Design of Belt Conveyor Speed Control System of “Internet+”

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Design of Belt Conveyor Speed Control System of "Internet +"

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Abstract. In this paper, a belt conveyor speed control system based on "Internet +" is designed by using the embedded web and single-chip microcomputer. By monitoring the running state of the belt conveyor, adjusting the speed between the two stages of the belt conveyor, real-time monitoring of the speed between the two stages of the belt conveyor, and two levels of the difference between the speeds is used as the input parameter of the speed control PID algorithm to achieve a smooth transition between the two stages of the belt conveyor. The system has the advantages of strong expandability, strong portability, high efficiency and environmental protection.

1. Introduction

The metallurgical industry is one of the nine key energy-consuming industries in China. In recent years, outdated technical equipment, mismatched system, and backward control technology have become the fundamental reasons that restrict the development of energy-saving and emission-reduction technologies in the industry. Among the key equipment of metallurgical bulk material handling technology, the belt conveyor has the advantages of large loading capacity, economical reliability and convenient operation, etc. In recent years, it has gradually developed toward long distance, large volume and high belt speed. However, belt conveyor power is usually configured according to the maximum traffic volume and its constant speed operation mode results in a waste of energy consumption when the system is started up or the load is changed.

In recent years, adjusting the belt conveyor speed control method has more energy-saving potential based on the instantaneous flow rate of materials on the conveyor belt. Some scholars have studied the control method for the belt conveyor to achieve the best loading efficiency from the perspective of regulation, in order to provide decision reference for operators [1]. For small or medium-sized belt conveyor systems, the “open loop control” [2] is sufficient for the transport of short-distance material streams. For long-distance or complex belt systems, closed-loop control should be used to accommodate to various system conditions and disturbances. Proportional integral controller (PIDs) is one of the most widely used controllers in the industry. The value of the PID parameter also depends on the determination of the actual parameters of the project [3]. In order to obtain better performance, relevant experts at home and abroad have proposed different solutions. Wei Xiaofang of Shanxi Xishan Coal and Electricity Co., Ltd. introduced PLC control system, and built the PLC centralized control system of belt transportation through the design of hardware and software part of PLC control system. Finally, the anti-interference measures of PLC control system were given. By applying the PLC control system, the efficiency of transport belt is improved [9]. Zeng Fei of Wuhan University of Science and Technology used STM32 to develop a belt conveyor speed measuring platform to transmit the measured belt speed through remote communication to ensure the safe application of belt conveyor speed control technology [10]. In order to maximize the energy efficiency of belt conveyor speed control and energy saving control technology, she discusses and analyzes the relevant research situation at home and abroad from three aspects: belt conveyor conveying state detection, variable speed transmission control, system optimization and intelligent decision making. Based on the establishment of a simulation experiment platform for speed regulation control of belt conveyor at bulk cargo terminals, the coordination control mechanism of multi-belt conveyor was studied by combining multi-agent and coordination theory, and the energy-saving control model of belt conveyor group was constructed and optimized [11]. The above research has achieved some beneficial results. However, due to the complexity of the system structure, the practicality and effectiveness of the current system speed control strategy need further study. Based on this, this paper designs a belt conveyor speed control system, through the monitoring of the running state of the belt conveyor, adjusts the speed between the two stages of the belt conveyor, effectively reducing the huge belt conveyor the energy loss, the system has the advantages of strong practicability, high expandability and strong portability etc.

2. The hardware design of belt conveyor speed control system

Assume that a horizontally running belt conveyor structure is shown in Figure 1. In this structure, the belt conveyor is a uniform rod-shaped body, and the tension of the belt conveyor is constant during operation, and the tension is independent of the position.

