Design of the Transmission Device of the Some Type of the Manipulator

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Abstract. The transmission part of a manipulator is presented in the paper. The part of manipulator transmission device is analysed and the part of manipulator transmission device is designed. Design and calculation of suction hand is represented. The driving motor is checked, the calculation of the equivalent moment of inertia of the transmission system is gained, the motor moment frequency characteristic is presented, and the starting torque of the stepping motor is determined. And the schematic diagram of the overall structure and the schematic diagram of the motor connection plate is presented. The theoretical support and design reference for the design of the transmission device of the manipulator is presented in the paper.

1. Introduction
Manipulator is a new device developed in the process of automation and mechanization production. In industrial production, manipulator has a very wide range of use. The basic function is to grab an work piece from a specified location and transport it to another specified location. The mechanical arm replaces manual labour, with high operation precision, improving product quality and production efficiency [1]. In the mechanical industry, it can be used for the assembly of parts, the loading and unloading of processing work piece, handling. The assembly manipulator takes the rigid high arm as the main body, it may carry on each kind of operation automatically according to the signal which sends from the outside. It can save huge work piece conveying device, compact structure and strong adaptability. When the work piece changes, the flexible production system is easy to change, which is beneficial for the enterprise to continuously update the marketable variety, improve product quality, and better meet the needs of market competition. At present, the level of industrial robot technology and its engineering application in China is still far from that of foreign countries, and the application scale and industrialization level are relatively low. The research and development of manipulator has an important impact on the improvement of China's automatic production level, the research and design of manipulator is very meaningful [2-4].

2. Design of the Air Suction Hand
2.1. Structure of the Air Suction Hand
The suction cup is used to form negative pressure to hold the work piece. The suction hand is suitable for carrying thin pieces, such as thin iron sheet, silicon steel sheet, plate, paper, thin-walled fragile glassware, curved shell, etc., especially glassware and non-metal sheet, the adsorption effect is more obvious. Compared with the gripper hand, the air-suction hand has a simple structure, light weight and uniform surface adsorption force distribution, but the suction surface should be smooth, without holes and oil. According to the method of forming negative pressure (or vacuum), air suction hand can be
divided into vacuum type, air negative pressure type and squeeze exhaust type suction cup. The suction hand used in the design is shown in figure 1.

Figure 1. The Schematic diagram of the suction hand

2.2. Calculation of the Suction Hand

Proposed operating conditions: load \( W = 10 \text{N} \).

The suction force of the vacuum chuck during the start-up process is:

\[
P = \frac{S}{K_1 K_2 K_3} \Delta p
\]

- \( S \) - suction cup area (mm\(^2\)), \( S = \frac{\pi}{4} D^2 \), \( D \) is suction cup diameter;
- \( K_1 \) - the safety factor of the suction cup when the work piece is started, \( K_1 = 1.2 \sim 2 \);
- \( K_2 \) - coefficient of the operating condition, generally \( K_2 = 1 \sim 3 \);
- \( K_3 \) - coefficient of azimuth. When the sucker is vertically adsorbed, \( K_3 = f^-\)1, \( f \) is the friction coefficient. When the rubber sucker is adsorbed, \( f = 0.5 \sim 0.8 \). When the sucker is absorbed horizontally, take \( K_3 = 1 \);
- \( \Delta p \) – the differential pressure of the suction cup from inside to the outside (MPa).

For vacuum suction cup, the suction cup adsorption work piece should be guaranteed to be absorbed at the start. During the transfer process, the vacuum degree in the suction cup increases with time, and the adsorption work piece becomes more and more reliable.

Micro vacuum pump KVP04, vacuum degree -40kpa, suction cup ZPT32UN-A8, diameter 32mm, nitrile butadiene rubber material; Take 1.2 for \( K_1 \) and take 1 for \( K_2 \), take 0.8 for \( f \), and take 0.04 MPa for \( \Delta p \).

\[
P = (\pi /4 \times 32^2) / (1.2 \times 1 \times 0.8)
\]

Then \( P = 21.45 \text{n} \), and the suction cup meets the requirement.

3. The Check of the Drive Motor

3.1. Calculation of the Equivalent Moment of Inertia of the Transmission System [5, 6]

(1) Inertia of motor rotor \( J_D \).

The inertia of motor rotor from the stepper motor product manual is represented as:

\[
J_D = 0.8 \text{kg} \cdot \text{cm}^2
\]

(2) The translation of the moment of inertia of the ball screw \( J_S \).

Consider the screw as a homogeneous cylinder.

\[
J_S = \frac{1}{2} mR^2
\]

\[
m = \frac{1}{4} \pi d_1^2 L \rho_{\text{steel}}
\]

Where: \( d_1 \) - outside diameter of ball screw thread
- \( L \) - the length of the screw
\[ m = \frac{1}{4} \pi \times 15.1^2 \times 0.888 \times 7.85 \times 10^3 = 1.25 \text{ kg} \]

\[ J_s = \frac{1}{2} \times 1.25 \times \left( \frac{1}{2} \times 1.51 \right)^2 = 0.36 \text{ kg/cm}^2 \]

From the size and performance parameters of the inner circulation ball screw pair series in the mechanical design manual, \( d_1 = 15.1 \text{ mm} \).

The full length \( L \) of the lead screw is 888 mm.

(3) The reduction of the inertia of the forearm movement \( J_G \).

