Design and Implementation of Intelligent Monitoring System for Brake Shearing Machine

To cite this article: Yong Wang et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 472 012014

View the article online for updates and enhancements.
Design and Implementation of Intelligent Monitoring System for Brake Shearing Machine

Yong Wang1,a, Jiamin Zhu2,b,*, Sheng Chen3,c, Jun Yu4,d and Dabing Chen5,e

1,2,3 School of Mechanical Engineering, HeFei University of Technology, HeFei, 230009,China
4,5MaAnshan ZhongYa Machine Tools Manufacturing Co. Ltd., MaAnshan, 243131, China
E-mail: ¹ywang9868@163.com, ²1192457501@qq.com, ³1905058587@qq.com, ⁴631686773@qq.com, ⁵249471281@qq.com

Abstract. In order to obtain the working state of the brake shearing machine, the paper proposed a monitoring system designed for the key data of the shearing machine such as the throat deformation, the temperature of the shearing cylinder and the vibration of the upper tool holder. The selection and connection of the hardware and the method of setting up the wired and wireless networks of the monitoring system are specified first in this paper. Then the methods of data acquisition and processing are put forward. Finally the functions of the host computer and the cloud server as well as the structure of the software are illustrated in detail. The monitoring system is suitable for the production line which contains many sheet metal machine tools, and it is of reference significance to establish a larger range of machine tool monitoring system.

1. Introduction
As the basic industrial equipment of sheet metal industry, shearing machines are widely used in many fields. The intelligent monitoring system of them will be an important part of the future sheet metal intelligent factory. But at present, there are few theoretical researches or engineering applications in this field [1].This paper presents a monitoring system which can collect, store and transmit the key data during the operation of the brake shearing machines, so that the intelligence degree of the traditional brake shearing machines can be improved. On the one hand, by analyzing the monitoring data, the shearing machine manufacturing enterprises can obtain the first-hand operating parameters so that they can make the machine tools more responsive to customer needs, on the other hand, machine tool production and application enterprises can better understand the use of equipment through the monitoring system, and more effectively supervise the equipment.

2. The Monitoring System Overall Design
The monitoring system is mainly composed of three modules: the data acquisition module, the cloud storage and management module, and the information display and processing module. The data acquisition module mainly relies on the sensors of temperature, acceleration, strain, etc., to obtain the operating status information of the brake shearing machines via wired or wireless networks. The cloud storage and management module uses the internet to send information collected by sensors to cloud servers for classification and storage, and thereafter for data sharing. The information display and processing module mainly relies on the on-site client software and cloud server software of the brake shearing machines. Figure.1 shows the architecture design of the monitoring system.
The monitoring system uses Wireless Sensor Network (WSN) to achieve sensor data acquisition and transmission. The mating hardware includes sensors, gateways, and controllers, etc. WSN is composed of spatially distributed routers and terminal nodes. A typical WSN system consists of routers, terminal nodes, and gateways. The distributed measurement nodes communicate with the central gateway wirelessly. The central gateway is responsible for the node authentication, message buffering, and network coordination from the IEEE 802.15.4 wireless network to the wired ethernet bridge. In this way, the measurement data collected by the sensors can be collected, processed, analyzed and displayed via the WSN network, as shown in figure 2.

**Figure 1.** Architecture design of the monitoring system

**Figure 2.** WSN network monitoring system
The WSN measurement nodes [2] can be configured as terminal nodes or routers using the NI Measurement & Automation Explorer tool. In the both configurations, nodes can collect measurement data from sensors, control their DIO channels, or program through the LabVIEW WSN for some more advanced functionality. To reduce power consumption, at the most of time, the terminal nodes are in the low-power sleep mode and are only awake when doing sampling and transmitting data and other interior information processing. However, the router nodes must always be awake to relay data from other nodes back to the gateway, extending the distance and reliability of the network.