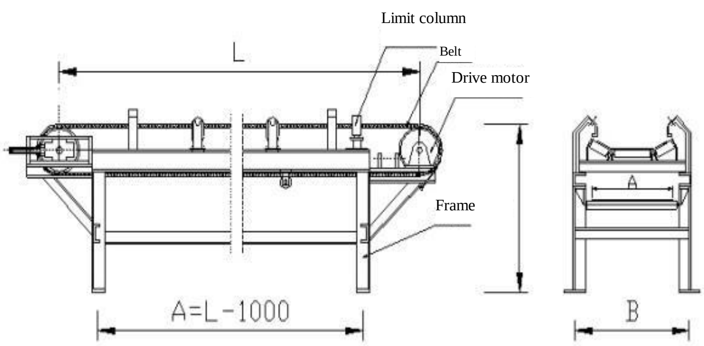

Figure 1. The sketch of belt conveyor system

2.1. Speed measuring part

The belt conveyor speed measurement function is realized by AB two-phase incremental photoelectric encoder. The photoelectric encoder has three working modes: 360pulses/rev, 400pulses/rev and 240pulses/rev. This system uses a 400pulse/rev photoelectric encoder. The AB two-phase incremental photoelectric encoder generates a pulse signal that can recognize high and low levels by a phase difference of 90 degrees between phase A and phase B. Since the belt conveyor motor is unidirectional rotated, only phase A is required to set to low, the MCU detects the level property of Phase B at all times. When a high level is detected, the counter is incremented by one until it reaches 400 pulses. The external loop is incremented by one until how much is transferred in one second is calculated. The photoelectric encoder has a wide range of applications and is mainly used for intelligent control of various displacement change measurements for measuring the speed and acceleration of a rotating electrical machine. The dimensions of the photoelectric encoder and the photoelectric encoder are shown in Figures 4 and 5, respectively.

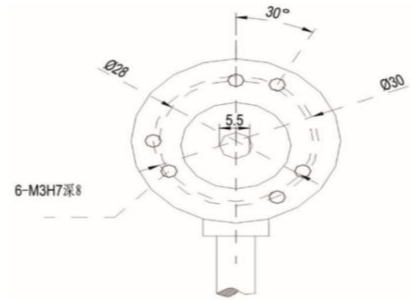

Figure2. Photoelectric encoder physical map Figure 3.Photoelectric encoder size chart

2.2. Testing the material part

The material detection part of the belt conveyor adopts an infrared pair tube sensor, and the brightness of the surrounding environment has little influence on the sensor. The sensor consists of a pair of infrared transmitting tubes and receiving tubes. The infrared pair tube sensors usually emit a fixed frequency of infrared light. If there is a material flow on the belt conveyor, the infrared light is absorbed and reflected by the material stream, and the remaining diffuse reflection of infrared light is received by the light-receiving tube of the infrared pair tube. After the conversion by the conversion circuit, the LED display light on the infrared pair tube becomes bright, and the signal output port outputs a low level.

2.3. Wireless transmission module design

The wireless transmission module uses the NRF24L01 wireless transceiver module. The NRF24L01 wireless transmission module operates at 2.4 GHz. At this working frequency, the wireless transmission module has the characteristics of long transmission distance and strong penetrability, which can basically meet the belt conveyor at the port. The wireless data packet is normally transmitted under the above conditions. The wireless transmission module NRF24L01 printed circuit diagram is shown as 4.

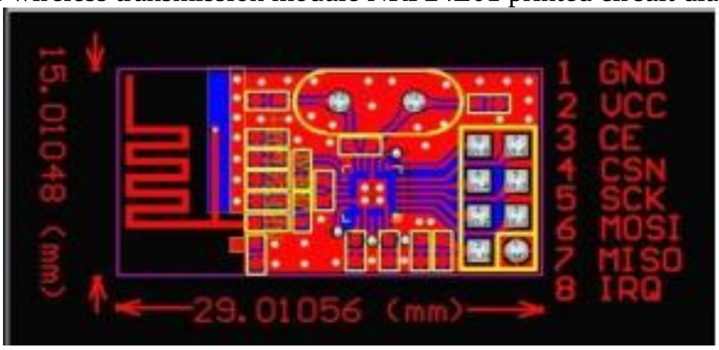

Figure 4.Wireless transmission module NFR24L01 printed circuit diagram

2.4. Network transmission module design

The W5500 network transmission module is a hardware device integrated with the TCP/IP protocol stack. The user can directly implement the network transmission protocol on the hardware device by directly calling the relevant protocol packet. Therefore, the system uses the W5500 network transmission module to implement server functions.

