Design of spindle room temperature and humidity monitoring system based on LORA wireless communication

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Abstract: Radial tires are influenced by various factors such as their internal structure and material characteristics, necessitating strict control over temperature and humidity during production. Excessively high or low temperature and humidity in the spindle room can affect the bonding performance between rubber and steel cord, thus precise monitoring of the temperature and humidity in the spindle room is required. This system upgrades the traditional single-point temperature and humidity detection to a systematic solution based on the LoRa wireless communication architecture, addressing issues such as low real-time data accuracy, low data precision, and the inability to provide real-time warnings for abnormal temperature and humidity conditions in the on-site environment. The system is easy to install, offers comprehensive monitoring, is scalable, and operates stably and reliably, providing high economic value in practical use.

Key words: temperature and humidity; LORA; wireless communication

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0 Introduction

In the rubber product industry, rubber has stringent requirements for the production site environment (such as temperature and humidity). To ensure the quality of rubber products, effective control of relevant temperature and humidity is necessary.

The warehouse for rubber raw materials has stringent requirements for temperature and humidity. High temperatures can easily lead to oxidation and aging, while low temperatures can cause rubber to become hard and brittle. Excessively high humidity can cause rubber to absorb water, expand, and promote mold growth, whereas excessively low humidity can cause rubber to become hard and crack.

The temperature and humidity in the spindle room are also crucial. If the humidity is too high, moisture will accumulate on the surface of the steel cord, which can lead to rusting in severe cases, affecting the adhesion between the rubber and the steel cord. If the humidity is too low, operators will feel thirsty and extremely uncomfortable.

Rubber is extremely sensitive to temperature during the production process of semi-finished products in the internal mixer. The temperature of each stage plays a decisive role in the extrusion process. If the temperature of each stage changes, the extrusion speed, extrusion temperature, and expansion rate of the extrusion process will all change, leading to instability in the extrusion operation and seriously affecting the quality of the semi-finished products, and thus the quality of the tires.

The reason for regulating the temperature and humidity in the molding workshop is to ensure the stability of the production environment and reduce variables in production, thereby guaranteeing the consistency and quality of the tires produced. During the manufacturing process, the physical and chemical reactions required for tires are influenced by environmental factors such as temperature and humidity. Therefore, by controlling the temperature and humidity in the workshop, it can help ensure the suitability and consistency of the tires during production.

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The original temperature and humidity control was implemented as individual controls. For example, the temperature and humidity in the workshop were measured on-site and displayed on the on-site LED screen, while the temperature of the temperature control system was measured on-site and displayed on the instrument of the temperature control system, without any alarm function.

In the information age, traditional measurement and display methods have clearly fallen short of digital requirements. In response to this situation, our company has designed a process temperature measurement system to manage temperature and humidity within the factory.

The nail house temperature and humidity monitoring system designed in this paper, based on LoRa wireless communication, utilizes a high-precision temperature and humidity chip to perform high-frequency data collection on-site. The data is then uploaded to the sensor receiver and the host computer system via a wireless communication network, ensuring real-time, accurate, and reliable on-site data collection. When anomalies in temperature and humidity occur on-site, the sensor receiver display unit can provide on-site audible and visual alarm notifications, while the host computer management system can also issue corresponding alarm notifications. This effectively addresses the challenges of real-time monitoring and timely alarm dissemination for nail houses, achieving a 7x24-hour wireless data monitoring and transmission online system for temperature and humidity. This system holds significant economic value in practical applications.

1 System composition and working principle

The nail house temperature and humidity monitoring system based on LoRa wireless communication designed in this paper primarily consists of wireless temperature and humidity sensors, sensor receiving and display devices, upstream communication networks, and host computer servers, which are installed discretely on-site. The specific system block diagram is shown in Figure 1 below.

Firstly, the LORA parameters of the temperature and humidity sensors and the sensor receiving and display devices are set to the same frequency and the same group, ensuring interoperability between the two in terms of data transmission and reception. The wireless temperature and humidity sensors are installed in corresponding locations inside the nail house, performing high-precision data collection and processing for the temperature and humidity at the respective points. The data is transmitted to the temperature and humidity sensor receiving and display device via LORA wireless communication. The temperature and humidity sensor receiving and display device receives the data transmitted by the on-site installed temperature and humidity sensors, completes local display, data processing and recording, alarm prompts, and simultaneously uploads the information to the upper computer management system through the Ethernet network. The upper computer software installed on the server records the on-site data, performs statistical analysis and display of reports, and realizes functions such as real-time data monitoring, historical data query, hourly/daily/weekly/monthly/annual report query, alarm prompts, and monitoring.

