Simulation Analysis of Three Finger Manipulator Based on Delta Mechanism

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Abstract: The subject mainly takes the three-fingered manipulator as the research object, and designs a new three-fingered manipulator for grasping circular parts. The power is driven by motor, the power is more stable, and the structure is more stable with three-link mechanism. The complex vector method and Newton-Euler formula method are used to calculate and analyze the manipulator. The manipulator is simplified as offset crank-slider mechanism. The kinematics curves are drawn by MATLAB software, and the displacement, velocity and acceleration of the three-fingered manipulator are obtained. Then, the kinematics and dynamics simulation analysis of the three finger mechanical gripper is carried out by using Adams software. The kinematics parameters of the three finger mechanical gripper are obtained. The theoretical analysis results are compared with the simulation results of Adams software. The theoretical analysis and software simulation results show that the error is small, which verifies the correctness and feasibility of the theoretical calculation, and lays a foundation for the subsequent optimization and improvement of the three-fingered manipulator gripper and the solution of dynamic parameters.

1. Introduction

With the development of society and the progress of science and technology, the division of labor [1-3] in society is becoming more and more detailed. Especially in the modern mass production, the manipulator has been integrated into various industries so far. Many industries have been inseparable from the manipulator. The manufacturing industry does not need to say much. Medicine, aerospace and other industries also need it. Human beings are inseparable from the manipulator. We must continue to develop and innovate, improve the manipulator and robot, and benefit mankind. Manipulator technology is an interdisciplinary comprehensive technology, which involves mechanics, mechanics, electric hydraulic technology, automatic control technology, sensor technology, computer technology and other scientific fields [4-6]. Manipulator is a kind of man-made automatic machine, its main function is to complete the work required by people. The characteristics of manipulator artificial intelligence and the advantages of being able to adapt to the harsh environment will have great development space in the future industrial field.

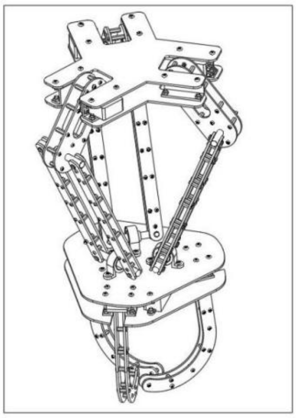
2. Theoretical analysis of the three finger mechanical gripper

In this paper, the parts above the three finger mechanical gripper [7], that is, the static platform, the active arm, the driven arm and the moving platform, are simplified into offset crank slider mechanism, and analyzed by Newton Euler formula.

Before the kinematic analysis of the manipulator [8], the velocity and acceleration of each joint of the manipulator are required first, which is the basis of the mechanical solution of the manipulator [9]

The manipulator consists of two parts: the mechanical claw and the mechanical arm. The arm is divided into active arm and driven arm. Analysis of displacement, velocity and acceleration of moving platform.

The arm part can be simplified as an offset crank slider mechanism, as shown in Fig.2. The kinematic analysis of the mechanism is carried out by using the analytical method. Firstly, the position equation of the three finger manipulator is established. Through the derivation of time, the velocity equation is obtained, the second-order derivation is obtained, and the acceleration equation is obtained. The offset crank slider mechanism is a single degree of freedom system with only one independent variable. In this case, the crank angle is also the angle of the active arm, so the specific motion parameters and the automatic change of the mechanism can be established the mathematical relation between quantities [10].



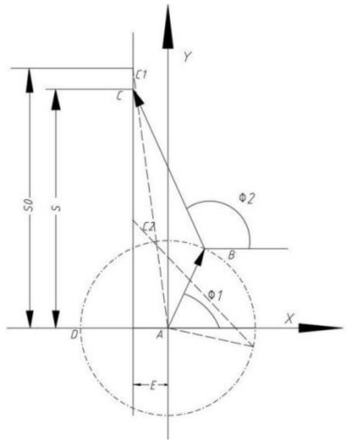


Figure 1. Two dimensional model of manipulator Figure 2. Crank slider mechanism

By using the complex vector solution method, the kinematic geometry of the offset slider crank mechanism is regarded as a closed vector polygon in the complex plane, and each component is regarded as a vector.