The W5500 network transmission module supports TCP, UDP, IPV4, ARP, IGMP, and PPPOE protocols. The W5500 module integrates 32K bytes of internal on-chip buffer to store transmitted and received data packets, and supports 8 independent Socket programming. The corresponding working mode can be indicated by the indicator light. The module supports 5V or 3.3V power supply. The W5500 network transmission module uses SPI transmission protocol. The SPI transmission protocol can easily exchange data between the W5500 network module and the MCU bus. The W5500 adopts an energy-saving working mode. When a network packet is sent to the W5500 hardware device, the W5500 is automatically woken up to forward and encapsulate the network packet. The core circuit of the W5500 network module is shown in Figure 5.

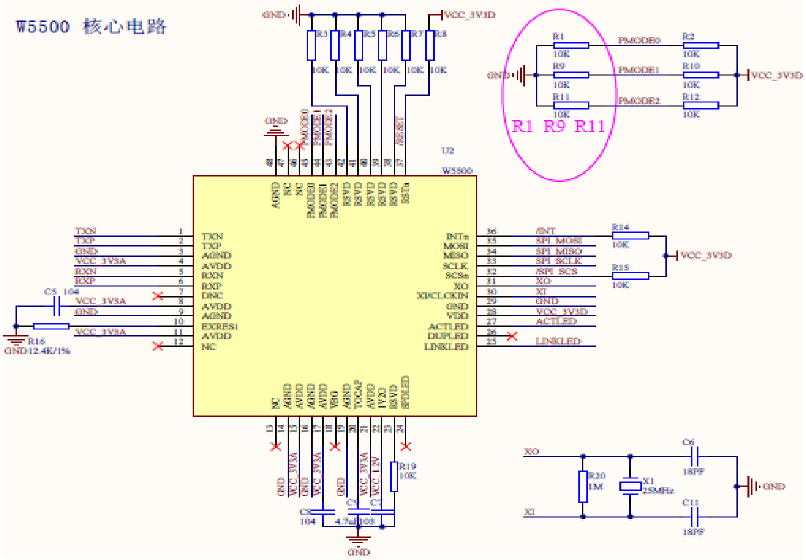

Figure 5.W5500 module core circuit diagram

2.5. Speed control module

The speed control module mainly adopts a 12/24V dual isolated DC motor drive board. The module uses a combination circuit and a PN junction control method of the triode to drive the belt conveyor motor. The motor is prevented from receiving a large current, and the rotation speed of the belt conveyor is smoothly adjusted to provide conditions for verifying the implementation of the intelligent PID algorithm. The module output channel includes two channels, each rated output current is 7A, and each peak value output current is 50A. In this paper, the input voltage is 12V, the driving force of each drive of the motor drive board is strong, the low-voltage control circuit, the control power supply is easy to find, convenient to use, and supports a wide range of PWM waves. The motor drive module is more precise in adjusting the speed of the motor. The frequency range supporting PWM is 0-10kHz, and the single-chip control motor rotation wiring is shown in Figure 6.