The working table is a moving part, whose mass is converted to the inertia of horizontal movement of the ball screw axis, which can be calculated according to the following formula:

\[ J_G = \left( \frac{V}{2m} \right)^2 m_x \]

Where: \( v \) - moving speed of table, cm/min; 
\( n \) - screw speed, RPM; 
\( m_x \) - moving parts mass, kg;

\[ J_G = \left( \frac{240}{2\pi \cdot 600} \right)^2 \cdot 9.57 = 0.04 \text{ kg/cm}^2 \]

The moment of inertia of the coupling:

\[ J_L = 0.085 \text{ kg/cm}^2 \]

The equivalent moment of inertia of the system

\[ J = J_D + J_S + J_G + J_L = 0.8 + 0.36 + 0.04 + 0.085 = 1.285 \text{ kg/cm}^2 \]

3.2. Check for the Moment Frequency Characteristics of the Motor

The maximum static torque of the stepping motor \( M_{j_{\text{max}}} \) refers to the positioning torque of the motor, and \( M_{j_{\text{max}}} = 2.4 \text{ N \cdot m} \).

The nominal starting torque of the stepping motor is \( M_{m_{q}} \); the relation of the maximum static torque \( M_{j_{\text{max}}} \) is: \( M_{m_{q}} = \lambda M_{j_{\text{max}}} \). The value for \( \lambda \) can be found from the product specification of the motor.

\[ M_{m_{q}} = 0.707 \times 2.4 = 1.70 \text{ N \cdot m} \]

The starting torque of the stepper motor can be calculated as follows:

\[ M_{k_{q}} = M_{k_{a}} + M_{k_{f}} + M_{0} \]

Where: \( M_{k_{q}} \) - the no-load starting torque; 
\( M_{k_{a}} \) - the acceleration torque of motor shaft from static to maximum fast forward speed during no-load start; 
\( M_{k_{f}} \) - the friction torque on motor shaft when no load is applied; 
\( M_{0} \) - the additional friction torque;

The calculation of no-load starting torque \( M_{k_{q}} \) is presented as follows:

(1) Acceleration torque \( M_{k_{a}} \)

The acceleration torque \( M_{k_{a}} \) can be calculated according to the following formula:

\[ M_{k_{a}} = J \varepsilon = J \frac{2\pi n_{\text{max}}}{60t} \cdot 10^{-2} \]

\[ n_{\text{max}} = \frac{\nu_{\text{max}}\theta}{\delta_{p}} \]

Where: \( J \) - equivalent moment of inertia of the system; 
\( \varepsilon \) - Epsilon and loss is the maximum angular acceleration of the motor;
\( n_{\text{max}} \) - motor speed corresponding to the maximum feeding speed of moving parts;
\( v_{\text{max}} \) - maximum feeding speed of moving parts;
\( \theta \) - the step moment Angle of the stepper motor;
\( \delta_p \) - impulse equivalent of the stepping motor;

\[
n_{\text{max}} = 600 \text{rpm}
\]

(2) No-load friction torque \( M_{\text{kf}} \)
The no-load friction torque \( M_{\text{kf}} \) can be calculated according to the following equation:

\[
M_{\text{ka}} = 1.285 \cdot \frac{2\pi \cdot 600}{60 \cdot 0.2} \cdot 10^{-2} = 4.04 \text{N} \cdot \text{cm}
\]

Where: \( L \) - maximum stroke of ball screw, cm
\( \eta \) – the total efficiency of the transmission system, eta = 0.9

\[
M_{\text{kf}} = \frac{4.96 \cdot 60}{2\pi \cdot 0.9} = 52.63 \text{N} \cdot \text{cm}
\]

(3) Additional friction torque \( M_0 \)
Additional friction torque \( M_0 \) can be calculated according to the following equation:

\[
M_0 = \frac{F_p L}{2\pi \eta}
\]

\[
M_0 = \frac{2.29 \cdot 60}{2\pi \cdot 0.9} = 24.30 \text{N} \cdot \text{cm}
\]

Thus, the starting torque required by the stepper motor can be obtained as follows:

\[
M_{\text{ka}} = M_{\text{ka}} + M_{\text{kf}} + M_0 = 4.04 + 52.63 + 24.30 = 80.97 \text{N} \cdot \text{cm}
\]

\[
M_{\text{ka}} = 0.81 \text{N} \cdot \text{m} < M_{\text{mq}} = 1.70 \text{N} \cdot \text{m}
\]

The starting torque required by the stepper motor is less than the nominal torque of the stepper motor, and the stepper motor meets the requirements.

The schematic diagram of overall structure and motor connection plate, the schematic diagram of the base and the attachment plate of the suction, are shown from figure 2 to figure 5.

**Figure 2.** The schematic diagram of the overall structure

**Figure 3.** The schematic diagram of the motor connection plate
4. Conclusion
The part of manipulator transmission device is analysed and the part of manipulator transmission device is designed. Design and calculation of suction hand. The driving motor is checked, the calculation of the equivalent moment of inertia of the transmission system is gained, the motor moment frequency characteristic is presented, and the starting torque of the stepping motor is determined. And the schematic diagram of the overall structure and the schematic diagram of the motor connection plate is presented. In the field of machinery, generation after generation of engineers constantly optimize the product structure and data in the actual production. The experience of predecessors is very worthy of reference, but continuous innovation is needed. Better products can be obtained in this way.

5. Acknowledgments
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6. References
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