ELECTRICAL CONTROL DESIGN FOR DRIVING SYSTEM OF SERVO MOTOR

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ABSTRACT: With the rapid growth of economy, the demand from different products for packaging is increasing, thus more needs are to meet on the performance of laminating machine. There are disparities between laminating machine made in China and other countries with advanced level in working speed. In order to solve the problem, a study on the electrical motor design is carried out. Servo motor is used to achieve smooth variable motion of paper drive shaft so as to reduce the velocity when the flute rams upper paper and avoid the folding and bending of paper. Through speeding up the moving speed of paper, the average speed of laminating is achieved, thus completing paper lamination at a rapid speed, which means the working efficiency of laminating machine is improved. Complete speed curves of paper transferring are made, tested and debugged in the study to meet different working demands. Research results show that the system can solve problems in upper paper folding and also improve the working efficiency and performance of laminating machine.

KEY WORDS: servo motor, laminating machine, electrical control design, upper paper.

1 INTRODUCTION

Full-auto flute laminating machine is an important machine for processing packaging board. It laminates the upper paper in various materials with pictures printed and the bottom paper by gluing, positioning and pressing process so that preparation work for die cutting and forming process are completed [1,2].

Xin J F et al. proposes a plan for pulse and continuous speed of laminating machine. Polynomial fitting MATLAB program is used to get quadratic curve and cubic curve. The control of quadratic carve is verified by integration method. It turns out that motion speed of machine speeds up at the same impact [3]. Wang X H et al. designs a new positioning method for correcting direction of upper paper aiming to settle down problems about deviations in working and low accuracy of positioning of laminating machine. Under the control of motion control card, servo motor works in correcting and rectifying direction of upper paper, which obviously improve the accuracy of upper paper positioning [4]. With the purpose of solving problems about paper supply interruption, Ye L M et al. improve the structure of bottom paper suction and the front lay to enhance the positioning accuracy of both upper and bottom paper. In addition, swinging arm structure is employed to make shaft joint adjustment more stable [5].

Improvements are made in upper paper drive system of flute laminating machine through electrical motor control design to replace traditional mechanical drive structure and the improved machine is experimented.

2 GENERAL DESIGN FOR THE SYSTEM

Control kernel for the system is PLC of Panasonic FX0. Control kernel sends signals to servo motor controller through high speed pulse, and the stroke of motor rotation is in proportion to the number of pulse signals; meanwhile, the speed of motor rotation is also appropriate to the frequency of pulse signal [6,7].

After collecting the speed of bottom paper drive shaft, the compiler sends signals to PLC through pulse and gets the number of pulse using high speed counter. The set algorithm is used to know the number of pulse sending to servo motor controller, thus getting the rotation rate of the ground motor [8,9]. By making use of the compiler of the servo motor, the controller can confirm the real stroke of the motor, monitor and correct it at the same time.

Staff can set the parameter through the touching screen of human-machine interface. Parameters conclude rotation rate of motor, period of upper and bottom paper coinciding and changing speed rate of servo motor. Figure 1 shows the frame of the system.

When the previous system is improved, the live shaft connecting bottom paper in the laminating system is removed at first, and the new servo motor, then, is fixed on the wallboard to connect with upper paper by using synchronous belt with double reduction. For speed control, the drive shaft of

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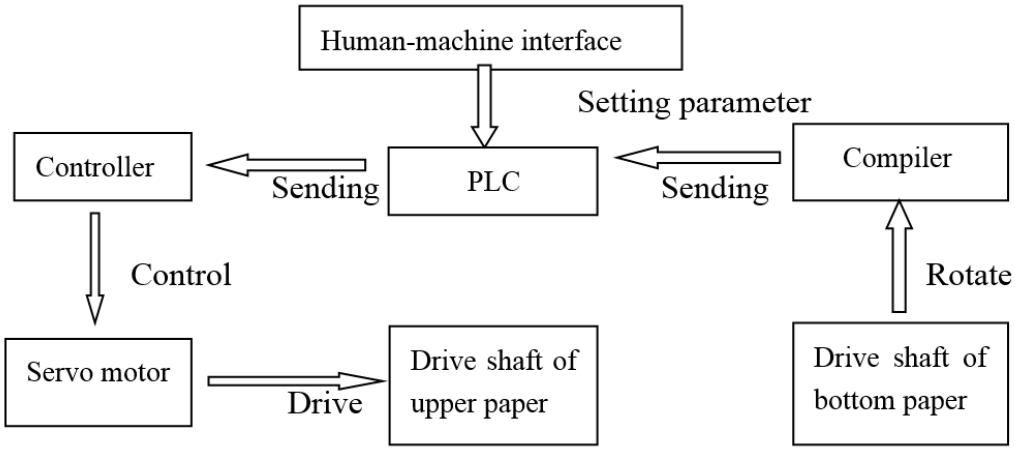


