Physical Application of Mechanical Parts and Components Simulate in Receivable Auxiliary Multifunction Mechanical Hand and Claw

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Abstract. Based on the analysis of current office work status and office robots, this paper proposes a design scheme of intelligent mechanical gripper which can transfer data and move objects independently to assist daily office work. It is proposed to design mechanical structure, including mechanism motion design and part structure design, and to use Autodesk Inventor to design and simulate mechanical parts and components. Dimensional and strength checks are carried out on key components, and stress analysis is simulated by using stress analysis module included in Autodesk Inventor. Finally, the mechanical structure design scheme and control system design scheme for the mechanical gripper are proposed. The overall design mainly centers on the functions expected to be completed, and innovates different organizations in combination to achieve the intended objective.

Keywords: Mechanical claws, Office support, Worm gear and worm.

1. Introduction
Office workers, also known as white-collar workers, started with a definition of lifestyle from the West, and then began to have the concept of white-collar in China. White-collar workers in our country are generally referred to as those who work in offices and in office buildings for secretarial or other clerical work. According to statistics, the number of white-collar workers currently accounts for about 37.6% of the total population, of which about 90 million are white-collar workers aged 30-40 years. According to the current population of China, the number of white-collar workers has reached 526.4 million. According to statistics, the average working time of office workers in Chinese cities is 8.2 hours, which has exceeded the stipulation in the Labor Law that the average working time per day should not exceed 8 hours. At present, the working pressure of office workers in our country is generally high. In modern large office areas, companies are densely staffed and a large amount of data needs to be transferred to different departments every day. However, most of the office staff are busy and do not get much free time to transmit information, which also leads to the phenomenon that many new or interns need to help the old employees run errands and lack of real work exercise. This also leads to the late submission and omission of documents, resulting in reduced office efficiency. There is therefore an urgent need for an office-assisted robot for the transportation of data and for assisting in other tasks. Improve office automation and intelligence, reduce human resources costs and improve work efficiency.
2. Research significance

In accordance with the current working situation of white-collar workers in China and the requirements of service direction of office work, this device is designed for daily office work, data transmission between different locations and document arrangement. It is safe, efficient and stable.

The device has the following features:

1) Be able to complete the transmission of office-related documents and materials independently, and have mechanical claws to complete grabbing and other actions, and independently complete the grabbing and placement of items.

2) The device is designed as a temporary storage platform to temporarily store the data to be transferred, and at the same time, large items can be placed to complete the transportation of various items.

3) The mechanical claw of this device is connected by three-phase balancing arm, which can ensure the stability of the mechanical claw to a great extent. Therefore, when grabbing containers containing liquid such as coffee and water cups, it can prevent the spilling of internal liquid and improve the safety.

4) The design of the obstacle-crossing gear train enables the unit to be lifted as a whole, increases the distance between the chassis and the ground, can overcome most obstacles, and has greater traffic capacity to adapt to most scenarios.

3. Conceptual design

3.1. Overall design

As shown in the diagram, the overall structure of the sub-parent receiving mechanical gripper is designed with modular function. The overall structure consists of four modules, i.e., mechanical gripper module, walking module, lifting module and temporary platform module. The female take-up mechanical claw consists of a larger female claw and a smaller sub-claw, while the outer female claw consists of four bionic mechanical fingers. One or two finger connections are hydraulically driven and the finger root connections are gear connections. All four fingers can be retrieved into the receiving slot on the outside of the arm by rotation and gear rotation. The smaller sub-claws extend the mechanical arm of the parent claw through the fork-cutting mechanism, supplement the space position by the rocker slider mechanism and open the mechanical claws by means of line drive. The lifting module is lifted by a screw driver and is connected to the mechanical claws of the mother through a stable platform. The obstacle-crossing wheel of the walking module is lifted by the rotation of connecting shaft arm driven by the motor and worm wheel to increase the height of chassis and increase the stability of the device.

Figure 1. Unit overall drawing.
3.2. Mechanical structure design

3.2.1. Walking module. As shown in the illustration of a walking module, there are two working modes, folding mode and stretching mode, which can be switched between modes by turning the gear train support 90 degrees. Normally, it is folded. When it needs to cross the obstacle, it can switch to the mode of over-obstacle. Lift the device as a whole and increase the distance between chassis and ground.

![Figure 2. Model diagram of integral drive chain.](image)

3.2.2. Mechanical arm section. The mechanical arm is mainly composed of two arms, and the universal joint connection is used between the two arms and the lifting module, so that the mechanical arm can rotate in all directions. It greatly increases the overall flexibility of the robot hand grab module. At the same time, the hollow design of the mechanical arm guarantees the strength of the mechanism to meet the service requirements, at the same time, it can reduce the overall weight and save the manufacturing materials.

