Wireless Condition Monitoring Technology for Intelligent Bearing System Based on Remote Cloud Platform

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Abstract: Ensuring the safe, reliable and trouble-free operation of rolling mill bearings is an important task for equipment maintenance of rolling production line. It is of great engineering significance to monitor the running state of rolling mill bearings by using big data technology. This paper discusses the technical system of bearing health monitoring for rolling mill from four aspects: remote monitoring technology, bearing fault diagnosis technology, wireless sensing technology and remote cloud platform monitoring technology, and discusses its application prospect, providing a basis for its future engineering realization.

Key-Words: Rolling mill bearings; Remote monitoring; Fault diagnosis; Wireless sensing; Remote cloud platform

1 Introduction

The rolling mill is a key equipment in the rolling production line, and the safe operation of the rolling bearings on the rolls restricts the working state of the rolling mill. In our country, 70% of rolling mill bearing failures are failures[1], that is, abnormal failures, and most of them are fracture failures. When the rolling mill is in operation, the whole set of bearings bear a large radial rolling force[2] and are easy to be suddenly damaged during working, this making the rolling mill unable to work

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normally. The reasons of bearing failure can be roughly divided into two aspects: one is internal factors, such as design, manufacturing process and quality of raw materials, the other is external factors, such as installation adjustment, maintenance and repair of bearings during use. In order to ensure the continuous and stable operation of the rolling mill, on-line monitoring of rolling mill bearings is carried out, faults can be found early, and maintenance or replacement measures are taken in advance to avoid major accidents, thus obtaining better economic benefits.

There are mainly two kinds of monitoring status of rolling mill bearings. One is to use embedded monitoring mechanism to monitor online, that is, integrates chips with collection and preliminary analysis functions into the controller and arrange them near the rolling mill on site. This monitoring method will cause related problems. One is that the collection of physical quantities cannot be too limited due to the operation function of the embedded controller, and there will be problems such as insufficient monitoring data. In addition, due to the complex environment on the rolling mill site, the embedded device will inevitably face environmental interference such as oil pollution, which will affect its monitoring accuracy. The other is off-line regular monitoring, with technicians regularly monitoring in different periods. This monitoring method will also cause the problem of insufficient monitoring data.

Firstly, this paper analyzes the status quo of remote monitoring technology of mechanical equipment running status from equipment condition monitoring technology, remote diagnosis center system and multi-thread technology, and then analyzes the status quo of bearing fault diagnosis and early warning technology, wireless sensor technology and remote cloud platform technology. By analyzing and studying the research status of key technologies, this paper provides a basis for solving the problems that may arise when using remote cloud platform to intelligently monitor rolling mill bearings.

2 Remote monitoring technology of mechanical equipment running status

2.1 Equipment Condition Monitoring Technology

Typical mechanical equipment status monitoring methods mainly include offline regular monitoring, online detection offline analysis and online monitoring. With the development of computer and network communication technology, remote online monitoring based on network technology is in the key research and high-speed development stage. Remote monitoring system integrates distributed computer technology, cross-platform connection technology, web technology and signal monitoring technology to form equipment status monitoring technology with multi-level information interaction and resource sharing, which greatly reduces the investment cost and improves the efficiency of enterprise operation. The current development trend in this field is:

1) The state monitoring and diagnosis system is developing into a modern management system. In terms of monitoring methods, replace regular monitoring and itinerant monitoring with real-time online monitoring. There are many monitoring parameters, which gradually include all-round information of enterprise equipment operation. It includes the existing functions of real-time monitoring, state analysis, fault diagnosis and prediction of modern enterprise equipment, and is being expanded to a huge modular program package with the economic management of the whole process of equipment as the technical core, making the state monitoring and diagnosis system one of the indispensable main means in the modern enterprise management system engineering.

