Kinematics Simulation of the Cam Mechanism of the Zipper Machine Based on ADAMS

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Abstract. The metal zipper forming process is complicated in process, and the coordinated movement of each component is closely related. In order to more thoroughly understand the zipper chain forming process, and clearly show the coordinated action process of the metal zipper parts, the kinematics simulation of the metal zipper punching and punching mechanism. The results of the motion simulation can also check whether the design of the mechanism is correct or not, and whether there is structural interference between the components. The virtual prototyping technology can fully reveal the motion state of each component of the machine. The simulation results show that the punching and punching mechanism performs the kinematic data of the end punching needle. By analyzing these data, the motion law of the end of the mechanism can be analyzed to pave the way for further optimization of the mechanism.

1. Introduction

The metal zipper is an important equipment for the production of garment zippers, which can produce metal zippers of various specifications through a series of complicated processes. The main working principle is to realize the process of Y-type copper cutting, tooth point stamping, extrusion onto the tape by cam transmission, thereby forming a whole zipper. With the rapid development of society and the improvement of labor costs, higher requirements are placed on the performance of the zipper, namely, higher production efficiency, less vibration and lower noise. The core mechanism of the zipper is mainly a cam striking mechanism, which has the characteristics of high rotation speed, compact structure and large inertia force. The ADAMS software [1] is a visual virtual prototype software developed by Mechanical Dynamics Inc. of the United States. It is also the most widely used dynamic simulation software in the world. By establishing a simulation prototype of a mechanical system, it can reflect the movement of the physical prototype more realistically. Processes are thus widely used in the field of mechanical dynamics. Many scholars have used ADAMS to simulate the dynamics of the cam drive system. The typical ones are: Wan Zhaoyan [2] and other based on ADAMS, the elastic dynamics model of the high-speed cam mechanism is established, and the motion curve of the follower is obtained. The dynamic characteristics of the high speed cam mechanism under different push rod stiffness are analyzed. Liu Xiaoyue [3] used dynamic analysis of the high-speed cam mechanism by numerical analysis method, which proved that the numerical analysis method can be applied to the dynamic analysis of high-speed
cam mechanism. Jin Gouging [4] used the finite element method to establish the dynamic model of the rigid-flexible coupled cam system. The natural frequency model of different orders was taken to investigate the natural frequency and vibration mode of the high-speed cam mechanism, and the modal interception order was analyzed. Calculate the impact of accuracy and speed. Xuan Guantao [5] optimized the high-speed cam NURBS profile by using the improved artificial fish multi-objective dynamics optimization algorithm, and reconstructed the cam profile by using non-uniform rational B-spline (NURBS). The cam single degree of freedom elastic dynamics model verifies the correctness of the multi-objective optimization algorithm.

2. Creating the Cam striking mechanism model of the Zipper machine

2.1. Working principle
The cam striking mechanism is the core component of the exhaust microphone, which can be simplified as shown in Figure 1. When the cam rotates around the O point, the swinging arm BAC swings around the point A by the roller B in contact with it, so that the punching CD CD is intermittently reciprocated, and the amplitude and period of the punching point are 4.13 mm and 0.043, respectively. In order to allow the roller and the needle to return to motion in a high-speed motion, a spring is added to the roller and the needle to provide the necessary preload.

![Figure 1. Sketch diagram of stamping and punching mechanism](image1)

2.2. CAD model import into ADAMS
The 3D model created in CREO is saved in Para solid (.x.t) format and then imported into the ADAMS software. The stamping and punching mechanism model imported into ADAMS is shown in Figure 2.

![Figure 2. Stamping and punching mechanism model](image2)
As shown in Figure 3, the CAD model of the punching system is divided into four parts: Bearing_L_1, Swing_Arm_L_1, Stamping_L_1 and Slideway_L_1 before importing the model according to the motion relationship of each component. The names of all the parts of the subsystem are shown in Figure 3: (a) Two Marker points are respectively established at the center of the bearing section to establish the constraint pair between the bearing and the swing arm; (b) Marker points are established at the center of the circular hole in the red marked area of the schematic to establish the swing arm and ground (c) Stamping_L_1 is in real-time contact with the swing arm, and is pressed by the swing arm to slide along the Y direction on the Slideway_L_1; (d) The Slideway_L_1 is fixedly connected to the base of the fuselage by a nut.

