Design and Analysis of a Linear Conveying System

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Abstract: Based on the transportation demand of medium- and short-distance materials, this paper proposed a method to design and analyze a conveyor system, which has simple structure, low cost and flexible drive. A simplified system model was established and the design method of the system was introduced. Geometric equations, velocity and acceleration calculation formulas were obtained through mathematical analysis calculations. The simulation model was established through ADAMS, so as to obtain the kinematics law and verify the design accuracy. The organization and its design analysis process can provide references for the design of similar products.

1. Introduction

Rack and pinion mechanisms, conveyor belts, conveyor chains, etc. are often used during the medium- and short-distance transportation, but these systems or methods have problems of complicated installation and processing, high cost or low accuracy. According to the work needs of a certain device, a multi-link type conveying mechanism is proposed to realize medium- and short-distance conveying. The device uses a combination of multiple parallelogram systems and crank slider systems, which can reduce the volume and weight of the frame. It can be driven by electric motor, hydraulic motor or oil cylinder to increase the accuracy of transmission. Through the design of the fixture, the system can adapt to different work objects. Figure 1 is a schematic diagram of the mechanism. The difference in the position of the clamp in the extended and retracted states of the mechanism is the conveying stroke.

![Figure 1: Schematic diagram of conveyor system](image)

2. Analysis of Working Principles

The simplified working principle of the whole organization is shown in Figure 2. The system is mainly composed of 6 connecting rods except for the clamp, connecting plate and sliding block. The sliding block moves linearly on the frame, the connecting rods 1, 2 and other parts are hinged with the frame. The components satisfy the geometric relationship:
\[ \frac{A}{a} = \frac{B}{b} = i \] (1)

A slider crank structure is formed by the slider, connecting rod 1, connecting rod 2 and frame of the system. The connecting rod 1, the connecting rod 2, the connecting rod 3, and the connecting rod 5 form a group of parallelogram structure. The movement of the hinge point of the connecting rod 5 and the fixture is always opposite to the movement direction of the slider within a certain proportion. The slider 4, the connecting plate, the slider 3, the connecting plate, the frame and the connecting plate, the connecting rod 5, the connecting rod 6, and the clamp respectively form two groups of parallelograms, so that the clamp always maintains a fixed angle during the movement. Through the combination of the above multiple systems, the movement of the fixture is always a linear movement proportional to the movement of the slider.

Figure 2: Mechanical schematic diagram of conveyor system

The system can be driven by oil cylinders and electric cylinders, which push the slider to move linearly. If the driving speed and stroke of the slider are \( v \) and \( l \) respectively, the moving speed and stroke of the fixture satisfy

\[ \frac{V}{v} = \frac{L}{l} = i \] (2)

If the system uses swing cylinders, hydraulic motors, and electric motors as prime movers, the connecting rod 3 should be driven to rotate, that is, \( \alpha \) changes with time. Using the positional relationship of connecting rod 3, connecting rod 5 and the frame, the movement speed and acceleration of the fixture can be analyzed.

The mechanism satisfies the geometric constraints, that is,

\[ H = A \sin \alpha - B \cos \beta \]
\[ X = A \cos \alpha + B \sin \beta \] (3)

Since \( y \) is a fixed value, the above equation takes the derivative of time to satisfy

\[ A \cos \alpha \frac{d\alpha}{dt} + B \sin \beta \frac{d\beta}{dt} = 0 \]

\[ v = -A \sin \alpha \frac{d\alpha}{dt} + B \cos \beta \frac{d\beta}{dt} \] (4)

According to the above formula, the relationship between the movement speed of the fixture and the driving speed can be obtained as

\[ v = -(L_{2} \sin \alpha + L_{2} \cos \alpha \tan \beta) \frac{d\alpha}{dt} \] (5)
Because in the mechanism design, \( h \) and \( H \) are default values. The initial positions of \( L \) and \( l_1 \) are determined by the initial values of \( \alpha \) and \( \beta \), designed by the geometric relationship, which are fixed values. At any time, the above equations can be used to solve the kinematic parameters.

3. Design and Implementation
Firstly, the design of the system determines the lengths of the connecting rods \( A \) and \( B \) and the frame size \( H \). Other structural dimensions and forms can be specifically designed using mechanical design theory. The fixture can be designed according to the characteristics of the work object. Generally speaking, according to the target object, the working stroke \( L \) and the fixture height \( H \) can be clarified, and the range of the included angle \( \alpha \) can also be preliminarily predicted. The analytic equation can be used to initially determine the length \( A \) and \( B \). Then it is required to comprehensively consider the force situation and structural layout, and clarify the ratio \( I \), so as to determine the main parameters of the system. Then it is needed to carry out detailed design in conjunction with mechanical design theory to obtain the required mechanical devices.

After the design is completed, the limit state of the system can be checked to verify whether the parameters are reasonable.

Take a conveying device as an example. The conveying distance of the device is \( L=1.3 \text{m} \), and the height of the center of gravity of the goods is 900 from the center of the boom. It is preliminarily estimated that the included angle \( \alpha \) ranges from -30 to 30, according to the state equation obtained by the geometric relationship.

\[
H = A \sin \alpha - B \cos \beta = A \sin \alpha_1 - B \cos \beta_1
\]

\[
L = X_1 - X_0 = A \cos \alpha_1 + B \sin \beta_1 - A \cos \alpha_0 - B \sin \beta_0
\]

According to the above calculation results, the structural parameters \( A=1200 \text{mm} \) and \( B=900 \text{mm} \) are determined. According to the on-site structural constraints, if \( i=3 \), other parameters can be confirmed. The device design is completed by combining factors such as stress analysis and installation conditions.

4. Simulation Verification
After the overall mechanism size and coordinate origin are determined, the simulation software ADAMS is used to analyze the device, according to the design requirements. In the case of using a linear drive device to push the sliding block, the sliding block speed of 0.1 m/s is set and the simulation time is 3s, so as to obtain the movement law of the load. According to the simulation results, it can be seen that the load can keep moving horizontally, with the speed at 0.4 m/s. The simulation shows that the system can realize horizontal conveying, and the speed is proportional to the linear drive speed.

Figure 3: Three-dimensional model of conveying device
In the case of using the motor drive mechanism to move, the drive speed is set to 20°/s and the simulation time is 3s, in order to obtain the movement law of the load. According to the simulation results, the slider speed range is 74.99 mm/s to 106.88 mm/s, while the load speed range is 299.04 mm/s to 427.30 mm/s. The two speed directions are opposite at any moment, with the speed ratio close to 4. The driving angular displacement is 60°, and the load displacement is 1.19 m, in the simulation time. According to the above simulation, it can be verified that the design organization meets the requirements.

5. Conclusion
(1). This paper proposed a linear conveyor system. The medium- and short-distance conveying function was realized by the combination of slider and multi-link mechanism, which has the advantages of simple structure, low processing difficulty and low cost.
(2). This paper derived the analysis and design method of the conveyor system through the mathematical analysis method. Finally, computer simulation was used to verify the accuracy of the design. The design and analysis methods of this organization can provide a theoretical reference for the design of other similar products.

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