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DEVELOPMENT OF INSPECTION SYSTEM FOR TOOL PRESETTER

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ABSTRACT

In order to conform to the concept of smart factory for industry 4.0, this paper developed a low-cost tool measuring machine included the structure design, hardware planning of the server, electromechanical control, drive system, human machine interface, communication between hardware and software, software development, and so on. The proposed measuring system provided more flexibility and integration with peripheral equipment for the requirements of industry 4.0. Compared with a Germanic measuring machine, experimental results showed that the percentage of errors of the designed inspection instrument were 0.004 % and 0.003 % for the tool length and diameter measurements of a square end mill, respectively.

Index Terms - Industry 4.0, tool measuring system, tool presetter.

1. INTRODUCTION

Many countries advance in the goal of the industry 4.0 due to the rapid development of industrial manufacturing in recent years. The enterprises increase the number of CNC machine tools in order to improve production capacity and remain in a competitive environment. With the use of a great quantity of machining machines, the supply of tool inspection instruments which can quickly and accurately measure the relevant parameters of cutting tools falls short of demand on the market. Currently, some of them belong to off-line measuring machines that can not only measure the tool dimensions and store in the database but also transmit the tools data by connecting with the manufacturing center. So far the measuring techniques are more mature, but the price of measuring machines is expensive. Furthermore, the research and development of technology are the company's know-how so the development has less flexibility for end users.

Most users of CNC machine tools still set up cutting tools on the machine by applying the spindle as a presetter, this situation results in the reduction of the utilization rate to set the tool information. There are 63.9 % companies make a tool presetting on the machine and only 16.6 % adopts a presetting device outside the machine [1]. The presetting of tools is usually performed manually, and requires more time for the preparation of the machine. To avoid spending time on setup, the mainly solution for reducing machine downtime is based on the use of the tool presetter which is outside of a machine tool to increase productivity [2-3]. The tool presetting has the functions of specific data output which automatically formatted for post processing, it enables to link different machines for readable output format and transmits data via RFID, DNC, network, or FTP server to a machining center [4-6]. The tool-setting data can be converted by DITS to the NC format and saved this information as a file in a DNC directory. There is no interruption for NC machining [2].

This paper developed a tool measuring machine to make the measurement data to be stored in database which presented by PHP, and measure basic geometries of the tools automatically. Each machine at the production line can obtain data from the database to complete the compensation at anytime and anywhere with the machine network frame. It can effectively reduce preparation time, human error probability, and change the traditional production mode of manufacturing industry substantially.

2. STRUCTURE DESIGN OF TOOL INSPECTION INSTRUMENT

The main purpose of the tool inspection instrument is accurately measure the basic geometry of the tool dimension. Measurement of the tool profile using the backlight illumination method and the focus position of the lens is based on the rotation axis, so that it does not need to install the auto focus axial device in the Y direction. Measurement of the focus position method is to capture the image of the correction rod of the CCD on the rotary motion platform and utilize Sobel operator to calculate the clarity value. Therefore, only two linear motion platforms and a rotary motion platform needed in the axial motion design. Furthermore, the installation of the optical scale could feedback the position signals. The linear motion platforms represent the moving directions of the X and Z axes which are driven directly by the linear motors. And the rotary motion platform is driven by the servo motor which mounted on the hollow rotating platform. It's a fixed axis. Because of the different characteristics of the tool measurement point, it is necessary to move the vision system or rotate the C-axis to image the tool profile detection position into the CCD camera. Fig. 1 is the schematic diagram of the tool inspection instrument.

In the assembly, the parallelism between the linear slides requires high accuracy to avoid the Abbe error in moving processes, which lead to the positioning error and affect the accuracy of measurement. The central line of the rotation spindle must be parallel the vertical slide rail to ensure that the measured plane are perpendicular to the optical axis of the lens. The tool shank and the handle mount must have higher precision to reduce the runout error during the motion processes. Optical scale installation requires parallelism between the main ruler and the direction of the moving platform.

