Design of Automatic Control System for Constant Tension and Linear Speed of Rewinder Machine

Dong Wei, Lin Chen, Jie-Sheng Wang *, Xing Yao

Abstract—**Tension and linear speed control are the key links in many winding control system. When dealing with thin film and brittle materials in some production occasions, the material will be pulled off because of too big tension and the rolling material will run off with too small tension. So it is required to maintain the constant tension on the processed materials in the production process. Based on the structure of the winding system and its production technique, the model of the winding system is set up and the common tension controllers are analyzed. The PID controller is applied in the constant tension and linear speed control system in combination with the variation law of each parameter in the tension control system. Based on Siemens Sinamics S120 driver and two servo motors, Siemens 315T-CPU is selected as the main controller, and the Siemens S7-Technology development environment is adopted. By analyzing the control requirements, the equipment characteristics and various possible factors affecting the tension and linear speed instability of the winding system, the manual adjustment operation in the system is reduced as much as possible so that the winding system can realize the constant tension and linear speed automatic control. Finally, the feasibility of the design scheme are verified through the analysis of the experimental data and curves obtained through the experimental equipment, which can effectively improve the control accuracy of constant tension constant in linear speed winding system and ensure its smooth and safe operation.**

Index Terms—**Constant tension winding; Constant linear speed; Motion control**

I. Introduction

TENSION and linear speed controller are widely used in industrial and civil manufacturing. Precise tension control and linear speed control are required, which directly affects the quality of products in many industries, such as paper-making, printing, textile, leather processing, galvanized steel strip, etc [1]. Therefore, tension and linear speed control on the production line is an important link to improve product quality [2-3]. The traditional winding control system mostly depend on the half automation of human and machine collaboration at the same time. The lower degree of automation, the higher manual operation risk degree. The no-stability of tension and linear speed control in the production process will inevitably cause the fold deformation of coiled materials, affect the quality of product processing and waste a lot of coiled materials [4]. So the winding control system must have high control precision. Because the DC motor control scheme has commutators and brushes, it has high failure rate and seriously affects the production efficiency.

At present, there are two kinds of tension control systems. A tension controller is to adopt the magnetic powder brake as the clutch parts. Because the current and output torque of the magnetic powder brake inductor have good linear relation, the direct tension control method is usually adopted. A tension sensor is used to detect the tension values corresponding to the output of magnetic powder brake inductor current so as to achieve better dynamic tension control. This method is widely used in the low tension control system. The other is to use the frequency converter as the control unit and an asynchronous motor or a servo motor as the main actuator. By controlling the duty cycle output of the frequency converter, the torque and rotate speed of the motor are controlled to achieve the purpose of tension control. It is widely used in large-scale tension and speed control system.

By making using of T400 technology board, master-drive CUVC inverter and ABB tension transducer, the unwinder drive control of the rewinder machine for cigarette paper was proposed to realize the fixed tension control [5]. A DSP based control technique was proposed for the constant tension control on the rewinding roll of a paper machine by using the digital signal processing technique [6]. Based on the rewinder machine technical in paper-making industry, a rewinder automatic control system was designed to realize the optimized tension control loop [7]. The object oriented programming method was applied in the electric control system of rewinder based on PLC technique so as to solve re-usability and portability of the control system [8]. The S-surve acceleration and its control algorithm were used to solve the speed change problem in speed increasing and decreasing process through the real-time calculation of the programmable logical controller [9]. By dividing the rewinding process of a three-roll rewinder into three zones, a

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control strategy was proposed so as to enhance production efficiency and satisfy ultra-high quality requirements [10]. The PI controller including specific compensations and the LQG controller was adopted on an aluminium strip processing line and the simulation results demonstrate the effectiveness of both solutions [11]. Feedback control of web paper tension was proposed by using double PID controllers to improve the printing quality [12]. In order to carry out the constant line speed and the constant tension for the rolling of plastic films during reversal, the loop controller of the rotating speeds and the tension was adopted based on the PID functional instruction of FX 2N [13]. Aiming at the rewinding roll drive of a metal-film coating machine with multiple closed loops and multiple input and output variables, an artificial neural network algorithm was introduced so as to eliminate the coupling between the speed and tension control loops. Simulation experiments show the effectiveness of the proposed method [14]. Aiming at the problem of tension control and according to the winding process features, the mechanical device and the mathematical model of tension control system were established respectively and the fuzzy self-tuning PID controller was designed so as to realize the constant extension ratio of tapes and the consecration and the automation degree of winding process [15]. The linear speed controller of the winding system based on fuzzy PI controller was proposed based on the established mathematical model of the winding system in order to improve the transient and steady states of linear speed control in trip winding system [16]. Aiming at a metal film coating machine, a multiple-page mapping artificial neural network with a back-propagation training algorithm was proposed so as to decouple the speed and tension control loops. The simulation results show the effectiveness of this control algorithm [17].

Based on the analysis of winding control system and equipment, this paper proposes a tension control system with Siemens Sinamics S120 transmission controller as the main control unit. The mathematical model of the constant tension winding control system was established. The control mechanism of the control system was designed with mathematical model. The relevant parameters and indicators are analyzed, and relevant control parameters are calculated and determined. With Siemens Simatic STEP 7 programming software, the S7-Technology motion control system development platform was adopted to realize the logic design, advanced algorithm, safety protection and so on. The Siemens TIA Portal fully integrated automation development environment was used to design the human-computer interaction system, which is validated on the experimental platform of motion control system.

