The Formation and Development of Intelligent Processing Technology

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Abstract. As the foundation of intelligent manufacturing, intelligent processing is an advanced technology consisting of the theory of digital design and article intelligence, and an important technology of bringing about better quality, beneficial result and optimal control. In this paper, the domestic and overseas research progress is overviewed, and the technical conception of intelligent processing is stated. According to the major remaining problems and critical technologies, the developments of the intelligent processing technology are presented.

1 Research progress of intelligent processing

The intelligent manufacturing technology, a systemic integration involving digital design and manufacturing theory and AI (artificial intelligence), was put forward in the end of 1980s by mechanical engineering experts of developed industrial countries to solve the existing problems in the traditional process and meet the growing demand for better product performance. A few years later, the intelligent manufacturing was proposed with a series of intelligent processing initiatives and strategies emerging, among which the PMI, SMPI and NEXT plan have a significant influence.

In 2005, SMPI plan, a research of intelligent processing system, was put forward in America, mainly including the local activity based on the advanced equipment and the whole activity based on the processing technology.

Based on Sixth Framework Research , NEXT plan, a research about the next-generation production system, was published by European Union In 2002, mainly involving Processing Simulation and new technological development, R&D of new machines (the high-speed machine, open CNC system and optical fiber sensor application of optical sensor), research of light structure and machine components (including machine components of light materials, accuracy measurement of rotary shaft and air bearing, etc.) and R&D of parallel machines, etc.

In April, 2013, German brought up the Industrial 4.0 of which the core is Cyber-Physics System (CPS). Through CPS, the supply, manufacture and sales turn out to be digital and intelligent, which is conductive to achieving a rapid and effective supply of personalized products. By improving the level of intelligence, the intelligent factory is to be conducted, which has the advantages of adaptability, resource and human factors, ensuring the competitiveness of the German manufacture in the future industrial development.

In 1994, Intelligent Manufacturing International Cooperation Project was proposed in Japan. The plan covers the global manufacturing, manufacturing knowledge system, the distributed intelligent systemic technology of rapid product realization, etc. The ultimate goal is to develop a system that can help people and intelligent equipments breakthrough the limit of operations and boundaries.

Published by CIRP in 2003, PMI plan mainly refers to the establishment and research of machining process model (including cutting, grinding, forming process), the on-line monitoring of equipment (including the intelligent spindle system, the prediction of tool wear, etc.) and the research about the interaction between the two sections above in the process and equipment (including the description, simulation and optimization, and the structural behavior of the machine tool system).

In China, despite the weakness in the basic realization technology due to the poor basic capacity of the mechanical manufacturing and related disciplines, the research dealing with the necessity, main

problems, key technologies and methods have been actively conducted. In 1994, the key project "intelligent manufacturing technology" was conducted , which involves intelligent NC technology, intelligent quality assurance, monitoring and diagnosis technology, intelligent robots, intelligent processing center IMC, etc.. Moreover, a growing number of surveys and research have been implemented to develop the key technologies and application of the intelligent processing.

2 Technological content of intelligent processing

2.1 Technological content of intelligent processing

Based on digital manufacturing technology, intelligent processing is able to predict the potential processing and effect by modeling and simulation, and in actual processing the advanced equipment is utilized to monitor and control the process in real time. With the comprehensive consideration of theoretical knowledge and human experience and by using computer technology, intelligent processing is able to analyze, judge, reasoning, design and make decision in the perspective of a specialist to achieve optimized processing parameters and better state, finally improving the adaptability of the production system, obtaining the optimal processing performance and the best processing quality. Figure 1 shows the intelligent process.

As a new processing method based on knowledge management, intelligent processing combines the intelligent optimization and intelligent NC machining, of which the basic aim is to apply intelligent machine to implement automatic detection and control, and imitate human experts to deal with product processing, finally solving the problems which are uncertain or need human's interference. Meanwhile, processing information is collected, stored, enhanced and shared. In a word, intelligent processing has partly or even totally take over the brain activity of human experts in the process.
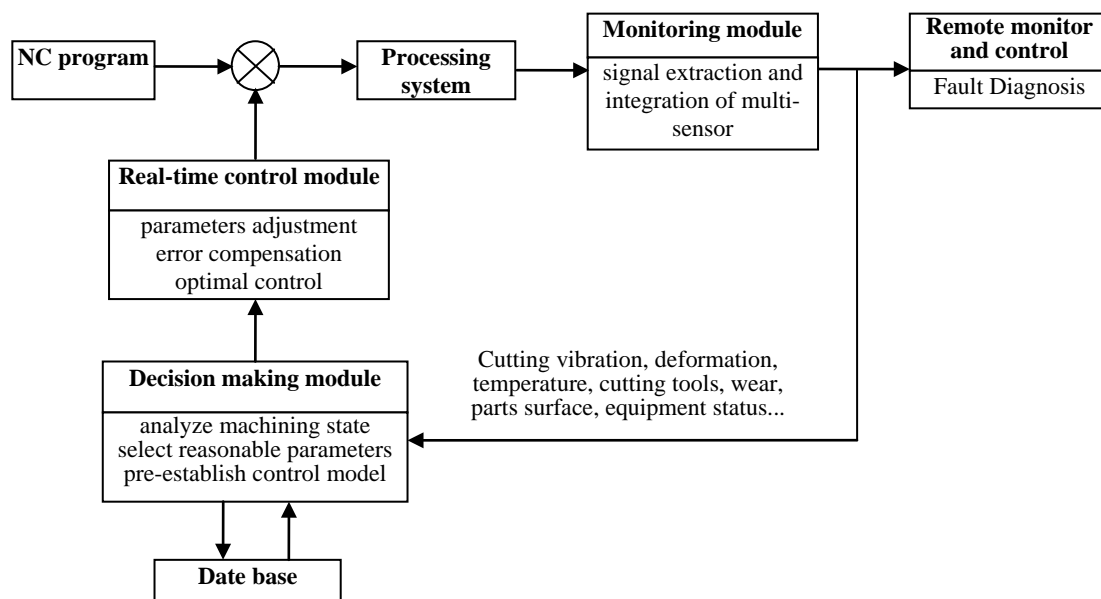

