Automation Of Machine-Building Production According To Industry 4.0

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***Abstract*—Low-priced individual goods are sought-after, which creates demand for resource-effective technologies and sustainably developing industry. Machine maintenance is performed according to machine builders’ regulations, while digital technologies offer approaches, based on on-line monitoring, diagnosing of equipment and comparing data with standards, set at the start-up stage. The computer numerical control (CNC) application, digital oscilloscope, monitoring servo-drives allows canceling scheduled irrelevant machine downtime.**

Keywords — digital production; informational model; preventive assessment of the status of equipment model data collection; model of data transmission; CNC system

I. INTRODUCTION

On the one hand, the changing of nature of consumer demand (new, customized, high-quality products), and, on the other hand, the emergence of new technologies, have created new industrial strategies, which have specific requirements for technology equipment [1].

The concept of industry 4.0 merges the real industry and the virtual reality into a model called "Digital manufacturing". One understands "digital manufacturing" as the information model of the high-tech industry, covering all stages of development and production from design to the obtainment of a finished functional product, implemented on the basis of advanced manufacturing, new materials, new information and communication provision, big data (Big Data) and cloud technologies. The model is implemented in the software system, which includes modeling tools, 3D visualization, analysis and collaboration that is focused on the simultaneous development of products and technological processes of their manufacture [2]. An important functional component of these models is information on all processes, including operational data and parameters of the technological equipment as well as of the items themselves.

Informational model of the digital industrial production is based on a unified informational space of the enterprise. The informational model includes: data model, the model of interaction of objects, the dynamic model and the model of functioning of object of management. The last is the most difficult, because it is connected with the objects operating in real time, such as computer numerical control (CNC) systems for machine tools, programmable logic controllers, motion controllers, programmable automation controllers (PAC), etc. [3]. This model allows one to get feedback on the real indicators of technological processes; it establishes the quantitative and logical relationships between variables characterizing the state of controlled parameters of technological operations [4].

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II. The information model for a preventive assessment of the technological system

Digital manufacturing has everything necessary for the organization of preventive assessment of production equipment, in order to arrange timely maintenance of equipment according to its condition on the basis of on-line monitoring, diagnostic, and comparison of its performance with the benchmark parameters established at the stage of machine tool setup (Fig.1).

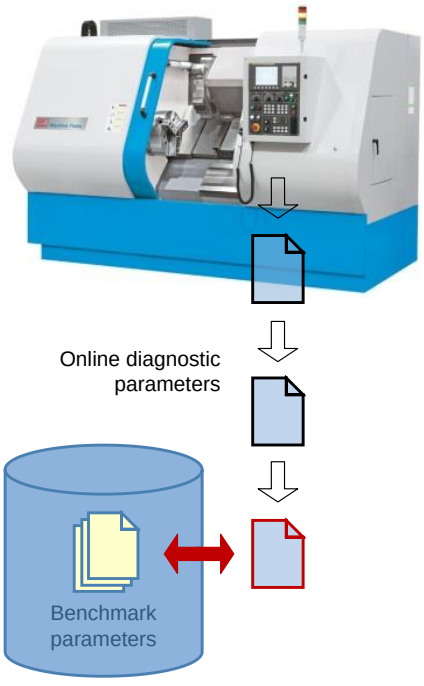

Fig. 1. On-line monitoring, diagnostic, and comparison of its performance with the benchmark parameters of machine setup.

But today, the maintenance of equipment is carried out according to the technical regulations and plans defined by the manufacturers of the equipment that often provokes undue reduction in performance of equipment, which is the frequently shut down for routine checks or which is broken, since the operational monitoring of critical conditions is not carried out.

The preventive assessment of the equipment condition of is an informational model that is built and works on the basis of the flows of information received from the control system of technological equipment (Fig.2). The latter is able to transfer the entire set of information for evaluating the actual state of the technological equipment [5].

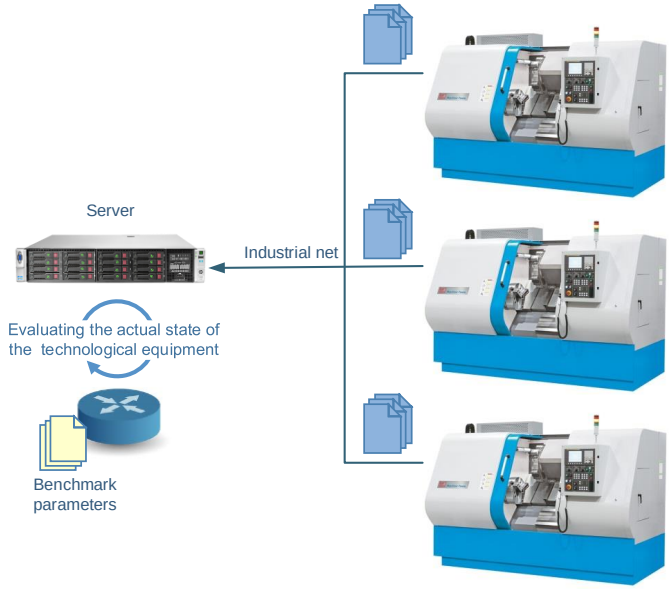

Fig. 2. Model of data collection on the state of technological equipment.