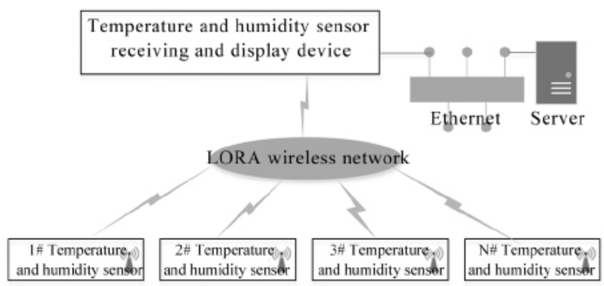

Figure 1 System composition block diagram

2 Hardware system design

2.1 Setting of detection points

After communicating with the horizontal technical department, the system's detection points were ultimately set based on several points that have a significant impact on tire quality. The main focus is on the temperature and humidity of raw material warehouses, which have high process control requirements, the temperature of the internal mixer process, the spindle room and extrusion temperature of semi-finished products, and the temperature and humidity of the molding workshop. The detailed point settings are as follows:

(1) Raw material warehouse: environmental temperature and humidity of the warehouse.

(2) Mixing process: Temperature and humidity of the rubber drying room, ambient temperature and humidity,

temperature measurement in the three mixing zones, temperature measurement of the inlet and return water pipelines, and temperature measurement of the splicing and laying of rubber sheets.

(3) Semi-finished product process: temperature and humidity of nail room, inlet and return water pipelines of open mill, temperature measurement during glue supply, glue discharge, and curling, temperature measurement of cooling water tank, and environmental temperature and humidity.

(4) Forming process: environmental temperature and humidity.

2.2 Introduction to hardware system structure

The temperature measurement system primarily consists of wireless temperature and humidity sensors installed on-site, a wireless sensor receiver and display unit, and an upper computer software.

(1) wireless sensor

Measure and upload the data from the monitoring points.

(2) On-site display receiver

Receive and display the data sent by wireless sensors within the group.

(3) upper computer software

Store and analyze on-site data, and automatically generate corresponding reports and diagrams based on the configuration.

2.3 On-site temperature and humidity detection unit

The core function of the on-site temperature and humidity detection unit is to collect and process the temperature and humidity data on site, and upload the processed data to the sensor receiver display via LORA wireless communication. This unit primarily consists of a thermostat circuit, a power module circuit, a storage module circuit, a temperature and humidity acquisition module circuit, a serial communication circuit, a LORA wireless communication module circuit, and an LED indicator circuit. The system block diagram is shown in Figure 2.

The power module circuit provides various voltage levels for each module in the system, ensuring sufficient energy input for all modules to operate. The storage module primarily stores the local device parameters and records relevant data during operation. The temperature and humidity acquisition module converts the temperature and humidity in the environment into corresponding digital signals and performs comprehensive data processing. The serial communication module uses wired communication for local configuration of device parameters and passive data acquisition and transmission through wired communication. The LORA wireless communication module interacts with the sensor receiving and display device through wireless communication, uploading local data to the sensor receiving and display device and executing various instructions issued by the sensor on the display device. The LED display module mainly indicates various working states of the device on-site through LEDs, providing information about the device's working conditions to facilitate subsequent troubleshooting of the device.

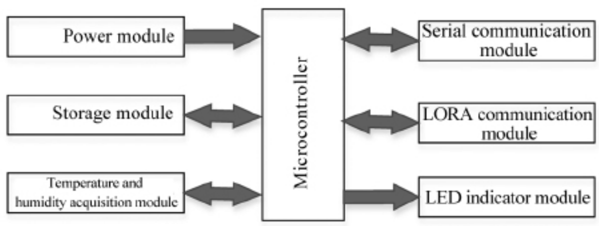

Figure 2 System block diagram of on-site temperature and humidity sensor unit

2.4 Temperature and humidity parameter detection circuit

The temperature and humidity parameter detection circuit converts the temperature and humidity in the environment into corresponding digital signals and performs comprehensive data processing. The model used in this device is SHT31, and the specific circuit is shown in Figure 3 below.

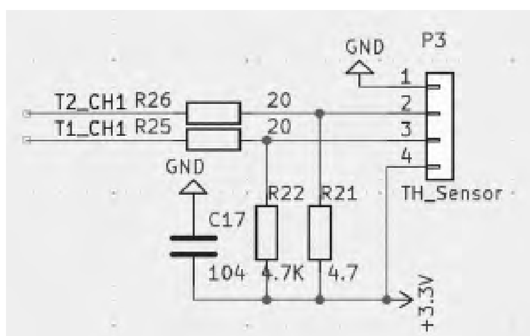

Figure 3 Temperature and humidity detection circuit

SHT31 is an ultra-small digital temperature and humidity sensor packaged in DFN, utilizing the IIC communication method, facilitating easy interface communication with system microcontrollers. Its operating voltage ranges from 2.15V to 5.5V. In this system, the device operates at a voltage of 3.3V. The temperature measurement accuracy can reach ±0.5℃, while the humidity measurement accuracy is not lower than ±3%RH. In the temperature detection circuit depicted in Figure 3, T2_CH1 and T1_CH1 are connected to the system microcontroller. P3 represents the temperature and humidity sensor, C17 denotes the filter capacitor, R21 and R22 are pull-up resistors, and R25 and R26 serve as current-limiting resistors to protect the microcontroller ports.