Figure 1: System Frame

upper paper is driven by servo motor making speed increasing motion and then speed reducing motion.

3 SERVO MOTOR

3.1 Maximum rotation speed of motor

The choosing of motor primarily depends on the speed of quick stroke. The rotation speed of motor with quick stroke should not exceed the rated speed [10, 11].

$$n = \frac{V_{\max} \times u}{P_h} \times 10^3 \le n_{nom}$$

In the equation, n_{nom} refers to the rated speed (r/min); n refers to the rotation speed at quick stroke; $V_{\max}$ refers to linear motion speed; u refers to drive ration of the system; $u = n_{motor} / n_{leadingscrew}$.

In the actual producing process, when stroke of the upper paper is 16oomm, the shaft with the diameter of 30mm is to drive it and all stroke is completed within 20 circles of upper paper moving. According to the requirement of transmitting 6000 papers per hour, and there are three flutes in each chain, the rotation speed of upper paper is about 19r/min/.

Double reduction is chosen with the ratio of 1:6 in that load moment of the servo motor needs to be appropriately reduced. The rotation speed of servo motor should not exceed 200r/min. Most servo motor can meet the condition according to demands for torque.

3.2 Inertia matching and load inertia counting

Load inertia JL needs to be controlled within IM of 2.5 times of motor inertia so as to ensure enough angular acceleration, quick response of the system and its certainty. That is,

$$I_L = \sum_{j=1}^{M} J_j \left(\frac{w_j}{\omega} \right)^2 + \sum_{j=1}^{N} m_j \left(\frac{V_j}{\omega} \right)^2$$

In the equation, I_L refers to rotation inertia of each rotary parts; j refers to angular speed of rotary parts; m_j refers to quality of moving parts; V_j refers to speed of moving parts; ω refers to angular speed of servo motor.

After field test, it is known that the torque of upper paper shaft when it works is less than 10N·m. If the speed reduces, the torque of servo motor is less than 2N·m. It can be concluded that the rotation inertia of motor should be below 2×10－4kg·m2 according to weight of each parts and angular speed the motor needs.

As stated above, type of motor is SEM80B08303HN of MOTEC and driver is SED－0823 /30.

Rated power of the motor is 750W, rated torque is 2.4N·m, rated rotation speed is 3000r/min and rotation inertia is 1.03 (10-3kg·m2).