3. Theoretical analysis of the grasping of the three finger manipulator

Known parameters: length of driving arm, rotating speed of driving arm, its rotating range is -12.34°~ 97.66°, the change of angle with time t is, length of driven arm, offset.Parameters to be determined: moving platform displacement s, velocity V, acceleration a, connecting rod speed, angular velocity.

3.1 Kinematic analysis of slider and connecting rod

Take the center a of the crank fixed hinge as the coordinate origin, take the sealed closed-loop ABCD, and the vector equation is [11]

$$\overrightarrow{AB} + \overrightarrow{BC} = \overrightarrow{AD} + \overrightarrow{DC} \tag{1}$$

The modules of the above vectors arel_1,l_2,E,s, and the angles are φ_1,φ_2,180°,90°.In the exponential form of complex number, it is expressed as :

$$l_1 e^{i\varphi_1} + l_2 e^{i\varphi_2} = -E + is \tag{2}$$

Expand formula (2) according to Euler formula:

$$l_1(\cos\varphi_1 + i\sin\varphi_1) + l_2(\cos\varphi_2 + i\sin\varphi_2) = -E + is \tag{3}$$

If the real part and the imaginary part are equal, then

$$\varphi_2 = \arccos\left(\frac{-E - l_1\cos\varphi_1}{l_2}\right) \tag{4}$$

$$s = l_1\sin\varphi_1 + l_2\sin\varphi_2 \tag{5}$$

Deriving (2) time to:

$$l_1 i\omega_1 e^{i\varphi_1} + l_2 i\omega_2 e^{i\varphi_2} - iv = 0 \tag{6}$$

Adjust equation (6) to:

$$\omega_2 = \frac{-l_1\omega_1 sin\varphi_1}{l_2 sin\varphi_2} \quad (7)$$

$$v = \frac{-l_1\omega_1 \sin(\varphi_1 - \varphi_2)}{\sin\varphi_2} \quad (8)$$

The derivation of formula (6) to time is:

$$l_1 i\alpha_1 e^{i\varphi_1} - l_1\omega_1^2 e^{i\varphi_1} + l_2 i\alpha_2 e^{i\varphi_2} - l_2\omega_2^2 e^{i\varphi_2} - ia = 0 \quad (9)$$

The formula (9) is arranged to be :

$$\alpha_2 = -(\frac{l_1\omega_1^2 cos\varphi_1 + l_2\omega_2^2 cos\varphi_2}{l_2 sin\varphi_2}) \quad (10)$$

$$a = -(\frac{l_1\omega_1^2 cos(\varphi_1 - \varphi_2) + l_2\omega_2^2}{sin\varphi_2}) \quad (11)$$

Among them, (4), (7), (10) is the mathematical model of the connecting rod movement, (5), (8), (11) is the mathematical model of the slider movement.

If the displacement, velocity and acceleration of the slider are all taken as positive Y axis, and the angle, angular velocity and angular acceleration of the active arm are substituted with the function of time, then the mathematical model describing the movement of the slider is revised to [12]:

$$s = \sqrt{(A+B)^2 - E^2} - (l_1 sin\varphi_1 + l_2 sin\varphi_2) \quad (12)$$

$$v = -\frac{l_1\omega_1 \sin(\varphi_1 - \varphi_2)}{sin\varphi_2} \quad (13)$$

$$a = -\frac{l_1\omega_1^2 \cos(\varphi_1 - \varphi_2) + l_2\omega_2^2}{sin\varphi_2} \quad (14)$$

3.2 Generate function image

Using MATLAB software and reference formula (12), (13) and (14) editing programs, draw the speed image of the slider as shown in Fig.3. The vertical axis in the figure represents the speed, and the horizontal axis represents the time. From the curve in the figure, it can be seen that the movement speed of the slider is regular. When the slider is in the middle of the whole stroke, the speed is the fastest, about 120mm /s. when the slider is at both ends of the whole stroke, the speed is the slowest, zero. That is to say, when the active arm is in the middle angle within the allowable rotation range of the design, the speed of the slider is the fastest, and the speed is the slowest at the limit angle.

