### Research Article
# Remote Monitoring System for Machinery-electric-hydraulic Coupling Vibration of Food Processing Rolling Mill Screw-down System

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**Abstract:** Machinery-electric-hydraulic coupling vibration seriously affects the control accuracy of the food processing rolling mill. In this study, a remote vibration sensor monitoring method based on network technology is put forward. By using Siemens PLC, the state monitoring device is designed to realize the parameters measurement, such as vibration, current, pressure, force and temperature, etc. Then the parameter information is transferred to the configuration software system through the ethernet interface. The research result shows that the network-based remote sensor monitoring system of machinery-electric-hydraulic coupling vibration plays a key role in ensuring the normal work for food processing rolling mill screw-down system.

**Keywords:** Configuration software, food processing rolling mill, machinery-electric-hydraulic coupling, sensor monitoring

## INTRODUCTION

There is an increasing requirement of improving the operation quality of food processing rolling mill due to the severe operation condition which is characterized by high speed, high pressure and high precision. For the food processing rolling mill, the hydraulic screw-down system, which is a combination of precision machine, hydraulic pressure, electricity and electron, is a necessity in the process of rolling sheet, strip and foil. According to the force analysis of the food processing rolling mill screw-down system, the load is transferred in vertical direction, that is, rolling force is the main stress of food processing rolling mills. Frame, screw-down oil cylinder, roller and bearing chock are the main effective objects. Vibration is not caused by external excitation force, but a periodic vibration excited by the alternating force generated by the system itself. The vibration frequency is close to the natural frequency of the device. In the initial stage, the vibration intensity of food processing rolling mill screw-down system may be weak, but with the production process, appearance frequency of broken parts will gradually increase, which mainly due to the exceeded amplitude with a certain period of time. Intense self-excited vibration may also lead to sudden rupture of components and large system noise, even major damage. For machinery-electric-hydraulic coupling vibration system, off-line diagnostics is an effective way to analyze and solve the vibration problem. However, besides the existence of the lag, off-line diagnosis and analysis is still imperfect, significant damage may have occurred before the

system diagnostics. By using the technologies of computer, network, sensor, fault diagnosis and signal processing, vibration fault identification and pre-warning system based on the parameter state characteristic is designed. Focused on these problems, thorough researches have been conducted and a series of achievements have been achieved (Brusa *et al.*, 2010). In Bin *et al.* (2010), a numerical simulator developed in the Matlab/Simulink environment was used for sendzimir cold food processing rolling mill to distinguish the effects of chattering, rolls unbalance, motor dynamic irregularities and bearing fault. In Dongxiao *et al.* (2014) the nonlinear dynamics equation of coupled electromechanical drive system of food processing rolling mill was established with nonlinear friction drag based on Lagrange-Maxwell theory, which was used for characteristics analysis of complex electromechanical coupling in the main drive system. In Youngdeuk *et al.* (2012a), periodic, period-doubling, chaotic motion and a series of complex movements of the food processing rolling mill were produced with the changes of the external disturbance force and an effective theory reference for the research of inhibition of food processing rolling mill vibration problem was provided. In Youngdeuk *et al.* (2012b) and Xiao-qiang *et al.* (2014), a mathematical model of a cold food processing rolling mill including the driving system is proposed, the model is reliable enough to be compatible with experimental and theoretical analysis. In Haoran *et al.* (2011), a computer simulation analysis was presented by an ANSYS finite element harmonic response analysis module and the conclusion was

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obtained that the tensional vibration and axial vibration will cause the phenomenon of coupling vibration under certain conditions. In Maria and Susanna (2013), a kind of hysteretic nonlinear vertical vibration dynamic model which considers hysteresis of strip's plastic deformation was established. In Skripalenko *et al.* (2011), chatter in food processing rolling mills was the undesirable vibration observed in most of the food processing rolling mills operating at high speed and rolling thin strip. Three basic types of chatter can be classified in food processing rolling mills: torsional, third-octave mode and fifth-octave-mode chatter.

