The study and design of tension controller

G Jun and X Lamei

School of Automation, Wuhan University of Technology, 122 Luoshi Road, Wuhan, Hubei, P. R. China

Email: guo_jun_2012@163.com

Abstract. Tension control is a wide used technology in areas such as textiles, paper and plastic films. In this article, the tension control system release and winding process is analyzed and the mathematical model of tension control system is established, and a high performance tension controller is designed. In hardware design, STM32F130 single chip microcomputer is used as the control core, which has the characteristics of fast running speed and rich peripheral features. In software design, μC/OS-II operating system is introduced to improve the efficiency of single chip microcomputer, and enhance the independence of each module, and make development and maintenance more convenient. The taper tension control is adopted in the winding part, which can effectively solve the problem of rolling shrinkage. The results show that the tension controller has the characteristics of simple structure, easy operation and stable performance.

1. Introduction

Tension control is a kind of control technique that the tension can change according to the requirement during winding. Early development in our country, the light industry enterprises mostly belongs to the labor-intensive enterprises. These enterprises have low technology content, and the production is basically done by hand. People don't attach importance to the development of factory automation. Under this big background, the tension control industry is a major industry in light industry, and development is particularly difficult. With China's leap-forward development, market demand and quality requirements for all kinds of coil products continuously improve, the traditional production mode have already can't satisfy people's demand, forcing enterprises to develop in the direction of more efficient and reliable automation. Therefore, the tension control technique has been greatly improved. Nowadays, tension control technology has been widely used in all walks of life and plays an important role, such as fiber, printing, packaging, wire, plastic film, textile and other industries.

Now there are various types of manual or automatic tension controller, among them, the manual controller is simpler, single function, automatic tension controller function is more, but the low control precision, response speed is slow, some products even use 51 single chip microcomputer hardware platform, this product not only increase the hardware cost, but also greatly reduced the speed and reliability of products. In this paper, a multi-function tension controller is designed to combine the manual automatic functions, which can be changed seamlessly, adding more functions and reducing the difficulty of operation.

2. Tension control system

2.1. Introduction to tension control system

Tension control system plays an important role in the whole production line, in addition to people familiar with the roll tension control, release and rectifying control, intermediate control, some even use floating roll control. The tension controller designed in this paper is mainly used for rewinding, and also controled the intermediate tension. The schematic diagram is shown in figure 1.

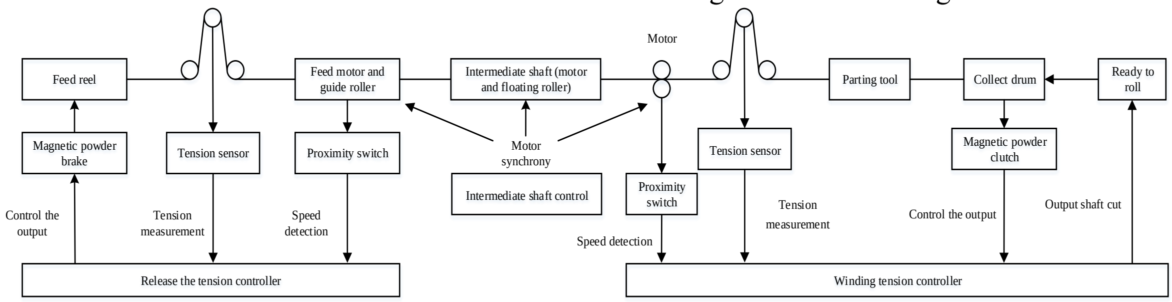


Figure 1. The tension control block diagram of production line.

In this paper, the constant tension control mode is used in the volume part of the tension controller, and the winding may use the constant tension control mode, and also may use the variable tension control mode. By measuring the speed of the spindle motor, the volume diameter of the roll can be calculated and the roll speed of the current volume is calculated, so that the operator can monitor the production line in time. Need to synchronize the middle section of the motor, i.e., production line at runtime, synchronous tension controller to make the motor in the middle with the same speed, and then to control the tension on the coil. In addition, the roller control can achieve good results under suitable conditions. If they are mixed, the effect is better.

2.2. Mathematical model of tension control system

The tension is produced by the combination of the release volume and the drive motor. The tension control mode has the torque and speed modes. Two kinds of control mode difference lies in the different of the actuator. The actuators of torque control are generally magneto-powder motor or torque motor driven by actuators, while the actuators of speed control are generally controlled by inverters.