2) The state monitoring and diagnosis instrument system is developing towards networking, intelligence and openness. In the structure of monitoring system, distributed monitoring is used instead of centralized monitoring, and networked monitoring system is used instead of microcomputer centralized monitoring system. The network of the monitoring system is a distributed computer network in the topology structure, with a factory or a certain range of units as the object to set up a decentralized data collection station, and the data collected by the data collection station will be sent to a centralized diagnosis center after certain processing. Monitoring system networking is the concrete application of computer network technology in equipment diagnosis technology, and it is also the inevitable trend of the development of contemporary equipment monitoring technology. The further implementation of neural network algorithm and diagnosis expert system makes diagnosis more intelligent.

2.2 Remote Diagnosis Center System

With the development of large-scale and automatic units, the rapid development of computer technology and network communication technology, and the increasing

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safety and economic requirements of unit operation, the establishment of remote diagnosis and analysis center has become an inevitable trend of development. By combining network communication technology, equipment fault diagnosis technology, signal analysis and processing technology, a powerful and comprehensive remote diagnosis center will be established to realize data remote sharing and remote diagnosis so that experts from all over the world can consult online anytime and anywhere, becoming a hot spot in the research of equipment condition monitoring and fault diagnosis system in the near future[3-14]. A typical remote center structure is shown in Fig.1.

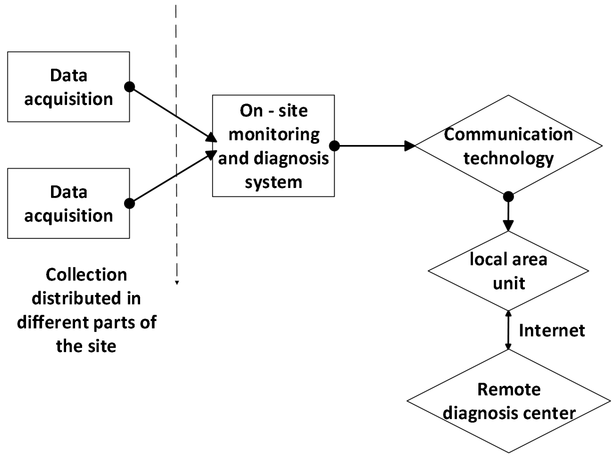

Fig. 1. Typical System of Remote Diagnosis Center.

The so-called distributed computing means that two or more software share information with each other. These software can run on the same computer or on multiple computers connected through the network. Distribution includes data distribution and operation distribution. Distributed computing has the following advantages over other algorithms:

1) Rare resources can be shared;

2) Through distributed computing, the computing load can be balanced on multiple computers;

3) The program can be placed on the computer most suitable for running it.

Among them, sharing rare resources and balancing load is one of the core ideas of computer distributed computing. As a matter of fact, distributed computing is a new type of computing technology developed rapidly with the Internet technology and specialized in complex scientific computing. Network computing is a kind of distributed computing. With the continuous progress of network technology, Web computing running on the Internet has become a new development direction of distributed computing. At the same time, due to the heterogeneous nature of the Internet, transparent access to different software and hardware platforms has become an important issue in Web computing. A large amount of engineering data to be calculated is divided into small blocks and sent by the server to each participant through the client. The participant's computer analyzes the data and automatically uploads the calculation results to the server after completion. The server unites the calculation results to draw a conclusion [15-19].

There are many kinds of distributed application architectures, including multi-layer network architectures, such as two-layer C/S architecture and B/S three-layer architecture. The XML technology is integrated into the distributed computing environment to produce a distributed pattern based on XML. The middleware technology is combined with the distributed application architecture to form a three-tier model based on middleware. Among them, the distributed network architecture based on middleware, i.e. deploying distributed computing environment (middleware) on the network computing platform, providing development tools and public services, supporting distributed applications, realizing resource sharing and collaborative work, is gradually being applied to equipment state monitoring and remote diagnosis systems.

In the development of equipment distributed remote diagnosis application system, there are mainly three distributed middleware technologies: OMG's CORBA (Common Object Request Broker Architecture), Microsoft's Active X/DCOM (Distributed Compound Object Model) and Sun's Java / RMI [20-21].

