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INTELLIGENT DIAGNOSTICS OF MACHINING PROCESS IN CNC MACHINES

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Abstract: *The paper dealt with basic approaches of intelligent systems implementation in manufacturing processes diagnostics of CNC machines. There are several approaches such as either the usage of external or internal intelligent systems. The goal of implementation is the control of manufacturing process in order to influence the examined process quality and economy. The present development in field of artificial intelligence allows the directly implementation of intelligent components into CNC machine software and hardware in form of agents.*

Key words**:** *intelligent component, vibration, CNC machine, agent, effector, sensor.*

1. INTRODUCTION

The present requirements of quality and the increasing the labour productivity are not possible to make through the use of present conventional methods in manufacturing process. The confirmation of mentioned fact is the computer integration manufacturing and control with implemented the diagnostic systems based on the artificial intelligent components.

At present, the numerical control technology is undergoing a fundamental transformation from a closed-type-specific open-loop control mode to the open general-purpose real-time dynamic model of the development of the whole closed-loop control. In an integrated basis, the goal is the intelligent ultra-thin, ultra-small size NC system based on a combination of computer, multimedia, fuzzy control, neural network and other areas of science and technology to obtain numerical control system of the high-speed and high-precision process. The efficient control of process can be automatically amended, adjusting the parameters and compensation to achieve an online intelligent fault diagnosis and treatment of the basis of the network CAD/CAM and CNC systems; and employing networking tools to achieve the central centralized control of the group control process.

The high-speed CPU (Central Processing Unit*)* chips, RISC (Reduced Instruction Set Computing**)** chips, as well as multi-CPU control system with high-resolution absolute detection components results the machinery manufacturing key performance indicators development direction to high-speed, high-precision, high-performance speed, accuracy and efficiency of technology. The digital servo systems provide possibility to improve the dynamic and static characteristics of CNC machine.

The flexible system contains two aspects: the flexibility of CNC system itself, a modular CNC system design. The CNC system flexibility and CNC machine modularity allow meeting the needs of different users. The flexible group control is based on the requirements of various manufacturing processes. The group control system automatically dynamically adjusts maximizing the effectivity of material flow and information flow. The intelligent CNC system with group of control elements provides on-line computing the production time by specific CNC machine. The operating of CNC machine is simpler regarding the number of CNC machine programmer steps. The artificial intelligence develops possibilities of maximum implementing the human knowledge into virtual models of designed products.

The present development of science and technology integrates artificial intelligence of control systems into CNC system that caused more realistic and online systems based on intelligent behaviour. The numerical control technology outcomes the results of artificial intelligence development of field as adaptive control, fuzzy control, neural network control, expert control, learning control, feed-forward control.

The implementing of artificial intelligence system into CNC system allow to achieve innovative steps in form of development of new generation of CNC machines which provides possibilities of adaptive control, expert systems in technological process, tool management, fault diagnostic, high-speed processing and the system of permanent manufacturing control. [6, 9]

In the field of hardware and software of CNC systems, the CPU, RISC chips and large-scale integrated circuit programmable FPGA (Field-Programmable Gate Array), EPLD (Electrically Programmable Logic Device), CPLD (Complex Programmable Logic Device**)** and ASIC (Application-Specific Integrated Circuit**)** application allow to achieve the change the conventional CNC machines into intelligent machines. The intelligent CNC machines use the flat-panel displays with high-tech, light weight, small size, low power consumption, easy to carry, etc. [2 and 9].

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2. INTELLIGENT SYSTEMS

At the present time the systems are suitable for local response of solution the usual problems and communicate with special modules only in case of need (e.g. failure). It is shown that such relatively independent modules are useful for unpredictable situations, optimal configuration of manufacturing machine, i.e. increasing the fault resistance of machine.

The ideas of implementation the relatively independent systems based on mentioned facts were occurred and developed in field of three disciplines (Fig. 1):

Holonic systems that dealt with online control of processes and related to events occurrence that is applied to independent unit sets,

Multiagent systems are the agents that are static or relatively rigid affixed to information sources,

Mobile agents are program modules that are able to self-move in computer network, self-activate in host computers and self-generate their clones.

Multiagent systems are based on similar principle as holonic system, but in comparison with holon, the agent is independent computing unit that is based on individual abilities of agent or of team of agents. This fact allows formation of multi-agent concept that watches independently the communications among the agents and recommends the functional upgrading or modification of multiagent structure [1, 3, 6, and 7].

3. DESIGN OF INTELLIGENT SYSTEMS FOR CNC MACHINE

Designing of intelligent - multiagent system with use of external agents is realized in university workroom with CNC vertical machine Pinacle VMC 650S. During the cutting, the presence and position of workpiece, the tool temperature and spindle and workpiece vibrations are monitored. The sensors are connected with agents directly. The agents have specific domain knowledge and the aims are achieved by means of actions. The agents are linked each other to be able to communicate. The system comprises also effectors that are influenced by agents. The given multiagent system is described by figure 2 [4].