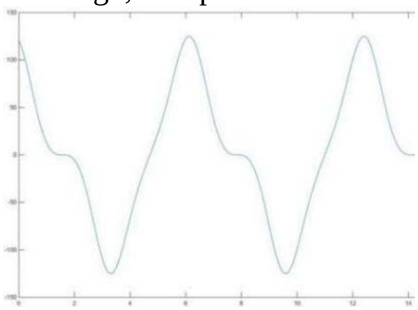


Figure 3. Change of velocity of moving platform with time

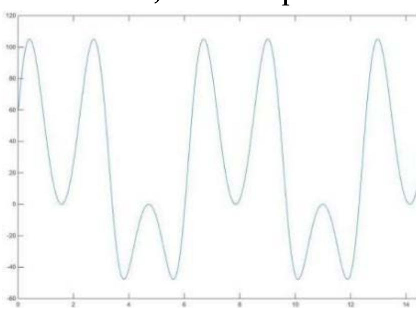


Figure 4. Change of acceleration of moving platform with time

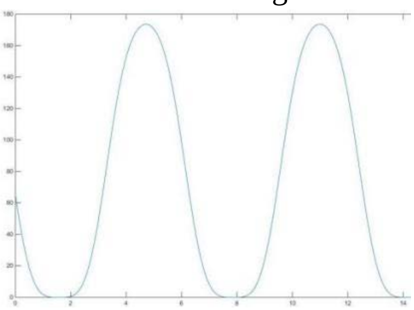


Figure 5. Change of displacement with time

Fig.4. shows the acceleration image of the slider. In the figure, the vertical axis represents the acceleration, the horizontal axis represents the time, and the acceleration curve of the slider is also very regular. However, compared with the speed image, it is more complex. When the slider is in the middle position, its acceleration is zero, and at this time, its speed is the fastest. When the slider is in the limit position, its acceleration is the largest, but its speed is zero. In the figure, there are two peaks, two troughs, and two waves the valley values are all zero, but the peaks are different, one is about $120mm/s^2$, the other is about $-50mm/s^2$.

The image of displacement changing with time is shown in Fig.5. In the figure, the horizontal axis represents time and the vertical axis represents displacement. It can be seen from the figure that the displacement stroke of the slider on the straight line is about 175mm, and when the slider is at the limit position, it still stops for a little while.

The components above the gripper of the manipulator are simplified as the offset crank slider mechanism. The algorithm of the mechanism is used to calculate the displacement, velocity and acceleration of the moving platform as well as the relationship between the acceleration and time. Through the calculation of these parameters, the function is obtained, and the kinematic function image is drawn by MATLAB.

4. Software simulation of three finger manipulator

4.1 Kinematics analysis of three finger manipulator based on ADAMS

To draw the three-dimensional drawing of the three finger manipulator, it is necessary to assemble the parts. Import ADAMS software for simulation, as shown in Fig.1.

The kinematic analysis of the three finger manipulator is to take the motion of the three finger manipulator relative to the fixed reference system as a time function without considering the forces and moments that cause these motions [15]. In this paper, the space track of three finger manipulator is expressed by time function. The kinematic models of the driving arm, the driven arm and the gripper are established respectively. The kinematic analysis of the end of the driven arm, that is, the moving platform, is mainly studied.

4.2 Restraint and drive

It is a very complicated thing to impose constraints on the model, because there are many constraints required for the joints of this manipulator, which need to be careful. As long as there is a mistake, the simulation of the model will fail. Next, you start to constrain the model.