Manufacturers of technologic equipment can supply the software tools for diagnostics and configuration of servo drives and remote modules I/o electrics (digital oscilloscopes, logic analyzers, etc.). Also industry produces the external instrumentation (oscilloscopes, bulbar, laser interferometers and trackers motion), which allow a quickly and efficiently estimating parameters of individual components of the technical system so as to process them and make decisions [6, 7].

The external measuring devices, though more expensive, provide more precise measurements since while estimating their manufacturing errors, they take into account the whole complex of inaccuracies: the inaccuracy of machine tool chain, the inaccuracy of dimension of the workpiece, mechanical and thermal deformation of the system "the machine - the fixture - the tool - the part", the error of the machine feeder etc. But to make the measurements, one has to stop the machine, which means the loss of machine-hours.

Measuring with the tools built-in of CNC usually do not require long shutdowns of the treatment process, the results can be obtained in several minutes. The accuracy depends on if external measurement position sensors installed in the machine (linear, angular), or the information comes from sensors on the engine [8].

The idea of the proposed solution consists in building of the correspondence model between measurements obtained from external measuring devices (fixed at the stage of commissioning) and measurements obtained from the built-in tools. This decision will allow monitoring and evaluating information on the status of the technological machine with more accuracy (Fig.3).

However, despite the fact that the tools built-in the CNC system and external devices have a common purpose, they differ much in such parameters as the transmission format, the presentation of results, etc. [9, 10].

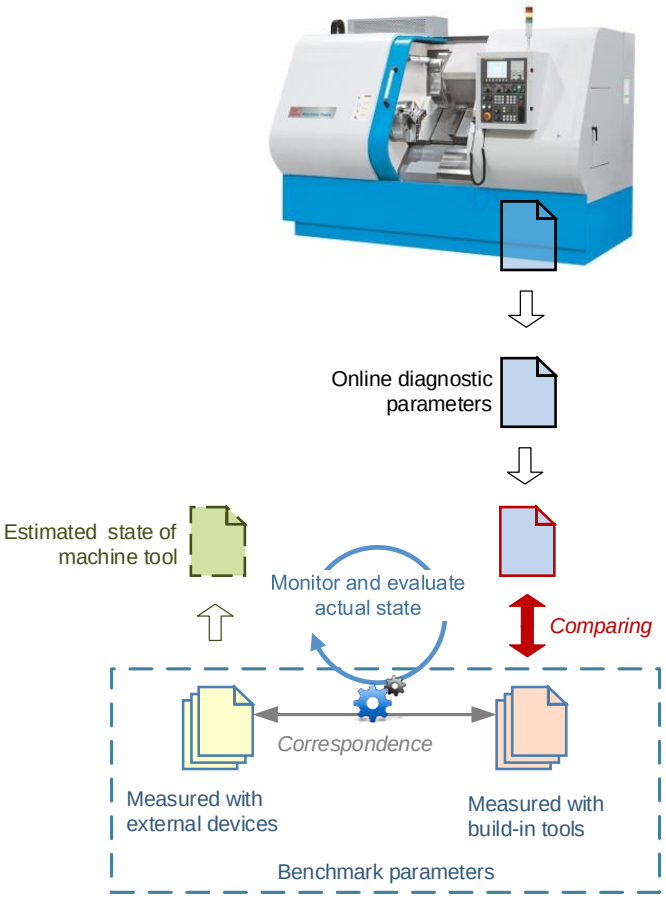

Fig. 3. Model of the correspondence between measurements obtained from external measuring devices and the measuring obtained from the built-in tools.

That is why, for example, it becomes impossible to compare the measured data with the internal data of the CNC system,

which is of critical importance for the operation of control algorithms.

III. The Architectural Model of the Embedded-in CNC the System of Data Collection from the Technological System

CNC system has all the necessary information on the state and motion parameters of the servo drive for configuration and diagnosis settings of the control circuits. If the analysis needs more data from the drive, which is not related to traffic control, they can be added into the list of parameters of the cyclic exchange between the actuator and the kernel of the CNC system [11, 12]. High speed industrial protocols, such as SERCOS III and EtherCAT, have special arrangements for the transfer values of the additional list of parameters in the cyclic data. They can be added during operation without taking the device parameterization.

For the configured measurement points there is a mechanism that allows recording in real time the data in almost any area of the memory SoftPLC controller, and the kernel of the CNC system (Fig. 4). This powerful tool allows tracking the interaction between various kernel modules of the control system.

Data collection of the measurements in the diagnostic subsystem takes place in the context of the main thread of the kernel. The work under the pressure of real-time imposes appropriate restrictions on the software used at this level and architectural solutions [13].

