

Analysis of the Performance of Rolling Screw Transform Mechanism

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Abstract—According to the basic principle of the Screw-driven, a new mechanism named rolling screw transform mechanism is designed in this paper, which is input straight reciprocating motion and output rotation. The motion performance and of the mechanism is analyzed, the motion equations, such as displacement, velocity, acceleration, are established. Simulation is present with numerical method, the changing laws of displacement, velocity, acceleration are found based on the simulation curve. The surface numerical model is established, the transmission performance is obtained by analysis.

Keywords—Screw-driven, Rolling screw transform mechanism, Motion performance, Transmission performanc

I. INTRODUCTION

Screw mechanism is a widely used traditional institutions[1]. Its transmission performance is studied roundly, which is imported rotation and output linear motion[2-3]. It also has another side, that is input linear motion and output rotation. This basic transmission method is studied by Liang Xichang[4-5], etc. in recent years, which is named a named special screw mechanism. The studies focuses on the basic principles, transmission calculations and structural optimization are carried out, and the structural parameters are optimized in connection with the case of engineering application.

According to the basic principle of the Screw-driven, a new mechanism named rolling screw transform mechanism is designed in this paper, which is input straight reciprocating motion and output rotation. The motion performance and transmission performance of the mechanism is analyzed, the motion equations, such as displacement, velocity, acceleration, are established. Simulation is present with numerical method, the changing laws of displacement, velocity, acceleration are found based on the simulation curve. The surface numerical model is established, the transmission performance is obtained by analysis.

II. BASIC STRUCTURE

The basic structure of the rolling screw transform mechanism is shown in Figure 1.

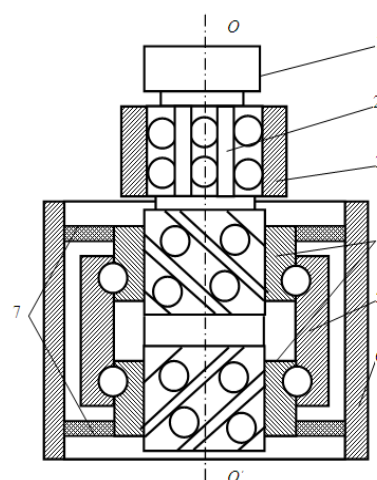


Figure 1. The structure of the rolling screw transform mechanism

1-Piston 2-Axis 3-Spline housing 4- Scroll covers
5-Thrust cover 6-Rotary cover, 7-Overrunning coupler

The axis 2, the scroll covers 4 and balls composed of two rolling screw pairs which turn in the opposite direction. The axis 2, the spline housing 3 and balls composed of rolling spline pair. Its function is to allow axis 2 move along axial direction, and not allow the axis 2 turn, in order to ensure the piston 1 move up and down. So that the piston in motion is only affect by the axial force. The scroll covers 4, the thrust 5 and balls composed of thrust pairs which allow the scroll covers 4 turn and not move along axial direction.

When the piston 1 and the axis 2 move down, the scroll cover above turn, which is driven by the boll scroll above the axis 2. The rotary cover 6 can turn under the role of the overrunning coupler above. When the piston 1 and the axis 2 move up, the scroll cover below turn in the same direction owing to the opposite direction of the spiral. The rotary cover 6 can turn through the overrunning coupler below. Therefore, no matter how to the piston move, the rotary cover 6 turns in the same direction, the continuous rotation can be gotten through reciprocating motion.

III. MOTION ANALYSIS

The piston moves up and down, the rotary cover turns in the same direction. In one period, the rotary cover turns from

0° to 180° when the piston moves down, and turns from 180° to 360° when the piston moves up. The main calculating data are these: the pitch diameter of the screw r is 20mm, the pitch angle β is 45°, the lead of the screw L is 125.6mm, the rotate speed n is 1500rpm.

A. Position Analysis

When the rotary cover turns from 0° to 180°, the displacement equation of the piston can be expressed.

$$s = r\alpha \tan \beta \tag{1}$$

When the rotary cover turns from 180° to 360°, the displacement equation of the piston can be expressed.

$$s = r(2\pi - \alpha) \tan \beta \tag{2}$$

The changing law of the displacement is found based on the calculated result, which is showed in the figure 2.

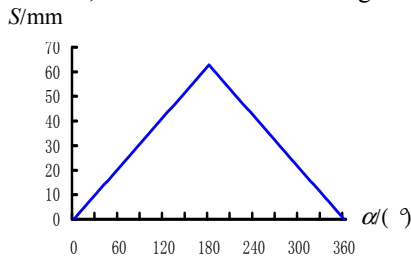


Figure 2. The displacement curves of the piston

Figure 2 is the displacement curves of the piston. As shown in the figure 2, the change of the displacement is periodical in the work course of the piston, the period is 360°, the maximum change value is 62.8mm.