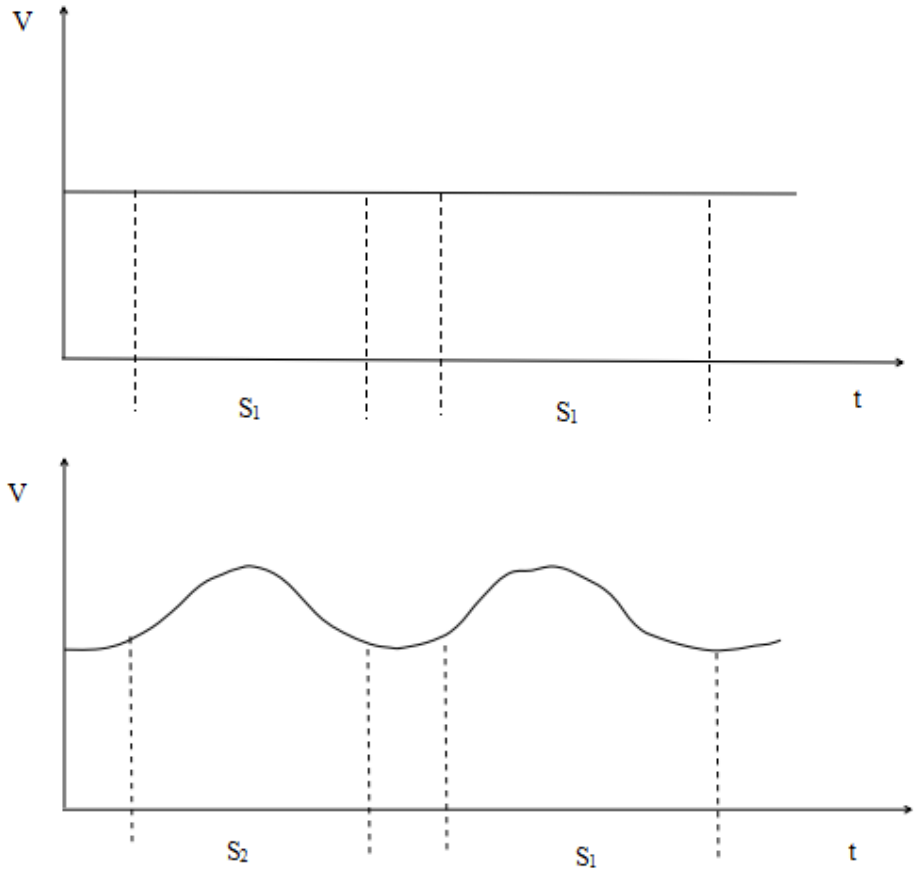


Figure 2: Schematic diagram of rotation speed

4 ROTATION SPEED OF SERVO MOTOR

In the drive system of laminating machine, the key is to accurately control the rotation speed of upper paper shaft (12-14).

The relation between rotation speed of bottom paper shaft and time is shown in Figure 2. The drive stroke of a bottom paper from the beginning to the end is S1; the drive stroke of a upper paper from the beginning to the end is S2. In order to avoid the bending of upper paper when laminating machine operates at quick speed, the beginning speed of upper paper should be limited below the rated limit bending, and the speed can be increased later to reduce the impact on it. Then the speed can be increased so that the rotation speed of motor can be smoothly changed and the problems about sudden speed change is overcome. In the process of motor operating, S1 is, all the time, equivalent to S2×cosα, and α refers to intersection angle of upper paper drive surface and the bottom.

5 CALCULATING ROTATION SPEED OF SERVO MOTOR

Generally, in actual work, rotation carves are made by using electronic cam software [15]. Attention should be paid to three important parameters, namely, the number, rate and point of pulses of the principal axis. The number of pulses the compiler receives in a complete operation period is the maximum pulse of principal axis; the all stroke of servo motor is the product of the rate of pulse and ordinate; total points recorded in the driver stage is the point of pulse. The rate of pulse should meet the following formula:

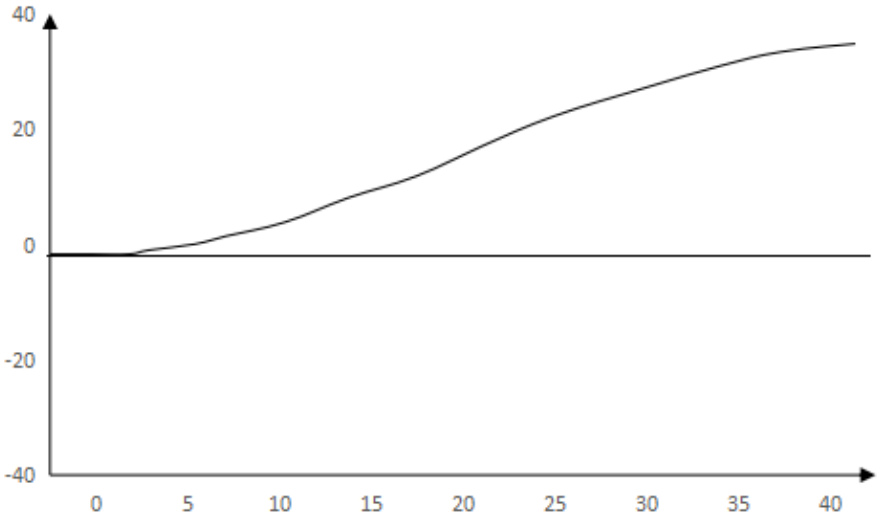
$$T = \frac{N}{M}$$

In the formula: T is the rate of pulse; N refers to the maximum stroke of pulse of a upper paper; M refers to the maximum pulse of principal axis. When editing carves, the number of pulse that driver receives after a paper finishes a period needs to be tested at first, and later the rate of pulse can be calculated by the accuracy of servo motor and drive ratio.

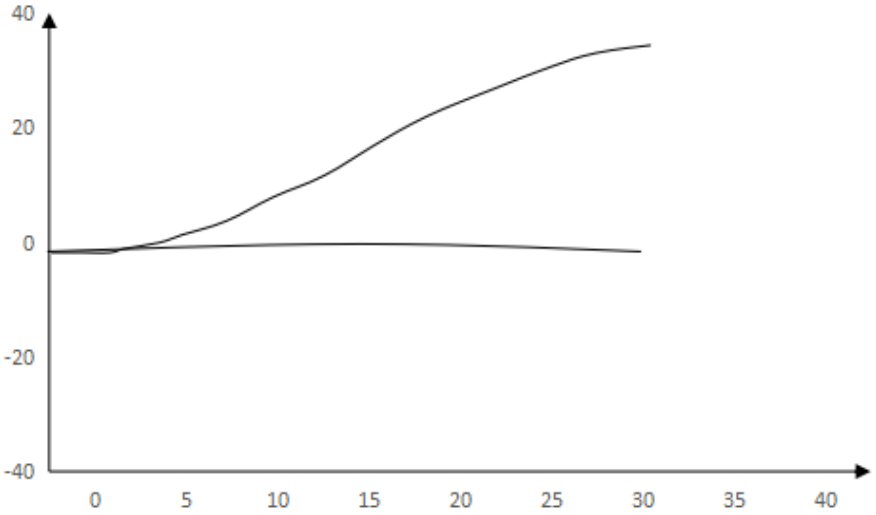
In practice, the number of pulse that the driver receives after a period of the bottom paper is 9600, that is, the number of pulse of principal axis is set to 9600. Resolution power of servo motor is 4000 pulses in each circle. There are 26 teethes in drive chain driving the upper paper, while there are 104 teethes in chain wheel in push pawls. A complete speed period of stroke is the distance between two push pawls. When the whole rotation chain operates a period, gear wheel of rotation chain driving the upper paper needs to operate 104/4=4 circles, namely, drive shaft of upper paper needs to operate four circles. Given that the rotation ratio of servo motor and upper paper rotation shaft is 1:6, servo motor needs to operate 4×4=24 circles. The number of pulse that the driver sends to servo motor is 24× 4000=96000.

In curve editing software, ordinate of the curve period end is 40, and the rate of pulse should be set to 96000 /40=2400.