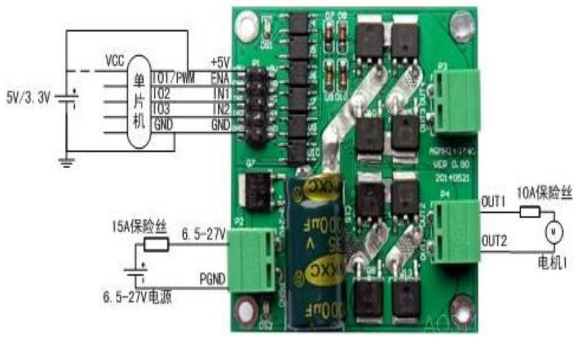

Figure6. MCU control motor rotation wiring diagram

When the single-chip microcomputer is used to control the rotation of the motor, the single-chip microcomputer selects a suitable voltage gear position, the single-chip microcomputer is connected to the input port of the motor drive board, and the computer design control program is transmitted to the ROM of the single-chip microcomputer. When the system is running, the program of the motor driver board is controlled to execute, and the code is directly loaded into the running memory. The MCU will directly transfer the processing result of the code to the input port of the motor driver board through the DuPont line. The motor of the belt conveyor is connected to the OUTPUT port of the motor drive board, and is responsible for the voltage control of the belt conveyor according to the control signal input from the input port, thereby realizing the start, reverse rotation, braking and speed adjustment of the belt conveyor.

When the driver circuit is working, a large current flows through the circuit. If the input terminal of the driver chip is directly connected to the processor, the microprocessor may be damaged and the ship may be out of control. Therefore, a photoelectric coupling circuit is added in the circuit, so that the two parts of the circuit are completely isolated to realize the function of protecting the click drive circuit.

3. Belt conveyor speed control system software design

3.1. Speed measurement part of the program design

The belt conveyor uses an AB two-phase incremental 400-pulse photoelectric encoder, through which the rotational speed information of the belt conveyor motor can be received. The photoelectric encoder is two phases A and B. When the encoder shaft rotates at a certain angle, the two phases of the AB will have a 90 degree angle difference. At this time, the encoder output signal will appear once high. When the rotating shaft rotates once, 400 times of AB phase intersect and vertical will appear. The speed of the belt conveyor motor can be measured by detecting the high level of the unit time in the single-chip port. There are four pins of the encoder, which are VCC, GND power supply interface, a phase output port and B phase output port signal interface.

After the speed of the belt conveyor is calculated, the data is stored in the buffer variable NRF24L01_TxBuf of the wireless transmission module of the single chip microcomputer, and then the data is directly processed and sent to the main control board for the calculation of the input value of the webpage display and the intelligent PID algorithm.

3.2. Network transmission part of the program design

The belt conveyor adopts W5500 network transmission module, and the speed measured by the speed measuring module is displayed on the webpage. If W5500 network transmission module wants to deal with the main control chip W5500, connection mode must firstly be established, here the only way W5500 module provides for data exchange is SPI bus. Therefore, the main control chip STM32 can communicate with the W5500 network transmission module to transmit and receive related data packets only by following the SPI protocol. After the W5500 and STM32 establish a communication channel, communication is required, and some preparation is required before communication. During the migration process, the STM32 first sends a request, and the SPI sends the request to the W5500 module. The W5500 module calls the API in the socket integrated on the board (API is an interface provided by sockets which packs many trivialities into several versatile functions.), prepare the specific content that needs to be transmitted.

3.3. Embedded Web Programming

The Web as a server can remotely view the speed of the belt conveyor. The code of the Web page is stored in the ROM of the main control board STM32.

The running process of the embedded Web server is as follows: HTTP data is encapsulated into TCP packets. When TCP is transmitted, the connection is established through three handshakes and the TCP packets are encapsulated into IP data packets and transmitted to the Internet through the network hardware interface.

3.4. Wireless Transmission Module Programming

The wireless transmission module uses the NRF24L01 wireless transceiver module, through which the speed information collected by the belt conveyor photoelectric encoder can be transmitted, and the next-stage belt conveyor also receives the rotation information sent by the upper stage through the NRF24L01, The speed is offset by the speed of the conveyor of the class to serve as an input to the intelligent PID algorithm. The NRF24L01 wireless module uses the SPI interface, and the microcontroller can communicate with the module using the SPI protocol to send and receive data packets. The communication between the NRF24L01 module and the single-chip microcomputer only needs to control the pins: chip select line CSN for chip operation, clock line SCK for chip, chip control data line MISO and MOSI, single-chip microcomputer and NRF24L01 communication medium IRQ during communication. Chip mode control line CE. The programming idea of NRF24L01 is:

The basic idea of programming the firmware of NRF24L01 is as follows:

Set CSN to low, enable the chip, and configure various parameters of the chip.