B. Velocity Analysis

The equation (1) and (2) are differentiated to time, the velocity equation can be obtained.

When the rotary cover turns from 0° to 180°, the velocity equation of the piston can be expressed.

$$v = r\omega \tan \beta \tag{3}$$

When the rotary cover turns from 180° to 360°, the velocity equation of the piston can be expressed.

$$v = -r\omega \tan \beta \tag{4}$$

The changing law of the velocity is found based on the calculated result, which is showed in the figure 3.

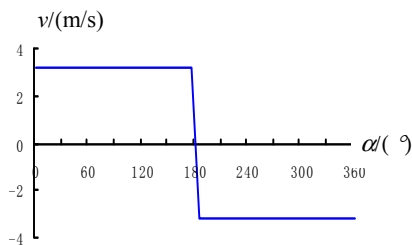


Figure 3. The velocity curves of the piston

Figure 3 is the velocity curves of the piston. As shown in the figure 3, the change of the velocity is periodical in the work course of the piston, the period is 360°. When the rotary angle is less than 180°, the velocity is above zero, the value is 3.14m/s. When the rotary angle is more than 180°, the velocity is below zero, the value is -3.14m/s.

C. Acceleratio Analysis

The velocity equations are differentiated to time, the acceleration equation can be obtained. Because the velocity is unchanged on the whole, the acceleration is zero.

$$a = 0 \tag{5}$$

The changing law of the acceleration is found based on the calculated result, which is showed in the figure 4.

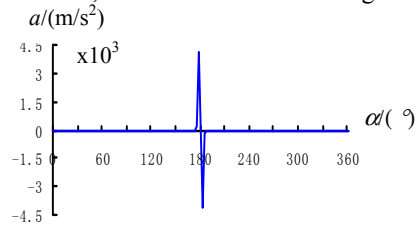


Figure 4. The acceleration curves of the piston

Figure 4 is the acceleration curves of the piston. As shown in the figure 3, the acceleration of the piston is 0 in most cases, at the turning position the acceleration is acrophase, the value is 4134m/s².

Above all, the motion performance of the rolling screw transform mechanism is excellent. In one period, the velocity and the acceleration are stable. So there is no inertial force, the mechanism runs reposefully.

IV. DYNAMIC ANALYSIS

A. Force Analysis

The piston moves up and down, the rotary cover turns in the same direction. The reciprocating motion change rotation through the mechanism. When the middle diameter of the rotary cover is effected by the force F_c , the force effected on the piston F can be indicated.

$$F = \frac{F_c}{\tan \beta} \tag{6}$$

The factors such as the friction loss are considered, the letter η is used to express the transmission efficiency. And the motion of the force M and the middle diameter D are introduced to express the force F_c , the equation (6) can be shown as bellow.

$$F = \frac{2M}{\eta D \tan \beta} \tag{7}$$

It can be obtained that the pitch angle β is the main factor affect the piston force F . When the pitch angle β is more than 45°, the force F_c is more than the force F , it is a mechanism which can increase the force. But When the pitch

angle β is less than 45° , the force F_c is less than the force F , it is a mechanism which can decrease the force.

B. Efficiency Analysis

Figure 5 is the surface model of the rolling screw with OO' as the axis. Block A , block B and ball C make up rolling screw pair. Block A , block F and ball D make up rolling spline pair. Block B , block G and ball E make up rolling thrust pair.

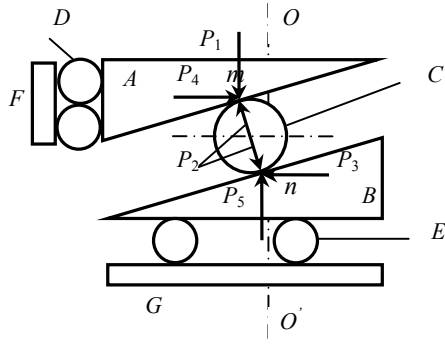


Figure 5. The surface model of the rolling screw

When the force P_1 acts perpendicular to the block A , the pressure will be formed from ball C to block A . There are three forces on the point m : P_1, P_2, P_4 . The force can only act on the vertical contact line in the rolling screw pair, or the ball will run. And the friction can be ignored because the rolling friction coefficient is small, only from 0.001 to 0.002. So the forces on the point m are balanced.