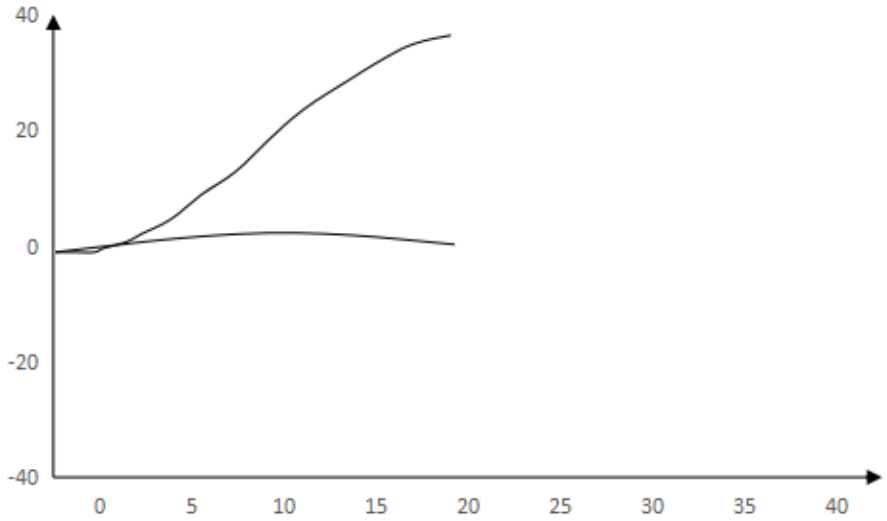
In order to complete rotation curves above and count the accurate number of pulse through using servo controller, operation curves of servo motor are edited. The comparisons of editing cam curve are shown in Figure 3. In the following four figures, the line meaning the stroke of motor is above and the motor rate line is below. It can be seen that the stroke of the motor is unchanged, while the rate of motor in the four figures is constantly increasing and the time that elbow bending takes become shortened. The stronger changes the motor rate, the less time it takes to complete its all stroke and the more rapidly it drives upper paper. If the changing of motor rate is too strong, it is likely that upper paper will leave the flute as a result of inertia. Thus, proper curve can ensure the smooth drive for upper paper when it is in high speed drive.



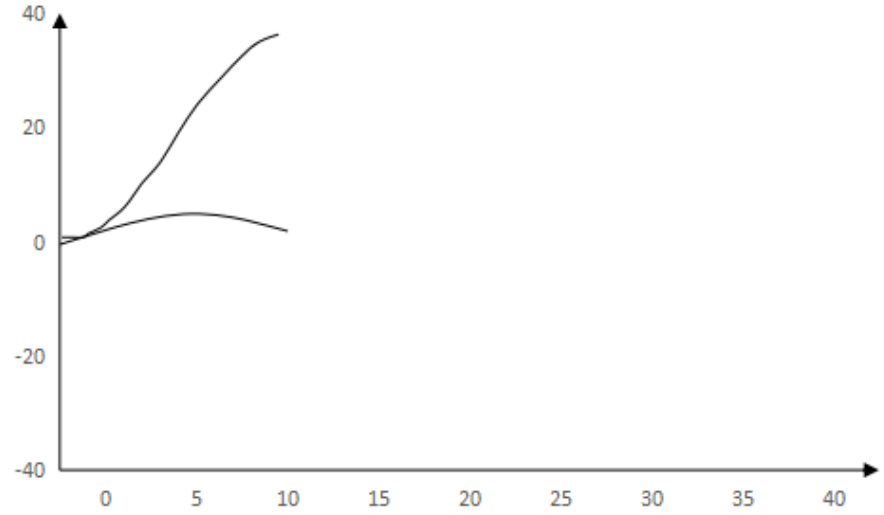
(a) Pulse rate of principal axis is 40.



(b) Pulse rate of principal axis is 30.



(c) Pulse rate of principal axis is 20.



(d) Pulse rate of principal axis is 10.

Figure 3: cam curve editing

6 FIELD DEBUGGING

In field debugging, two kinds of upper paper with the standard of 520mm × 368mm and 1092 mm ×787mm are tested. As there are mechanical deviations, paper hysteresis appears according to previous parameters.

Thus, debugging is carried out constantly to reduce pulse rate so as to remove deviations. After debugging, pulse rate is set to 9480 and deviation is still less than 1.5mm after driving 6000 papers.

The final program shown in Figure 3 (c) is confirmed after debugging. Experiment data are shown in Table 1.

Table 1: experiment data

paper standard/mm	previous	improved
	extreme working efficiency/(paper number/h)	extreme working efficiency/(paper number/h)
520×368	≈7820	≈8610
1092×787	≈3200	≈3160
	laminating accuracy of 6000 papers /mm	laminating accuracy of 6000 papers /mm
520×368	1.24	1.13
1092×787	1.45	1.14

7 CONCLUSION

Servo motor, in the study, controls the rotation of laminating machine with changing speeds to correctly control the stroke position of upper paper, and meanwhile avoid the bending or folding of it due to impact under the high speed operation; by changing cam curves, the problem about strong vibration rising from the sudden changing of the speed of servo motor is solved. Works in practice prove that the working efficiency of advanced laminating machine is obviously improved.

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