2.3 Multithreading Technology

The on-site monitoring system is the first link in the entire architecture of the remote diagnosis center. Its stability, reliability and accuracy have a direct and significant impact on the performance of the remote diagnosis center and should have the functions of real-time alarm and simple diagnosis. The on-line or off-line monitoring system can directly adopt Windows operating system and use related programming software to perform data collection, display, storage and other functions. At the same time, the field system should also have the functions of simple calculation and alarm. This requires the application software to realize these functions simultaneously and concurrently. Using Windows multi-task mechanism and multi-thread technology can meet this requirement [22].

Threads are the simplest unit of code execution that can be scheduled by the system, and are the path to program execution within a process. All programs are compiled to generate intermediate code, and the isolation, loading and unloading of these intermediate codes and the provision of security boundaries are implemented through the application domain. At this point, a process can contain one or more application domains, and an application domain can contain one or more threads. This effectively adds a new security boundary between the process and the thread.

No matter within the same process or between different processes, each application domain is independent of each other, and the delivery of messages and objects can only be achieved through remote communication between these different application domains [23-24].

3 Bearing fault diagnosis and early warning technology

Fault diagnosis of rolling bearings includes identification, judgment and prediction of the running state of bearing equipment [25]. It is necessary to make full use of the data collector/analyzer to analyze and deal with the state characteristics of rolling bearings under motion conditions, and to make fault diagnosis analysis under expert system analysis according to the characteristic information parameters provided by the fault detector, including the analysis of the fault or failure mechanism of rolling bearing equipment and its components [26-27].

In general, the running state of the bearing can be preliminarily judged by analyzing the time-domain waveform of the fault signal. The time-domain statistical analysis of the signal is mainly to realize the preliminary fault diagnosis by selecting appropriate time-domain parameters and indicators. The common time domain statistical parameters or indicators are mainly divided into two categories: statistical parameters with and without parameters. Among them, the statistical parameters with key parameters mainly include: the mean value reflecting the average vibration trend of the signal, the mean square deviation reflecting the dispersion degree of the signal, the minimum value reflecting the maximum value of the dynamic range of the signal, and so on. However, kurtosis, margin, peak value and so on are the main statistical indicators of dimensionless quantities [28-29]. For example, bearing faults can be classified by combining mean square deviation with neural network [30].

The frequency domain analysis of signals is another main method of fault diagnosis technology, and the most typical one is vibration monitoring and diagnosis method based on frequency spectrum analysis, which mainly reflects the type and degree of fault by using the changes of amplitude, frequency characteristics and vibration response of vibration signals to discover hidden fault sources in time and provide more sufficient and scientific analysis basis for fault diagnosis. Among the frequency domain analysis methods of fault signals, Fourier analysis and the corresponding fast Fourier transform algorithm (FFT) were widely used earlier. Fourier Transform (FT) is the core of Fourier analysis. It is mainly through transforming the time domain signal into the frequency domain to achieve the purpose of analyzing and studying the frequency spectrum and transformation law of the signal in the frequency domain. For example, in 2006, Cui Bowen and Ren Zhang proposed an inverter fault detection and diagnosis method based on Fourier transform and neural network, which realized the positioning of the inverter fault bridge arm and the separation of fault components [31]. In the same year, an improved fast Fourier transform algorithm was proposed by Jiang Gang and Xiao Jian. Its main approach is to make the structure of each stage of the operation basically consistent by changing the structure of butterfly operation, thus reducing the access and addressing time of intermediate data, simplifying the calculation process, and finally significantly improving the operation efficiency [32]. However, Fourier analysis method is only suitable for analyzing continuous and stable time domain signals. However, when the bearing fails, the corresponding vibration signal is generally not stable and continuous, and the related fault characteristic signal is generally in the lower frequency band, easily submerged by noise and difficult to detect, so the traditional Fourier analysis method can not effectively extract the fault characteristic of the bearing. In 1946, an algorithm to study the local time-frequency characteristics of signals was proposed. It mainly added a sliding time window on the basis of Fourier transform, known as Gabor transform, and then gradually developed short-time Fourier transform (STFT), also known as windowed Fourier transform [33]. For example, a variable window short-time Fourier transform is applied to time-frequency analysis for fault diagnosis of rotating machinery, and a higher time-frequency resolution is obtained [34]. In 2012, Tang Xian Guang and others proposed a rolling bearing envelope analysis method based on independent component analysis based on short-time Fourier transform. This method first analyzes the vibration signal with STFT energy spectrum, filters and extracts the envelope waveform, and finally performs fault diagnosis by comparing the envelope spectrum of each independent component with the theoretical fault frequency of the rolling bearing [35]. However, the shortcoming of short-time Fourier transform is that its window function is fixed and it is not easy to analyze time-varying signals. When the time domain resolution is good, the frequency domain resolution is poor, and when the resolution is lifted off the frequency domain resolution, the time domain resolution will decrease.