However, the above researches are mainly based on the off-line diagnosis method, which is unable to determine the working status of food processing rolling mill screw-down system when fault occurs. According to the corresponding vibration fault form of the mechanical structure, electrical parameter and hydraulic fluid characteristics of the food processing rolling mill screw-down system, on-line fault identification and location of machinery-electric-hydraulic coupling vibration can be achieved by real-time fusion of the three aspects of information. In this study, a vibration fault diagnosis method of food processing rolling mill screw-down system is proposed based on the network technology. Machinery-electric-hydraulic coupling vibration parameters are on-site acquired and displayed. Centralized monitoring is realized by the computer network technology and long-distance data transmission and sharing are realized through WEB publishing technology of the upper computer software. Real-time detection of problems of food processing rolling mill screw-down system is realized and the occurrence of major accidents of equipment is thus reduced.

In this study, the state monitoring device is designed to realize the parameters measurement, such as vibration, current, pressure, force and temperature, etc. Then the parameter information is transferred to the configuration software system through the ethernet interface. The research result shows that the network-based remote sensor monitoring system of machinery-electric-hydraulic coupling vibration plays a key role in ensuring the normal work for food processing rolling mill screw-down system.

## GENERAL SCHEME OF THE MONITORING SYSTEM AND SENSOR TYPE SELECTION

In this study, vibration parameters characteristic, including vibration, pressure, force, servo valve current, of six frames of the cold food processing rolling mill screw-down systems (F1 Unit~F6 Unit) were 24 h-online monitored. The monitoring parameters are shown in Table 1.

General scheme of the network monitoring system is shown in Fig. 1. Pre-acquisition and processing

Table 1: Monitoring parameters

| Measuring point | Sensor name | Number |
|---|---|---|
| Crossbeam | Accelerometer | 12 |
| Sensor shell | Accelerometer | 6 |
| Bearing chock | Accelerometer | 12 |
| valve station | Accelerometer | 6 |
| Indenter | Force sensor | 6 |
| Oil pressure | Pressure sensor | 12 |
| Servo valve | Displacement sensor | 12 |
| Controller output | Current sensor | 6 |
| Oil temperature | Temperature sensor | 6 |

station is designed by using SIEMENS S7-200CPU226PLC. Analog acquisition module (EM235) and the ethernet module (CP243-1) are expanded. System monitoring parameters including vertical vibration signal of crossbeam, vertical vibration acceleration signal of the displacement sensor shell, vertical vibration acceleration signal of the bearing chock, vertical vibration acceleration signal of the valve station of the hydraulic system, force signal of the indenter, displacement signal of the servo valve spool and current signal controlled by the servo valve, etc. After the process of signal preprocessing, filtering, the signal is acquired by the analog module EM235 and the parameters are analyzed and processed to extract the signal feature information. Therefore, the running status of equipment is determined. The acquired information is transmitted to the touch screen through the RS485 interface of the programmable controller main module, by which local display and analysis of the parameters are achieved. The modifying, downloading and debugging of the acquisition and control program are obtained through RS485 interface of the controller main module in the debugging computer. The real-time monitoring system is used for real-time data sampling, display and storage, as well as the realization of alarm. Six sets of pre-acquisition and processing stations were configured in the system to realize the measurement of machinery-electric-hydraulic coupling vibration parameters of six frames of the cold food processing rolling mill. Remote data is transmitted to the network interface through the RJ45 interface of the Ethernet module CP243-1. Then, real-time acquisition of vibration parameters is achieved in the monitoring computer through the network interface. Software programming based on WEB publishing technology was adopted in the monitoring computer. Based on local area network, the client/server architecture was adopted in the system, fault diagnosis software of the server was installed. Remote monitoring was realized by the remote WEB monitoring computer through the network.

