Kinematics analysis of transmission mechanism of electronic jacquard machine based on virtual prototype and vector method

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Abstract. Aiming at the problem that the electronic transmission mechanism of the electronic jacquard machine is difficult to design, a kinematic analysis of the mechanical transmission mechanism of the electronic jacquard machine is proposed to clarify the kinematic performance of the electronic transmission mechanism. Based on the vector method, the kinematics mathematical model of the mechanical transmission mechanism of the electronic jacquard machine was established, and the matrix of the displacement, velocity and acceleration curve of the pulling blade was obtained. After the parameters are selected, the correctness of the mathematical model is verified through virtual prototype modeling and simulation. Through simulation analysis and verification, it is found that the numerical calculation results of the solution matrix are consistent with the simulation results of the virtual prototype model, and the peak error does not exceed 0.42%, which provides a certain theoretical basis for the study of electronic jacquard transmission mechanism.

1. Introduction

Electronic jacquard machine is the most widely used kind of shedding mechanism. At present, the transmission mechanism is still a mechanical structure, and this structure will inevitably lead to the problems of low energy utilization [1] and high component wear [2]. In order to improve the defects caused by the structure, it is necessary to replace them electronically. When electronically designing the transmission mechanism of an electronic jacquard machine, it is necessary to clarify the kinematic performance of the electronic transmission mechanism so that its kinematic performance can meet the actual production requirements. Therefore, it is necessary to analyze the kinematics of the mechanical transmission mechanism, and use the kinematic performance index of the existing mechanical transmission mechanism as the design index of the electronic transmission mechanism.

At present, in major electronic jacquard machine manufacturers, the kinematic performance analysis of mechanical transmission mechanism mainly adopts empirical methods and simulation methods. Hu Chaobin [3] uses Solidworks to model the electronic jacquard machine, and uses ADAMS to analyze the kinematics of the model. Lou Hongbiao [4] uses ADAMS to analyze the dynamics of the electronic jacquard machine modeling. Due to the low accuracy of the empirical method and the high cost of time for modifying the model of the simulation method, in order to improve the efficiency of the design process, mathematical modeling of the mechanical transmission mechanism is proposed, and a set of mechanical transmission mechanism parameters of the electronic jacquard machine is established to correspond to its kinematic performance Mathematical model.
The kinematics analysis method of the mechanism can be divided into graphic method and analytical method. Because the graphic method is more complicated for dynamic mechanism analysis, the analytical method is often used. Common analytical methods include vector method [5], triangle method [6] and so on. Due to the high degree of kinematic coupling of the mechanical electronic jacquard transmission mechanism, this paper uses the vector method to analyze its kinematics, and establishes the matrix of the displacement, velocity and acceleration curve of the pulling blade. Select the gear type electronic jacquard machine parameters of Yantai Songhe Song Science and Technology Application Engineering Co., Ltd. as the input value, and use MATLAB to assist in solving the matrix. According to the parameters of the electronic jacquard machine of this model, modeling and analysis are carried out in the ADAMS software, and the simulation curves of the displacement, speed and acceleration of the pulling blade are obtained. By comparing the numerical calculation results with the simulation results, the correctness of the mathematical model is verified.

2. Kinematics analysis of transmission mechanism of electronic jacquard machine

2.1. Description of electronic jacquard machine
The function of the transmission mechanism of the electronic jacquard machine is to convert the torque of the motor into the driving force of the pulling blade, and the movement of the pulling blade provides power for the needle selection mechanism of the electronic jacquard machine, and the needle selection mechanism provides a certain load for the pulling blade. The influence of this load on the movement of the pulling blade is not considered for the time being, so the pulling blade is set to run under no load. The pulling blades of the electronic jacquard machine are divided into two groups of pulling blades, inside and outside. This article only takes one group of pulling blades as an example to carry out modeling analysis based on its mechanism diagram. Figure 1 is a schematic diagram of the mechanism movement of the transmission mechanism of an electronic jacquard machine. The rotation of the component 1 drives the other components to move.