It is necessary to understand the motion mechanism of the manipulator, and then apply appropriate constraints to each joint. The relationship between the driving arm and the driven arm is a rotation relationship, so a rotation pair should be applied, and attention should be paid to the rotation center and direction; the relationship between the mechanical gripper and the movable platform bracket is also a rotation relationship, and a rotation pair should be added; the relationship between the driven arm and the bearing is still a rotation pair; a fixed pair should be added between the static platform and the earth, a fixed pair should be added between the static platform plate and the static platform bracket, etc. As for the drive, just add three identical drives to the three motors.

4.3 Kinematic parameter curve

The function of the angle and time of the active arm in the figure is set by itself. The reason why the image of the function is translated upward is that the middle position of the rotation of the active arm does not coincide with the zero position selected by ADAMS software. The function is shifted up a certain distance, that is, the zero angle is set in the middle of the rotation range of the active arm. As shown in Fig.6. Fig.7 shows the change of the angular velocity of the active arm with time. From the figure, it can be known that the function of the angular velocity and time of the active arm is a sine function. Its maximum angular velocity is about 55 ° / s, and the minimum angular velocity is zero. It appears at the limit angle. From this, it can be known that the active arm accelerates and decelerates in the process of rotation, which means the change of the angular acceleration.

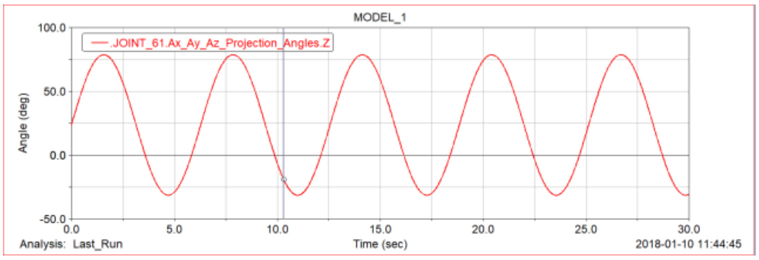


Figure 6. Change of angle of active arm with time

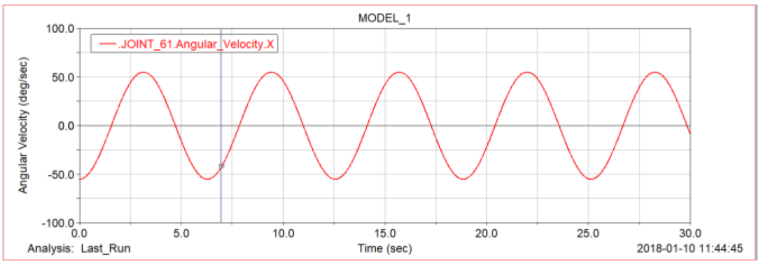


Figure 7. Change of angle speed of active arm with time

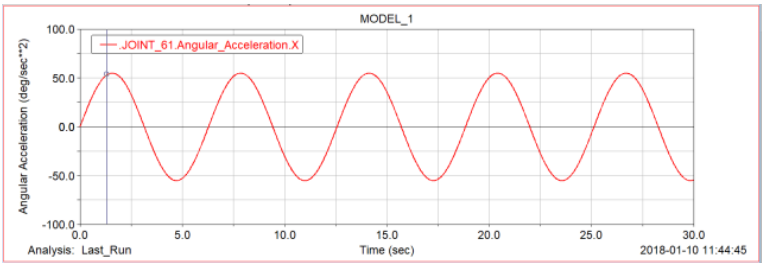


Figure 8. Change of angular acceleration of active arm with time

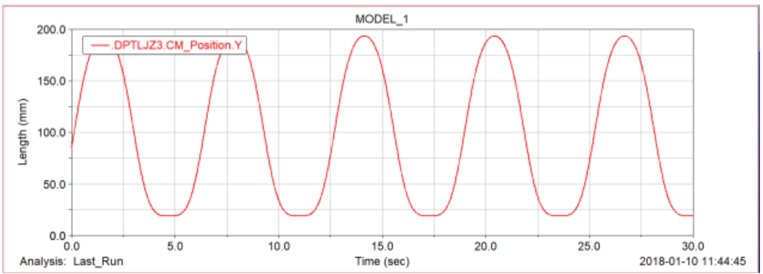


Figure 9. Change of moving platform displacement with time

Fig.8 shows the change of the angular acceleration of the active arm with time. It can be seen from the figure that the angular acceleration image of the active arm is almost the same as its acceleration image. When the moving platform reaches the limit position, its acceleration is the largest, and when it reaches the middle position, its acceleration is zero. When the driving function is - 55D (0.43+sin (time)), it can be seen from Fig.9. That the displacement range of the moving platform is about 19mm-194mm, and the stroke is about 175mm.

