Design of a real-time monitoring and automatic adjusting system for the belt tension of telescopic machines

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Abstract. In order to solve the problem of belt deviation, this paper designs a real-time monitoring and automatic adjusting system for the belt tension of telescopic machines. The system obtains data through the MCU, an ADS1246 chip and a full strain bridge, transmits the data through Zigbee network, and displays the data through the industrial control screen, thus realizing the real-time monitoring of the belt tension. The master MCU performs algorithm calculation firstly, and then performs real-time control of the motor through the CAN bus, so as to achieve automatic adjustment of the tension. This paper designs corresponding circuits and software according to each functional module. The results show that the real-time monitoring and automatic adjusting system is of great timeliness and accuracy, and has good application and promotion value.

1. Introduction
With the acceleration of the industrialization process, the requirements for transportation equipment in industrial production have become higher and higher. Therefore, it is inevitable that transportation equipments develop in the direction of increasing transportation distance, belt speed, transportation volume and deepening intelligence[1]. The extensive application of computer technology in sensor instruments has promoted the rapid development of modular multi-function instruments, the continuous upgrade of intelligent network of instruments, and the gradual miniaturization of monitoring instruments[2-3].

The telescopic machine is a common equipment for loading and unloading goods in long box trucks, which can load and unload cartons, woven bags, special packages, etc. It has the advantages of improving loading and unloading efficiency, reducing labor intensity, reducing labor costs, and reducing the rate of damage to goods[2]. However, the problem of belt deviation is common in industrial transportation.

The rollers of the telescopic machine are mainly supported by the fixed screws at both ends. When the force at the two ends of the screw changes, the relative position of each roller will be offset and when the difference in force between both ends exceeds a certain range, the belt of the telescopic machine will deviate. But at present, the deviation of the telescopic machine belt is generally adjusted manually by experience. In addition, it is also a problem that the installation space is narrow and the number of nodes to be measured is large. There, based on the research progress and the latest results of monitoring technology at home and abroad, this paper builds a real-time monitoring and automatic adjusting system to solve the problem of belt deviation.
2. Overview of the system design

The system design scheme is shown in Figure 1. The force change of the screw is converted into an analog signal through the full strain bridge. The analog signal is converted into a digital signal through a 24-bit high-precision AD chip. Finally, the force value is transmitted to the master control microcontroller through the Zigbee module.

The master control microcontroller communicates with the industrial control screen through RS232, and displays related data such as force value and serial number on the industrial control screen. In addition, parameters can be set on the industrial control screen, and the belt deviation parameters obtained by the simulation can be stored into the master control microcontroller. The master control microcontroller performs corresponding numerical calculations according to the deviation parameters, and can obtain the allowable range of the difference in force between the two ends of the roller, so as to determine the deviation of the belt. Finally, the master control microcontroller performs real-time control of the motor at the end of each screw through CAN bus.\[5-6\]

3. Design of hardware circuits

3.1. Data acquisition circuits

In order to ensure the measurement accuracy, two planes of the screw are respectively attached with two sets of parallel and aligned strain gauges. The strain gauges of each plane are perpendicular to each other. The center axis of one of the strain gauges coincides with the axis of the screw to reflect the change in force value, and the other strain gauge is perpendicular to the axis of the screw as a compensation plate for temperature and bending force.\[7\]. The data acquisition chip of this system uses ADS1246. ADS1246 belongs to a highly integrated, high-precision 24-bit analog-to-digital converter. The circuit diagram is shown in Figure 2.
3.2. Zigbee circuits
This system uses the CC2530 chip as the main chip of the Zigbee circuit. It can build strong network nodes with very low costs of material. It has extremely high receiving sensitivity and anti-interference performance, and requires very few external components. In order to improve the signal strength, this circuit also designed a power amplifier circuit, which involves a balun circuit. The balun circuit is a balanced-unbalanced converter, which can convert single-ended signals into differential signals and perform impedance matching, which greatly improves the anti-interference ability. The circuit diagram is shown in Figure 3.

![Zigbee circuit diagram](image)

Figure 3. Zigbee circuit.

4. Architecture of platform software
4.1. Overall design
This system collects data through AD chips, transmits data through Zigbee networking, CAN bus and RS232, and performs numerical calculation and control through the MCU, so as to form a real-time monitoring and automatic adjusting system of the belt tension of telescopic machines. The system includes a hardware layer and a software layer. The hardware layer includes a chip, a peripheral circuit, and an HAL abstract hardware layer, which are the basis of software operation. The software layer can be divided into three layers: the hardware driver layer, the middle layer, and the user layer, which are transmitted and supported from bottom to top. The system software architecture is shown in Figure 4.