Fig.1 the process of intelligent manufacturing

2.2 Basic features of intelligent processing

According to the content and basic working principle of the intelligent process, it can be summarized that the intelligent processing has the following basic features:

(1)Partly help human to make decisions. In the intelligent processing system, the knowledge expert system is utilized to deal with those processing information difficult to quantify, also the process route, part machining plan and cutting parameters are automatically determined. Furthermore, the problems arise from processing can be work out efficiently without the interference of human.

(2) A comprehensive utilization of artificial intelligence and computational intelligence. With the assistance of computer, the numerical method is used to quantitatively analyze the numerical or

symbolic information which can be identified by the computer. Moreover, symbolic reasoning techniques have found the application for quantitative analysis of the information hard to quantify. With regard to the qualitative analysis which has no accession to formalization, expert system seems like a good choice.

(3) Multi information perception and fusion. Through various sensors around, the state of every unit is monitored in real time such as vibration, cutting temperature, tool wear, etc., to provide basic data for the decision analysis.

(4) Self-adaption. According to the processing state provided by sensors and the data supported by database, intelligent processing system is access to automatic adjustment of cutting parameters, optimized processing state and optimal control.

(5) Inheritance of processing experience. Intelligent processing technology is not from scratch, but the accumulation and expansion of the process of knowledge and experience.

2.3 Basic structure of intelligent processing system

Intelligent processing involves many academic fields such as materials science, information science, intelligent theory, mechanical machining, mechanical dynamics, automatic control theory and network technology. Generally speaking, intelligent processing technology system mainly includes:

(1) Modeling and simulation module. Based on different factors having an influence on machining quality, such as the state of workpiece, cutting tools and machine, as well as parameters and processing technology, machining process model is simulated for the optimization and selection of parameters, and the process control instruction, etc..

(2) Process monitoring module. Through the sensors around, the process is monitored in real time, including cutting force, processing temperature, cutting tool wear, vibration, spindle torque, etc..

(3) Intelligent reasoning and decision making module. According to the established system control model, process route, machining program of the parts and cutting parameters are determined by means of knowledge base searching and even the expert system.

(4) Optimal process control module. Based on real-time state of workpiece, significant steps as parameters selection and error compensation are taken to improve the accuracy, shorten the process and improve the processing efficiency.

3 Main problems and key technologies in the field of intelligent processing

3.1 Problems existing in the present machining system

The traditional self-adaptive system based on mathematical models hardly has an efficient control over the mechanical cutting process of highly nonlinear, uncertainty, time variability and random disturbance. As the foundation of modern manufacturing technology, there are the following processing problems in NC technology:

(1) NC machining process is not always in a stable state. In actual machining process numerical control, there exist many complicated physical phenomena, such as the heat distortion of the workpiece, the elastic deformation of the clamping system and the vibration of the processing system, In actual machining process numerical control, there exist many complicated physical phenomena, such as the heat distortion of the workpiece, the elastic deformation of the clamping system and the vibration of the processing system, which results in unexpected errors and even unqualified shape accuracy and surface quality despite the "correct" machining process.

(2) NC cutting tools are not always in an ideal state. The tool wear condition is affected by various factors such as the stability of the clip, the rationality of cutting parameters, the uniformity and consistency of the processing materials, which bring about an inaccurate judgement of tool wear state. Meanwhile, vibration and crack of tools also lead to the dynamic changes of the processing system, adding to the difficulty to maintain the stability of the machining process.

(3) CNC machining system is not always in the optimal state. For a long time, the designer's attention has been concentrated on improving the structure rigidity and the positioning accuracy of

the feed mechanism, instead of the comprehensive consideration of the interaction between NC equipment and machining process, while the influence on machine deformation caused by cutting heat and environmental temperature changes often lead to an unpredictable results.