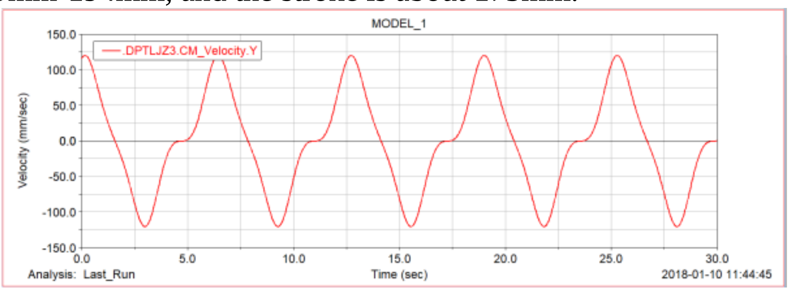


Figure 10. Change of velocity of moving platform with time

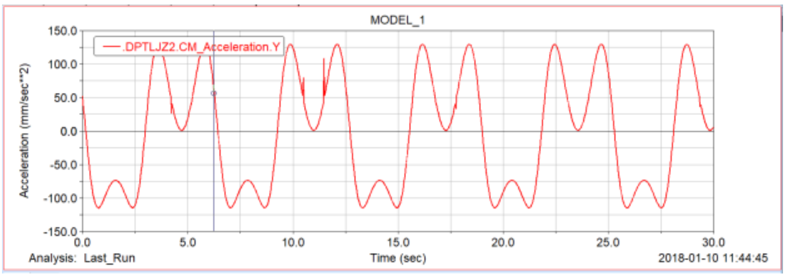


Figure 11. Change of acceleration of moving platform with time

When the driving function is -55D (0.43+sin (time)), the speed change rule of the moving platform can be known through Fig.9. The maximum speed is about 120mm/s, the position where the active arm is 42.66°with the static platform, and the position where the speed is the lowest is the limit angle of the movement.

When the driving function is -55D*(0.43 + sin(time)), the acceleration variation law of the moving platform can be known through Fig.11, and its maximum value is about 130mm/s^2.

5. Comparative analysis

Comparing Fig.3 with Fig.10, it can be found that there is little difference between the function image and the value. Comparing Fig.4 with Fig.11. There is a big difference in figure change. First, the peak value is different. The reason for the error is that the solution method of ADAMS software is different from the solution method of the subject. The two troughs in Fig.4. Are all zero, while the one in Fig.11 is zero and the other is -75mm/s.

6. Conclusion

This paper mainly analyzes the kinematics of the three finger mechanical gripper. The power is driven by motor, the power is more stable, and the structure is more stable; The three finger manipulator is simplified as offset crank slider mechanism. The complex vector and Newton Euler formula are used to calculate and analyze the manipulator theoretically. The kinematics curves are drawn by MATLAB software, and the displacement, speed and acceleration degree of the three finger manipulator are obtained; ADAMS software is used to simulate the kinematics and dynamics of the three finger manipulator. The kinematic parameters of the three finger manipulator are obtained; The theoretical analysis results are compared with the simulation results of ADAMS software. The error between theoretical analysis and software simulation results is small, which verifies the correctness and feasibility of theoretical calculation.

Acknowledgments

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