A brief discussion on the application of automatic weighing systems for finished tires in the tire industry

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Abstract: With the rapid advancement of smart factory construction in the tire industry, traditional weighing tools have become inadequate to meet the process requirements and management needs of intelligent production. To address issues such as waste caused by weight errors in raw materials and finished tires during tire production, and the inefficiency of manual sampling inspection, an automatic weighing system for finished tires based on PLC and MES systems has been designed. This system integrates scanning devices, dynamic weighing sensors, AD analog converters, and other equipment, achieving dynamic and precise weighing and real-time data sharing through Ethernet transmission. The system boasts strong stability, accurate measurement, and high automation, effectively realizing weight control and product traceability throughout the entire tire production process. It provides support for the upgrading of enterprise industrial structure and the intelligent development of the industry.

Key words: PLC; dynamic weighing; MES system; scanning device; remote monitoring

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0 Introduction

In the process of intelligent transformation in the tire industry, product quality control and refined cost accounting have become key elements of a company's core competitiveness. Tire weight, as a core indicator that runs through the entire process from raw material procurement, production and processing to finished product delivery, has a direct impact on product quality stability and corporate economic benefits through its precise control. Traditional weighing methods rely on manual operations, which have defects such as large data errors, delayed feedback, high labor costs, and inability to achieve full-process traceability. These methods have become difficult to adapt to the construction requirements of smart factories in the context of Industry 4.0. Shandong Wanda Baotong Tire Co., Ltd. has designed and developed an automatic weighing system for finished tires to address existing production pain points. Through the deep integration of automation technology and information management, it has built a full-process, intelligent weight control system, providing a practical example for the intelligent upgrade of the tire industry.

1 Current status of the enterprise

1.1 Core issues in weight control

In the current tire production process, there are two prominent issues in the weight control link: First, there is a significant weight deviation between the input of raw materials and the output of finished tires, resulting in severe waste of rubber raw materials and directly increasing the production costs of enterprises. From the formula adjustment in the mixing workshop, to the processing of components such as rubber sheets, inner liners, and steel cord fabric in the semi-finished product workshop, to the vulcanization and molding of

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finished products, there is a lack of precise control over weight transfer in each link, causing material loss beyond a reasonable range. Second, the weight inspection method for finished tires is outdated. The quality assurance department only adopts manual sampling inspection mode, which cannot achieve full batch coverage inspection. Manual sampling inspection not only poses a risk of missed inspections but also results in delayed feedback of inspection data, making it difficult to quickly adjust production process parameters, affecting product quality stability, and also causing a waste of human resources.

1.2 Existing production condition constraints

The company's existing automatic conveyor line runs north-south, with a total length of 120 meters and a conveying speed of up to 30 meters per second. However, it faces issues such as a long line, a large number of conveyor motors, and significant vibration and jitter during operation. If weighing equipment is directly installed, the vibration interference will significantly reduce weighing accuracy, making it impossible to meet the precise requirements of the production process for weight detection. Furthermore, data sharing among departments is poor, and the transfer of weight data between the Production Planning Department, Quality Assurance Department, and Business Accounting Department relies on manual statistics and reporting. This leads to issues such as data lag and statistical errors, affecting the timeliness and accuracy of production decisions.

2 Design scheme

2.1 Overall system architecture

The automatic weighing system for finished tires is centered around the MES system, integrating devices such as scanning devices, dynamic belt scales, PLC controllers, network servers, and host computers to form a fully intelligent system encompassing "weighing collection, data transmission, analysis, and control". The system utilizes the circular structure of the automatic sorting conveyor line, with two layers of dynamic belt scales installed below the upper and lower scanning devices to achieve continuous active weighing. The start and stop of the weighing machine are controlled by external interlocking signals, interfaced with the MES system through a DP interface. The MES system actively reads the weighing data and determines whether the tire weight is qualified, while storing and archiving the inspection results and product information through the internal network server. The Production Planning Department, Quality Assurance Department, and Business Accounting Department can query the weight data of tires of various specifications in real time through the "tire barcode logistics management system" of the MES system, achieving full-process weight control from raw material formulation to finished product delivery, as shown in Figure 1.