In this paper, the roller adopts torque control, and the driving roller adopts speed control. The roller connects the magnetic powder brake, the drive roller connects the asynchronous motor, the brake moment produced by the magnetic powder brake is determined by the tension controller, and the speed of the asynchronous motor is set by the frequency converter. The torque control method maintains the tension of the coil. The speed control method is convenient to control the speed of the volume. This combination can achieve better control effect.

2.2.1. The part of unwinding. The roller adopts torque control mode, and the speed control mode is adopted for the feeding motor, as shown in figure 2. The control signal of the magnetic powder brake is the current of 0~4A. The larger the current, the greater the braking torque. If the volume is expected to speed v, motor angular velocity as the ω, driven roller radius r, the driven roller speed for n, a logarithm of asynchronous motor for p, the inverter output voltage of U_f, inverter external 0~10V analog voltage signal U, U is proportional to the U_f, proportion coefficient is k, asynchronous motor slip into s. There is a following relationship.

$$U_f = k \times U \tag{1}$$

$$n = \frac{60U_f}{p}(1-s) \tag{2}$$

IOP Conf. Series: Earth and Environmental Science **113** (2018) 012150 doi:10.1088/1755-1315/113/1/012150

$$\omega = \frac{2\pi}{60} n \tag{3}$$

Substitute formula (1) and (2) into (3) equation:

$$\omega = \frac{2k\pi}{p}(1-s)U \tag{4}$$

The relation between linear velocity and angular velocity is:

$$v = \omega \times r \tag{5}$$

Substitute formula (4) into (5) equation:

$$v = \frac{2k\pi r}{p}(1-s)U \tag{6}$$

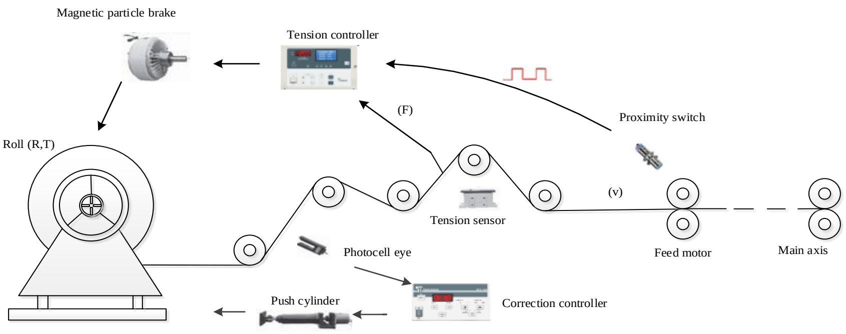


Figure 2 The part of unwinding.

It can be seen from (6) that r, k and p are all fixed values. When the slip rate s is certain, the speed of the coil is directly proportional to the analog voltage input of the frequency converter. The analog voltage input of inverter can be given by PLC to adjust the winding speed of the production line. The winding speed can also be adjusted by the tension controller, such as the need to control the intermediate shaft tension, and the tension controller can be used to control the tension in this section with the speed mode. The control output range of the controller is 0-10V, which can be connected directly with the converter to adjust the motor speed.

2.2.2. The part of winding. The winding method of winding motor is mainly divided into constant tension control mode and variable tension control mode. The constant tension control way is that coil tension keeps constant when coiling. And variable tension control way have some curve changes in the process of coiling tension, which is also called the taper tension control mode. The control of winding tension and roll control are slightly different. In the rolling part, the radius of the drum and the moment of inertia are decreasing, while the winding part is the opposite, the radius of the drum and the moment of inertia are increasing. Due to these differences, the tension and volume of the roll are different.

The magnetic powder clutch is used as the actuator. According to the characteristics of magnetic powder clutch, the higher the excitation current of the magnetic powder motor, the greater the moving torque is obtained. According to

$$T = F \times R \tag{7}$$

Obviously, as time goes on, the winding radius will gradually increase. In order to keep the tension constant, the torque must be compensated, and the amount of compensation is determined by the magnitude of the excitation current in the magnetic powder clutch. The current is directly proportional

IOP Conf. Series: Earth and Environmental Science **113** (2018) 012150 doi:10.1088/1755-1315/113/1/012150

to the transmission torque. The constant tension control can cause incisions in the wound, which can then form the chrysanthemum-like folds along the edge of the drum. To avoid this, when the radius increases, the tension should be reduced. Then taper control should be adopted, which is to calculate the output value of the current controller based on the current volume diameter and the taper coefficient of the set.