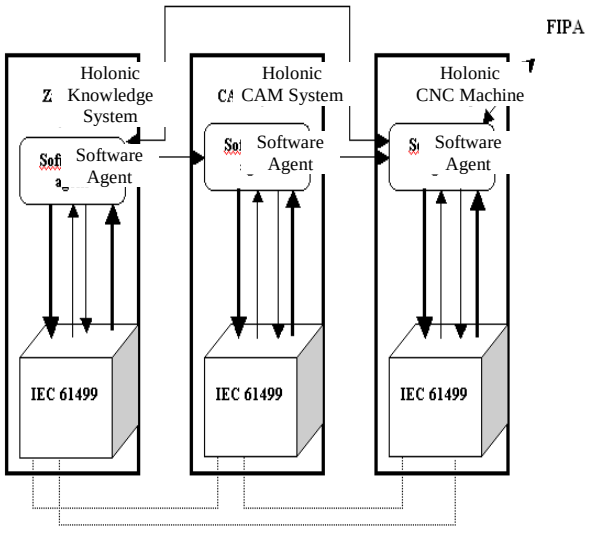

Fig. 1. Application of intelligent system.

3.1. Components of intelligent system

- Sensors:

Workpiece presence sensor - its aim is the monitoring of workpiece position or its presence in working machine.

Vibration sensor - its goal is the monitoring of vibrations of workpiece and spindle.

Temperature sensor - its goal is the monitoring of temperature of cutting tool or selected machine parts.

Tools wear sensor - its goal is the monitoring of tool wearing.

- Agents:

Agent 1 – goal – the prevention of start up the machine either without or with workpiece in incorrect position, action, the prevention of start up the machine, domain knowledge – right position (presence) of workpiece.

Agent 2 – goal – the prevention of inaccuracy of manufacturing cased by vibrations, action – decrease table feed, domain knowledge – critical vibrations, corresponding feeds.

Agent 3 – goal – the prevention of tool damage caused by temperature, action – let flow the cooling fluid, domain knowledge – critical temperatures, the volume of cooling fluid.

Agent 4 – goal – the prevention of tool wearing of blank cutting process and the decreasing the quality of machined surface

- Effectors:

Effector 1 is a switch that the aim is switch off the equipment to agent in order of position (presence) sensor signalises incorrect position or absence of workpiece.

Effector 2 is a servo-drive of CNC vertical working machine, its aim is to decrease the table feed to agent order in case if the sensor signalises the abnormal vibrations.

Effector 3 is a pumping devise for cooling fluid, its aim is to get the cooling fluid into cutting area to agent order if the sensor signalises increasing temperature.

Effector 4 is the software of CNC machine control system that computes possible corrections of tool set up or stops of technological process or gives the command for tool change from CNC tool container.

Figure 2 shows the described design structure of intelligent system [6 and 7].

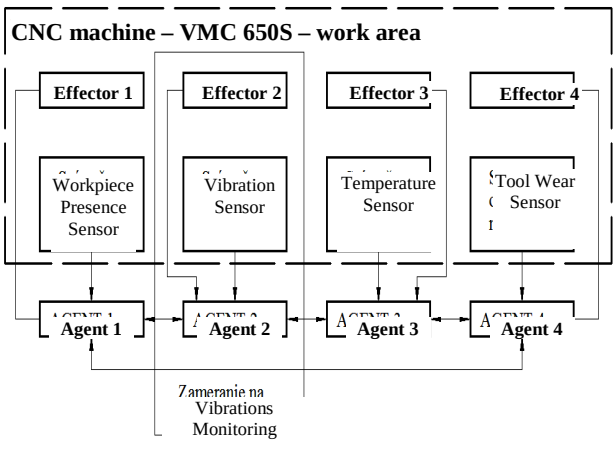

Fig. 2. Design of intelligent system with external components.

3.2. Application of intelligent components into CNC machines

Designing of intelligent system involving the internal components is realized for CNC machines e.g. MAZAK machines.

CNC machines Mazak are designed as intelligent machines. The machines comprise so called neural network that by means of integrated intelligent components in each machine system responses to changes of working environment. The following functions are known:

- Minimalization of vibrations (Fig. 3) that are generated during movement of work table or tool support, the movement precision in all coordinate axes are influenced and the machining time is shortened. This function reduces vibrations of tool tip and thus insures high quality of machined surface.
- Intelligent thermal protection – if the temperature is changing during the cutting, the cutting precision is undesirably influenced. The intelligent thermal protection automatically modifies the temperature changes moreover it modifies spindle speed during technological operation resulting in stability required machining precision. As the temperatures of the machine units change due to operation and as well as changes in the room temperature, displacement of parts of the machine will affect machining accuracy. The Intelligent Thermal Shield automatically compensates for changes in the temperatures as well as changes in spindle speed operation to ensure stable machining accuracy. Additionally, to minimize heat distortion in order to ensure stable machining accuracy, the machine units that generate heat are arranged symmetrically. Intelligent safety protection – in case of manual manipulation of machine axes, machine setting up or the measuring the tool, the CNC display system shows 3D model to control outside interference (Fig. 4). In case of unacceptable interference, the machine stops. This function decreases setting up time (incidental time) of machine.
- Mazak Voice advisor – informs which switches were chosen and advises required warning. It considerably decreases problems caused by human factor. [8]

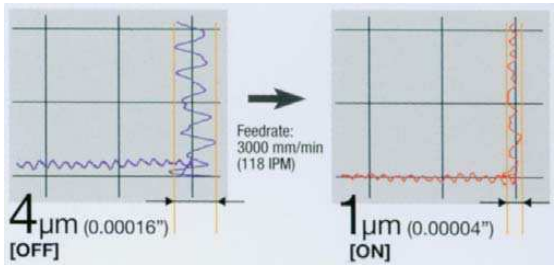

Fig. 3. Decreasing of vibrations.