Unlike Fourier transform and short-time Fourier transform, wavelet transform can analyze signals in detail, mainly because wavelet transform can perform local transformation on the two-dimensional scale of time and frequency as needed and has flexible operation functions such as translation and expansion [36]. Therefore, more and more fault diagnosis systems begin to adopt the method of combining wavelet analysis to deal with non-stationary rotating machinery fault signals. For example, in 2014, ru Qiang Yan et al. comprehensively introduced and analyzed the application methods of wavelet in the field of mechanical fault diagnosis [37]. Ming j zuo et al. performed continuous wavelet transform on the signal when only one sensor collected the signal, then generated a series of corresponding wavelet coefficients at different time scales, and finally applied these wavelet coefficients to gear fault diagnosis [38]. Kumar et al. selected sym let wavelet as wavelet function to transform bearing vibration signal into dwt to detect bearing outer ring fault width [39]. Cheng Junsheng et al [40] proposed a new method for fault diagnosis of rolling bearings. Firstly, a pulse response wavelet for the fault characteristics of rolling bearings was constructed, and then the fault characteristic frequency of bearings was extracted by combining the continuous wavelet transform method. Finally, an energy spectrum autocorrelation analysis method was proposed on this basis.

Ruqianganyan, Roberts. Gao et al [41] proposed an effective mechanical fault diagnosis method based on harmonic wavelet packet transform in 2004. This method mainly decomposes the collected vibration signals into a series of sub - bands, extracts the key characteristics of each sub-band signal based on Fisher linear judgment criteria, and finally uses them as an input to a neural network classifier to judge the health status of the system. A concept of using wavelet packet decomposition and reconstruction method for noise reduction of rolling bearing vibration signals is proposed by the following peak [42], which is mainly based on the relevant characteristics of wavelet packet transformation, such as the signal can be decomposed into different frequency bands according to the required time-frequency resolution. Duan Chendong et al [43] have done a lot of research on the fault diagnosis method of rotating machinery bearings by using the second generation wavelet, and achieved good results.

4 Wireless Sensor Technology

The node structure of wireless sensor mainly includes data processing and control module, wireless communication module, energy supply module and sensor module. In the sensor module, information is mainly collected and data converted in the area where it is located, and the sensor equipment is mainly used to sense and obtain external information. In A/D conversion, the required analog information is converted into a digital type signal. In the data processing and control module, it is necessary to control the nodes of the sensor. In the microprocessor, it is necessary to coordinate and manage the work of each part of the nodes and use the embedded CPU for processing. In the wireless communication module, it is necessary to be responsible for wireless communication, exchange and control messages, and collect data. In the energy supply module, it is necessary to provide other equipment and systems with the energy needed for normal operation [44].

The wireless sensor network integrates sensor technology, embedded computer technology, network technology, wireless communication technology, etc. It can use various integrated micro sensor nodes to detect various environmental parameters in a distributed manner, and these measured parameters are transmitted wirelessly to the data center in an ad hoc multi-hop manner, thus realizing distributed wireless monitoring of environmental parameters [45]. Compared with common wired testing methods, wireless sensor networks have their own unique characteristics.

(1) Micro-volume, low power consumption and low cost, wireless sensor networks are mainly used in simple and small signal monitoring systems, so its sensor nodes have the advantages of micro - volume, low power consumption and low cost, which enable the sensor nodes to be manufactured in large quantities and can be deployed in large areas with large signal coverage area, ensuring the integrity of signal measurement [46].