It can be obtained.

$$P_2 = \frac{P_1}{\cos \beta} \tag{8}$$

Likewise, there are three forces balanced on the point n : P_2, P_3, P_5 .

$$P_3 = P_2 \cos \beta \tag{9}$$

So the level force making the mechanism move can be obtained through equation (8) and (9).

$$P_3 = P_2 \cos \beta = P_1 \tag{10}$$

Above all, the direction of force is changed from vertical to level, but the value of the force is unchanged through the mechanism. Because the contact points are all rolling friction, the rolling friction coefficient is small. So the mechanism has high transmission efficiency.

V. PITCH ANGLE INFLUENCE

Through all of the equations above, it can be obtained that the pitch angle β is the main factor affect the transmission performance, such as the displacement of the piston, the velocity of the piston, the force affected on the piston and the transmission efficiency of the mechanism. When the pitch angle β change from 0° to 90° , the affections can be expressed through the simulation curves in Figure 6 to Figure 9.

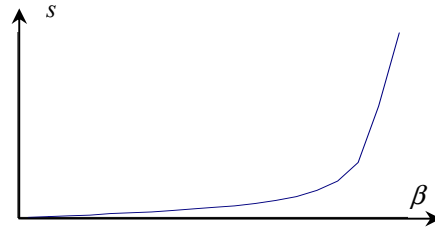


Figure 6. The displacement curves

Figure 6 is the displacement curves of the piston with the change of the pitch angle β . As shown in the figure 6, the displacement is increasing with the pitch angle β . When the pitch angle β is 0° , the displacement is 0, but when the pitch angle β is 90° , the displacement is infinity.

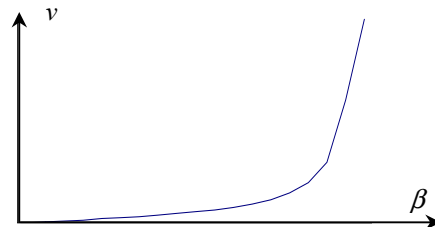


Figure 7. The velocity curves

Figure 7 is the velocity curves of the piston with the change of the pitch angle β . As shown in the figure 7, the velocity is increasing with the pitch angle β . The change law of the curve is the same as the displacement curves. When the pitch angle β is 0° , the velocity is 0, but when the pitch angle β is 90° , the velocity is infinity.

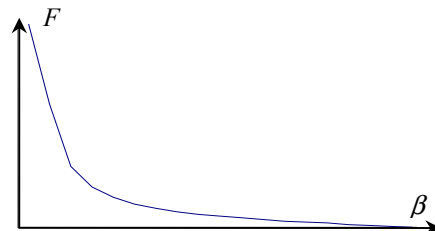


Figure 8. The force curves

Figure 8 is the force curves of the piston with the change of the pitch angle β . As shown in the figure 8, the force is decreasing with the pitch angle β . The change law of the curve is opposite of the displacement and velocity curves. When the pitch angle β is 0° , the force is infinity, but when the pitch angle β is 90° , the force is close to 0.

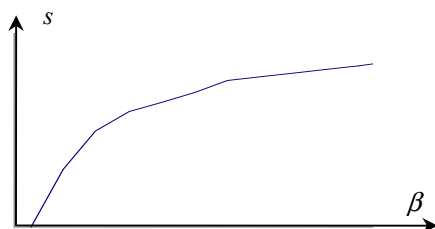


Figure 9. The transmission efficiency curves

Figure 9 is the transmission efficiency curves of the piston with the change of the pitch angle β . As shown in the Figure 9, the transmission efficiency is increasing with the pitch angle β . When the pitch angle β is 0° , the transmission efficiency is 0, but when the pitch angle β is 90° , the transmission efficiency is close to 100%, can reach 98%.

Above all, the pitch angle β is the main factor affect the transmission performance. The biggest pitch angle β is designed, the farther and faster the piston moves. But the force on the piston is opposite, the biggest pitch angle β is designed, the smaller the piston is accepted. When the pitch angle β is small and is equal to the rolling friction angle, the transmission efficiency is 0. The transmission efficiency is increasing with the pitch angle β , can reach 98%.

VI. SUMMARIES

According to the basic principle of the Screw-driven, a new mechanism named rolling screw transform mechanism is designed in this paper, which is input straight reciprocating motion and output rotation. The motion performance of the mechanism is analyzed, the motion equations, such as displacement, velocity, acceleration, are established. Simulation is present with numerical method, the changing laws of displacement, velocity, acceleration are found based on the simulation curve. The surface numerical model is established, the transmission performance is obtained by analysis.

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