![Figure 1](image-url)  
1-Large shed roulette; 2-Small shed roulette; 3-Long tie rod parts; 4-Short tie rod parts; 5-blade holder plate; 6-small tie rod connector; 7-pull blade; 8-anti-wear roller

2.2. Kinematics analysis and modeling
According to the vector method, the transmission mechanism shown in Figure 1 is modeled to find the closed vector polygon, as shown in Figure 2. The XOY coordinate system is established with point C.
as the origin, the end point of the component is named length, $\theta_i$ represents the angle between the component and the X axis, where $\theta_i$ is the value of $\omega t + \pi / 2$, and the value of $\theta_i$ is $\pi / 2 - \omega t$.

Equation (1) can be obtained for the closed vector diagram shown in Figure 2(a), where the lengths of CE and EG are known, the angles of $\theta_4$ and $\theta_5$ are known, and the unknown quantities are CG and $\theta_6$. Through sorting, Equation (1) can be transformed into matrix form, as shown in Equation (2).

$$\begin{align*}
\text{CE} \cdot \cos \theta_5 + \text{EG} \cdot \cos \theta_6 &= \text{GC} \cdot \cos \theta_4 \\
\text{CE} \cdot \sin \theta_5 + \text{EG} \cdot \sin \theta_6 &= \text{GC} \cdot \sin \theta_4
\end{align*}$$

(1)

For the closed vector diagram shown in Figure 2(b), Equation (3) can be obtained, where the lengths of BD, DF, FG, BC, and CG are known, the angles of $\theta_1$ and $\theta_4$ are known, and the unknowns are $\theta_2$, $\theta_3$. Through sorting, Equation (3) can be transformed into matrix form, as shown in Equation (4).

$$\begin{align*}
\text{BD} \cdot \cos \theta_4 + \text{DF} \cdot \cos \theta_2 + \text{FG} \cdot \cos \theta_1 &= \text{BC} \cdot \cos 0 + \text{CG} \cdot \cos \theta_4 \\
\text{BD} \cdot \sin \theta_4 + \text{DF} \cdot \sin \theta_2 + \text{FG} \cdot \sin \theta_1 &= \text{BC} \cdot \sin 0 + \text{CG} \cdot \sin \theta_4
\end{align*}$$

(3)

$$\begin{align*}
\begin{bmatrix}
\text{CE} \\
\text{EG} \\
\text{GC}
\end{bmatrix}^T \begin{bmatrix}
\cos \theta_5 & \sin \theta_5 \\
\cos \theta_6 & \sin \theta_6 \\
-\cos \theta_4 & -\sin \theta_4
\end{bmatrix} &= \begin{bmatrix}
0 & 0
\end{bmatrix}
\end{align*}$$

(2)

$$\begin{align*}
\begin{bmatrix}
\text{BD} \\
\text{DF} \\
\text{FG} \\
\text{BC} \\
\text{CG}
\end{bmatrix}^T \begin{bmatrix}
\cos \theta_1 & \sin \theta_1 \\
\cos \theta_2 & \sin \theta_2 \\
\cos \theta_3 & \sin \theta_3 \\
-\cos 0 & -\sin 0 \\
-\cos \theta_4 & -\sin \theta_4
\end{bmatrix} &= \begin{bmatrix}
0 & 0
\end{bmatrix}
\end{align*}$$

(4)
For the closed vector diagram shown in Figure 2(c), Equation (5) can be obtained, where the lengths of FG, FM₁, and GM₁ are known, the angles of θ₁₀₁, θ₃, and θ₈₁ are known, and the unknown is θ₉₁. Through sorting, Equation (5) can be transformed into matrix form, as shown in Equation (6).

\[
\begin{bmatrix}
FG + GM₁ = FM₁ \\
\end{bmatrix}
\]

Equation (7) can be obtained for the closed vector diagram shown in Figure 2(d), where the lengths of GM₁, M₁N₁, and GN₁x are known, the angle of θ₉₁ is known, and the angle of θ₁₁ can be obtained, and the unknowns are GN₁ and θ₁₁. Through sorting, Equation (7) can be transformed into matrix form, as shown in Equation (8).