**Accelerometer:** Based on the advantages of miniaturization, low cost, high performance, high reliability and anti- shock, KISTLER micro silicon accelerometer 8303A10 was adopted. Capacitive micro silicon accelerometer is mainly composed of the silicon
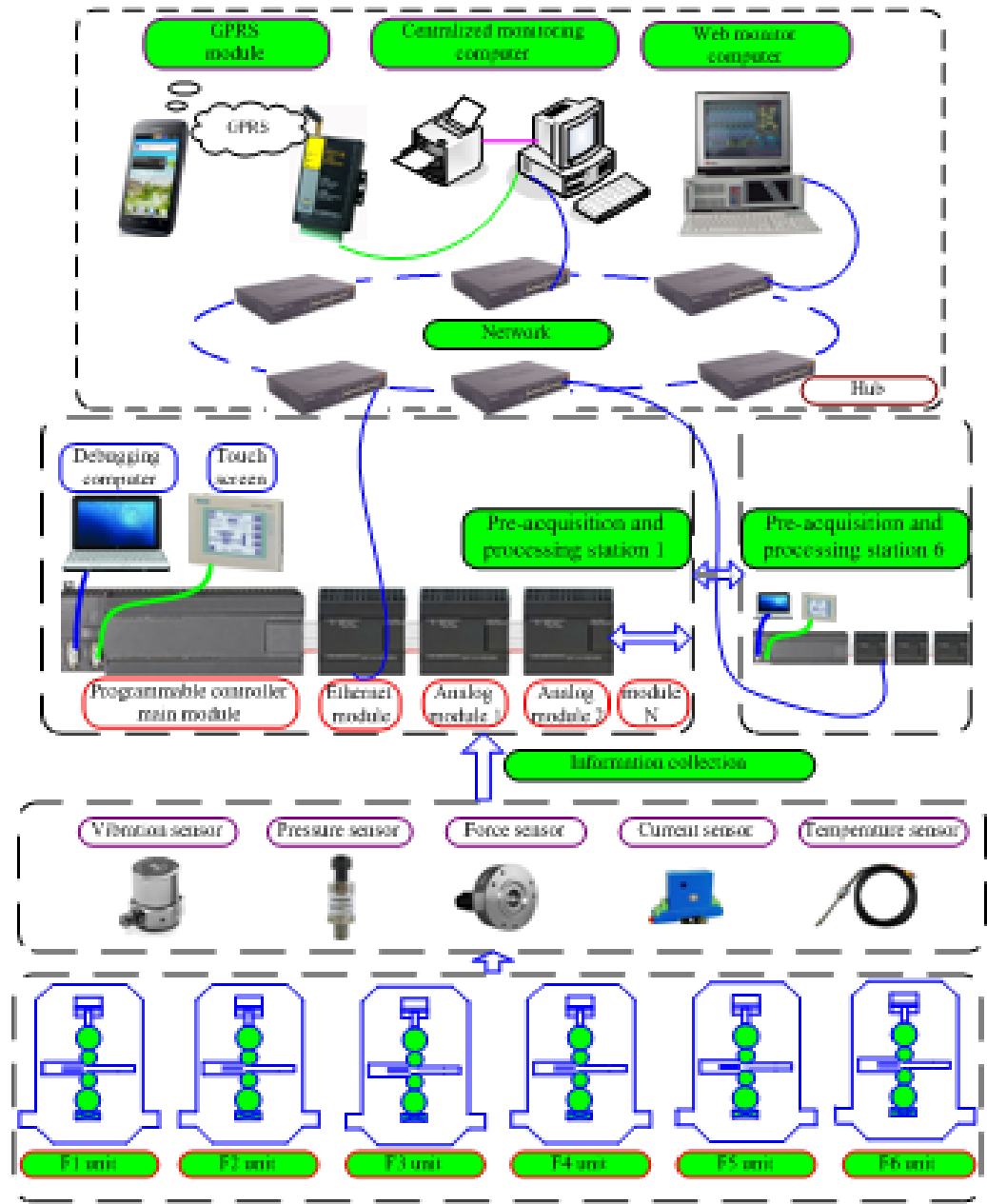
Fig. 1: General scheme of the network monitoring system

pendulous reed and the polar plate. The measurement range of the sensor is ±10 g, with a sensitivity of 100 mV/g and a supply voltage of 9~20 V.