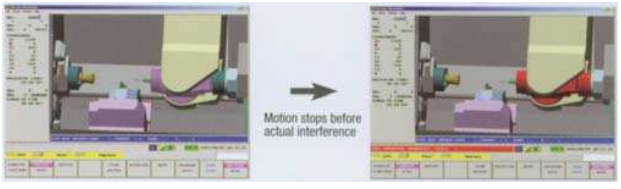

Fig. 4. Control of potential machine interference.

- Intelligent balance analyser - if fixtures and/or workpieces are loaded on the machine table in an unbalanced condition, safe machine operation as well as turning accuracy will be affected. This function analyses the balance of the table load and displays the amount of weight and locations that are required to eliminate the unbalanced condition. The same system will automatically stop table rotation if excessive vibration is detected.
- The Intelligent performance spindle monitors a variety of properties with sensors housed in the spindle – including temperature, vibration and displacement – and it provides useful information to the operator. Thanks to these data, machine problems due to the spindle can be prevented. Additionally, a considerable reduction of production loss due to machine down time can be realized.
- The Intelligent maintenance support function monitors the status of perishable items such as filters, cover wipers, and the operation history of several machine units.

This information is useful to determine a preventative maintenance program to prevent unexpected machine downtime. Additionally, when the replacement time is reached for items such as a filter, a pop-up window notifies the operator to ensure required maintenance is performed.

The control system of 6th generation for CNC Mazak machines of Japan company Yamazaki Mazak Corporation was developed and named Mazatrol Matrix. This system provides for users the high service quality, increasing the productivity and possibility of NC sequences simulation in order to control manufacturing process. The 64 Bit Twin-Engine Processor allows the high speed, high accuracy machining demands smooth machine control − when combined with sub-micron program data increments and 5-axis simultaneous commands, huge amounts of data are required to be calculated. The maximum vectorial feed rate used for machining complex surfaces is four times faster than the standard specification of the previous CNC system. This is made possible by the increased computing power of the new RISC-CPU.

Machine Programs can be made with minimum errors and time required for test cuts thanks to realistic machine 3D simulation displays that can be used for convenient program confirmation and checking for any machine interference. Additionally, this unique Mazatrol function makes it possible to simulate the machining of a new program during the machining of the current workpiece.

CNC machine producers designate the control systems of 6th and 7th generation by attribute “i” that means intelligent system (iFANUC, SINUMERIK 810D, OSP-P200, iMSNC, iHEIDENHAIN). The mentioned control systems in cooperation with integrated intelligent components in CNC machine (Fig. 5) provide the advantage, protection and help for users to prevent undesirable operating condition of machine. The mentioned property highly influences the productivity of machining process [2 and 8].

Fig. 5. CNC machine Variaxis 630-5X II.

4. CONCLUSIONS

The implementation of intelligent components into CNC machines is the result of the research and development in artificial intelligence field. The artificial intelligence knowledge is applied to development of the control and operation of the complex and risk systems and machines in mechanical engineering field. The present trend in field of automated workplaces with usage of High Tech CNC technique for cutting operations follows the following tasks:

- cutting the large volumes of material,
- minimizing the cutting time resulting in high speed cutting,
- optimization of energy consumption,
- increasing the tool life,
- high quality of machined surfaces.

To achieve the mentioned tasks, the intelligent components are available. The components are implemented either into mechanical parts of CNC machines (as Fig. 2 shows) or into software, i.e. into machine control system. The modern control systems use the environment of standard operating systems that are compatible with operating systems of CAD/CAM systems or expert systems. This fact allows identifying the risk shapes of workpiece geometry or detecting the errors of defining the technological cutting conditions by means of NC sequences simulation process.

The mentioned fact is the first level of technological process control of CNC machines. The second level is the online control of machine mechanical parts and tools by means of active elements (sensors) that communicate with agents as Fig. 2 presents.

Through the control system it is possible to control e.g. spindle vibrations, temperature of selected parts and precision of cutting and tool wearing. The intelligent components (agents) evaluate real state and accept the decisions for optimalization of technological process.

The final results of intelligent components implementation for CNC machines are:

- decreasing the number of machine failure,
- decreasing the incidental time needful for correction of NC sequences,
- increasing the tool life of used tools,
- high quality of machined surfaces,
- improvement of economic indexes.

It is necessary to mentioned that the implementation of intelligent components increasing the machine price and therefore it is needful to use the machines by right way. [1, 5, 6]

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