II. Tension Control Model of Winding System

A. Mathematical Analysis of Basic Components of Winding System

(1) Tension Control Model of Winding System

In order to ensure the production quality of materials, the crimping production process must ensure that the strips materials have constant tension when crimping, and the special process also requires a constant linear speed on the basis of constant tension. Therefore, before designing the winding system with constant tension and constant linear speed, it is necessary to analyze the winding system, transmission system and control system. It is the premise of realizing the automatic control of the winding system with constant tension and constant linear speed. There are many kinds of winding systems, but the main controlled variables are tension and linear speed. The controlled object adopted in this design is shown in Fig. 1. It is composed of the most basic mechanism of the unwinding roller, winding roller, tension sensor required by direct tension control, encoder roller required to collect linear speed of coiled material, and tension wheel required for static friction between tension sensor roller and encoder roller during winding. Tension refers to the pulling force between two sides of the object when it is under the action of pull. The purpose of tension control in winding is to realize stable material transfer, prevent deformation and ensure dimensional accuracy.

(2) Speed Control Principle of Winding Roller

The winding roller adopts the speed control mode. The linear speed of the winding system is determined by the winding motor speed, and the winding diameter of the winding roller determines the winding motor speed. The speed control of winding motor can be realized by:

$$\omega = \frac{2v}{D} \tag{1}$$

$$\omega = 2\pi n \tag{2}$$

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

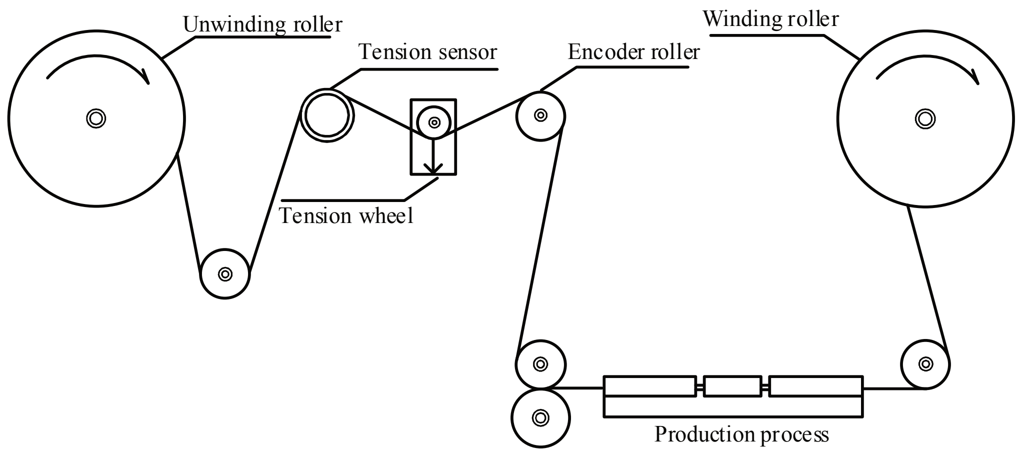

Fig. 1 Winding system model.

Based on Eq. (1)-(3), the motor speed can be defined as:

$$n = \frac{vi}{\pi D} \tag{4}$$

where, D is the coil diameter of the winding roller, v is the linear speed of the coiled material, ω is the angular speed of the motor, and n is the motor rotate speed.

(3) Load Characteristics of Unwinding Roller

Fig. 2 shows the model of the rollers in the winding system. Since the torque is equal to the product of the moment arm and force, the control system requires the tension of the coiled material to remain constant. The output torque of the motor should also change from large to small as the winding diameter of the unwinding roller changes. Therefore, the relation between the unwinding tension T and the motor torque can be described as:

$$M = \frac{TD}{2i\eta} \tag{5}$$

where, M is the tension torque, T is the unwinding tension, η is the mechanical efficiency of the transmission system, i is the reduction ratio, and D is the winding diameter of the unwinding motor.

(4) Detection Theory of Tension Sensor

The tension sensor used in this design has a measuring range of 0-150 N and an output voltage of 0-10 V. According to the actual installation mode of the tension sensor, the principle of tension meter detection is shown in Fig. 3.

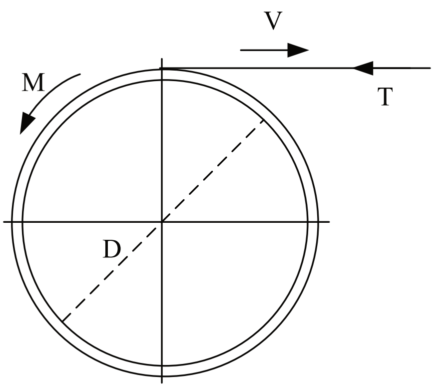

Fig. 2 Tension diagram of unwinding roller.

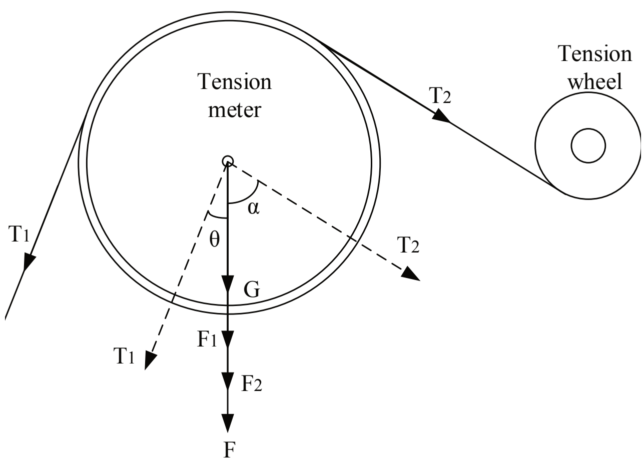

Fig. 3 Measurement theory of tension sensor.