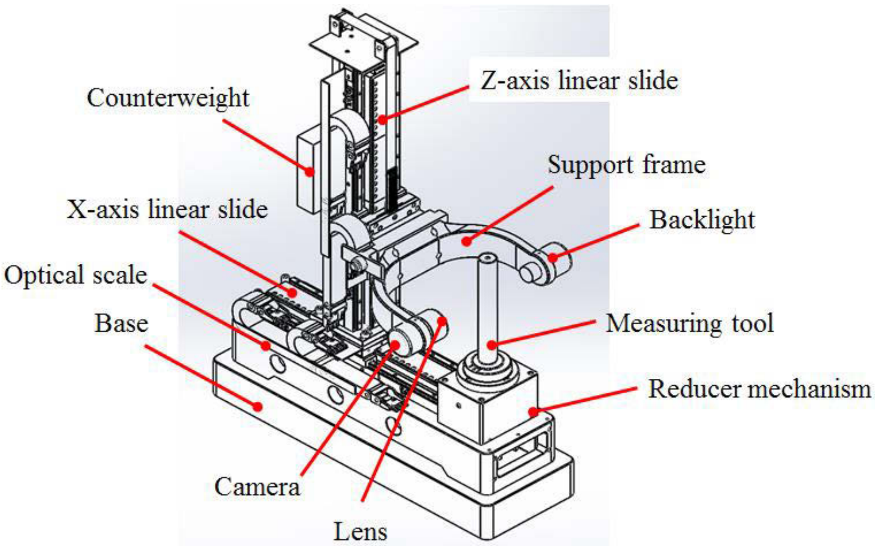

Fig. 1 Schematic diagram of tool inspection instrument.

3. PLANNINGS OF SERVER AND MECHATRONICS SYSTEM

The core of industry 4.0 is the connection between the equipment and the production line. One can use the internet system to execute the exchange of information to achieve intelligent manufacturing. In the paper, the tool inspection instrument is assigned as a server by applying Ethernet to connect with machines of the machining center. It forms the communication interface of one-to-many or many-to-one. The instrument can make the tool data and controller format stored into database so that the production line can acquire information by USB, Ethernet, and DNC. The instrument also can capture a variety of information of machine devices through communication, such as machine status, cutting time, and other parameters. The environmental planning of the server is shown in Fig. 2.

The accuracy of the inspection system must accomplish the micron level, so the tool instrument adopts a closed loop control system and detects the feedback signals of optical scales by the controller to improve the accuracy of measurements. The encoder mounted on the servo motor sends the feedback signals to the servo drivers, at the same time the drivers sends ±10 V signals to adjust the speed and rotation directions of servo motors. Fig. 3 is the diagram of the closed loop control system.

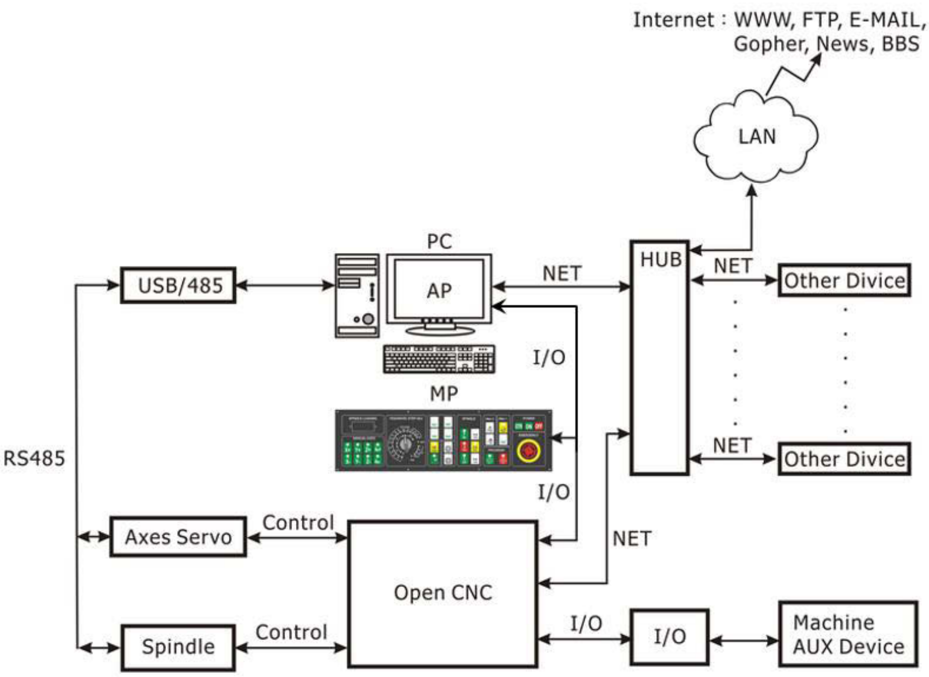

Fig. 2 Environmental setup of server.

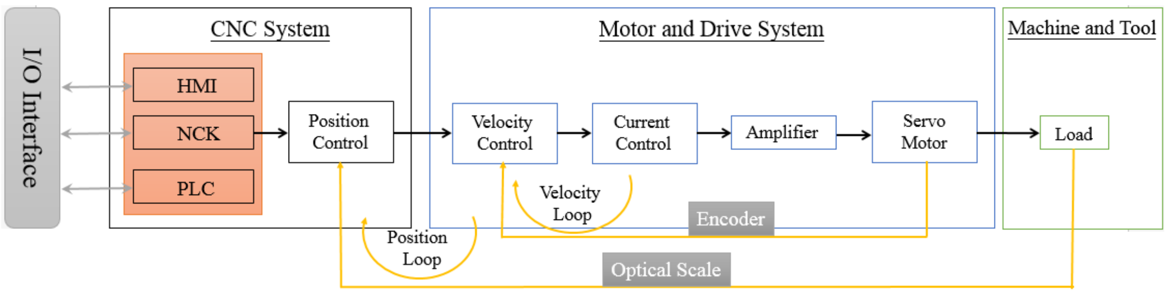

Fig. 3 Block diagram of closed loop control system.

