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The Visual Control of Minuteness Wire Twister Machine

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Abstract

A new control system of minuteness wire twister machine is introduced in this article, which realizes the visual control taking the touch screen as the core and making AC servo motor and stepping motor as the drive components. The key technique is to automatically control and compensate the position errors between the angular displacement of principal axis and ball screws displacement. The control system solves the problem of yawp existing in the equipment, and the touch screen can actualize man-machine conversation and various control parameters are clear at a glance.

Keywords: PLC, Touch screen, Twister machine, Ball screws

1. Introduction

The application range of minuteness wire twister machine becomes more and more extensive, which includes the winding of enamel-insulated wire, the winding of mutual inductance loop and so on. The production characters include continual production on the semiautomatic twister, large outputs in unit time, higher degree of automatic control for technics parameters. The production technology of China gets behind foreign countries (Cai, 2002, p.5-7). Therefore, we adopt PLC and touch screen control to design this minuteness wire twister machine which can make the operation of the whole equipment simpler. The characters of this machine include following aspects.

(1) Mutual operation. Several equipments of different manufacturers can work in one same system and actualize information exchange. Accordingly users can freely select equipments provided by different manufacturers to integrate system.

(2) Higher reliability of control. This machine transfers the control function to the locale, and the intelligentization and digitization of the general line on the spot make control quicker and exacter.

(3) Low fees of installation. This machine can fulfill the requirements of different line diameters, and the winding process is highly efficient and stable, which can fully enhance the production efficiency. And it also offers a more efficient method to actualize volume-production and guarantee quality of products for minuteness wires.

2. Principle and function requirements

The winding of the twister machine includes spiral winding and circuit winding. This equipment can implement the circuit winding of minuteness wires, which requests the rev of principal axis and the ball screw fulfill the requirement that when the principal axis rotates one circuit, the ball screw goes for the distance of one line diameter, thus two neighbor tiny lines will have no apertures (Mai, 1997, p.25-27). This equipment uses rotary coder to check the rev of the principal axis, PLC to check signals of sensor for controlling the cutting feed of the step motor. The coder gives certain numerary pulse as a timing unit, so the step motor will follow the frequency and drive across-thread-stand to make reciprocate with certain speed and complete the dense winding of minuteness wires.

The work requirements of this equipment include following aspects.

(1) The principal axis should be droved by servo motor and the rotary coder will gather the rev of the principal axis.

(2) The follow movement should be droved by step motor and PLC controls step motor to emit the number of pulse.

(3) Both left breakpoint switch and right breakpoint switch need one apiece and the continuous pulse output is needed.

(4) Two limited switches are demanded and the across-thread-stand can implement reciprocate automatically.

(5) Setting up on/ off pushbutton.

(6) The touch screen displays the work situation and basic parameters.

The diameter of the minuteness wires are small (generally being 0.10-0.50mm) and the rev of the principal axis is very high, so the minuteness wires must guarantee continual winding and have no superposition or jumping lines. Based on above production requirements, we adopt DVP24ES00T2 PLC and TD220 touch screen, which can not only fulfill the requirements of winding precision, but also reduce production cost and make the whole equipment possess small volume, perfect function and convenient operation (seen in Figure 1).

3. Design and implementation of minuteness wire twister machine

3.1 Design of mechanism

For the winding machine, because it directly influence the quality of product, the production efficiency of loop, so the design of the winding machine is very important, which needs considering the automatic switching when the loop rounds one circuit, convenient alteration in certain range for the diameters of molding loops, replacing of molding loops of various standards, and convenient adjustment of various components of corresponding twister machine (Wu, 2002). This machine requires simple and convenient structure, high efficient drive, high precise orientation, drive reversibility and long useful life. We take ball screws as the driver machine and confirm the precision and length of screws according to the conditions such as using condition, maximal rev and stroke of the principal axis. Because the single nut has small pre-fasting errors, so it is always used in precise orientations with middle or light loads. Therefore, we select FFB ball screw with inner cycle alteration broke pre-fastening nut. To ensure the movement of the across-thread-stand is stable, the strict parallel degree between glide guide track and screw are requested and the beeline bearing guide is adopted. When the continual winding of minuteness wires is implemented, under the condition of redundant time, the core fixing machine of the principal axis must be stable and convenient for dismantling and fulfilling the requirements of different line diameters. Thus, this machine adopts double finial movement support and double directional circularity jumping to ensure certain precision range.

For the strain machine, the winding loop is fixed on the bracket stand and strained by the felt through the spring and across-thread-stand, so the stain will change, the spring rotates and the tiny line will flex automatically. The machine has simple structure and low costs and it can fully fulfill the production requirements (seen in Figure 2).

3.2 Design of control part

The minuteness wire twister machine mainly includes three parts.