The angle between the coiled material tension T and the pressure F of the sensing element is θ and α, respectively. Then the relationship between the sensing element and the tension T is described as follows.

$$F_1 = T_1 \cos\theta \tag{6}$$

$$F_2 = T_2 \cos\alpha \tag{7}$$

$$T_1 = T_2 \tag{8}$$

$$F = F + F_2 - G \tag{9}$$

Therefore, the tension detected by the tension meter can be calculated by:

$$F = T(\cos\theta + \cos\alpha) - G \tag{10}$$

where, T_1 and T_2 are the tensions of the coiled material, F_1 and F_2 are the component forces of the tension sensor of the coiled material, and F is the resultant force of the tension of the coiled material detected by the tension sensor.

(5) Theory of Motor Output Electromagnetic Torque

According to the theory of motor output torque analyzed by the unwinding roller model in Fig. 2, the electromagnetic torque generated by the motor is calculated by:

$$M = C\phi I \tag{11}$$

where, C is the motor torque constant, ϕ is the flux of the motor, and I is the motor armature current. Tension torque generated by the coiled material on the unwinding roller is defined as:

$$M_T = \frac{TD}{2I\eta} \tag{12}$$

where, T is the unwinding tension, D is the winding diameter of the unwinding roller, I is the reduction ratio, and η is the mechanical transmission efficiency. According to Eq. (11)-(12), the uncoiling tension is calculated by:

$$T = \frac{K\phi I}{D} \tag{13}$$

where, $K = 2I\eta C$ is a constant.

Therefore, under the base speed, the magnetic flux ϕ remains constant (full magnetic). I changes in direct proportion to D, and the torque T remains unchanged. The motor is regulated by the constant torque. Above the base speed, the motor is in the state of weak magnetic acceleration, and the armature voltage remains unchanged. If the torque T is constant, $\phi I / D$ remains unchanged and the motor is in a constant power speed regulation.

(6) Control Method of Tension

There are two kinds of tension control strategies (open-loop and closed-loop). One is direct tension control and the other is indirect tension control. Indirect tension control is an open-loop control method. Through the static and dynamic analysis of the tension control system, the electrical physical quantity is calculated to meet the control requirements. The tension is controlled by changing the parameters of the motor. This is usually achieved by controlling the speed difference between the two motors. Fig. 4 shows a strips materials winding system. The linear speed of the coiler is V_1, and that of the tension roller is V_2. In the winding, in order to ensure the existence of tension between the strips materials, it should make $V_2 > V_1$. At this point, the strips materials will be subjected to tension and elastic deformation. Indirect tension control has the advantages of no need for tension detection components, simple control system structure and rapid control response, but the open-loop control method is difficult to give consideration to the rapidity of response and the stability of control effect at the same time. In the actual control scene, various unmeasured interference have a very serious impact on the system. The indirect tension control method can not make effective compensation for these disturbances, thus affecting the whole control effect. The direct tension control is a closed-loop control method. The tension feedback of tension sensor is usually used in the control system to compare with the tension value set by the system. It uses the deviation of the set-point and process value to control the motor torque. The control method is simple and the control effect is much better than the open-loop control. However, its disadvantage is that the control precision completely depends on the tension detection components, and the cost of tension detection components is high. The theoretical block diagram of the direct tension control system is shown in Fig. 5.

(7) Classical PID Controller

The principle of PID controller is shown in Fig. 6. The PID controller is the most commonly used control algorithm in industrial production, with excellent control performance, stable system and simple algorithm. In a control system, the PID controller and the controlled object constitute a closed-loop control system. The deviation signal is used as an input quantity of the PID controller. Based on the negative feedback principle, the control variable is output after being operated by the PID controller.

The PID controller is composed of proportion coefficient K_p, integral of input $\int_0^t e(t)dt$ and differential of input $de(t)/dt$. Its algorithm expression is described as:

$$y(t) = K_p \left\{ e(t) + \frac{1}{T_i}\int_0^t e(t)dt + \frac{T_d de(t)}{dt} \right\} \quad (14)$$

The deviation is defined as：

$$e(t) = r(t) - y(t) \quad (15)$$

where, K_p is the proportional coefficient, T_i is the integral time, and T_d is the differential time.

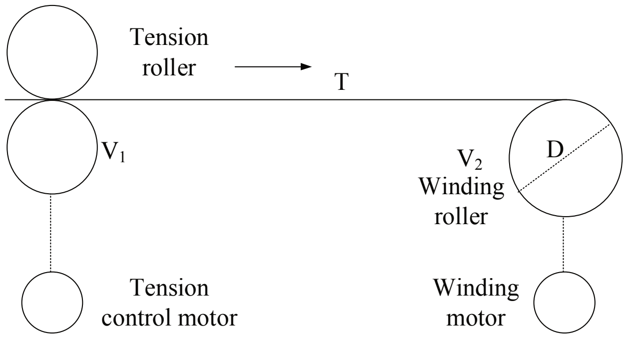

Fig. 4 Indirect tension control by speed difference.

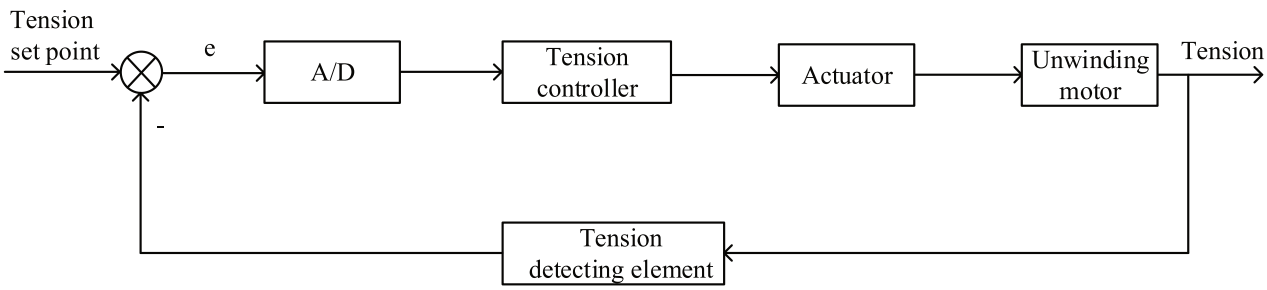

Fig. 5 Theoretical block diagram of direct tension control system.