2.5 LORA wireless communication circ uit

Considering the inconvenience of wiring in the nail house area, the large number of on-site devices, and the scattered installation locations of sensors, wireless communication is more suitable for data transmission in this on-site application scenario. Compared to WiFi and Bluetooth, LoRa has better penetration. Therefore, LoRa wireless communication is adopted to establish a data exchange channel between temperature and humidity sensors and sensor receiving and display devices, which facilitates system point expansion and on-site construction. The LoRa communication circuit adopts the recommended typical circuit, as shown in Figure 4.

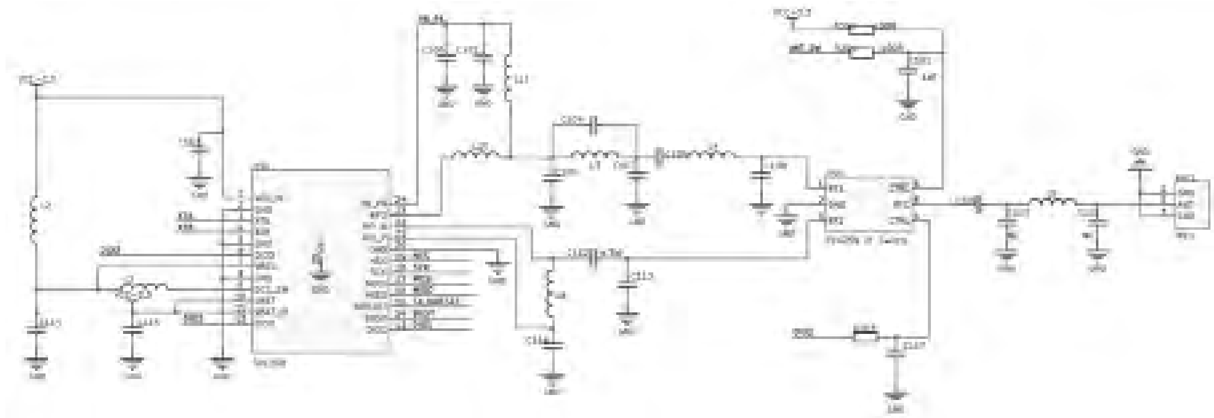

Figure 4 LORA wireless communication circuit

The LORA chip used in this system is SX1268, which is a long-range, low-power, high-performance wireless transceiver. In this design, LORA communication mode is adopted, with the following technical parameters: carrier center frequency of 433 MHZ, transmission power of 20 db, bandwidth of 250 khz, and spreading factor of 10. Under these technical parameters, the communication distance exceeds 1 km in unobstructed conditions, and is greater than 400 m in situations where there is obstruction and wall penetration in the nail house workshop. This fully meets the requirements of on-site application scenarios.

3 Software functions

The software part of this system mainly includes the programs for wireless temperature and humidity sensors installed discretely on-site and the programs for sensor receiving and display devices installed nearby in the on-site network cabinet. In the program design, a modularized hierarchical design concept is adopted according to the hardware circuit function modules, achieving portability, reusability, and maintainability of the application programs, as well as high reliability and efficiency in software design.

The program of the wireless temperature and humidity sensor achieves the collection and uploading of on-site temperature and humidity data, while the sensor receiving device implements centralized data reception and display. Due to the relatively simple functionality of the on-site application, a front-end and back-end system is adopted. Timing interrupts and external event-triggered interrupts are used to handle more urgent event tasks. The system flow is shown in Figure 5.

The system can provide real-time and historical curves for system operating parameters as needed, and can compare curves of measurement and control points as required, facilitating intuitive analysis of system operating conditions through graphical means. Additionally, the system provides Word and Excel report export functions for data queries, event queries, or other report queries, facilitating data statistics, organization, analysis, and printing, as well as quality traceability, providing first-hand data for decision-making.

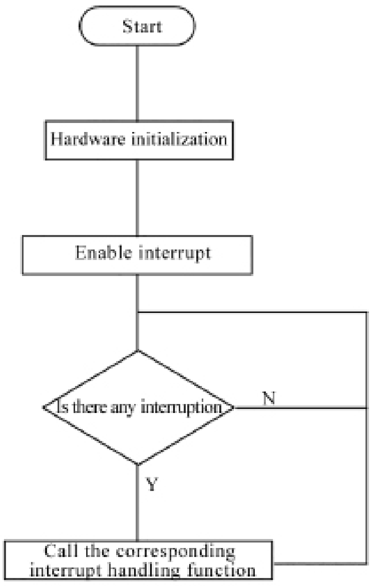

Figure 5 Software system flowchart

4 Conclusion

The nail house temperature and humidity monitoring system designed in this paper, based on LORA wireless communication, addresses the challenges of timeliness and accuracy in on-site data recording. By utilizing the high-precision temperature and humidity sensor SHT31 and the wireless LORA communication chip SX1268, the system ensures real-time and accurate data collection, achieving wireless monitoring and transmission of nail house temperature and humidity data 24/7. This system boasts advantages such as high measurement accuracy, wide coverage, simple maintenance, convenient expansion, and ease of implementation, making it economically valuable in practical applications.