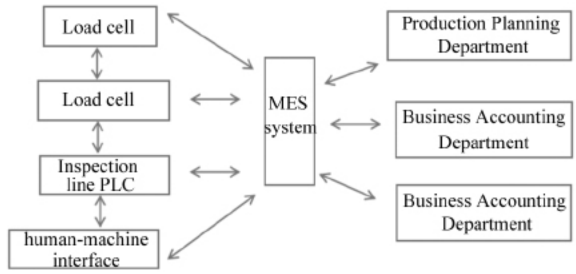

Figure 1 Overall architecture diagram of automatic weighing system for finished tires

2.2 Technical requirements for dynamic weighing scales

2.2.1 Electrical control requirements

(1) The weighing machine adopts a dynamic continuous weighing mode, with start and stop precisely controlled by external interlocking signals. It is equipped with a DP interface, supports active data reading and qualification judgment by the MES system, and can execute corresponding control instructions based on the judgment results;

(2) During the transportation and weighing process of tires, it is necessary to avoid situations such as tire squeezing and deformation, ensuring that the appearance and internal quality of the product are not affected;

(3) The motor circuit must possess safety features such as phase loss protection and grounding protection to ensure stable operation of the equipment;

(4) The belt scale must meet the operational requirements of high-speed conveying, high-precision dynamic weighing, no jumping, no deviation, low failure rate, and rapid maintenance, and be suitable for a three-shift continuous production mode.

2.2.2 Main technical parameters

The core technical parameters of the dynamic scale are strictly tailored to meet the needs of tire production, as detailed below:

(1) Equipment usage shifts: Three consecutive shifts of production (uninterrupted operation every month);

(2) Operating environment: Temperature range of 7~70 ℃, maximum relative humidity of 95%;

(3) Applicable tire specifications: semi-steel tires 13”~24”;

(4) Applicable tire outer contour diameter: φ520~φ920 mm;

(5) Applicable tire tread height: 120 ~400 mm;

(6) Maximum weighing capacity: 30 kg;

(7) Power configuration: Power supply AC3×380V, control power supply AC220V or DC24V;

(8) Air source requirements: 6 kgf/cm², 10M³/H (configured according to design standards);

(9) Transmission speed: 40 mmin (supporting variable frequency speed regulation);

(10) Weighing accuracy: Dynamic continuous weighing accuracy ≤±50 g, with a division value of 5 g.

2.2.3 Dynamic scale structural dimensions

The main material of the dynamic scale is carbon steel with paint coating, and there is one unit in total. It uses a power supply of AC380V. The specific structural dimensions must meet the installation requirements of the conveyor line, ensuring seamless integration with the existing production line without affecting the original conveying efficiency.

2.3 Tackling difficult problems in the plan

To address the issue of decreased weighing accuracy caused by vibrations in the automatic conveyor line, three core optimization measures were taken: First, a design was implemented to separate the dynamic scale from the overall frame, reducing the direct impact of line vibrations on the scale. Second, shock-absorbing pads were installed at the bottom of the weighing machine to effectively absorb vibration energy and reduce vibration interference. Third, the data transmission and processing procedures were optimized, with program enhancements made to the signal transmission process from the weighing transmitter and AD analog converter to the PLC, reducing errors caused by signal interference. Through these measures, the weighing accuracy of the dynamic scale was ultimately achieved with a comparative error of less than 50g compared to the static scale, meeting the production process requirements.

2.4 MES system data query and remote monitoring

2.4.1 Real-time monitoring by the host computer

After the real-time weight data of finished tires is uploaded to the industrial host computer, it is synchronized to the MES system through the internal network. The host computer can display key information such as tire barcode, tire embryo code, molding time, vulcanization time, actual weight, standard weight, and weight difference in real time. It also supports query and statistics by time period, automatically calculating the deviation between the total actual weight and total standard weight of finished tires within that time period, providing data support for production process adjustment. The host computer has a data export function, which can automatically generate Excel tables for data analysis and archiving, as shown in Figure 2.

Figure 2 Real-time monitoring data graph of the upper computer (updated graph)

2.4.2 Remote monitoring function

By logging into the integrated production and manufacturing control system, management personnel can remotely view all monitoring information on the host computer, including detailed weight data of individual tires, batch statistics, and more. The remote monitoring system also supports data export to Excel, facilitating remote office work and data sharing. It achieves 100% remote monitoring of finished tire weight, completely solving the problems of data lag and incomplete supervision in quality control and cost accounting. See Figure 3.

Figure 3 Login interface of remote monitoring system

2.5 Coordinated operation of scanning device and dynamic weighing system

When the finished tire is conveyed to the dynamic weighing machine, the start position photoelectric switch is triggered, activating the synchronous operation of the scanning dock and weighing sensor: the scanning dock identifies the tire barcode, while the weighing sensor collects weight data. After the tire has completely passed through the weighing machine, the end position photoelectric switch is triggered, completing one data acquisition cycle. The scanning device binds the identified tire barcode with the corresponding weight data, transmits it to the host computer via CCLINK communication, and then transfers it to the MES system database via Ethernet, achieving one-to-one correspondence storage of product information and weight data, providing core data support for product traceability.