3.2.3. Son and mother receiving robot. In order to accommodate the different sizes and shapes of objects in the office, the front robotic hand is designed as a child-parent receiving type. The female claw, consisting of four two mechanical fingers, is mainly used for grasping daily objects. When completing the clamping action (e.g., bottle-shaped object), the mechanical fingers are paired in pairs and the opposite fingers are opened and closed to complete the clamping; When the gripping action is completed (e.g., a spherical object), the four mechanical fingers open and drive at the same time to complete the action. Most of the action requirements in the office can be accomplished with a combination of four fingers. Each mechanical finger is driven between two segments by an electric push rod to achieve finger folding. The base of the mechanical finger is driven by gears, while the gears of the four finger fingers are driven at the same time to open the whole claw.

![Figure 3. Son and mother receiving robot.](image)
3.2.4. Lifting module. The lifting module is connected to the mechanical gripper module. The lifting module theme consists of a screw rod with three support rods around the screw rod to fix the direction of the lifting module unchanged. There is a motor on the top of the lifting module. When the mechanical gripper module needs to be lifted, the motor rotation drives the screw located below to rotate, and the thread located on the surface of the screw drives the overall lifting of the lifting module. The design of lifting module can make the grasping part of the mechanical gripper more flexible, adapt to the grasping environment of various heights, and accomplish the tasks of grasping and transferring with more.

3.3. Control system design
The device uses Arduino single-chip as the main control chip, uses gyroscope and acceleration sensor module to get the walking path of the device, uses motor drive plate to drive the motor in the walking module, and controls the switching of operation mode of the device. The power source of the device movement is the servo motor, so it is necessary to connect the servo controller and the main control chip. Communication of controlled computer is realized by using WIFI communication module and path planning is assisted by GPS module. The control scheme is shown as follows:

![Control scheme design](image)

**Figure 4. Control scheme design.**

4. Feasibility analysis

4.1. Gear calculations and checks
In the mechanical claw grasping module, a pair of identical gears engage with each other to achieve the opening of a single mechanical finger, and four pairs of gears cooperate with each other to achieve the opening and closing of the female claw in the letter mechanical claw to complete the grasping action.

In this gear mechanism, there are 2 pairs of bearings and 1 pair of spur gear. Take bearing efficiency as $\eta_1 = 0.98$, 9-stage accuracy spur gear efficiency is $\eta_2 = 0.96$. Since the transmission ratio is 1, the rotational speeds of both shafts are equal. Also known as $P_1 = P_2/\eta_1$ . Therefore $\eta = \eta_1^2 \eta_2 = 0.98^2 \times 0.96 = 0.92$, $T_o = 1.08 \text{ N-m}$

4.2. Verification calculations of gear contact fatigue and bending fatigue
Preliminary selection parameter $z_1 = z_2 = 8$, $X_1 = X_2 = 0$;
For asymmetric arrangement, take $\Psi_d = 0.6$;
Due to motor drive, the load of the worker is stable, and the table shows $K_d = 1$;
For the gear speed is not high, take $K_v = 1.04$;
For asymmetric arrangement, take $K_B = 1.14$, $K_d = 1.19$;
Then $K = K_v K_d K_B K_d = 1.04 \times 1 \times 1.14 \times 1.19 = 1.411$.
Design criteria: Since it is a soft tooth surface, it is calculated according to the contact fatigue strength of the tooth surface and then checked the bending fatigue strength of the root.
\[ \sigma_{HP} = \frac{\sigma_{Hlim}}{S_{Hmin}} \]  
\[ d_1 \geq \sqrt{\frac{112Z_E^2}{\sigma_{HP}} \cdot \frac{KT_1}{\psi_d u} \left( u \pm 1 \right)} = \sqrt{\frac{112 \times 189.8}{458.3} \cdot \frac{1.411 \times 1.08 (1 + 1)}{0.6 \times 1}} = 22.19 \text{mm} \]

\[ m = \frac{d_1}{z_1} = 22.19 \div 8 = 2.77 \]

Take \( m = 3 \), so

\[ a = \frac{1}{2} m (z_1 + z_2) = \frac{1}{2} \times 3 \times 16 = 24 \text{mm} \]

Where \( b_1 = \psi_d d_1 = 0.6 \times 24 = 14.4 \text{mm} \), because of the same number of teeth \( b_1 = b_2 = 14.4 \text{mm} \).

To prevent the tooth root from bending fatigue damage. Should enable \( \sigma_F \leq \sigma_{FP} \).

