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Research Paper

Adaptive synchronization control model of hub winding function on textile printing and dyeing machinery

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ABSTRACT

On the basis of analyzing electrical transmission of hub winding function with the textile printing and dyeing machinery, using recursive least squares estimation method, it has been established physical model of winding running (winding and unreeling) for AC asynchronous motor and adaptive speed control model. These have provide a reliable theoretical basis for formulating control strategies later and controlling steady rotational speed with winding motor accurately, and have laid the foundation for improving strain control precision and product quality. The simulation results are consistent with the theoretical analysis, and the validity of the models is verified.

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Key words: Hub winding; adaptive synchronization control; textile printing and dyeing; control model.

INTRODUCTION

The finished or semi-finished products in textile printing and dyeing production process, such as yarn and cloth, etc., are wound on the spindle or roller. For example, a mass of yarn is wound upon the spindle by warper machine in batches; much sizing yarn is wound on weaving driving shaft by sizing machine and slurry-dyeing combination machinery; and cloth roll is wound on driving roller by winding and dyeing machinery. The machinery have common problems in the winding process, that is, with constant strain control, and the winding diameter from small diameter to maximum diameter, and the strain of the yarn and fabric remain unchanged. It is required that there are constant speed and changeless strain and invariable torque to synchronous control when axis is wound and unreeled, and that adaptive synchronization control model and simulation study of hub winding function about textile printing and dyeing are established.

The control methods of hub winding function have mechanical differential speed control purely. DC motor adjusts speed and hydraulic system drive, etc.. DC motor control is used on many textile printing and dyeing machinery island, which can achieve only an effect on approximate changeless strain control, and there is textile printing and dyeing machinery controlled by single inverter, and unreeling is controlled by DC braking of asynchronous motor, and contactor is switched between inverter and DC brake as axis is wound and unreeled. Above these scheme, through analyzing their principle, they are approximate results under larger error, and there is a problem with constant linear velocity and changeless strain running, so that the control result is less than satisfactory. High-grade textile printing and dyeing machinery imported, some are controlled by hydraulic devices, and some are finished by servo, but also some are achieved by expensive engineering inverter, which the results are more ideal, but for the majority of domestic users, there is a large cost pressure. Therefore, there is a great of significance about study control model of hub winding function about textile printing and dyeing machinery.

CONTROL MODEL

Physical model

To ensure uniform dyeing in the textile dyeing and finishing processes, the two conditions must be sufficed:

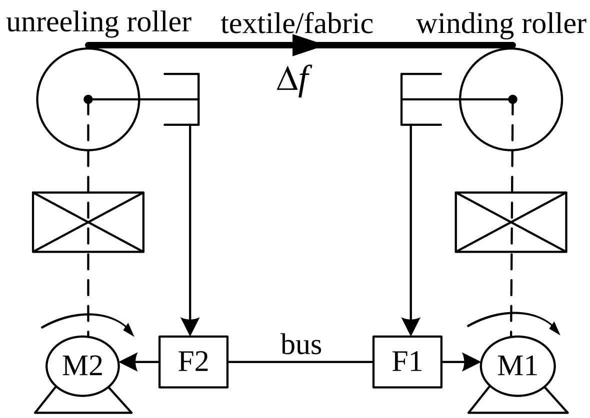

Figure 1: The physical model of hub winding function on textile printing and dyeing machinery.

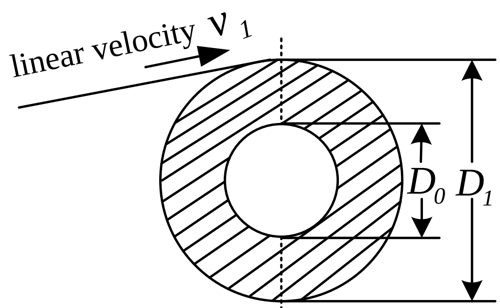

Figure 2: Relationship between a coil diameter of wingding roller and linear velocity.

one is that the fabric should maintain a constant strain in the running course, and the other is that it should be through the dye liquid with constant linear velocity. Thus the control system design of new electric drive for dyejigger (jig dyeing machine) is finished according to the machinery. Textile printing and dyeing machinery has different structure because of its dissimilar process flow, but its physical model is the same basically, and the main physical model of hub winding function is shown in Figure 1.

