machines (machine systems) and the whole complex of technological processes for manufacturing products of a given quality based on a rationally organized control process, operational processing of measuring information, its accumulation, generalization and accurate analysis of the process and product quality.

In this regard, the experience gained during the operation of CNC machines and flexible production systems is very interesting.

Automated measuring systems to ensure the operation of the technological module as part of a flexible production system must solve the following core functional tasks [2]:

1. The development of feedback signals in the function of moving the working bodies of the machine to ensure control of the movements of the machine in the modes of cyclic automation and program management.

2. The generation of feedback signals about changes in the parameters of the machine during processing to implement adaptive management.

3. The generation of measurement information signals about the parameters of the product, checked directly on the machine.

4. The generation of measurement information signals about the position of the cutting tool relative to the machine bases.

5. The generation of measurement information signals about the position of the workpiece relative to the machine bases.

6. The development of measurement information for diagnosing machine operation:
   - about the condition of the cutting tool;
   - about the kinematic accuracy of circuit bypass, equipment positioning;
   - about the geometric accuracy of the equipment;
   - about the correct functioning of the nodes and systems of the machine, including measuring ones;
   - about the correct functioning of the CNC device and automation equipment.

7. The development of measurement information about the parameters of the product when it is controlled outside the machine.

8. The development of measuring information for checking and adjusting the tool outside the machine.

In addition to the above-mentioned functional tasks, there is one more independent task - metrological support of automated systems.

Since the above-mentioned functional tasks imply the functioning of measuring systems in dynamic mode, the means of metrological support should also carry out verification not only in static but also in dynamic mode of operation.

An examination of the above-mentioned tasks shows that tasks 1, 2, 3 must be solved by measuring systems built into the processing machine, which can be attributed to the general group of systems - the “information interstructure” of the machine [2].

Tasks 7, 8 are solved by measuring instruments located outside the machine, which should be assigned to the second group of systems - “information interstructure” of the machine [2].

As for tasks 4, 5, 6, they can be solved both by the built-in measuring systems, and the means that operate autonomously outside the machine.

The determining factor in this case is the frequency of control. It is obvious that if information about a controlled parameter should arrive very often, then the corresponding systems should be built into the machine.

If it is possible to carry out periodic monitoring, appropriate tools can be located outside the machine and, due to this, provide maintenance for a group of machines, which is more economical.

Therefore, when determining the required composition of automated measuring instruments and their purpose, both within a specific operation and the entire technological cycle, it is very important to assess
the degree of impact of information received from the measuring tools on the manufacturing process.

Thus, in terms of implementing a systematic approach, it is necessary, on the basis of the accurate analysis of the technical operation within the entire technological process, taking into account the features of the processing process and the capabilities of the machine, to determine, based on technical and economic criteria, a balanced ratio of control tasks and the applied measurement systems.

3. Conclusion
The main directions of the development of measuring systems for machine tools should be based on a systematic approach both in terms of information support for achieving the required quality of manufacturing products at minimum cost in the entire technological cycle, and in terms of optimizing information structures.

Optimization of the building of information structures should be based on the accurate analysis of the technological process, including the process of monitoring products, machines, components and systems of machines, with a view to the rational minimization of control volumes, the composition of measuring instruments and their functions, the determination of reasonable requirements for the accuracy of measuring instruments, their automation level.

Particular attention should be paid to the creation of promising feedback devices for machine tools, accuracy control tools for machines and product control tools outside the machine, taking into account the features of the process and the functional capabilities of the processing equipment.

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