(2) The anti-interference ability is strong. Wireless sensor networks use radio waves to send or receive information data, avoiding a large number of long-line cables and improving the anti-interference ability of the system.

(3) Taking data collection and transmission as the center, the ultimate goal of establishing a wireless sensor network is to collect and transmit environmental parameters in a certain area, and does not need to establish a particularly complex network. Therefore, the system design mainly focuses on data collection and transmission.

(4) Data fusion, wireless sensor networks can use different types of sensor nodes to collect relevant environmental parameters, and finally process the data according to a certain data fusion algorithm to obtain corrected data, which can further improve the reliability and accuracy of signal measurement [47].

(5) Dynamic management technology: after the sensor nodes are deployed and started up, a plurality of independent nodes form a self-organizing network through corresponding technical specifications. When the nodes move, join or exit the network, they can organize existing sensor nodes to form a new network.

Wireless sensor networks not only have the characteristics of independent, distributed, multi-hop and other common wireless ad hoc networks, but also have the characteristics of self - organization, dynamic network topology, data-centric and so on, and their application prospects are more and more extensive [48].

The first is the distributed self-organization feature. In the application of sensor networks, because the position of sensor nodes cannot be accurately set in advance and the mutual neighbor relationship between nodes is not known in advance, the sensor nodes are usually deployed to a wide or inaccessible area by aircraft seeding. This requires that the sensor nodes have the ability of self-organization, can automatically configure and manage, and automatically forward monitoring data.

Second is the dynamic characteristics of network topology. The state of the nodes in the network changes correspondingly with the change of environmental conditions and the instability of the wireless communication channel, so the network topology is constantly adjusting and changing, which no one can predict accurately. The third is the resource-constrained nature of the node. The energy, communication capability, calculation and storage capability of sensor nodes are very limited. How to use energy efficiently is the primary design goal of sensor networks. In addition, the communication range of the nodes is also very limited. With the increase of the communication range, the communication power consumption increases sharply. Because the processor used by the sensor node is an embedded processor, it is small in size, relatively weak in computing power and relatively small in storage capacity. In addition, the sensor network also has the characteristics of low reliability and data - centric.

As a hot research topic in the field of information science and computer network, the key technologies of wireless sensor networks have the characteristics of multi-technology integration and cross-discipline, and each key technology needs to be broken through. At present, the key technologies of wireless sensor networks include energy-saving technology, network topology control, network protocol, network security, time synchronization, positioning technology, data fusion, data management and application layer technology, which can be summarized into three aspects: network communication protocol, network management technology and network support technology [49].

5 Remote Cloud Platform Technology

Cloud computing platform is the product of the integration of traditional computer technology and network technology such as distributed computing, parallel computing, utility computing, network storage, virtualization and load balancing [50]. With the development of Web technology and the improvement of chip and disk drive performance, the price has dropped, providing a basis for large-scale computer integration.

Using cloud platform technology, users can obtain a large number of public resources at a low price, thus realizing the functions required by users. Users can spend a small amount of money to customize cloud services on demand, such as opening the Alibaba Cloud server. Users can customize the disk capacity, CPU speed and network bandwidth of the server according to their own situation. Even if the demand increases, they can upgrade on the basis of the original service. If you want to implement other functions, the cloud platform can also provide 24-hour functional services. A typical application case of cloud platform is shown in Fig. 2.