(1) The principal axis system. It is droved by servo motor and the stepless speed adjustment of the principal axis is realized by the changes of voltage. The rev of AC servo motor is decided by the servo control voltage which corresponding value is in -10V~+10V. The positive or negative values of the voltage control the rotation with direction or reverse direction. The twister has higher requirement for the precision and stability of the motor rev. In the rotating process, the fluctuation of the speed must be small, and the rotating coherence of step motor at direction and reverse direction should be good. Therefore, this system adopts high precision D/A commutator (which precision is 0.012%), excessive low compensated voltage operation amplifier and high stability voltage norm to make up of D/A conversion circuit with high precision and low excursion.

According to the required rev of the output axis and the maximal rotary diameter which can be fulfilled, we select the motor with small power and big moment of inertia. To the control system design, we only consider that the motor work in the basic speed fully utilizing its power and without weakening magnetism. We adopt the maximal moment mode to adjust strain.

$$TD/2 = M_T = 2C_M \phi I \tag{1}$$

$$T = 2C_M \phi I / D$$

$$M_J = J\frac{dw}{dt} = \frac{GD^2}{375}\cdot\frac{dw}{dt} \tag{2}$$

$$J = \frac{MR^2}{2} \tag{3}$$

Where, T is strain, D is the diameter of the coiling block, M_T is the torsion produced by strain, C_M is the structure constant of the motor, Φ is the flux of the motor, I is the armature current, M_J is the moment produced by the moment of inertia, J is the moment of inertia, ω is the angular velocity, M is the quality of the copper wire, and R is the rotary radius.

Because this equipment mainly works in the constant rev, so according to the formulas we can know the moment produced by the moment of inertia is not big, which is mainly embodied in formula (1). The tensile strength of the copper wire is 140Mp, the density is 6.4g/mm^3, the maximal diameter of winding is 400mm, so the moments of inertia are M=6.4×3.14×400×50=401920g and J=0.5×402×0.2^2=8.04kgm^2, the torsions are T=140×3.14×0.25×0.25=27.5N and M_T=27.5×0.2×1.414=7.76Nm (where 1.414 is the proportional coefficient of square loop to round loop). Therefore, we can confirm the type of the selected servo motor and the drive proportion of the drive.

(2) The winding system (nuclear part). This control system is mainly composed by industrial computer, D/A conversion circuit, counter and the motor which can control the circuit and the panel input circuit. D/A conversion circuit bring servo control voltage of the master motor and the counter is used to accumulate the pulses outputted by the rotary coder. The computer confirms the angular velocity and rev through timely reading the values of the counter. The rev of the principal axis motor is preset by people who compute the servo control voltage and output it to the principal axis driver for controlling

the principal axis rev transmitted to the planned rev. PLC checks pulses outputted by the rotary coder, obtains the angular displacement and actual rev of the principal axis motor, outputs corresponding follow pulses and frequency, and ensures the rev of the step motor respond the master motor according to strict speed in the winding process. In the winding process, influences from various interferential factors will produce rev fluctuations of these two motors. Therefore, PLC must check the revs of these two motors at real time and correct the rev of the motor according to the rev errors. When the rev of the principal axis changes, PLC needs implement corresponding adjustments to the rev of the step motor to ensure the speed proportion between ball screw and the principal axis keep constant. At the same time, PLC also should check and eliminate the speed warp of the ball screw (Mai, 1997, p.25-27). The selection of the sampling period of the control system has many influences to the control precision and stability. Too long sampling period will reduce the response speed of the control system and too short sampling period will increase computation errors of the motor rev to reduce control precision and stability. Through experiments we find that the sampling period in 10ms-20ms has best effects.

It usually needs six or seven hours' continual winding to finish one loop, so tiny differences between two motor revs will produce big relative position errors. Therefore, the velocity errors between the angular displacement of the principal axis and the rev of the step motor must be controlled and compensated. When errors occur at the relative position, we can not adjust the speed between both sides to correct the errors because it will influence the changes of the local line arrangement width, and we can adjust the time which the screw stays at two points.

After long-term operation, it is avoidless for the zero of the voltage outputted by the D/A conversation circuit to produce excursion. When the voltage zero produces excursions, the rev errors of the motor at about zero rev are big and the rotary direction of the motor will change. So the zero excursions must be eliminated. We can change the output to the zero position of the excursion binary code of the D/A converter and reset the zero of control voltage to keep consistent with the zero of output voltage. The method to look for the zero of output voltage of the D/A converter after excursions is to check the rev changes of the motor at about zero rev and compare them with the output excursion binary code, accordingly obtain the corresponding value of the excursion binary coder at the zero of the output voltage.