3. Hardware Selection of the System

3.1. Data Measurement

The throat strain measurement: The Wheatstone bridge has a high reliability and accuracy when measuring micro-resistance and temperature changes [3]. The strain gauge configuration of the half-bridge (type I) takes into account the influence of the wire resistance on the measurement, and can simultaneously measure the axial and bending strains with high sensitivity. Therefore, the Wheatstone half-bridge circuit is used to measure the strain of the gate type plate shearing machine in this paper.

During monitoring the strain on the brake shearing machines, NI WSN-3214 module is used. WSN-3214 module has 4 analog input channels. Each channel can be individually configured corresponding to Wheatstone bridge single arm bridge, half-arm bridge, full bridge circuit settings, and they can be used specifically for strain measurement. Figure 3 shows half bridge connection circuit of WSN-3214 and the strain gauge. The sampling frequency, waveform size, and time interval can be defined according to the actual needs of the monitoring. The WSN-3214 can also be used as a mesh network router to access more nodes or extend network distance. When it is used as a gateway, the WSN-3214 can connect up to 8 terminals or 36 measurement nodes, supporting a 300-meter sight-distance range.

The temperature measurement of the hydraulic system: In order to avoid the high hydraulic cylinder temperature in shearing machines under high load conditions, it is needed to measure the hydraulic cylinder temperature. A platinum resistance temperature detector (RTD) is used for temperature detection in this monitoring system. Taking into account the influence of the wire resistance during measurement, a three-wire connection is used. A thin-film RTD with a nominal temperature resistance of 100 Ω and a TCR value of 3851 is selected to monitor the temperatures of the cylinders at both ends of the upper tool carrier of the brake shearing machine. The NI WSN-3226 module can directly measure platinum RTD with nominal temperature resistance of 100Ω or 1000Ω. Because of the non-strict linear relationship between resistance and temperature, the NI WSN-3226 also incorporates a Callendar-Van Dusen linearization algorithm to fit the curve.

Vibration measurement: in order to avoid forced vibration near the natural frequency when the gate type plate shearing machine works, which will affect the machine service life and processing quality, it is particularly important to monitor the vibration of the gate type plate shearing machine [4]. When the shearing machines are in operation, the blade fixed on the tool carrier is sheared in the Z-axis direction. The vibration of the tool holder along the X-axis and the Z-axis will affect the straightness and parallelism of the cut plate, so it needs to consider the vibration detection in X and Z directions of the tool carrier.

When monitoring the vibration of the tool carrier along the two axial directions, NI C Series 9304 module and a 780985-01 industrial accelerometer with BNC terminals are used. The NI 9234 module has 4 channels for high-speed, high-accuracy acquisition of dynamic signals, which are suitable for IEPE sensors [5]. The dynamic measurement range of the NI 9234 module is 102dB, and a 2 mA constant current IEPE signal conditioning circuit is built in, which can be used for accelerometer and microphone data acquisition. The 4 channels can achieve an acquisition speed up to 51.2 kS/s, and the built-in anti-aliasing filter automatically adjusts the sampling rate. It is compatible with single-module USB box, NI CompactDAQ, and NI CompactRIO hardware and is ideal for the detection of vibration and noise. Shown in figure 4 is the grounding connection circuit of NI9234.
Figure 3. WSN-3214 Half-bridge circuit

Figure 4. Grounding connection circuit of NI9234

3.2. Gateway and Controllers

The combination of wireless and wired sensor detection network constitutes the hardware system for data acquisition of the entire monitoring system. The WSN system also needs to configure the gateway and controller, and the controller module should be compatible with the NI 9234 module for wired detection. Therefore, the NI-9795 C series wireless gateway and the CompactRIO-based cRIO-9039 controller module are selected.

The NI 9795 wireless gateway and the NI WSN-32xx node are combined to form a wireless sensor network that can communicate with up to 36 wireless sensor network nodes. The CompactRIO-based cRIO-9039 controller module combines an open embedded architecture. It is with small size, ruggedness and includes custom timing, triggering, FPGA processing and modular I/O ports.