4. COMMUNICATION OF HARDWARE AND SOFTWARE

We employ Ethernet to connect the client with the manufacturing center, so that each device can also communicate with the others through the Internet of things. The software is based on C++ Builder for the development interface, and sent the images which captured by CCD to computer through the USB 2.0. A PC-based controller with the open system is utilized for the communication protocol and function database provided by the industry to design the human machine interface (HMI). In terms of network roles, HMI is like the end user, and the controller is the network server. They connect each other to proceed information communication for two-way. The TCP/IP protocol can obtain the correct communication data and the files can transfer completely by standard FTP. The diagram of communication for the hardware and software is shown in Fig. 4.

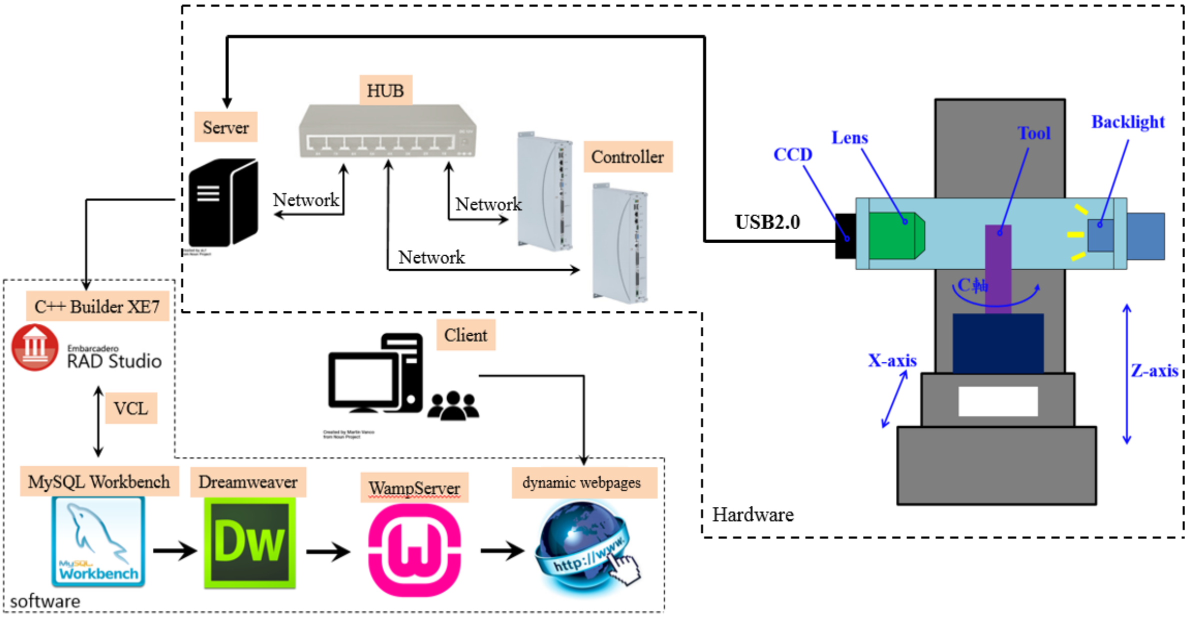

Fig. 4 Communication between hardware and software.

5. DEVELOPMENT OF THE INSPECTION SOFTWARE

The designed HMI is a graphical interface and displays the specific operation of the steps which have the distance measurement, angle measurement, database establishments of machining machine and tool offset, report export, output of the tool correction code, server data access and connection with the controller for tool correction and other functions. The required functions of the HMI are verified by the experiments and Fig. 5 is the main page for the measuring system. In this paper, the measuring mode of the tool inspection system transforms the pixel into the mechanical coordinates to calculate the geometry dimension of end mills. The program operations have the tool length measurement, diameter measurement, and other algorithms for image functions. We use the image superposition, least square method, and Sobel operator for the image processing.

Fig. 5 Main measuring page of HMI.

5.1 Tool length measurement

The first step is to input the tool length parameters in the measurement mode and find the flange position of the tool holder in the image window. Then the Z-axis moves to the tool point position to start the automatic measurement after reset the coordinate to zero of this axis. The tool length measurement records edge points by using Sobel operator in the ROI range and finds a nearest pixel coordinate distance from the origin point among these points. The algorithm converts the pixel into the mechanical coordinates and adds the gap value to obtain the tool length. Fig. 6 and Table 1 show the flow chart and measuring results of the tool length, respectively.