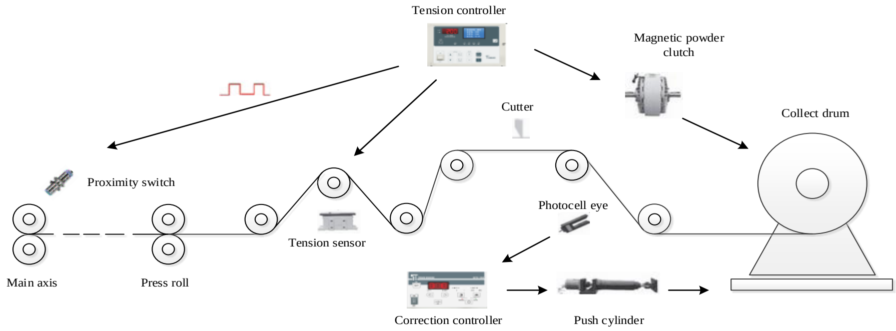


Figure 3. The part of winding.

3. Tension control system

Tension controller hardware mainly include single chip microcomputer minimum system module, power supply module, sensor input module, the output voltage control module, power amplification module, control input interface, the interface of speed, communication interface, the standard power supply interface, buttons, display, alarm, etc. The structure block diagram is shown in figure 4, and the content in the brackets indicates the terminal.

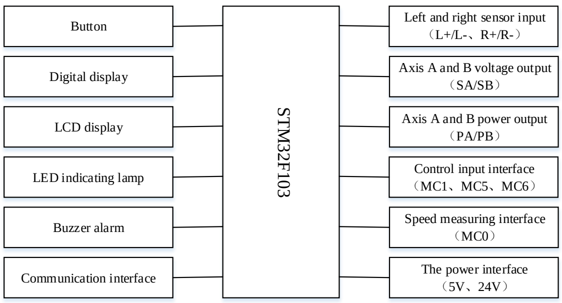


Figure 4. Hardware block diagram of tension controller.

Tension controller hardware circuit includes sampling circuit, the output voltage circuit, power amplifier circuit, speed measurement circuit, key circuit, power circuit and single chip microcomputer minimum system circuit, etc.

3.1. Sampling circuit

The sampling signal of the sampling circuit comes from the tension sensor. The sampling signal is small, and there are various interference signals in the circuit. Most of these interference signals are common mode interference, so the sampling circuit needs to amplify the signal as well as suppress the common mode interference. This design adopts the amplifier, which can achieve differential amplification, which can effectively suppress the common mode interference, and can easily change the magnification multiple, as shown in figure 5.

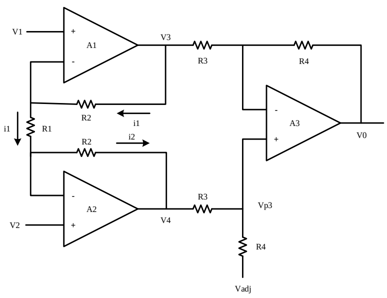
3.2. Voltage output circuit

The connection mechanism of the voltage output circuit is the torque motor or frequency converter. The output voltage is 0-10V, and the ripple should be less than 100mV. The specific implementation circuit is shown in figure 6.

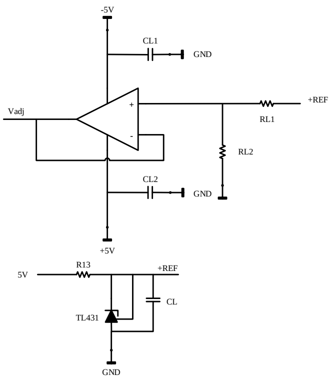
IOP Conf. Series: Earth and Environmental Science **113** (2018) 012150 doi:10.1088/1755-1315/113/1/012150

3.3. *Power amplifier circuit*

The power amplifier circuit has A and B two channels, and the two circuits are connected with the terminals PA and PB respectively. Terminal is generally connected with magnetic powder clutch or magnetic powder brake. In the two axes of A and B, one is the working axis, the other is the preparatory axis. The rated voltage of the working shaft is 4A and the output is PWM waveform. The circuit of the channel is shown in figure 8.



(a) The instrument amplifies the circuit.



(b) Reference voltage generation circuit.

Figure 5. Sampling circuit.