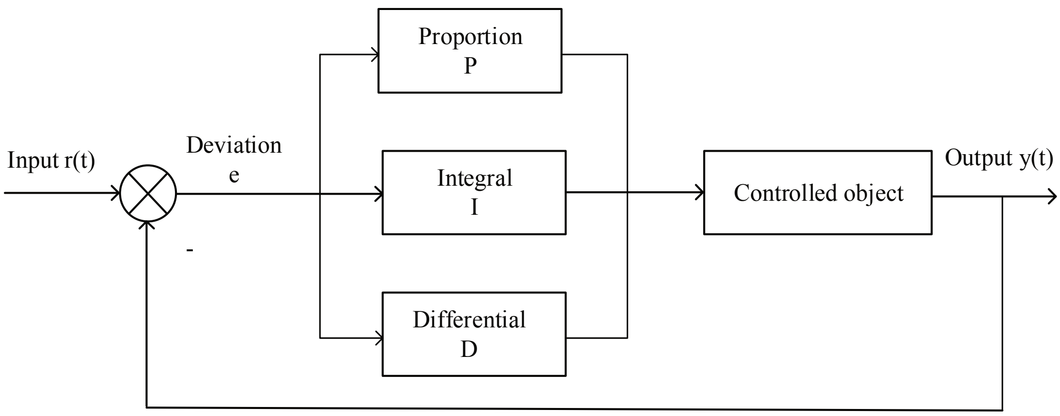

Fig. 6 Principle diagram of PID controller.

2.2 Design of Winding Controller of Constant Tension and Linear Speed

(1) Constant Linear Speed Controller of Coiled Material

Because the linear speed of the winding system is an important index to determine the production quality index, the determining factor of the winding linear speed is the speed of the winding motor. In order to achieve the accurate control of the linear speed, the method of theoretical calculation value and the PID correction value are combined. Based on the speed of winding motor controlled by winding diameter and the feedback value of motor speed are compared, the obtained deviation is used for real-time correction of winding motor speed to achieve higher control accuracy. The principle of constant linear speed control of coiled material is shown in Fig. 7.

(2) Design of Constant Tension Controller of Coil Material

The tension control method adopted in this system is direct tension control, and the motor torque is given by the feedback of the tension sensor. Motion servo is generally controlled by "three rings", which are position ring, speed ring and current ring from the outside to the inside. Winding motor and unwinding motor work in speed mode. However, the difference is that in order to avoid flying out due to the sudden fracture of the unwinding motor during the winding, the designed unwinding motor adopts the control mode of speed ring saturation. Constant tension control is achieved by limiting the amplitude of the output torque of the unwinding motor. As shown in Fig. 8, S120 sets the upper limit of the motor torque through the P1522 parameter.

(3) Analysis of Filtering Algorithm

Filtering is the operation of filtering the waveform of the specific frequency band which is harmful to the production in the collected signal and it is an important means to suppress and prevent interference. For example, because of the external electromagnetic interference of the encoder, assembly accuracy, code wheel eccentricity, photoelectric signal distortion, etc., the output pulse has edge jittery. In order to suppress this unwanted noise, it is necessary to filter the output of the encoder. The common filtering algorithms include median filtering method, arithmetic average filtering method, limiting average filtering method, recursive average filtering method, Kalman filtering method, and so on.

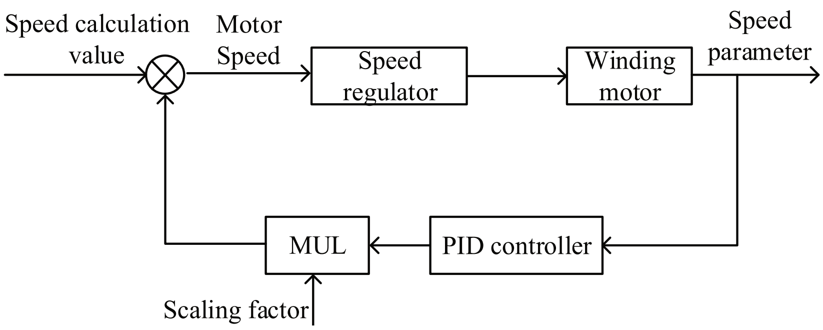

Fig. 7 Principle block diagram of winding motor speed controller.