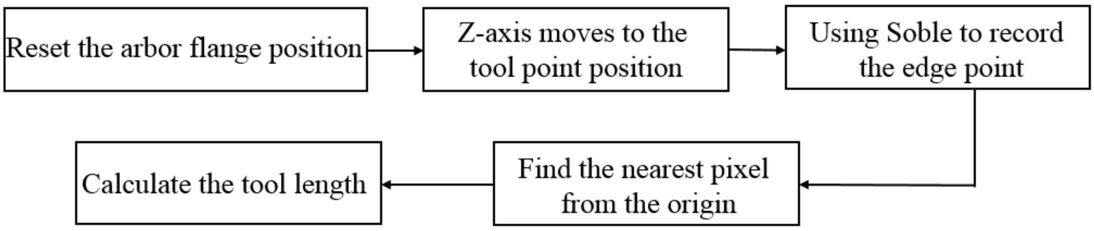

Fig. 6 Flow chart of tool length measurement.

Table 1 Measuring results of tool length of a square end mill.

No.	Measuring results by Zoller: Measurement value (mm)	Measuring results by Zoller: Average value (mm)	Measuring results by Zoller: Standard deviation	Measuring results of proposed system: Measurement value(mm)	Measuring results of proposed system: Average value (mm)	Measuring results of proposed system: Standard deviation	Percentage of error (%)
1	129.326	129.329	0.0028	129.329	129.324	0.005	0.004
2	129.336			129.324			
3	129.331			129.324			
4	129.329			129.328			
5	129.331			129.323			
6	129.326			129.329			
7	129.327			129.321			
8	129.327			129.317			
9	129.329			129.319			
10	129.329			129.324			

5.2 Tool diameter measurement

Firstly, the superposition method is employed on the left edge of the image for the diameter measurement. Then the algorithm searches the edge pixel along the horizontal direction within the ROI range, and converts the pixel coordinates into the mechanical coordinates. Calculating the distance between the mechanical coordinate of the edge point and the rotation shaft is the radius of the tool. Fig. 7 and Table 2 show the flow chart and measuring results of the tool diameter, respectively.

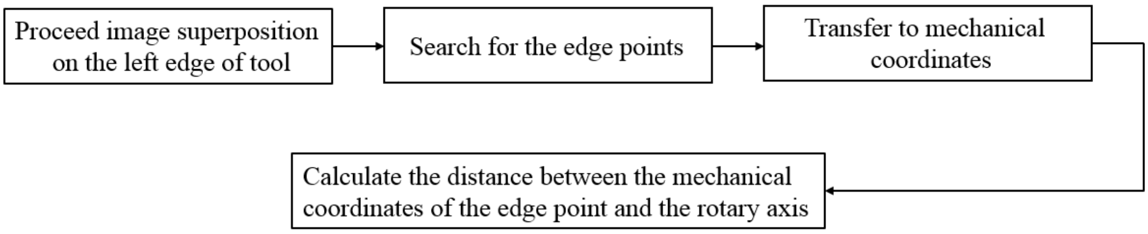

Fig. 7 Flow chart of tool diameter measurement.

Table 2 Measuring results of tool diameter.

No.	Measuring results by Zoller			Measuring results of proposed system			Percentage of error (%)
	Measurement value (mm)	Average value (mm)	Standard deviation	Measurement value (mm)	Average value (mm)	Standard deviation	
1	5.967	5.9665	0.0006	5.967	5.9667	0.0004	0.003
2	5.967			5.966			
3	5.966			5.966			
4	5.968			5.967			
5	5.966			5.966			
6	5.966			5.967			
7	5.966			5.967			
8	5.966			5.967			
9	5.967			5.967			
10	5.966			5.967			

6. CONCLUSIONS

The core of industrial 4.0 is the applications of Internet of things, intelligent equipment setup, big data analysis, and improvement of factory production processes, etc. To increase production flexibility and reduce significantly production costs and idle time of machines, enterprises must rely on the smart machinery and factory to implement the production model of industrial 4.0. However, the proposed tool presetter uses the off-line measurement to reduce the preparation time of processing and links to multiple processing machines in the manufacturing center. The designed instrument can carry out data collection, analysis, transmission with CNC machines by networking architecture, and then to be an intelligent equipment. Therefore, the tool presetter plays an important role in the smart factory and it can be designed to control the tool flow, consumption statistics, inventory, and cost. Moreover, compared with Zoller, the proposed inspection system has good accuracy for measuring the tool length and diameter of a square end mill.

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