(3) The upper computer control system. We use Taida TD220 as the operation display, and this touch screen has characters such as small volume and cheap costs and possesses extensive applications in the winding control. The touch screen communicates with PLC through data cable, and it can replace traditional smart operation display with control panel and keyboard (Cai, 2002, p.5-7). The control system of production line is simple, and parameters are few to be set. This touch screen uses menu to work and the operator can use touched switch to set up parameters such as the rev of the twister, circle number of winding, layer number of loop, line diameter of the minuteness wires and so on and change these parameters on the operation platform. Once these parameters are confirmed, the pulse number emitted by the step motor, the rev of ball screw and the rev of twister can be automatically regulated on the total product line. Under the automatic working condition, the touch screen can display the set line diameter of twister, record total circle numbers of single and complete journey, conveniently implement lathe on/off, frequency following, mistake alarming and display the moving situation of the motor.

3.3 Program flow and main I/O position explanation of PLC

The programming of PLC is the key to implement winding process. In this winding system, continual pulse output of PLC is the emphasis of the program, and the time and frequency of pulse emitted by PLC are controlled according to the rotary velocity of the principal axis. We should follow the rotary velocity of the master motor, select appropriate fractionized angle for the step motor, compute frequency and time of PLC combining the nut distance of ball screw to control the cutting feed of ball screw droved by the step motor, and strictly guarantee when the principal axis rotates one circle, the screw goes the distance of one line diameter (seen in Figure 3).

For example, when the principal axis rotates one circle, the minuteness wires directly twist on the principal axis, and the operator may adjust the rev of the principal axis through the frequency at any time, so the step motor must have enough time to respond and follow the frequency in the period that the master motor emits pulses, i.e. the time that the rotary coder emits pulses $\geq$the time that PLC emits pulses + the time that PLC implements pulses.

Supposed that the rev of the master motor is 1440r/min, the sampling time is T_C, the pulse output time is T_M, the step distance angle of the step motor is 0.036, the nut distance is 10mm, the line diameter is 0.5mm, the pulse output frequency is 20000Hz, the rotary coder emits 200 pulses in one circle, one sampling period includes 50 pulses, so the sampling time can be computed as follows.

$$Tc = \frac{50}{1440/60 \times 20} = 0.01(s)$$

And the pulse number needed by the step motor when it goes one quarter of one line diameter and receives 360/0.036=10000 pulses can be computed as follows.

$$\frac{10000}{\chi} = \frac{10}{0.5/4} \quad \chi = 125 \quad \text{(Pulses)}$$

The time that PLC emits 500 pulses can be computed as follows.

$$T_m = \frac{125}{20000} = 0.00625\,s, \text{ when } T_M < T_C.$$

The explanation of main I/O positions for PLC is seen in Table 1.

4. Conclusions

This control system successively adopts servo motor and step motor with high performance, D/A conversation circuit with high precision and low excursion, and convenient human-computer interface. The control process of minuteness wires winding is simple and the volume of winding equipment is fully decreased. The PLC programming has strong reliability, powerful functions and more flexibility. The characters of touch screen such as simple operation and extensive usage are fully embodied in the control system. The human-computer interface with humanization makes operator acquire few professional knowledge to conveniently and quickly operate the equipment. However the shortage is that we have not realized automatic formfeed, printing glue and paper cutting, which is the direction that we should continue to strive in the future design.

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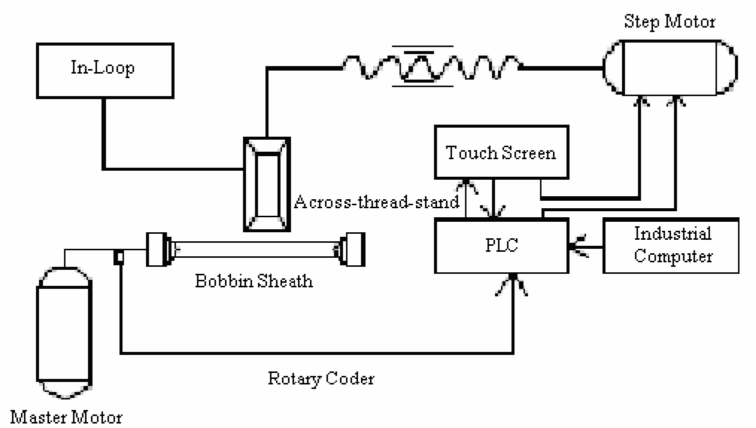