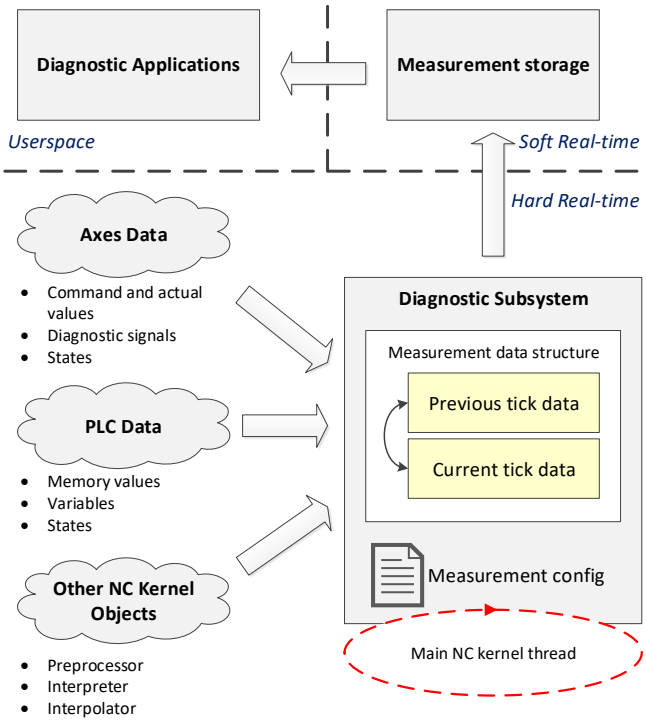

Fig. 4. Architectural model of special-purpose tools for diagnostics and configuration.

IV. The Use of the Tools Built-in Control System to Carry Out the Diagnosis of Industrial Equipment

A number of custom software tools for commissioning and diagnostics of CNC machine tools is developed based on the instrumentation configuration and the diagnosis of the servo drives and I/O electrics.

The application "Digital oscilloscope", created on the basis of the developed diagnostic tools and settings, measures and visualizes the values of the signals in time, for the analysis of flow transients in drive system. Due to the fact that the recording of measurement signals is produced in the core of the CNC system, command signals, actual position and the speed of the drive of the executive body of the machine as well as the internal values of the CNC system, used in the motion control, become available.

The application realizes zooming, cursors to view the accurate values of the measured signals, the possibility of combining the position signals of several axes to visualize the trajectories in the space.

"Digital oscilloscope" allows evaluating the response of the system to changing parameters of process control (Fig. 5). Measured data in this mode are collected with a lower sampling rate than in the mode of recording of measurement, the number of displayed signals is also limited. In this mode of the instrumentation working, inside the core systems are only values of the parameters, which are selected for display. The collected data are combined in small batches with a total duration up to 100 MS and sent to the user application, which allows one to reduce the traffic of the communication channel between the core of the CNC system and the terminal. For diagnostic applications, such a delay is not critical and does not affect the perception of information by the operator. A digital oscilloscope was used to set the proportional gain of the controller position loop SERCOSIII drive milling spindle in position control mode. The disagreement between the command and the current position of the axis was reduced in 2-3 times in the process of setting.

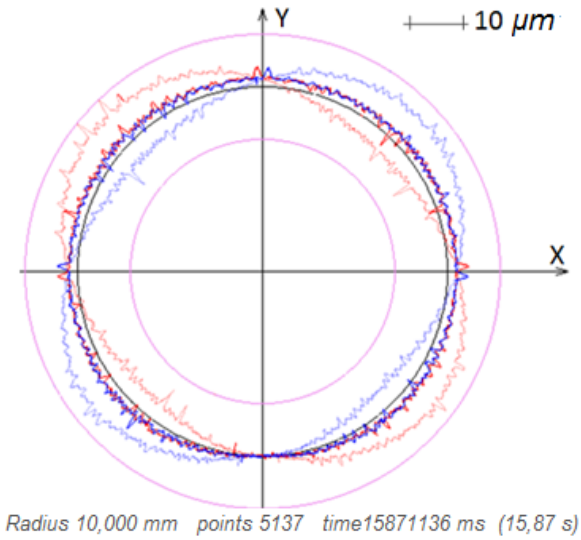

Fig. 5. Circle test application – a tool for compensation drives' dynamic response mismatch.

The test of the circle is regulated by ISO 230-4-2015 and is used during setting to minimize the contour errors of the movement axes on a circle and by aligning their dynamic characteristics.

In contrast to the use of external measuring devices, Circle test application allows one to evaluate not only the quality of the actual positional accuracy of the axes, but also the trajectory generated by the interpolator. Thus, developers of CNC system are provided with a feedback, which is important at the stage of the realization of control motion algorithms in the new system [14].

By means of these external and built-in tools it is possible to configure parameters of the components of the machine separately, as well as to make them work together. The use of the instrumentation for diagnostics and the measurement of motion parameters of servo-drives in a heterogeneous control system does not exclude the use of external tools for the final settings of the control system for the technological machine.

V. CONCLUSION

• The monitoring system of process equipment is the base for further development of digital productions,

• the built-in management tools for monitoring machine status allows one to collect and analyze almost any aspect of work machine components,

• the data of the actual state of the machine is used to set the parameters of the components of the machine separately, as well as to debug their joint work,

• the collection of data to analyze the operation of any equipment runs through the standard interfaces.

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