3.2 Key intelligent technology remaining to be solved

Up to now, some research on intelligent processing technology has been carried out in some domestic universities and research institutes, some achievements having been made. However, the research lacks systematicness, and is not well directed to the demand for the transformation and upgrading of machinery manufacturing industry, particularly lacking adaptability in the major national science and technology projects high-end CNC machine tools and basic equipment.

At present in the field of intelligent processing in our country, there exist following main problems and key technologies remaining to be done:

(1) Intelligent machining foundation platform for high - grade CNC machine tool. The implementation of the major national science and technology projects high-end CNC machine tools and basic equipment has facilitated technological innovation in the field of high - grade mechanical equipment, significantly improving the overall manufacturing capacity. However, the lag of the national platform for NC-tool-based intelligent processing and the research on the common technology of the intelligent processing technology directly influences and restricts the application effect of the national major scientific and technological achievements.

(2) Modeling and simulation technology of NC machining based on knowledge. The modeling and simulation of cutting tools, fixtures and other elements, coupled with the analysis and optimum design of cutting tool structure and load is carried out for the better cutting depth and feed rate to improve the processing efficiency and economic benefits, which is the basic way to link up the information channel of high grade CNC machine tools and equipment, and also the basis of intelligent processing.

(3) On line monitoring and error compensation technology for NC machining system. By using various sensors, remote monitoring and fault diagnosis technology, the vibration, cutting temperature, tool wear, machining deformation and equipment running status of NC machining process are monitored, and the processing parameters are adjusted in time according to the system control model.

(4) Fusion technology of intelligent processing strategy and NC system. The realization of intelligent control system has two key technologies. One is intelligent processing strategy, the other being the integration of intelligent processing strategy and NC system. The intelligent machining system is expected to get the great possible flexibility with the required accuracy and high productivity, and to change its control strategy according to the actual situation, ultimately achieving the optimal combination of quality, efficiency and cost.

(5) Intelligent components. The intelligent degree of NC machining process system is the basis of high efficiency, precision and high quality. The implementation of major science and technology projects of high-end CNC machine tools and basic equipment contributes to the significant increase to the machine intelligence level. Moreover, the intellectualization and realization method of the components made up of the handle, clamp, and tool are to lay a solid foundation for the implementation of the intelligent machining technology and application demonstration.

(6) Highly integrated and intelligent technology of machines. It is evident that the degree of automation of machine depends on the level of integrated automation. As the core unit of intelligent processing system, intelligent machine is expected to possess better control technique and ability of hierarchical information processing, and to coordinate each link of the processing function, finally improving the problem "intelligent island" and achieving the best in the whole.

(7) Intelligent detection and optimal control technology based on surface integrity. The excellent surface integrity (including surface morphology, surface texture, surface residual stress, surface hardening and texture feature) is the ultimate goal of intelligent processing. It is the key process to establish the mathematics - mechanics model based on the surface integrity of NC cutting, and to set up the feedback channel of information interaction between surface quality - cutting tools - tools - tool system - intelligent. Through the on-line intelligent monitoring and quality evaluation of the

surface integrity of the workpiece surface, and adjusting the position and orientation of the tool, cutting parameters and motion parameters in the right moment, the high-end CNC machine and processing system is to function adequately and a new way of achieving high quality, high efficiency, excellent control is to open up.

Obviously, the problems and key technology breakthrough above will promote the progress of the intelligent processing technology, and further improve the overall level of the manufacturing industry. The pace of manufacturing industry transformation and upgrading accelerated and the core competitiveness of the manufacturing technology enhanced.

4 Future Work of the intelligent processing

Since entering the first ten years of the twenty-first Century, intelligent manufacturing has been developing rapidly with a number of fruits achieved. Intelligent manufacturing equipment industry system initially has been formed, of which the main representative are new sensors, intelligent control systems, industrial robots, and automated production lines. Furthermore, a number of major intelligent manufacturing equipment with independent intellectual property rights have achieved breakthrough. However, there are still some problems in the practical application of intelligent processing, which need to be strengthened in the following aspects:

(1) Break through the construction of the intelligent processing theory system. In-depth study of basic theory and technology of intelligent processing must be enforced, including new sensing theory and technology, intelligent control and optimization theory, intelligent integrated planning theory and technology, intelligent machining technology research and application demonstration, construction and application technology development based on intelligent machining cutting system.

(2) Facilitate the development and application of intelligent numerical control equipment. On the one hand, in order to promote the implementation of high-end CNC machine tools and basic manufacturing equipment project and other national sci. & tech. ones, the national strategic measures is to continue and accelerated, on the other hand, weigh is attached to the research and application of the typical intelligent measurement and control device, forming a strong support for the development of intelligent manufacturing equipment industry.

(3) Establish the NC innovation platform with the university-industry cooperation to improve the ability of independent innovation in intelligent processing. It is essential to set up the alliance mechanism and information resource platform among high-end manufacturing enterprises, key universities and research institutions to achieve resource sharing and complementary advantages. Also there is a need to establish a sound system of intelligent processing personnel training and incentive mechanism, and to bring up a number of high level technology innovation team.

Acknowledges

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