Figure 1. Principe of Twister Machine

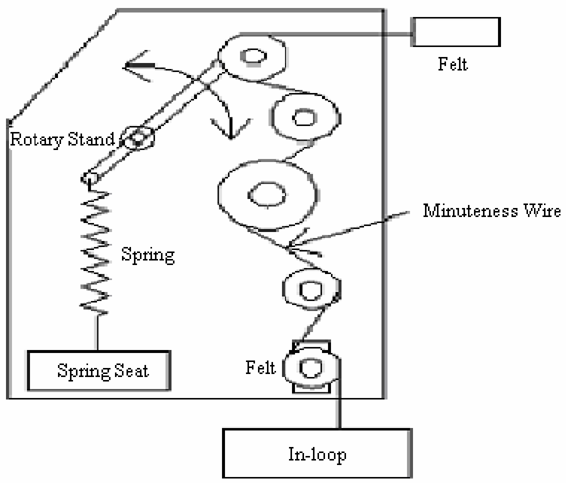

Figure 2. Sketch of Tension Structure

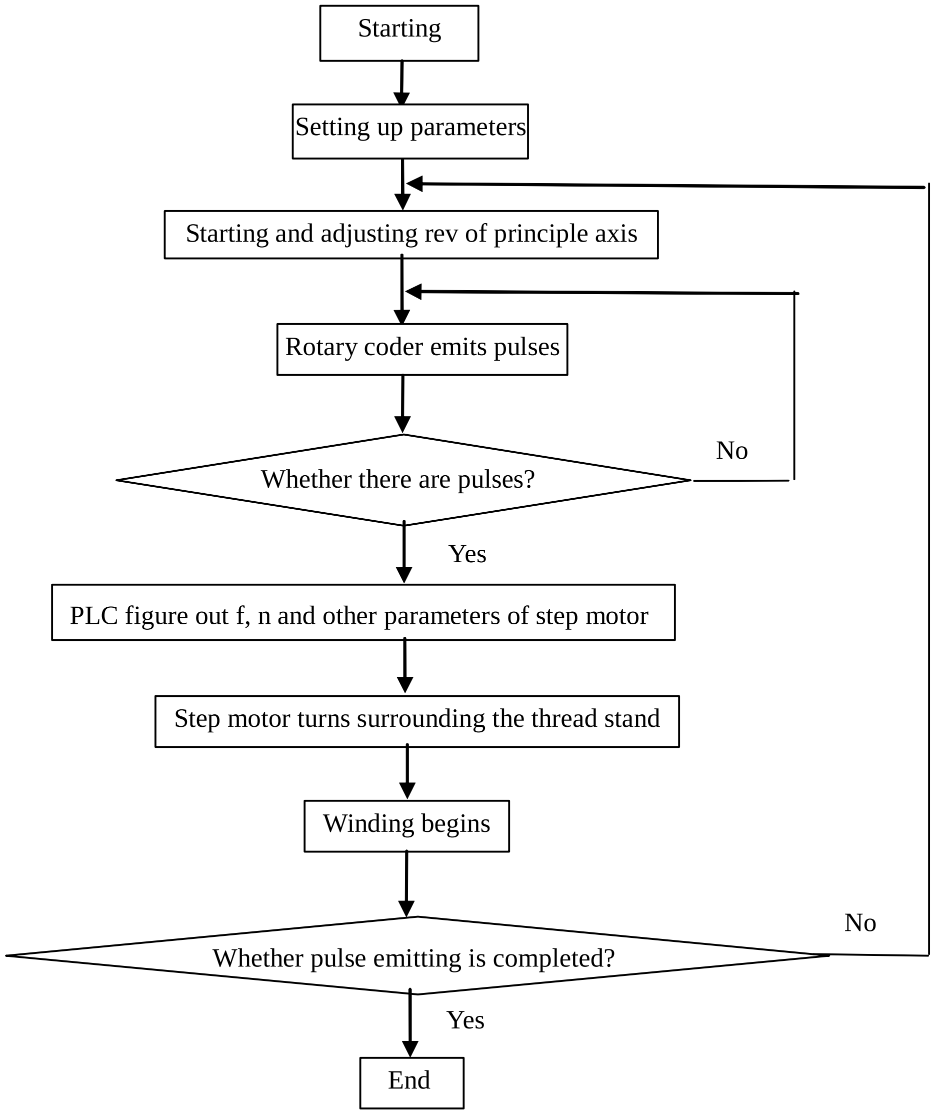

Figure 3. Program Flow

Table 1. Main I/O positions of PLC

Input signal of PLC	Address	Explanation
	X0	Input signal of direction power level
	X1	Input signal of electric pulse
	X10	Left limited switch
	X11	Right limited switch
Output signal of PLC	Y0	Output of high frequency pulse
	Y1	Direction power level of motor
Relative address of touch screen	D100	Total circle number of winding
	D150	Circle number of one way
	M200	Clearing of circle number
Special address	M1000	Constant switch point of watch operation
	M1028	Time-base change of timer
	M1029	Implementing over of watch pulse
	M7	X0 inspires M7 and keep M1029 ON