2.6 PLC control selection

2.6.1 PLC selection principles

PLC selection follows four core principles: first, to maximize the satisfaction of the control requirements of the controlled object and ensure that the system functions are compatible with the production process; second, to ensure the safety and reliability of the control system and reduce equipment failure rates; third, to strive for simplicity and economy, while taking into account the convenience of use and maintenance; fourth, to reserve expansion space to accommodate the future development needs of the enterprise. When selecting, it is necessary to comprehensively analyze the number of input and output points, memory capacity, functional requirements, and external device characteristics, and choose the product with the best cost-performance ratio.

2.6.2 Selection results

Based on the current equipment configuration in the company's workshop, and considering the high market share of Mitsubishi PLCs in the workshop and the moderate system scale, the final core equipment selection is as follows: PLC is selected as Mitsubishi Q series Q13UDEHCPU; network module is selected as QJ71E71-100; analog module is selected as QJ61BT11N; frequency converter is selected as Mitsubishi D700 series; and weighing transmitter is selected as XK3141(IND331) series. The selected equipment has strong compatibility and can seamlessly interface with the existing MES system and conveyor line equipment, ensuring stable system operation.

2.7 Operating principle of weighing sensor

This system employs a resistance strain gauge weighing sensor, whose core operating principle is to convert tire gravity into measurable electrical signals proportionally. When subjected to external force, the elastomer (sensitive beam) undergoes elastic deformation, causing the resistance strain gauge attached to its surface to deform accordingly, leading to changes in resistance value. The resistance changes are converted into voltage or current signals through a measurement circuit, processed by an AD analog converter, and transmitted to a PLC, ultimately achieving precise acquisition of weight data. This type of sensor boasts high measurement accuracy, strong stability, and adaptability to harsh industrial environments, meeting the requirements for dynamic continuous weighing.

3 Implementation objectives of the weighing system project

3.1 Build an intelligent management and control system

With the existing MES system as the core, two core systems are constructed: one is the intelligent equipment management CPM system; the other is the workshop automatic weighing system and finished tire intelligent sorting and conveying system. The MES system focuses on tire production process control, while the CPM system focuses on intelligent equipment management. The two systems are seamlessly connected through barcode technology and data exchange, forming a collaborative control system of "production control - equipment management".

3.2 Realize full-process visualized control

Through system construction, real-time weight control throughout the entire process from raw material input to finished tire delivery is achieved. Production management personnel can grasp key data such as rubber formula weight in the mixing workshop, weight of each component of semi-finished products, and weight of finished tires in real time through the upper computer or remote monitoring system, promptly detect weight deviations in the production process, quickly adjust process parameters, and reduce material waste.

3.3 Achieving closed-loop management of smart factories

Utilizing the system, we achieve intelligent and interactive seamless connection among people, machines, and materials, covering major processes such as rubber raw material processing, semi-finished product production, and finished product vulcanization and molding, enabling information management throughout the entire product lifecycle. Through data sharing and tracing, a complete closed loop is formed from production plan formulation, process execution, quality inspection to cost accounting, laying a solid foundation for the construction of a smart factory.

4 Implementation conclusion of weighing system

The implementation of the automatic weighing system for finished tires represents the practical outcome of the deep integration of industrial engineering technology, automation technology, IT technology, and industrial IoT. By integrating core technologies such as PLC, dynamic weighing, scanning recognition, and MES systems, the system effectively addresses prominent issues in tire production, including low weight control accuracy, data lag, and resource waste. It achieves three core values: firstly, reducing production costs by precisely controlling the weight deviation between raw materials and finished products, minimizing rubber raw material waste, and enhancing resource utilization efficiency; secondly, improving product quality by achieving full-batch inspection of finished tire weight, timely adjusting production processes, and ensuring product quality stability; thirdly, promoting intelligent upgrading of enterprises by realizing visual, traceable, and information-based management of the production process, thereby accelerating the optimization of the enterprise's industrial structure.

This system provides a comprehensive solution and practical standards for the construction of intelligent factories in the tire industry. Its core technology and implementation experience can be widely promoted within the industry, driving the rapid transformation of the tire industry towards Industry 4.0 smart factories and assisting the industry in achieving high-quality development. In the future, the system's functions can be further optimized by adding AI algorithms for predicting and automatically adjusting weight deviations, enhancing the system's intelligence level and creating greater economic and social benefits for enterprises.