2.3. Applying constraints

The main constraint relationships of the system are cam sub-constraint、Revolute joint、Fixed joint and Translational joint. The following constraint pairs are established according to the model import order.

Step 1 Establish a cam sub-constraint. In order to avoid the problem of reduced computational efficiency caused by the introduction of Contact, this simulation uses the Curve-Curve constraint in Adams to establish the cam constraint. The constraint profile requires the outer contour of the cam and the bearing. Since the accuracy of the model is reduced after the CAD model is introduced into Adams, the original cam contour is no longer smooth. Therefore, when the spline curve is used to identify the cam contour, a spline curve is obtained, which cannot be fitted. The following steps are used in this paper. Get the cam outline:

1) Create a section at the cam in Creo and use that section as a sketching plane;
2) Projecting a cam profile to the sketching plane to obtain a cam contour line, and saving the sketching plane;
3) Hide other parts, keep only the cam outline, export it in IGES (*.igs) format, and export the reference coordinate system to still select the reference frame derived by the model;
4) Import the cam contour into Adams in IGES (*.igs) format. When importing, pay attention to the entity corresponding to the cam contour, so that a complete cam contour can be added to the cam.

In addition, the bearing contours on the same motion plane as the contours obtained above are required. The bearing contour is established by using Construction Geometry: Arc/Circle in Adams. First select Add to Part, then select the corresponding bearing entity and the center Marker point, check Radius, define the radius, and finally check Circle to define the circular outline.

After the two spline contour curves of the cam pair are established, you can add Curve-Curve constraint, select 2D Curve-Curve constraint, and select two contour lines in turn to complete the cam sub-constraint.

Step 2 Establish a constraint pair between the swing arm and the bearing, select the Marker point of the center of the bearing section, and add a revolute joint to constrain the swing arm and the bearing.
In addition, Marker points are added to the center of the cross section of the two circular holes as shown in Figure 4. The first Marker point adds the revolute joint between the swing arm and the ground, and the second Marker points the added swing arm to rebound. Spring, spring stiffness is set to 600 N/mm, damping factor is 10.0, and preload is 0.

Step 3 Swing_Arm_L_1 and Stamping_L_1 are in real-time contact during the movement. The constraint relationship between the two parts is processed in the same way as the establishment of the cam pair, namely Curve-Curve constraint, and the contour is extracted. The steps are the same and will not be described here.

Step 4 Slideway_L_1 is fixed to the base of the fuselage. Therefore, select the Marker point at the center of the Slideway_L_1 to establish a fixed joint with the ground.

Step 5 Stamping_L_1 slides on Slideway_L_1 along the Y direction, so a Translational joint is added to the Marker point at the centroid of Stamping_L_1, where the slip direction is along the Y-axis direction.

In addition, a rebound spring is installed between Stamping_L_1 and Slideway_L_1, as shown in Figure 5, the Marker point is established at the center of the two circular sections marked in the figure, and the spring is connected, the spring stiffness is set to 600N/mm, and the damping coefficient is set. At 10, the preload is 0.

At this point, the constraints of the stamping system have been added.

3. Kinematics simulation calculation and result evaluation

After completing the constraint addition to the system, the simulation can be performed. The evaluation of the system mainly focuses on the change of the Y-direction displacement of the end point of the punching needle. Therefore, the corresponding Marker point is established at the end point of the punching needle to measure the Y-direction displacement variable. The simulation time is set to 0.1s and the simulation step is set to 1e-3s. After the simulation is completed, the F8 key enters the post-processing.

As shown in Figure 6, it is the Y-direction displacement-time curve of the end point of the needle:
As shown in the figure 6, the punching needle moves periodically along the Y direction, the motion period is 0.043 s, and the amplitude is 4.13 mm, which satisfies the requirement of the stroke device stroke amount $\leq 10$ mm. The period size is mainly affected by the cam profile curve. Therefore, the number of fitting points should be a little more when fitting the cam profile curve to approximate the real cam contour as much as possible. The phase size is mainly affected by the relative position of the initial cam pair. Since the initial CAD model has interference at the cam pair, the relative position of the cam pair is adjusted in the early stage of the simulation, so the accuracy of the phase needs further research.

4. Conclusion
The virtual prototype model of the cam striking mechanism of the zipper is established in the ADAMS environment, and then the kinematics simulation is carried out. The coordinated action process of each part of the metal zipper is clearly demonstrated through simulation, and the motion law of the end of the mechanism is analyzed. It laid the foundation for further optimization of the organization.

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