The arrow direction in Figure 1 is the fabric movement direction, where M1 is the winding motor, M2 is the unreeling motor. After the winding roller reaches number of turns set value, it stop the direction's running, and system changes the fabric running direction automatically. Here, M1 and M2 change unreeling motor and winding motor, respectively until washing or staining time achieves set process parameters. According to process machinery, when the fabric is in the washing or dyeing process, the surface remains flat and with no wrinkle, preventing the cloth damage from physical structure. Therefore, constant strain should always be maintained in the production process (the strain parameter set by the technology staff). If the cloth strain is uneven in the rolling process, it will make process length different at each running direction, and result in the defective cloth as a small roll and jumbo roll, especially when the strain is too small, it will lead to inaccurate velocity of the roller for speed, and result in oscillation.

Adaptive speed control model

Speed control model for winding roller

In the wingding process, the winding axes increase with the wingding time, the shaded area in Figure 2 is shown for the Formula (1):

$$S_1 = \pi(D_1^2 - D_0^2) / 4 = v_1 t_1 \rho_1 \tag{1}$$

The Formula (2) is deduced from the Formula (1), as follows:

$$D_0^2 = D_1^2 - 4 v_1 t_1 \rho_1 / \pi \tag{2}$$

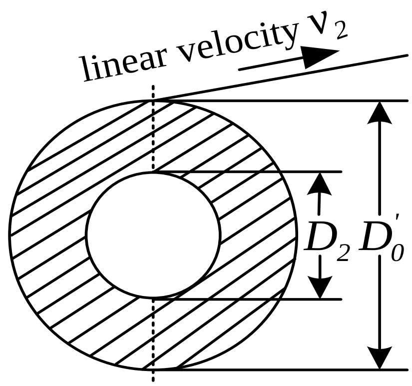

Figure 3: Relationship between a coil diameter of unreeling roller and linear velocity.

Wherein, D_0 is a coil diameter of wingding roller in the start time; D_1 is a coil diameter of wingding roller at any one time; t_1 is a cumulative time of wingding from coil diameter D_0 to D_1; v_1 is a linear velocity of fabric on wingding roller; ρ_1 is a fabrics thickness on wingding roller.

Ordering $k_1 = D_1^2$, $k_2 = \rho_1 t_1$, in order to obtain the consistent control mode with actual system, The formula (2) is as the estimated model, and k_1 and k_2 are identified through recursive least squares estimation method with forgetting factor. After the current estimated value of k_1 and k_2 are obtained, the current estimated value D_1 is obtained in the Formula (3):

$$\tilde{D}_1 = \sqrt{k_1} \qquad (3)$$

Because cumulative time t_1 is the sum of the sampling period T with machine steady-state operation, that is $t_1 = \sum kT$, t is a known variable, therefore, according to the measured value v_1, and using the recursive least squares estimation method, the real-time estimated values k_1 and k_2 are obtained, then the real-time estimated value of parameters D_1 is also obtained. Therefore, Formula (4) is given as:

$$v_0 = \pi D_1 n_1 = \pi D_1 \frac{60 f_1}{p}(1-s) \qquad (4)$$

Wherein, v_0 is a set parameter of linear velocity with wingding roller; p is a pole pair number of wingding motor; s is a slip of asynchronous motor.

The selected common inverter has function of vector control, so s - T_e static characteristics can be regarded as linear in the steady-state operation with motor. Here, the slip s is very small, after its error is ignored, and estimated value D_1 is obtained as given in Formula (5):

$$f_1 = \frac{p}{60\pi} \cdot \frac{v_0}{D_1} = p' \frac{v_0}{D_1} \qquad (5)$$

Wherein, $p' = \frac{p}{60\pi}$ is a constant coefficient, f_1 is a inverter frequency of driving wingding motor, so the formula (5) is named to mathematical model for speed control with wingding roller.

Speed control model for unreeling roller

In the unreeling process, the winding axis decreases with the unreeling time, so the shaded area in Figure 3 is shown for the Formula (6):

$$S_2 = \pi(D_0'^2 - D_2^2)/4 = v_2 t_2 \rho_2 \qquad (6)$$

The Formula (7) is obtained from the Formula (6):

$$D_0'^2 = D_2^2 + (4 v_2 t_2 \rho_2)/\pi \qquad (7)$$

Wherein, D_0' is a coil diameter of unreeling roller in the start time; D_2 is a coil diameter of unreeling roller at any one time; t_2 is a unreeling cumulative time from coil diameter $D_0^{'}$ to D_2; v_2 is a linear velocity of fabric on unreeling roller; ρ_2 is a fabrics thickness on unreeling roller. In normal circumstances, it is equal to a fabrics thickness on winding roller.