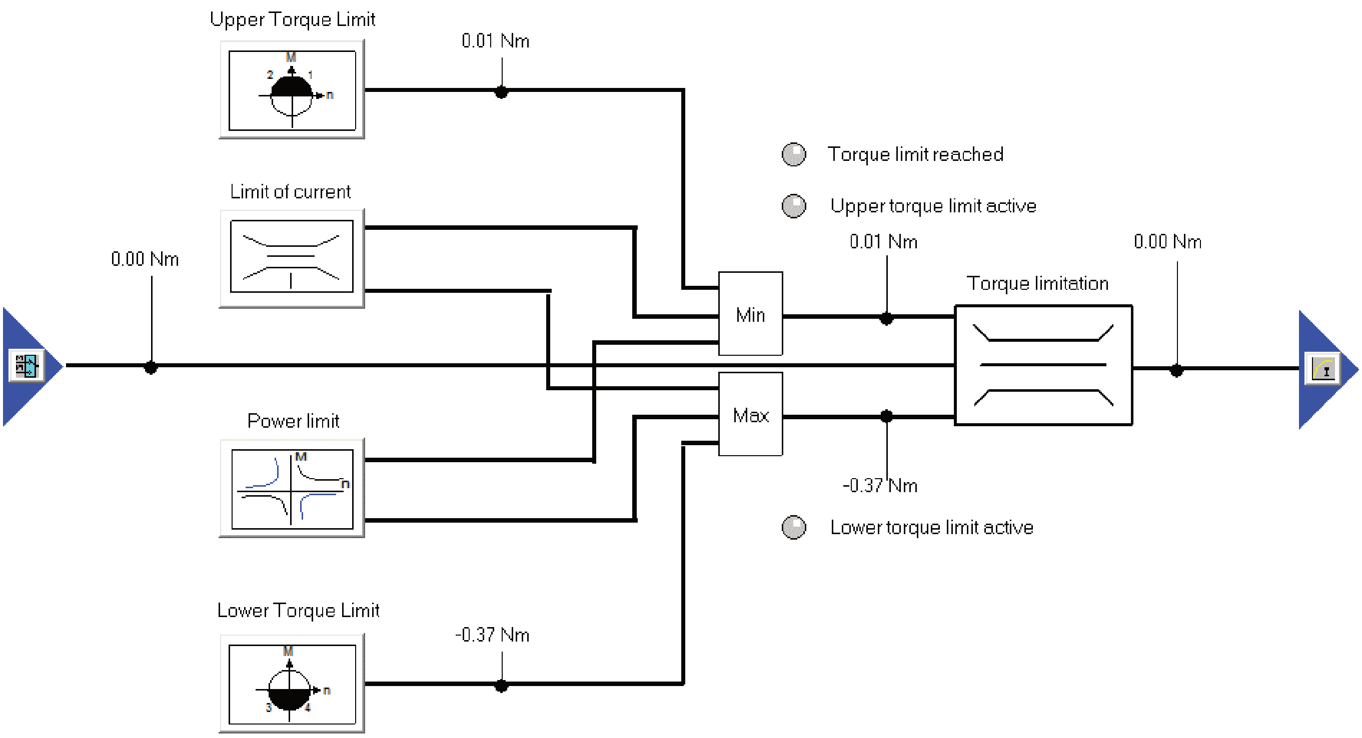

Fig. 8 Torque upper limit initialization by setting P1522 parameter of S120.

In this design, the filtering algorithm adopts recursive average filtering method. It is also called the sliding average filtering method, which can better overcome the periodic interference, has a good smoothness, and has a high utilization rate in the high frequency oscillation system. This method is shown in Eq. (16).

$$y(k) = \frac{y(k) + y(k+1) + \cdots + y(N+k-1)}{N} \quad (16)$$

where, $y(k)$ is the k -th sampling value, and N is the number of queue data.

Every time a new data is collected by this filtering algorithm, it will be placed at the end of the queue，and the data at the head of the queue will be deleted. The filter value is obtained by arithmetic averaging the data in the data queue collected each time.

B. Feed-forward Compensation of Tension Control

In view of the deficiency of the feedback system, it is necessary to make feed-forward compensation for the control system. In the tension control system, the output torque of the motor is composed of:

$$T_r = \frac{FD}{2i\eta} + T_{qi} + T_{qf} + T_{qw} \quad (17)$$

where, T_r is the set value of torque, T_{qi} is the compensation moment of inertia, T_{qf} is the compensation moment of friction loss, T_{qw} is the compensation moment of wind loss, and $FD/2i\eta$ is the tension required by the unwinding roller, which is calculated according to the set tension, winding diameter and transmission ratio.

Next, the effects and mathematical models of compensation moment of inertia, moment of friction loss and moment of wind loss are analyzed respectively.

(1) Compensation Moment of Wind Loss

The moment of wind loss in engineering is proportional to the speed of the motor, which is shown in Fig. 9. The compensation moment of wind is realized by:

$$T_{qw} = kv \quad (18)$$

where, T_{qw} is the compensation moment of wind loss, k is the proportional coefficient, and v is the linear speed of the coiled material. The determination of the proportional coefficient k is through on-site debugging.

(2) Mechanical Loss Compensation

The friction compensation moment is described by:

$$T_{qf} = \mu F \frac{D}{2} \quad (19)$$

where, D is the axial diameter, F is the resultant force of coil weight and tension, and μ is the axial diameter friction factor. In the practical engineering, the above compensation analysis is only a theoretical study. At present, most of the adopted compensation algorithms are to test the output torque at different rotate speeds when the motor is running continuously with empty load. It is considered that the measured torque is the friction torque, and its curve shown in Fig. 10. is fitted as a multiple power equation with the speed.

(3) Compensation of Moment of Inertia

The moment of inertia is a measure of a rigid body as it rotates about its shafts. It is represented by J and is the physical property that characterizes the object itself. If the hardware platform of a tension control system is determined, the moment of inertia of the shafts is also determined. The moment of inertia can be expressed as:

$$J = mr^2 \quad (20)$$

where, J is the moment of inertia, m is the mass, and r is the vertical distance from the particle to the shaft. The motion equation of the unwinding roller is described as follows.

$$T_e - T_L = J\frac{d}{dt}(J\omega) + \omega\frac{dJ}{dt} \quad (21)$$

where, T_e is the electromagnetic torque of the motor, T_L is the load torque, ω is the angular speed, and J is the inertia of the unwinding roller. In many cases, it is assumed that the moment of inertia is constant, that is $J = const$.

