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Development of sensing interface for preventive maintenance of machine tools

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Abstract

Machine tools are usually used over a long period of more than 10 years, so providing appropriate services are significantly important. Machine tool manufacturers, who develop their businesses worldwide, locate their service bases and parts centers across the world to improve their service quality and provide prompt services to customers. Moreover, if necessary maintenance work is identified before machine tools break down, machine tool manufacturers can make plans to provide systematic services, and users can prevent machine stoppage. This paper describes the development of the sensing interface and the technology to analyze the operating status of machines to implement preventive maintenance.

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Keywords: machine tool; preventive maintenance; sensor

1. Introduction

Machine tools are usually used over a long period of more than 10 years, so providing appropriate services are significantly important. Machine tools, known as complicated, high-accuracy machines, are usually composed of thousands of parts, and machine tool manufacturers must have service parts, even for discontinued machines, in stock over a long period of time. In case a machine breaks down at a customer's factory, a service engineer from the manufacturer must visit the customer to repair the machine as promptly as possible. Furthermore, as already mentioned, machine tools have complicated structures, so service engineers are required to have advanced knowledge of machines and electricity. Even if service engineers are qualified, identifying the cause of a problem and completely repairing the machine may take as long as several days. As a solution, preventive maintenance and predictive maintenance are considered to be effective; that is, maintenance is to be performed before a machine breaks down. As a sample of preventive maintenance, the operating time of the machine and the number of operations may be counted in the controller, and when the predetermined life span is reached, a warning message is displayed on the screen, instructing the operator to inspect the machine or replace some parts.

As more complicated example, if sensors for vibration, temperature, electrical power, oil level, and pressure are mounted on the machine, and signs of machine break down are detected, maintenance can be performed more accurately. Sensing technology is one of the most important functions related to IoT, Industry 4.0, and the Industrial Internet Consortium (IIC), which have received a great deal of attention in recent years Recently, many sensors have been effectively used in various fields, such as consumer appliances, health care, transportation, businesses, etc. Numerous sensors working together have made previously inconceivable functions a reality. Consequently, the production volume of sensors has increased, while production cost per unit has decreased.

Currently, linear and rotary scales for feed axes and rotary encoders for servo motors are probably the most important technologies for machine tools. These sensors a have greatly improved the accuracy of machine tools. For high-precision machine tools, absolute high-resolution rotary encoders are used to detect servo motor positions, and linear scales with resolution at the nm or pm level are used to further improve

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positioning accuracy of feed axes [1.2]. Both significantly contribute to improving positioning accuracy of feed axes. For rotary axes, direct drive motors and high-accuracy rotary encoders are employed to achieve high-speed, high-accuracy positioning [3]. High-accuracy touch sensors and non-contact sensors are used for measurement of work pieces and cutting tools in machine tools [4, 5].

Temperature sensors are installed in order to compensate for thermal deformation of machine tools [6].

These sensors are connected with the existing interface of CNC and PLC, which makes it easy for manufacturers to utilize them. According to the 2013 TSensors Summit, the volume in the mobile sensor market grew exponentially, exceeding annual increases of 200% between 2007 and 2012.

Visionary organizations foresee the growth in sensor demand growing from the billions of 2012 to trillions within the next decade [7] (Fig.1). Moreover, machine tool manufactures can utilize these sensors with reasonable cost.

Sensing data will be gathered for applications seeking to improve machining accuracy, shorten machining time, lower energy consumption, and reduce downtime through preventative, predictive, and remote maintenance [8, 9].

These sensing data applications must be supported by information technology, such as Artificial Intelligence (AI)

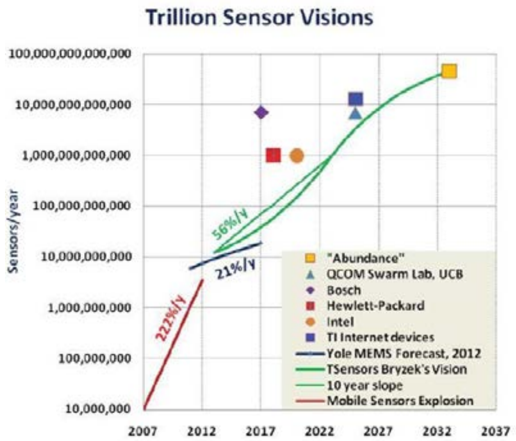

Fig. 1 Trillion sensor visions

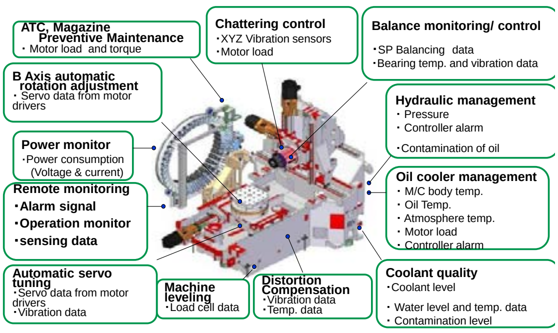

Fig. 2 Sensing application examples

Fig. 2 shows potential sensing applications. Sensing data is collected through the sensing network and monitored on operation screens. While some applications are already developed, others are still being refined. To further improve sensing applications, a huge volume of data from even more sensors is required.

Machine tool input-output (I/O) signal lines are usually connected to the Programmable Logic Controller (PLC). I/O signals are mostly digital binary at DC24V. Analogue signals can be received by the PLC, but a generic PLC is not suitable to receive high-speed analogue signals in sensing technology studies. The sampling rate required for acceleration sensors exceeds several kHz, which is several times the chatter vibration frequency. Since generic PLC control cycles commonly perform only in the millisecond range, we developed a platform that allows machine tool manufacturers to utilize sensor data without PLC or NC unit limitations. Therefore, this paper studies the implementation of sensors.

2. System design

The backbone of the sensing network was structured with 100BASE-TX Ethernet. Because sensors cannot be connected to the Ethernet directly, four types of interface boards for sensor signal inputs and Ethernet outputs were developed, as shown in Fig. 3[10].

The Data Acquisition FFT Board (DAQF) is designed to install at the spindle unit. Three acceleration sensors and two temperature sensors can be interfaced with this board. Each acceleration sensor, which is installed near the spindle bearings, detects vibration in the X, Y and Z directions, respectively. The installed locations of the spindle acceleration sensors are shown in Fig. 4. These sensors are used to detect chatter vibration, failure of the spindle bearings, and spindle collisions. Vibration frequency and amplitude are calculated by the analysis system and output to the machine controller via LAN. These results are utilized in applications to avoid chatter vibration and to detect failure of the spindle bearings. When the amplitude of the acceleration sensor exceeds a threshold level, the system determines that a spindle collision is occurring, and then the collision detection signal is output to the PLC high speed I/O. Two temperature sensors are installed in order to compensate spindle thermal deformation. The system structure is shown in Fig. 5.

The Data Acquisition Temperature Board (DAQT) is a general A/D converter board with a voltage input terminal and a thermistor interface. This system is developed to measure multipoint signals, such as temperature, and is designed to be interfaced with eight temperature sensors and three more general analogue sensors, such as liner sensors for chuck stroke detection. The Electrical Power Monitor Board (EPM) is connected to electrical current sensors and voltage sensors, which are placed at the three-phase power supply. Aside from calculating electrical power consumption, this function monitors power supply quality. The EPM monitors not only power consumption, but also diagnostic data from the oil cooler unit and hydraulic unit via the RS422 interface. It can also be interfaced with the newly developed coolant level sensor.