3.3. Hardware Architecture and Configuration

The monitoring system can be used for a lot of different sheet metal processing equipment to achieve the distributed monitoring of machine tools; meanwhile it is available for multi-state data acquisition by adding multiple types of sensors.

Figure 5 shows the overall hardware architecture configuration, including the accelerometer, strain gauge, three RTD sensors, and the corresponding three detection data acquisition modules: NI-9234, WSN-3214, and WSN-3226. The two main wireless acquisition nodes communicate with the NI-9795
wireless gateway to form a wireless detection network. The NI-9234 high-speed dynamic acquisition separately constitutes a wired detection network and is inserted into the Crio-9039 controller together with the wireless gateway NI-9795. The controller communicates with the host computer to collect commands and send and receive data.

The sensor installation position is shown in figure 6. When measuring the dynamic strain of the throat, the strain rosette arrangement is adopted for each side wall plate, and multi-channel data can be acquired; the middle part of the upper tool carrier is subjected to relatively great stress and deformation during the shearing process, so the accelerometer is arranged on the middle position of the upper tool carrier; The temperature sensors are arranged on the both sides of the shear cylinders.

**Figure 5. Hardware architecture**

**Figure 6. Sensor installation position**

4. Data Transmission and Management

4.1. Acquisition of Sensor Signals

When the signal is collected, the working status of the sensor is detected by the host computer or the control system, the operating time of the brake shearing machine is obtained, and the sensor signal is collected through the short distance wireless and wired methods. For the wired method, it is directly connected to the controller. The signal processing module in the controller processes the sensor signal and then connects the CDAQ or the computer. The computer or the CDAQ transmits the data to the
Taking into account the stability of data transmission, transmission distance and multi-sensor information collection, the short-range wireless data transmission ZigBee has advantages like long transmission distance, low power consumption and high reliability. Therefore, it is more appropriate for the establishment of wireless sensor networks. ZigBee supports mesh network topology, so it has greater network flexibility and can route packets from the terminal nodes to the gateway through the shortest path. The gateway can be connected to DAQ (Data Acquisition Equipment) or computer equipment via Ethernet, USB, and serial ports.

4.2. Data Processing on the Server

4.2.1. Data transmission. The information collected by the sensors is transmitted through the domain server, that is, the users of the brake shearing machines local area network server. And the VPN (virtual private) network is constructed by the same structure, which is used to assess the information of the work status of the gate type plate shearing machine issued in the company's local area network. The real-time monitoring and downloading of the shearing machine operating status parameters could be realized, which is shown in Figure 7.

![Figure 7. VPN application topology](image)

The required configuration of the domain server itself is very low, and the occupation of network bandwidth is also insignificant. Under normal circumstances, the domain controller will not be deployed to the external network because it is related to the security of the entire domain organization. If the user wishes to log in to the enterprise domain on the external network, it needs to set the gateway VPN function, which not only can guarantee the security of account password transmission, but also as easy access to network resources as the LAN.

4.2.2. WEB remote publishing. Remote monitoring generally includes B/S (Brower/Server) and C/S (Client/Server) modes. In C/S mode, each client has full authority to operate the server database, the server responds at the same time, which is easy to cause server lack of resource. Its system security is poor, and performance is low. The B/S mode conforms to the TCP/IP conventions. In the modern WEB-centric enterprise network, HTTP is used as the transmission protocol. In this mode, the client accesses the web server and the background database through the browser. The client only needs to install the corresponding browser. The server installs the WEB server software. The client sends a data upload request to the server through the browser. After the server responds, it can complete the indirect access to the server database.
The intelligent monitoring system based on the gate type plate shearing machine needs to integrate the operation data of company’s multiple shearing machines to realize remote monitoring. Therefore, the WEB release function of this system selects the remote monitoring method based on B/S mode.

