A Mechanism Design of Tool Changer Cutter for Miniaturized CNC Milling Machine

Jilei Xu [a], Tianwen Zhai [b] and Xiaofei Kong [c]

School of Mechanical and Electronic Engineering, Shandong University of Science and Technology, Shandong 266590, China.

[a]1249024845@qq.com, [b]289178781@qq.com, [c]1102581303@qq.com

Abstract

In the purpose of conforming the trend of miniaturizing, raising the working accuracy, and meeting the installation requirements of miniaturized CNC milling machine, a specialized automation set for changing- tool is being designed. This paper is mainly about the design of the mechanism of transfer arm. Firstly, through summarizing and analyzing the common mechanisms of changing-tool, the way of changing tool was made up with, as well as the separated activities of changing-tool. Secondly, the kinematics sketch of mechanism was drawn and the degree of freedom was confirmed by analyzing and calculating. Equipped with this automation set, the machining operation and maintenance mode can be made much easier than they used to be. That is to say, the low hardness material, such as woods and plastic can be processed in a more efficient way. At the same time, the work efficiency can be raised by saving time for changing tools manually.

Keywords

Miniaturized CNC machine, tool changer, mechanism of changing tools, mechanism of changing tools, movements of changing tools.

1. Introduction

With the development of modern science and technology, ordinary processing can not meet the special processing requirements[1]. On the one hand, ordinary machine tools have higher requirements for working environment, workshops, sites and so on. In general, they can not move the position at will. On the other hand, especially for some special mechanical parts with small size, high precision and small hardness. The traditional machining center has been unable to meet the requirements. Taking numerical control milling machine as an example, although the precision of the small CNC milling machine is improved, but because of the small size of the whole volume, there is a series of problems, such as inconvenient, time-consuming, difficult and troublesome, so that the processing efficiency is very low[2]. Therefore, based on the current situation, in order to meet the needs of the development of manufacturing industry and meet the requirements of technical development, we have designed a small CNC machine tool for tool change machine. The main contents of this paper are: through the analysis of the action decomposition and working principle of the manipulator, the design and check of the mobile phone structure of the small CNC milling machine tool change machine is carried out by[3].

As the key to the leap from CNC machine tools to small processing centers, the design of this special automatic knife exchange device has important strategic significance for the development of CNC machine tool industry in China, which is in line with the general planning of the manufacturing industry towards automation in China, which is in accordance with the general planning of China's manufacturing industry[4,5,6].

2. Technical Indicators and Schemes

2.1 Expected Goal

The design of mechanical mobile phone structure requires simple structure, reliable knife change function, low cost, suitable for promotion and use, to ensure that the changing of the knife time less than 8s, to improve efficiency, the main technical indicators as shown in table 1.

Table 1. the expected technical indicators of mechanical mobile phone structure

Mechanical arm length 200 mm	Diameter of claw φ50 mm
Manipulator length 80 mm	Angle of rotation of the manipulator 150°
Changing time 8s	Rotating angle of manipulator 210°

Through comparison and analysis, the connecting rod type cutter manipulator can solve the problem of lubrication and assembly well. On the one hand, the structure is simple, on the other hand, the cost is reduced, and the advantage is very obvious in the condition of changing the time of changing the knife. In summary, the connecting rod type is chosen as my transmission mode.

2.2 Change of Knife Action

1) the manipulator rotates 80 degrees first, then the manipulator rotates 70 degrees to close to the spindle tool, moves up the shoulder, drives the whole manipulator upward, and the tool enters the front of the manipulator's cutter's claws and dies the old cutter.

2) the tool changing mechanical arm drives the old milling cutter to drop vertically, and completes the action of pulling the knife.

3) when the mechanism goes down to the designated position, the arm begins to rotate back and turns to the top of the cutter head. The arm drops vertically until the old knife enters the designated position of the milling cutter, and then the old cutter is released by the manipulator.

4) in order to prevent the milling cutter from rotating and damaging the mechanical arm, the tool changing arm moves upward.

5) to control the rotating angle of the cutter disc, the new milling cutter is moving below the mechanical hand, the mechanical arm is moved down, the cutter enters the mechanical claw, the machine claw is stuck to the selected new milling cutter, and the cutter directives are realized.

6) the shifting of the sliding seat of the manipulator for changing the knife manipulator, and driving the manipulator to realize the movement of the cutter;

7) the arm is moved to the bottom of the spindle, and the shoulder slide is moved upward, and the new milling cutter is inserted into the spindle to complete the tool changing action.

3. Design of Motion Diagram

In order to express the action of changing the knife more intuitively, the space right angle coordinate system is set up, the Z axis is established in the vertical direction, the X and the Y axis are established by the right hand principle. The shoulder of the manipulator is equivalent to a fixed hinge which moves up and down. On the one hand, it can support the rotation of the manipulator and the arm, on the other hand, it is itself. The whole manipulator can move up and down through the moving pair and the column, so that this part moves along the direction of the Z axis in the process of changing the knife, and the rotation of the manipulator is carried out in the plane of the X and Y axis. As shown in Fig. 1, a schematic diagram of the tool changing mechanism is presented.

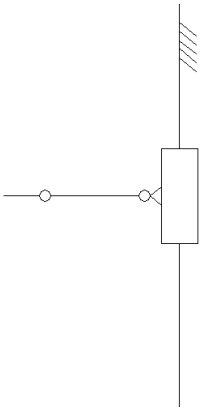

Fig. 1. mechanism motion diagram of a manipulator

4. Analysis of Mechanism Motion

In order to facilitate the analysis of the rotating movement of the manipulator and the arm, the Z axis is taken as the line of sight, and the limit position diagram of the rotating motion of the tool changing mechanism in the X-Y plane is made, as shown in Figure 2.