![System software architecture diagram](image)

Figure 4. System software architecture.
4.2. Data Filtering

The collected data is processed by a five-point-three smoothing algorithm, which can effectively remove high-frequency random noise in the signal, improve data quality, and is widely used in digital signal processing\textsuperscript{[10]}. The principle of the algorithm is to take five adjacent data points, fit a cubic curve, and then use the data value at the corresponding position on the cubic curve as the filtered result\textsuperscript{[11]}. The specific five-point smoothing formula is as follows:

\begin{align}
\overline{y}_{-2} &= \frac{1}{70} \times (69y_{-2} + 4y_{-1} - 6y_0 + 4y_1 - y_2) \\
\overline{y}_{-1} &= \frac{1}{35} \times (2y_{-2} + 27y_{-1} + 12y_0 - 8y_1 + 2y_2) \\
\overline{y}_0 &= \frac{1}{35} \times (-3y_{-2} + 12y_{-1} + 17y_0 + 12y_1 - 3y_2) \\
\overline{y}_1 &= \frac{1}{35} \times (2y_{-2} - 8y_{-1} + 12y_0 + 27y_1 + 2y_2) \\
\overline{y}_2 &= \frac{1}{70} \times (-y_{-2} + 4y_{-1} - 6y_0 + 4y_1 + 69y_2)
\end{align}

When the number of nodes is more than five, generally for the sake of symmetry, the first two points use the first two formulas, the last two points use the latter two formulas, and the rest use the middle formula for smoothing\textsuperscript{[12]}.

4.3. Zigbee networking

A big advantage of Zigbee is that it can be self-organized. The maximum number of network nodes is 65,000, and the network has strong self-healing ability and reliable communication\textsuperscript{[13]}. In addition, Zigbee provides data integrity checking and sound functions, and uses AES-128 encryption algorithm with high security performance\textsuperscript{[14]}. The number of measuring nodes of the telescopic machine is large. The distance between the measured nodes is long and the environmental interference is large. The Zigbee self-organizing network function can solve this problem well.

Building a complete Zigbee mesh network includes two steps: network initialization and nodes joining the network. There are two ways for a node to join the network: by connecting to the coordinator to enter the network or through an existing parent node\textsuperscript{[15]}. The flowchart is shown in Figure 5.

![Zigbee networking flowchart](image)

Figure 5. Zigbee networking flowchart.
5. Test and analysis of the system

5.1. System installation
The real-time data display interface and parameter setting interface of the system are shown in Figures 6 and 7, respectively.

![Real-time data display interface](image1)

![Parameter setting interface](image2)

The assembly diagram of the force-measuring device is shown in Figure 8.

![Force measuring device diagram](image3)

5.2. Test of accuracy and stability
For three types of telescopic machines, three prototypes were selected and tested for 1 month under the same environmental conditions. The test was performed for 10 hours every day, and personnel were recorded to record deviations and system response adjustments. After testing, the accuracy of the system reaches 97.5%. The system has good stability and accuracy.

| Time       | 10.28-11.01 | 11.04-11.08 | 11.11-11.15 | 11.18-11.22 | Accuracy |
|------------|-------------|-------------|-------------|-------------|----------|
| Deviation  | 3           | 2           | 3           | 3           |          |
| times      |             |             |             |             |          |
| Response   | 3           | 2           | 3           | 3           |          |
| times      |             |             |             |             |          |
| Accuracy   | 100%        | 100%        | 100%        | 100%        |          |
| Deviation  | 5           | 3           | 6           | 3           | 97.5%    |
| times      |             |             |             |             |          |
| Model 1    |             |             |             |             |          |
| Deviation  | 5           | 3           | 5           | 3           |          |
| times      |             |             |             |             |          |
| Response   | 5           | 3           | 6           | 3           |          |
| times      |             |             |             |             |          |
| Accuracy   | 100%        | 100%        | 83.3%       | 100%        |          |
| Deviation  | 2           | 4           | 3           | 3           |          |
| times      |             |             |             |             |          |
| Model 2    |             |             |             |             |          |
| Deviation  | 2           | 4           | 3           | 3           |          |
| times      |             |             |             |             |          |
| Response   | 2           | 4           | 3           | 3           |          |
| times      |             |             |             |             |          |
| Accuracy   | 100%        | 100%        | 100%        | 100%        |          |

6. Conclusion
Modern industrial production pays more attention to the multi-functional and intelligent products. At present, but for telescopic machines, the adjustment of the belt deviation mainly depends on manual labor. In view of the complex industrial environment and the current situation of enterprises, this paper designs a real-time monitoring and automatic adjusting system. The system is based on an industrial single-chip microcomputer, equipping with functional modules such as data acquisition, data transmission, data display, and motor control, and it can carry out accuracy and stability tests. But to
scale up the platform to industrial production, instruments and equipments will need to be tested to exacting standards. Due to the time of research and development, there are naturally many shortcomings in the design, so it is hoped that successors will correct and improve them.

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