If TX mode, fill the Tx FIFO.

After the configuration is complete, determine the status of 24L01 to be switched through the PWR_UP and PRM_RX parameters in CE and Config.

The IRQ pin goes low in three cases: the Tx FIFO is sent and receives an ACK; the Rx FIFO receives the data; the maximum number of retransmission is reached. The IRQ is connected to the external interrupt input pin and processed by the interrupt program.

3.5. Control Module

The belt conveyor control module is mainly controlled by the intelligent PID hardware setting. The speed information of the upper conveyor belt is transmitted to the next level main control center via the NRF24L01 wireless transmission module. The main control board takes the speed difference between two stages as the input value of the intelligent PID algorithm. The input value of the intelligent PID algorithm is calculated and predicted by the preset PID parameters, and a predicted value of the next stage speed is output. The motor drive module adjusts the speed of the next-stage conveyor through the PWM wave according to the speed prediction reference value, so that the belt conveyor can reach the balance faster, more stably and more accurately.

The PID process is to control the controlled quantity through the error signal, and the controller itself is the sum of the three steps of proportional, integral and differential. Here we specify (at time t): the input is rin (t); the output is rout (t); the deviation is err (t) =rin (t)-rout (t). The control law of PID is:

$$u(x)=k_p\left(err(t)+\frac{1}{T}\int err(t)dt+\frac{T_D derr(t)}{dt}\right) \tag{5}$$

4. Conclusion

"Internet +" is "Internet + various traditional industries", using information and communication technologies and Internet platforms to allow the Internet to integrate deeply with traditional industries and create a new development ecology. This paper is based on the concept of "Internet +" to design a smart PID belt conveyor speed control system. When the belt conveyor is soft-started, it automatically executes the program of inspection of material flow and adjusts the belt speed according to the material flow on the conveyor belt. The speed of the conveyor is transmitted to the Web server through the W5500 and STM32 main control chip to realize remote monitoring of the belt conveyor.

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References

[1] Tumbull D, “A game changer mining IPCC and continuous mining solution are set to gain more ground”, Bulk Solids Handl, pp.8-16, April 2013.

[2] G. Lodewijks, AJG. Nuttall, “Dynamics of decentralized driven belt conveyors”,.[*In:Proceedings of the 9th International conf. Bmsht pp125–37, 2007*]

[3] *A Treaties on Electricity and Magnetism*, 3rd ed., Vol. 2, Oxford: Clarendon Press, 1892, pp. 68-73.

[4] I. S. Jacobs and C. P. Bean, *Magnetism*, 3, G. T. Rado and H. Suhl, Eds., New York: Academic Press, 1963, pp. 271-350.

[5] M. Smith, “Title of paper optional here,” unpublished.

[6] K. Rose, “Title of paper with only first word capitalized,” in press.

[7] Y. Yorozu, et al., *IEEE Trans. J. Magn. Japan*, 2, pp. 740-741, August 1987 [*Digests 9th Annual conf. Magn. Japan*, p. 3012, 1982].

[8] Conveyor Equipment Manufacturers Association. Belt conveyors for bulk materials [J]. (fifth edition)CEMA, 2002(55): 97-103.

[9] Wei Xiaofang. Research and practice of belt conveyor system based on PLC control [J/OL]. Mechanical and electrical engineering technology, 2018 (12): 116-117 [2019-01-21].

[10] Fan Shiqi,Wu Qing,Zeng Fei,Li Weilong.Design of Belt Speed Monitoring Platform for Belt Conveyor[J].Logistics Technology,2015,34(03):272-274.

[11] Zeng Fei,Wu Qing,Chen Xiumin,Dai Chaolei.Research Progress in Speed Regulation and Energy Saving of Belt Conveyor in Bulk Carrier[J].Manufacturing Automation,2013,35(17):1-4.