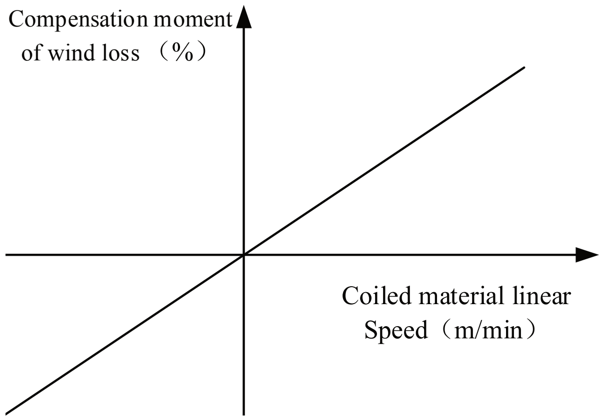

Fig. 9 Relationship between compensation moment of wind loss and linear speed.

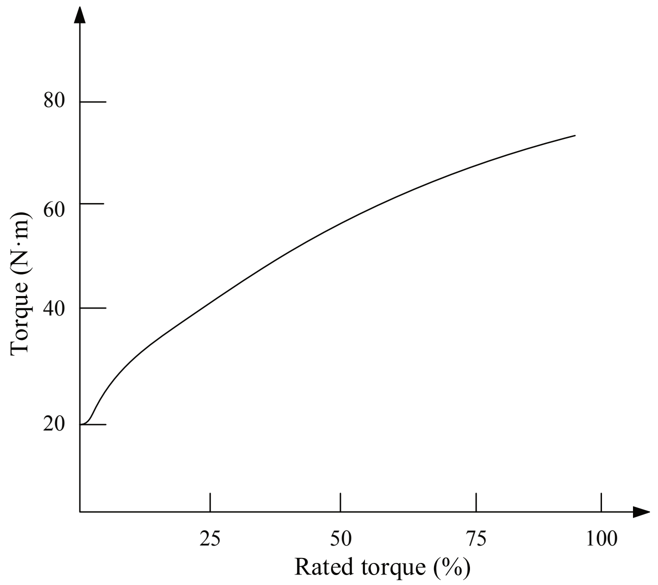

Fig. 10 Fitting curve of motor friction torque.

So obtain:

$$T_e - T_L = J\frac{d\omega}{dt} \tag{22}$$

In view of the deficiency of inverter feedback control, the moment of inertia artificially increases or decreases the output electromagnetic torque of the motor while the system is accelerating or decelerating, so as to accelerate the response speed. When the moment of inertia is compensated, a cylindrical rigid body with mass *M* and radius *r* can be obtained by analyzing the moment of inertia of the system. Its moment of inertia *J* is calculated by Eq. (23).

$$J = \int_0^M r^2 dM \tag{23}$$

Therefore, the compensated moment of inertia is calculated by:

$$T_{qi} = J\frac{d\omega}{dt} = (\int_0^M r^2 dM)\frac{d\omega}{dt} \tag{24}$$

III. Hardware Configuration and Software Design of Winding System

A. Hardware Configuration and Preparatory Settings of Winding System.

In order to realize the cooperative work of each hardware device and the control index of the project, the hardware must be configured by the software platform. In this design, SIMATIC Manger STEP7 V5. 5 SP4 is used for realizing the hardware configuration. The PLC controller needs to read the feedback speed and torque current of each motor encoder from the driver in real time. At the same time, parameters such as the given speed and torque should be written into the driver to realize the control of the motor. Therefore, the correct communication between PLC and S120 drive system is the key to realize the design of the winding system. PLC is the first type of main station, which can complete the bus communication and the management of each hardware. HMI is the second type of main station, which can complete data reading and writing, fault diagnosis and other operations of each station. The operation screen is configured with the SIEMENS TIA fully integrated automation platform to realize the communication between HMI, PLC and CU320. PLC and HMI are real-time communication.

(1) Hardware Configuration of Winding System Device in STEP7

A new project is created in SIMATIC Manger. In this project, insert a SIMATIC T station, and configure in the hardware configuration item HW CONFIG according to the corresponding hardware model and version number. Note that the hardware version, model number, and order number must be consistent with the hardware configuration to be compiled. The CU320 control unit and IM174 module are mounted on the PPROFINET bus and PROFIBUS bus respectively, and the corresponding IP address and PROFIBUS address without conflict is allocated. As PROFINET and PROFIBUS network buses used in this design are used for communication between devices. A large number of traditional I/O wiring is improved, which brings great convenience to configuration and hardware connection. The view of NetPro network with configuration completed in STEP7 is shown in Fig. 11. The hardware configuration of STEP7 and S7-Technology is shown in Fig. 12.

(2) Configuration and Parameter Reading of External Encoder

Since the external encoder of the system is connected to the fouth channel encoder input interface of IM174 interface module. The fouth channel needs to be configured in IM174 module configuration, where the encoder type is TTL and the resolution is 1024. The configured IM174 interface module is shown in Fig. 13. An external encoder is inserted in S7-Technology and configured to be rotary with a 1024 resolution. Since the diameter of the encoder roller is 50 mm, it is necessary to set the measured distance in the mechanical characteristics of the encoder as 157 mm when the encoder rotates one cycle. Create and activate the external encoder data blocks. The reading of external encoder data needs to generate the data blocks of encoder by the S7-Technology process package. The activation of the encoder needs to invoke the FB432 function block in the S7-Technology process package library function with OB1.

(3) Configuration and Parameter Reading of Tension Meter

The tension sensor of this project is connected to the first part of the digital quantity input module, and its address is set as PIW272 in the configuration. The measuring range of the tension sensor is 0-150 N, and the output voltage is 0-10 V. It can be used for this project after the range conversion. The net measurement value of the tension meter minus its own gravity is the reading value of the tension meter minus the measurement value of the analog signal input module without material winding. This value is obtained by calculating the force analysis mathematical model function of the tension meter. Invoke FC105 for range conversion is the measured tension value. Two angles 8° and 76° of the model can be measured. For simplicity, the SCL language is used to read tension values.