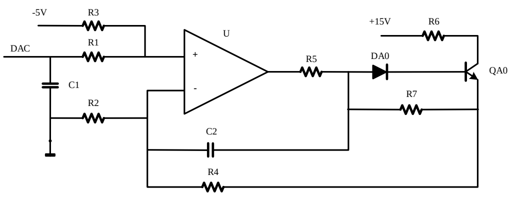


Figure 6. Voltage output circuit.

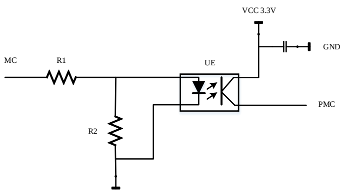


Figure 7. Speed measuring circuit.

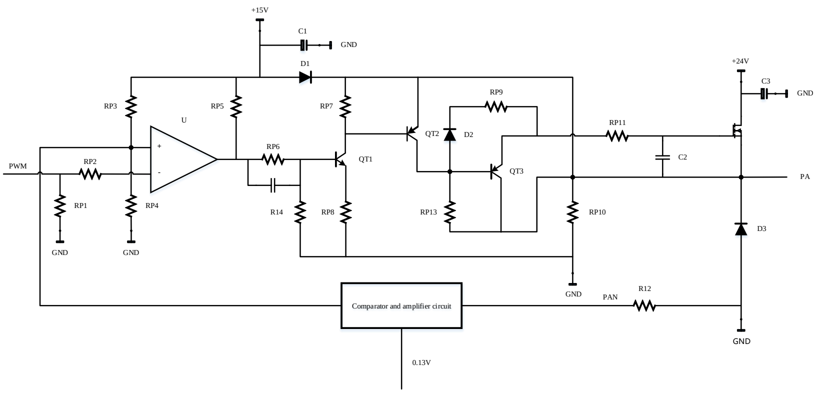


Figure 8. Power amplifier circuit.

3.4. *Speed measuring circuit*

Speed measuring circuit and key circuit voltage waveform is square wave, so the two circuits are the same, but the difference of different voltage frequency. The speed measurement circuit has a much higher voltage frequency than the key circuit. Therefore, the speed circuit usually adopts high - speed optical coupling, and the key circuit adopts ordinary optical coupling. The speed circuit is shown in figure 8.

3.5. *The power supply circuit*

IOP Conf. Series: Earth and Environmental Science **113** (2018) 012150 doi:10.1088/1755-1315/113/1/012150

In switching power supply, when the switch tube in conduction or disconnected, current and voltage waveform overlap area, the area will produce power loss, especially in high frequency, the power loss is bigger, and the switch tube heating. This paper adopts the LLC resonant power supply, and its MOS switching tube can realize ZVS, and the diode can realize ZCS, which can achieve high conversion efficiency. In the design, the power supply is divided into rectifying filter circuit, LLC resonant circuit and feedback adjusting circuit. Some will increase the power supply overload protection circuit.

3.6. Single chip microcomputer minimum system circuit

The STM32F103 single-chip microcomputer is used in the minimum system circuit of the single chip microcomputer. The microcontroller low prices, fast speed, its rich peripherals, not only reduce the peripheral hardware construction and reduces the cost, but also makes the reliability of the circuit is greatly improved, widely used in industrial control field.

4. Software design of tension controller

The main basis of tension controller software design is the mathematical model of tension control system and the hardware basis of tension controller. The parameter initial value is set according to the actual experience. It can be adjusted only slightly, the tension controller can work normally. Software design is based on the μC/OS-II operating system.

Tension calculation process for the algorithm design of a key, mainly including sampling, tension calculation, zero calibration process, and the corresponding procedures for startup tasks, sampling task, tension computing tasks, zero calibration tasks.

The process function of the process module is prepared according to the process flow of the site, and its function flow chart is shown in figure 9. When the power is switched on, the tension controller is in the preparation state, and there is only a small output, and the output is adjustable. The output is called the weak magnetic output. When the speed exceeds preset or terminal start switch is connected to the power of 24 volt, tension controller will enter a state of start, and the output value of a relatively large, maintain output after a period of time, the controller automatically jump into tracking status. When the spindle speed drops to 0.8 times the preset speed or the power supply is cut off, the tension controller will exit the tracking state and go to the stop state. After the shutdown time is over, the controller will be back to the preparatory state, the process will end and the process will be repeated.