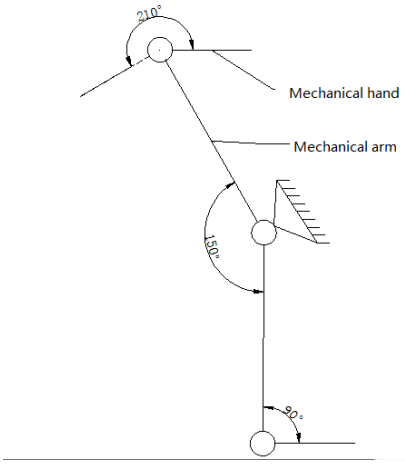

Fig. 2. The limit position diagram of the rotating motion of a manipulator

4.1 Motion Analysis of Mechanical Arm

As the manipulator and the shoulder are connected through the hinges, the rotation motion of the manipulator is assumed to be the acceleration of the circular motion. In order to ensure the changing of the knife time, the time used to define the rotation of the manipulator is 2S, and the angular acceleration is expressed by the circular motion formula.

$$\varphi_1 = \frac{1}{2}\alpha_1 t^2 = \frac{1}{2}\alpha_1 \times 2^2 = 2\alpha_1 \tag{1}$$

In the form of: φ_1——A rotating angle of a manipulator;

t——Working hours.

It is also known that the rotation angle of the manipulator is the same, so

$$\varphi_1 = 150° = \frac{5}{6}\pi \tag{2}$$

Formula (4-1) and (4-2) are combined.

$$\alpha_1 = \frac{5\pi}{12} rad/s^2$$

The maximum angular velocity is set to $\omega_{\max 1}$,so

$$\omega_{\max 1} = \omega_0 + \alpha_1 t = \frac{5\pi}{12} \times 2 = \frac{5\pi}{6} rad/s \approx 2.62 rad/s$$

Also $\omega_0 = 0$,the maximum linear velocity of a mechanical arm is expressed as a representation of $v_{\max 1}$:

$$v_{\max 1} = \omega_{\max 1} \times l_{臂} = \frac{5\pi}{6} \times 0.2 = \frac{\pi}{6} m/s \approx 0.52 m/s$$

4.2 Kinematic Analysis of Manipulator

On the other hand, the manipulator is also connected by the hinges and the manipulator, and the motor is powered by the control motor. The rotation motion of the manipulator is also accelerating the circle motion. The rotation angle of the manipulator is known from Figure 2. In order to ensure the knife changing time, the time of the manipulator rotation is defined as 2S,According to the circular motion formula

$$\varphi_2 = \frac{1}{2}\alpha_2 t^2 = \frac{1}{2}\alpha_2 \times 2^2 = 2\alpha_2 \tag{3}$$

In the form of: φ_2——A rotating angle of a manipulator；

α_2——Angular acceleration of the circular motion of a manipulator；

It is also known that the rotation angle of the manipulator is also known.so

$$\varphi_2 = 210° = \frac{7}{6}\pi \tag{4}$$

Formula (4-3), (4-4) joint:

$$\alpha_2 = \frac{7\pi}{12} rad/s^2$$

If the maximum angular velocity is set to $\omega_{\max 2}$,

$$\omega_{\max 2} = \omega_0 + \alpha_2 t = \frac{7\pi}{12} \times 2 = \frac{7\pi}{6} rad/s \approx 3.67 rad/s$$

The maximum line velocity of the manipulator is expressed as $v_{\max 2}$:

$$v_{\max 2} = \omega_{\max 2} \times l_{手} = \frac{7\pi}{6} \times 0.08 = \frac{14\pi}{150} m/s \approx 0.3 m/s$$

5. Conclusion

According to the design of the connecting rod type cutter manipulator, it can be more reliable to realize the knife change. The hinge motion pair and the moving pair belong to the lower pair. The contact area of the motion pair is relatively large. It can solve the problem of lubrication and maintenance well relative to other ways. It can also reduce noise sound, better shock absorption, and ensure the knife change. Under the conditions of between, it is also more cost-effective.

The control of the degree of freedom of the whole mechanism is 3, which can not only ensure that the mechanical hand is flexible, but also has no waste, which solves the difficult problem of the small numerical control machine tool changing. In addition, the angular velocity and angular acceleration

of the manipulator during rotation are not too large, and within a reasonable range, the mechanism is more secure. Generally speaking, the market potential of the design and development is relatively large, which has a new meaning for the development of China's NC industry and meets the market demand.

References

[1] Liu Dong. Multi Dody Dynamics Simulation of double Cam Linkage Automatic Tool Changer (MS., Dalian University of Technology, China 2010), p.11-14.

[2] Liu Wei. Automatic Tool Change System for NC Machining Center, Machine Tools and Hydraulics, Vol. 1 (2005) No.5, p.58-60.

[3] Wang Libo. Design and Strength Analysis of Heavy Automatic Knife Exchange Mechanism (MS., Beijing University of Technology, China 2014), p.7-9.

[4] Deng Kangyi. Research on Structure Design and Servo Control of Pneumatic Manipulator (MS., Xi'an University of Architecture and Technology, China 2008), p.11-25.

[5] Qi Jinkai. Research on Structure Design, Analysis and Control of Pneumatic Manipulator (MS., east china university, China 2006), p.11-16.

[6] C Obreja, G Stan, D Andrioaia, M Funaru. Design of An Automatic Tool Changer System for Milling Machining Centers, Applied Mechanics & Materials, Vol. 371 (2013) No.1, p.69-73.