For the matrix shown in Equation (8), the motion state of other pull blades can be represented by modifying the subscript. Equations (2), (4), (6), and (8) are combined to obtain the motion equation matrix of the entire electronic jacquard transmission mechanism as shown in Equation (9). After modeling the matrix in MATLAB/Simulink [7], the displacement curve data of any point can be obtained, and the velocity and acceleration curve of this point can be obtained by seeking the first derivative and the second derivative.
3. Kinematics analysis and modeling

3.1. Simulation modeling

In order to verify the correctness of the above theoretical analysis, select the size parameters of the gear drive electronic jacquard machine prototype of Yantai Song and Song Science and Technology Application Engineering Co. LTD. The specific parameters are shown in Table 1. Based on the model shown in Figure 1 and the geometric dimensions shown in Table 1, a three-dimensional model of the mechanical transmission mechanism of the electronic jacquard machine was established using Solidworks, as shown in Figure 3. Import the model into the ADAMS software [8], and set the corresponding motion pair according to the motion relationship between the components. This simulation does not consider the friction between the moving pairs, and the components are only subjected to the interaction force between other components and gravity. The rotation speed \( \omega \) of component 1 is set to 600 rpm.

Table 1. A table with Mechanism parameters of electronic jacquard machine transmission mechanism.

| Attributes                                      | Attributes | Value (mm) |
|------------------------------------------------|------------|------------|
| Large shed roulette eccentricity               | BD         | 55.0       |
| Eccentricity of small shed roulette            | CE         | 47.5       |
| Pull rod length of large shed roulette         | DF         | 335.5      |
| Pull rod length of small shed roulette         | EG         | 328.0      |
| Center distance of shed roulette               | BC         | 300.0      |
| Length of bevel edge                           | FM\(_i\)/GM\(_8\) | 61.0       |
| Length of the upper edge of the broach         | FG         | 360.0      |
| The length of the bottom of the broach plate   | M\(_1\)M\(_8\) | 505.6      |
| Horizontal distance between pull blade and G point | GN\(_i\)X | 402.8-73.2×i |
| Broach connector length                        | M\(_i\)N\(_i\) | 140       |

1-Large shed roulette; 2-Small shed roulette; 3-Long tie rod parts; 4-Short tie rod parts; 5-blade holder plate; 6-small tie rod connector; 7-pull blade

Figure 3. Three-dimensional model of mechanical transmission mechanism of electronic jacquard machine.

3.2. Comparative analysis

It is only necessary to verify the correctness of the kinematic analysis results by comparing the displacement, velocity and acceleration curves of any pulling blade that is N\(_1\)~N\(_8\). Therefore, this paper selects the displacement, velocity and acceleration curves of point N\(_1\) for comparative analysis.
The comparative analysis diagram is shown in Figure 4. Figure 4(a), 4(b), 4(c) are the displacement, velocity and acceleration curves of point N1.

It can be seen from Figure 4 that the results calculated by the numerical analysis in the kinematic analysis are that the peak displacement of the pulling blade is 115.0mm, the peak velocity is 1010.44mm/s, and the peak acceleration is 16654.04 mm/s². The calculation result is basically the same as the simulation result, and the peak error does not exceed 0.42%, which verifies the correctness of the matrix equation in Equation (8).

![Figure 4](image)

**Figure 4.** Comparison of Simulink calculation and ADAMS simulation results.

4. Conclusions

The kinematics analysis of the electronic jacquard mechanical transmission mechanism was carried out by the vector method, and the mathematical model corresponding to the mechanical transmission mechanism parameters of the electronic jacquard machine and its kinematic performance was established. The peak error between the simulation results and the numerical calculation results was verified by ADAMS simulation. 0.42%. Based on the mathematical model, the parameters can be modified to quickly design the kinematic characteristics required by the electronic transmission mechanism, which provides a certain theoretical basis for the development of the electronic transmission mechanism of the electronic jacquard machine.

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