**Pressure sensor:** Honeywell P7620A pressure sensor was adopted. The pressure sensor works by detecting the static and dynamic pressure of the hydraulic oil, with proportional voltage or current signal output. The sensor is composed by an internal resistance bridge circuit, with characteristics of high anti-allergic and anti-peaking. A voltage or current signal proportional to the hydraulic pressure is produced and amplified by the integrated circuit with functions of compensating the

temperature drift. In this study, output current is 4~20 mA and the measurement range is about 0~250 bar.

**Force sensors:** MAGTROL LB234 load measuring bolt was used to measure the load and force, as well as provide overload protection. Ordinary pin is replaced by the measuring bolt with strain gauge, which is directly mounted on the force area and could generate a signal proportional to the measured load. The load measuring bolt consists of two ring grooves and an axis hole. A strain gauge transducer with full bridge configure is installed in the hole near the outer ring groove. When the force is applied on the load bolt
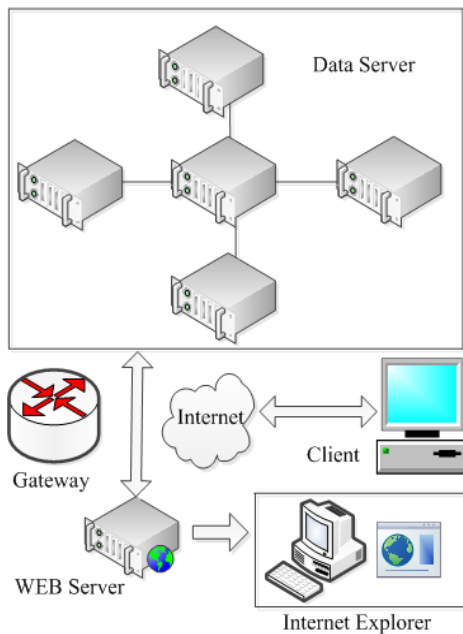
Fig. 2: WEB monioring system

along the measuring axis, an output signal with respect to the force is generated under the effect of the strain gauge. Strain gauge bridge power supply and the output voltage signal are amplified by the external amplifier. The matching Load Monitoring Unit (LMU) is used for measuring the output signal of load-force-weight of the strain gauge sensor, providing the excitation current and amplifying the output of the full bridge measurement.

**Current sensor:** ETCR010D current sensor with weak current detection was used. According to certain rules, the measured current information is detected and converted into an electrical signal or other forms of information which are able to meet certain required standards, thus, the transmission, processing, storage, display of the information are realized. Based on the working principle of the electromagnetic isolation and magnetic modulation of the transformer, the measured DC micro-current is converted into direct current, DC voltage and output isolated standard analog or digital signal.

**Temperature sensor:** According to the thermistor measurement principle, the temperature coefficient of most the thermal resistors with semiconductor material is negative used, that is, the resistance decreases with the temperature increasing. Temperature changes may cause large resistance changes and therefore it is the most sensitive temperature sensor. The volume of the thermistor is very small, but its response to temperature changes is fast. For thermistor, a current source is a need. The small size also makes it extremely sensitive for auto-thermal errors. Small size is the advantage,

which makes it quickly stabilized and not cause heat load. In this study, pt100 temperature sensor was adopted and measuring temperature range is from -200°C to + 200°C.

Monitoring system is an open distributed system (Fig. 2). The subsystem of the data server is used for receiving and processing the data which is send from the pre-acquisition and processing station, as well as the request of the application SQL database. The operator only needs a computer with Internet IE browser client, by which a monitoring interface efficiently synchronized with the KingView configuration software operation system is obtained through the Internet/Intranet. Thus, real-time remote monitoring of food processing rolling mill screw-down system is realized.

## CONCLUSION

Machinery-electric-hydraulic coupling vibration of six frames of cold food processing rolling mill (F1 Unit~F6 Unit) are monitored. The online analytical diagnosis is presented to timely grasp the operating conditions of the mill down system and early detection of abnormalities, which may provide technical basis for the rational design and maintenance.

## ACKNOWLEDGMENT

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