B. Automatic Control of Winding System

(1) Automatic Controler Design of Constant Line Speed

The speed control of winding motor is calculated by the formula $\omega = v / r$, where ω is the preset rotational speed (rpm) of the rewinding motor, r is 1/2 of the reel diameter of the rewinding roller, and v is the preset winding linear speed. The linear speed of the winding system is an important index to determine the quality index and the determining factor of the winding linear speed is the speed of the winding motor. So in order to realize the accurate control of the linear speed, the PID controller is adopted in this project. When the FB41 PID module is interrupted to invoke in the OB35 cycle, the winding motor rotational speed and the feedback value of motor rotational speed calculated by winding diameter are compared, and the obtained deviation is used to make real-time correction for the winding motor speed.

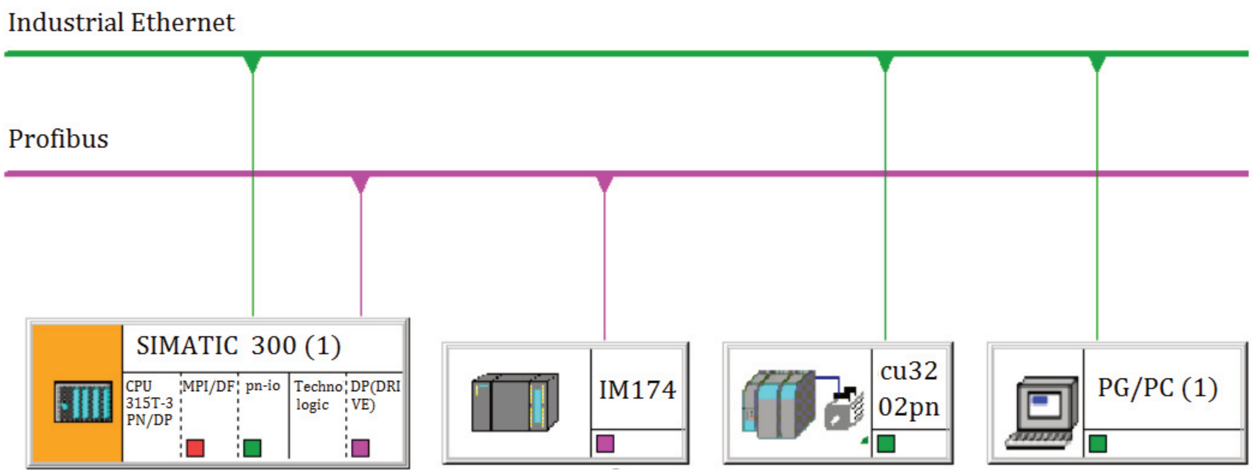

Fig. 11 Diagram of STEP7 network configuration.

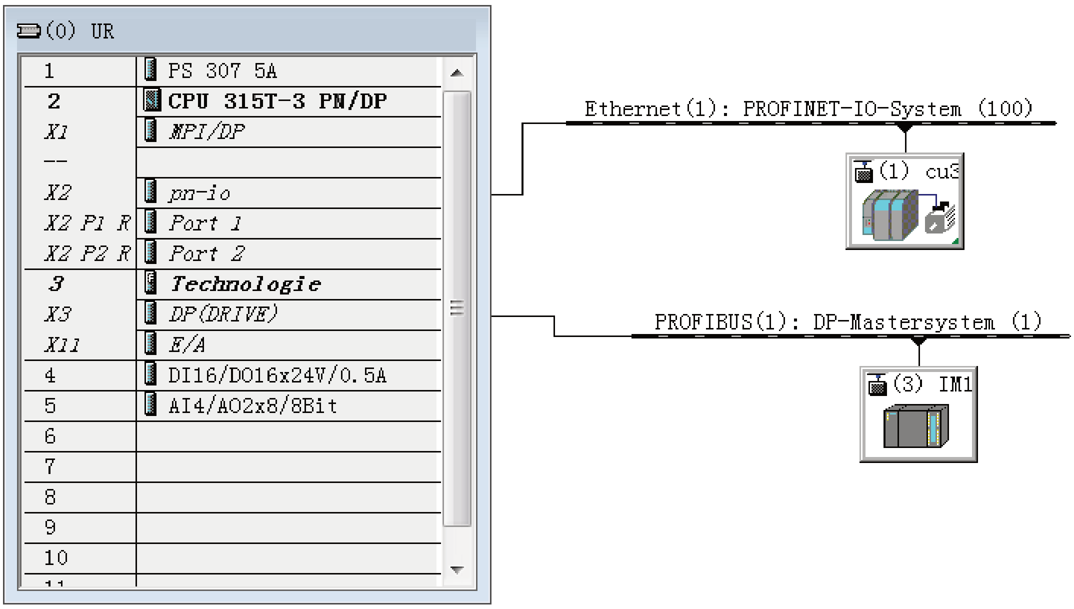

Fig. 12 Overview of STEP7 and S7T hardware configuration.