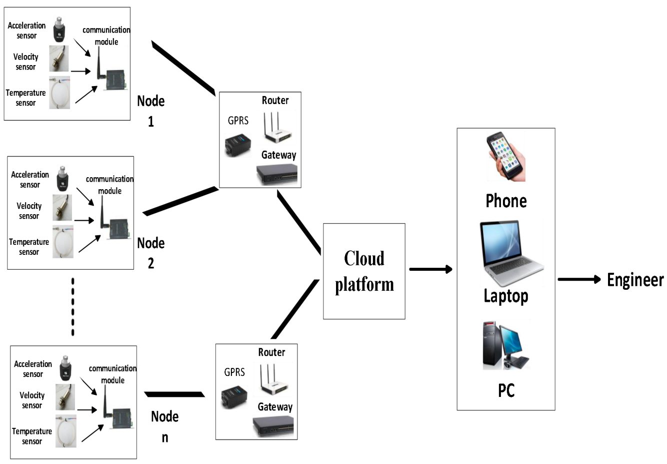

Fig. 2. Typical Application Cases of Cloud Platform

The United States regards cloud technology and its industry as one of the important means to maintain the country's core competitiveness. In 2011, the Federal Cloud Computing Strategy explicitly proposed to encourage innovation, cultivate markets and promote the development of industrial chains, and cloud services have been applied in the army, the Ministry of Justice, the Ministry of Education and other departments [51]. In September 2012, the European Union launched the " Strategy to Unlock the Potential of Cloud Computing in Europe", setting standards for cloud services and clarifying market policies [52]. In 2013, the UK even allocated funds for cloud computing projects to solve problems such as lack of interoperability, data recovery capability and authentication of cloud services [53]. South Korea formulated the " Cloud Computing Comprehensive Revitalization Plan" in 2011 and vigorously built the cloud computing infrastructure [54]. Japan also encouraged manufacturers to develop cloud technologies in the report " Cloud Computing and Japan's Competitiveness Research" released in 2010 [55].

The commercial development of cloud platforms is relatively fast. The most famous commercial cloud computing platforms in the market are microsoft azure Platform [56], Google Cloud Computing Platform, IBM Cloud Computing Platform, Oracle Cloud Platform, AMZ ON Cloud Computing Platform, EMC Cloud Computing Platform, Alibaba Cloud Platform, Baidu Open Cloud Platform, Digi Company ID IGI Cloud Platform and so on.

Tan Zhihu, Yang Lili, etc. studied from the aspects of inconsistent access interfaces and access delays of different cloud platforms, designed a cloud storage gateway and realized unified management and seamless connection of multiple cloud storage platform interfaces [57]. Zhang Xu and Chen Xionghua studied the networking technology of wireless sensors in the forest environment and designed a cloud-based gateway to realize the monitoring of ecological environment in the forest and provide technical support and data decision-making services for precision forestry [58]. Tian Yubo and others have designed a monitoring system based on cloud platform for the management of modern pastures, which has a positive effect on food safety. Yu Xiufang and others have built a book-accompanying CD Mirror server based on cloud storage architecture [60], enriching and perfecting the library's service means and providing better services for readers. Chen Yong and others designed a cloud-based monitoring system for mine fire remote monitoring, providing security for staff [61]. Huang Xiaoyuan studied the scheduling of vehicle networking on the cloud platform and provided a solution for vehicle scheduling [62]. Mohanarajahg designed an open source cloud platform RAP Yuta to help robots reload and connect to the database, providing technical support for the development of robot technology [63]. Subas Ish Moha Patra proposed a hybrid of cloud computing and wireless sensor networks, and realized a ubiquitous cloud platform for healthcare [64] using visual sensors and clouds.

6 Conclusions

Through combing the research results at home and abroad, the current research direction of remote monitoring technology is mainly from equipment condition monitoring and fault diagnosis technology, remote diagnosis center system and multi-thread technology. The research on bearing fault diagnosis technology mostly focuses on signal processing, and the more mature technology sometimes includes frequency domain analysis and harmonic transformation analysis. The research focus of wireless sensor technology is on the one hand the structure and function of sensor body, and on the other hand the characteristics and key technologies of wireless sensor network. Most of the research on remote cloud platform technology focuses on cloud platform management in places such as forests, pastures and libraries, and is widely used in the medical field, but it is still rarely used in workshops and other industries.

On the whole, there is less research on the combination of remote cloud platform, wireless sensor technology and traditional industrial product monitoring such as rolling mill bearings, but there is a broad prospect to introduce low-cost and high-efficiency cloud platform and wireless sensors with convenience and advanced dynamic management technology into traditional industrial rolling mill bearings. At present, it is particularly necessary to integrate different technologies of different platforms and set up appropriate communication and transmission protocols in order to form a complete wireless status monitoring technology for rolling mill intelligent bearings based on remote cloud platform.

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