Ordering $k_3 = D_2^2$, $k_4 = \rho_2 t_2$, after the current estimated value of k_3 and k_4 are obtained, the current estimated value D_2 is obtained in the Formula (8):

$$\tilde{D}_2 = \sqrt{k_3} \tag{8}$$

Similarly, the Formula (7) is as the estimated model, and k_3 and k_4 are identified through recursive least squares estimation method with forgetting factor. According to the measured value v_2 and unreeling cumulative time t_2, the real-time estimated values k_3 and k_4 are obtained, then the real-time estimated value of variable parameters D_2 is also obtained in the Formula (8).

Finally, the Formula (9) is gotten if the effect of unreeling motor M2 is ignored:

$$v_0 = \pi D_2 n_2 = \pi D_2 \frac{60 f_2}{p} \tag{9}$$

From estimated value D_2, the Formula (10) is obtained:

$$f_2 = \frac{p}{60\pi} \cdot \frac{v_0}{D_2} = p' \frac{v_0}{D_2} \tag{10}$$

Wherein, f_2 is a inverter frequency of driving unreeling motor, so the Formula (10) is named to mathematical model for speed control with unreeling roller.

RECURSIVE LEAST SQUARES ESTIMATION METHOD

The estimated models of parameters k_1、k_2、k_3 and k_4 with recursive least squares estimation method are shown in Formulas (11) and (12):

$$y_1(k) = \phi_1^T(k)\theta_1^T \tag{11}$$

$$y_2(k) = \phi_2^T(k)\theta_2^T \tag{12}$$

Wherein, $y_1(k) = D_0^2(k)$, $\phi_1^T(k) = [\phi_1(k) \quad \phi_2(k)] = \left[1 \quad -\frac{4v_1}{\pi}(k)\right]$, parameter vector $\phi_1^T = [k_1 \quad k_2]$; $y_2(k) = D_0^{'2}(k)$, $\phi_2^T(k) = [\phi_1^{'}(k) \quad \phi_2^{'}(k)] = \left[1 \quad \frac{4v_2}{\pi}(k)\right]$, parameter vector $\phi_2^T = [k_3 \quad k_4]$.

Recursive least squares estimation algorithms are given in Formulas (13) and (14):

$$\hat{\theta}_1(k) = \hat{\theta}_1(k-1) + K_1(k)[y_1(k) - \phi_1^T(k)\hat{\theta}_1(k-1)] \tag{13}$$

$$\hat{\theta}_2(k) = \hat{\theta}_2(k-1) + K_2(k)[y_2(k) - \phi_2^T(k)\hat{\theta}_2(k-1)] \tag{14}$$

Wherein,

$$K_1(k) = P_1(k-1)\phi_1(k)[\phi_1^T(k) \times P_1(k-1)\phi_1(k) + \mu]^{-1}$$

$$K_2(k) = P_2(k-1)\phi_2(k)[\phi_2^T(k) \times P_2(k-1)\phi_2(k) + \mu]^{-1}$$

With forgetting factor $\mu \in$ (0.9, 1)

$$P_1(k) = \mu^{-1}[I_1 - K_1(k)\phi_1^T(k)] \times P_1(k-1) \tag{15}$$

$$P_2(k) = \mu^{-1}[I_2 - K_2(k)\phi_2^T(k)] \times P_2(k-1) \tag{16}$$

Wherein, I_1 and I_2 are unit matrixes with the same order as $P_1(k)$ and $P_2(k)$ respectively.

Criterion functions are given in the Formulas (17) and (18):

$$V_{N1}(\theta) = N^{-1}\sum_{i=1}^{N}\mu^N[y_1(k) - \theta_1^T\phi_1(k)]^{-1} \tag{17}$$

$$V_{N2}(\theta) = N^{-1}\sum_{i=1}^{N}\mu^N[y_2(k) - \theta_2^T\phi_2(k)]^{-1} \tag{18}$$

Ordering $P_1(0)=\alpha^2 I_1$, $P_2(0)=\alpha^2 I_2$, α is a large enough real number; $\hat{\theta}_1(0)=\varepsilon, \hat{\theta}_2(0)=\varepsilon$, ε is a small enough real vector.

THE ENDING

Based on the recursive least squares estimation method, it is established that the control model of hub winding function with textile printing and dyeing machinery, and the simulation results are consistent with the theoretical analysis, and the validity of the models is verified. The establishment of control models have provide a reliable theoretical basis for formulating control strategies later and controlling steady rotational speed with winding motor accurately. These can make textile printing and dyeing machinery obtain higher precision of strain control, reduce oscillation by inaccurate velocity of the roller for speed, decrease yarn filoplume and fabric chromatism, etc., and can improve product quality; therefore, it has a very broad application prospect. The principle and the method can also be applied in papermaking and wire stock industries.

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