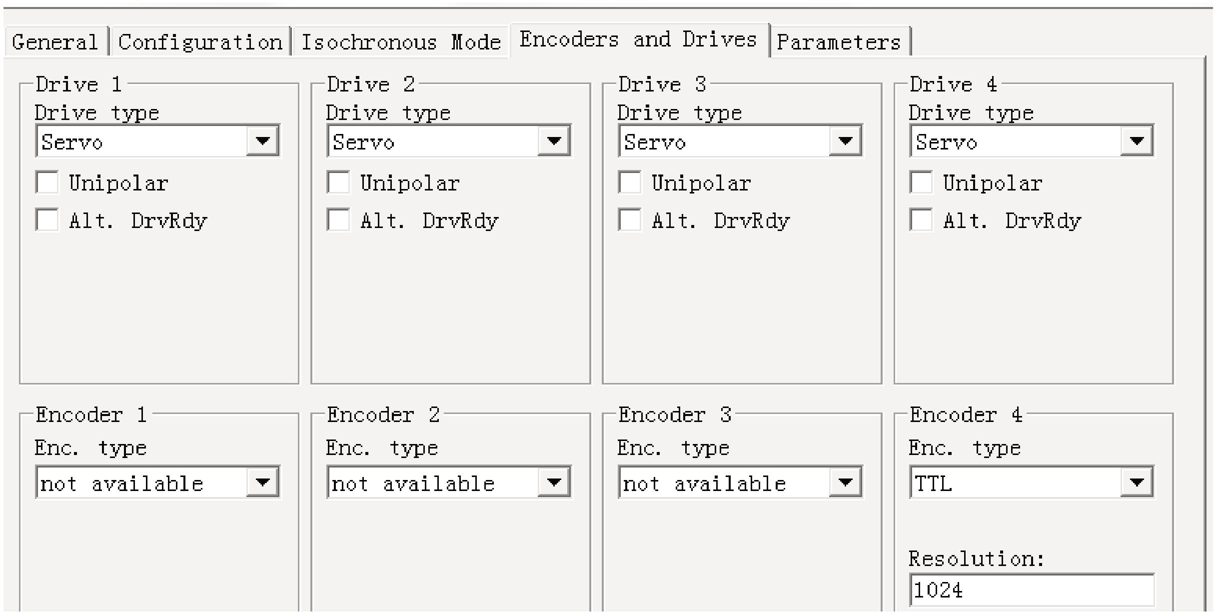

Fig. 13 Configuration of external encoders.

(2) Automatic Control Program Design of Constant Tension

The automatic control of the tension is realized by controlling the torque of the unwinding motor. The torque of the unwinding motor consists of the torque calculated through the unwinding diameter, the acceleration and acceleration torque compensation of the unwinding roller, the friction torque compensation of the motor and the reducer, the inertia compensation of the unwinding roller, the wind loss compensation and the motor's unloaded torque. In this design, the winding motor adopts the method of speed saturation and changes the upper limit of torque to control the tension. The given torque is calculated by the winding diameter and acceleration ratio of the unwinding roller, plus all the compensating torque. The upper limit of the torque of the winding motor is given, which is corrected by the OB35 interrupt PID algorithm in real-time. Finally, a satisfactory automatic control effect of constant tension is obtained.

At the same time, in order to avoid large fluctuation of tension caused by sudden change of speed during modification of winding speed, the winding motor speed is increased by the ramp to the new set point and decreased by the ramp to the new set point. The design idea is to write the ramp function. In each modification of the linear speed set by the winding system, the given linear speed is processed by invoking the ramp function and then the speed is given to rotational speed of the winding motor.

(3) Control Logic Design of Winding System Start-up

First of all, the winding system needs to set up the tension of the winding materials. At this time, the unwinding motor runs at a certain speed, and the unloaded torque of the winding motor is given, which can be regarded as static. When the tension is greater than the preset tension threshold, the tension establishment of the system is completed. The second step is to start winding. The winding motor turns forward at a certain speed, while the unwinding motor turns backward at a given small speed with a torque slightly greater than the unloaded torque. After 2s, the winding diameter is calculated. The third step is the signal output after winding diameter calculation. The torque of the unwinding motor and the rotational speed of the winding motor are automatically controlled by the PID controller so as to realize the automatic control of the constant tension and constant linear speed.

C. Design of HMI Touch Screen Software

Human machine interface (HMI) is to realize the conversion between device information and human. In this design, the control panel selects the Siemens KTP 700 BASIC PN and the interface selects PFOFINET which can communicate directly with PLC or S120. The screen selects 7-inch true color LCD touch screen, which has 8 programmable function keys and can be programmed to achieve operator management, measurement data collection, data recording and reality, alarm and parameter configuration and other functions. The PROFINET bus of KTP 700 BASIC PN can be connected to PLC through Cat 5 or higher Ethernet cable inter-changer. In order to communicate with PLC normally, it is necessary to establish S7ONLINE connection with PLC in configuration. Communication program selects the communication program of SIMATIC S7 300/400, and the correct allocation of PLC and touch screen physical hardware is consistent with the IP address.

(2) HMI Interface Design

The HMI interface functions include start and stop control of the motor, winding diameter presetting, tension setting, linear speed setting, actual tension reading, motor inching, PID parameter fine-tuning, real-time speed curve monitoring, real-time tension curve monitoring and alarm logging and other functions. The operation status screen can visually view the current operation status of the winding system and realize the monitoring of the current motor parameters, system tension, winding diameter and running line speed.

D. System Performance and Parameter Debugging

So far, the design of the constant tension and constant linear speed control system in the winding system based on SIEMENS S120 driver has been completed. Because the precise transfer function of system cannot be obtained, the parameter tuning method of the tension PID controller and linear speed PID controller adopt the experience test method. The linear speed accuracy deviation is setting $\pm 0.2m/\min$, and the tension accuracy deviation is setting $\pm 2N$. System performance has been able to meet most of the process requirements.

IV. CONCLUSION

Tension control system is a relatively complex control system, which includes mechanics, electrical engineering, measurement, control, hydraulics and other subjects. In this paper, the design of the constant tension and constant linear speed winding system based on SIEMENS S120 driver is completed. In the context of the industry 4. 0, digital industry and production efficiency have been placed in the main position of industrial manufacturing. This design applies SIEMENS PROFINET and Drive-CLiQ field-bus to tension control winding system, which effectively improves the production efficiency and process performance.

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