5. Software Function
Combine the functions should be realized in this system with the functions required by software. The functions of the monitoring system software are determined as follows:

1. Display the working status of the server, including IP address, port number, working mode and so on.
2. The receiving status of data can be controlled and the relevant parameters can be modified artificially.
3. Display wireless network module login, including module ID, phone number, current dynamic IP, and so on.
4. Remote monitoring center and work data can be updated in time to ensure data consistency.
5. Display the operation state of the brake shears, record abnormal data and give an alarm.
6. The data can be stored reliably in the corresponding tables of the server database, and the historical data can be queried as needed.

6. Software Architecture
According to the software system requirements, the intelligent monitoring system based on brake shearing machine is divided into three subsystems: data collection, information management and on-line state monitoring.

Shown in figure 8 is the work flow chart of the intelligent monitoring software system of the CNC brake Shearing machine. The data collection system will store the data of stress, temperature and vibration acquiring from the sensor in the local disk and send it to the remote cloud server according to the agreed transport protocol.

The on-line condition monitoring system is the core of the software. The system uses graph to process the data of the sensor and displays the working state of the gate shearing machine used by field worker or remote worker.

Information management system is the core of the whole system, with functions of manage information of the machine tool model, enterprise name, machine tool operation status, sensor installation. It is the link between the users and online status monitoring system.

Shown in figure 9 is the user interface of Online Status Monitoring System designed in this paper.

![Figure 8. Work flow chart of software system](image-url)
7. Conclusion
Aiming at the phenomenon of low intelligence of traditional brake shearing machine, this paper designs an intelligent monitoring system for the on-line monitoring of the throat deformation, shearing cylinder temperature and vibration of the upper tool holder, expounds the collection method of the key data and the transmission and processing method of the system data. The function and system software architecture of host computer and cloud server are expounded. The monitoring system is suitable for the production line which contains many sheet metal machine tools, and it is of reference significance to establish a larger range of machine tool monitoring system.

Acknowledgement
This research was financially supported by the Anhui Provincial Major Research and Development Project < JZ2017AKKZ0987>, Anhui Provincial Digital Design and Manufacturing Key Laboratory Performance Subsidy Project < JZ2016AKSY1100>.

References
[1] ZHAO Fei, MEI Xuesong, LI Guangdong, TAO Tao, JIANG Gedong. Machining Error Online Monitoring and Compensation of Numerical Control Forming GearGrinding Machine [J]. Journal of Mechanical Engineering, 2013, 49(1): 171-177.
[2] JIN Min, LUO Enze, ZHOU Xiang. Wireless Communication Protocol for Remote Intelligent Monitoring of Construction Machinery [J].China Mechanical Engineering, 2011, 22(19): 2316-2324.
[3] H Jiang, JG Vogel, S Nihtianov. A Power-Efficient Readout for Wheatstone-Bridge Sensors with COTS Components [J].IEEE Sensors Journal, 2017, PP (99):1-1.
[4] ZHU Shaowei, Li Weidong, Tang Liming, Du Li.ARTIS Tool Monitoring System Using in Milling of Aerospace Structural Components[J]. China Mechanical Engineering, 2016, 27(15): 2040-2043.
[5] YANG Zhe, CAO Lifang, WANG Yutian, HOU Peiguo, LI Hongjin, CHENG Pengfei, Pan Zhao. Analysis of Circuit Noise in Integral Electronics Piezoelectric Accelerometer [J]. Journal of Vibration, Measurement & Diagnosis, 2016, 36(05): 948-953+1026-1027.
[6] ZHANG Qiang, WANG HaiJian, LI liYing, LIU Zhiheng. Online Monitoring of Shearer’s Pick Wear Based on ANFIS Fuzzy Information Fusion [J]. Chinese Journal of Scientific Instrument, 2016, 27(19): 2607-2614.