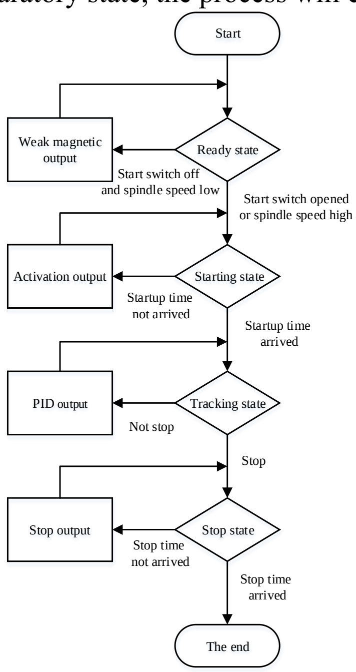


Figure 9. Process flow diagram.

5. Conclusion

In this paper, a high performance tension controller is designed based on the process of winding and roll. The tension controller roller adopts torque control and the drive roller adopts speed control. Torque control can keep the tension constant of the volume, and the speed control can control the winding speed of the coil. Taper tension control is added to the winding part, and the taper tension control can effectively solve the problem of incisions. In the design of hardware circuit, STM32F103 single chip is used as its control core, which has the characteristics of fast running speed and rich peripheral setting. In software design, μC/OS-II operating system is introduced to improve the efficiency of single chip microcomputer, enhance the independence of each module, and make development and maintenance more convenient.

Acknowledgment

I would like to express sincere gratitude to my advisor, associate professor Lamei XU. She gave me a lot of constructive suggestions and creative new ideas during the accomplishment of my thesis.

References

[1] ZHANG Fei. The Research on Tension Control System of the Papermaking Machine[D]. Hu Nan: Central South University, 2012.
[2] LIU Xinchuan, LIU Donghui. Automatic Coiler[J]. Rubber/Plastics Technology and Equipment, 2015, 41(1): 35-37.
[3] HUANG Longsheng, CHEN Fenghua. Preliminary Exploration of Automation Technology of Machinery Manufacturing Control System[J]. China Science and Technology Review, 2010, 21(2): 19.
[4] Han Zhaohai. The Design and Implementation of the Configurable Function Blocks Tension Controller[D]. Wu Han: Wuhan University of Technology, 2012.
[5] WANG Zengyang, ZHOU Yong, ZHENG Xiaoping. A New Detective of Hooke's Law[J]. Journal of Higher Correspondence Education(Natural Sciences), 2009, 22(1): 37-38+42.
[6] Wang Cheng. Study on Magnetic Powder Clutch with High Performance for Vehicle[D]. Nan Jing: Nanjing University of Science and Technology, 2012.
[7] Cheol Jae Park, I Cheol Hwang. New Tension Control at The Head of Strip in Hot Strip Finishing Mill [J].Journal of Materials Processing Technology. 2008, 206(3): 69-77.
[8] Rodrigo Carraseo, M Anibal Valenzuela. Tension Control of a Two-Drum Winder UsingPaper Tension Estimation. IEEE Transations on Industry APPlications, 2006.
[9] Sheng-le REN, Hua LU, Yong-zhang WANG. Development of PLC-based Tension Control System[J]. Chinese Journal of Aeronautics, 2007.
[10] ZHOU Yongxin. Yarn Constant Tension Control System Development[D]. Shang Hai: East China University of Science and Technology, 2014.
[11] MU Ming. Research on a Tension Control System of Printing Press Based on Motion Controller[D]. Bei Jing: Beijing Institute Of Graphic Communication, 2014.
[12] K. Kaneko, K. Ohnishi. Accurate Torque Control for a Greared DC Motor Based on an Accelreation Controller. In Proc IEEE IECON'92, 2011, 2: 395-400.
[13] XU Xiaoyong, SUN Yu, JIANG Qinghai. Modeling and Design of Thin Film Tension Control System[J]. China Mechanical Engineering, 2013, 22(18): 2452-2457.
[14] LIU Jingnan. Studay and Realization of Tension Controller[D]. Ha Erbin: Harbin Institute of Technology, 2008.
[15] Lee C W, Shin K H. A Study on Taper-tension Control Considering Telescoping in The Winding System. IEEE Transactions on Industry Applications.2010.
[16] Luo Zhongming, Liu Zhuofu, Zhang Jia. The Design of Musical Instrument Tuning System Based on stm32f103 Microcomputer. 2012 International Conference on Measurement, Information and Control (MIC), 2012: 79-82.