It can be seen from the data that the checking formula for flexural fatigue strength of tooth roots is:

\[ \sigma_F = \frac{2000KT_1}{b m^2 z_1} Y_F Y_e \leq \sigma_{FP} \]

\[ Y_e = 0.25 + \frac{0.75}{\varepsilon_a} \]

Take \( \varepsilon_a = 1.4 \)

\[ Y_e = 0.25 + \frac{0.75}{1.4} = 0.25 + 0.54 = 0.79 \]

Find out \( Y_F = 4.0 \)

\[ \sigma_F = \frac{2000KT_1}{b m^2 z_1} Y_F Y_e = \frac{2000 \times 1.411 \times 1.08}{14.4 \times 3 \times 3 \times 8} \times 4.0 \times 0.79 = 9.29 \text{MPa} \]

\[ \sigma_{FP} = \frac{\sigma_{Hlim} Y_T}{S_{Fmin}} Y_N = \frac{220 \times 2}{1.4} \times 1 = 314.3 \text{MPa} \]

Calculated \( \sigma_F \leq \sigma_{FP} \), so the bending fatigue strength of the gear root meets the requirements.

5. Component stress analysis

The mechanical leg of the walking module is the most important component supporting the whole device, and its strength check results play a key role in the overall stability and safety of the device. Here, one of the four mechanical legs is selected as the research object, and the selected material scheme is shown in the table below

| Table 1. Material selection |
|-----------------------------|
| **Name** | **Steel, alloy** |
| Routine | Steel, alloy |
| Mass density | 7.73 g/cm³ |
| Yield strength | 250 MPa |
| Ultimate tensile strength | 400 MPa |
| Stress | Young's modulus |
| Poisson's ratio | 0.3 ul |
| Shear modulus | 78.8462 GPa |
| Part name | Sports leg |
| Bearing 619-6-2Z GB_T 276-94 |
| Washer 1 |
| Washer 1 |
| Leg 1 |
| Leg 2 |
| Leg tube |

The stress analysis scheme is shown in the figure
Results obtained after analysis:

| Table 2. Stress result analysis |
|---------------------------------|
| **Name** | **Minimum value** | **Maximum** |
| Volume | 65930.6 mm³ |  |
| Quality | 0.509644 kg |  |
| Mises equivalent stress | 0.444954 MPa | 6076.13 MPa |
| First principal stress | -1149.35 MPa | 6767.18 MPa |
| Third principal stress | -4441.73 MPa | 335.311 MPa |
| Displacement | 0 mm | 6.87106 mm |
| Safety factor | 0.0411446 ul | 15 ul |
| Stress XX | -3127.45 MPa | 3748.82 MPa |
| Stress XY | -1887.94 MPa | 1464.83 MPa |
| Stress XZ | -1540.86 MPa | 1418.68 MPa |
| Stress YY | -4104.61 MPa | 6610.02 MPa |
| Stress YZ | -1766.37 MPa | 1721.07 MPa |
| Stress ZZ | -3496.41 MPa | 3216.29 MPa |
| X Displacement | -2.82267 mm | 2.32639 mm |
| Y Displacement | -6.05898 mm | 0.00755759 mm |
| Z Displacement | -2.46817 mm | 1.26475 mm |
| Equivalent strain | 0.00000188459 ul | 0.0268047 ul |
| First principal strain | -0.0000426574 ul | 0.0307312 ul |
| Third principal strain | -0.0205345 ul | 0.0000358955 ul |
| Strain XX | -0.0148317 ul | 0.0173632 ul |
| Strain XY | -0.0119723 ul | 0.00928915 ul |
| Strain XZ | -0.00977131 ul | 0.00899649 ul |
| Strain YY | -0.0186276 ul | 0.0297346 ul |
| Strain YZ | -0.0112014 ul | 0.0109141 ul |
| Strain ZZ | -0.0159589 ul | 0.0146272 ul |

From the analysis results, it can be seen that the stress analysis of mechanical legs can be checked and passed, which shows that the scheme has good strength conditions and that the structure has good stability under this material scheme. The analysis results show that the size design and material selection of the walking module meet the working requirements under the actual working load.
6. Conclusions
The device employs mechanical claws of bionic mother and child, which greatly improves grasping stability and robustness. Flexible material used at fingertips can protect the object to a certain extent. The structure design of the parent-child structure achieves a more complex grasping task through the combination of two mechanical claws, which can better adapt to the complex office scene. The use of obstacle-crossing gear train can achieve the overall lifting of the device, increase the ability of obstacle-crossing and expand the scope of application of the device. Three-way balancing arm is used to maximize the stability of the mechanical gripper. It has great advantages and application prospects in assisting daily office work and transferring items in large office buildings.

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