The design of pneumatic manipulator for optical shaft production line

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Abstract. Manipulator is a powerful tool for human to work safely, realize production automation and improve labor productivity. On the basis of summarizing the research and development status of manipulator, this paper comprehensively analyzes the function of pneumatic carrying manipulator on optical axis production line, and combines the actual project of the enterprise to design the mechanical and electrical integration of pneumatic carrying manipulator. This paper analyzes the performance requirements and working characteristics of pneumatic conveying manipulator and combines with the characteristics of optical shaft production line. I comprehensively analyzed and designed the mechanical structure, drive system, transmission mode and its stability of the manipulator.

1. Introduction

Machinery industry is vigorously developed in China, which is closely related to the development of various fields. Whether it is the former traditional industry, the consumer industry that provides daily necessities for people, or the aviation and aerospace industry and the newly popular emerging industry, they all need all kinds of mechanical equipment. Machinery industry has ensured the demand for various forms of equipment in various fields, accelerated the development of various industries, and made outstanding contributions to the development of national economy and the research and development of technologies in various departments.

Manipulator's running route, grasp, release function is set in advance, in actual production, according to different production mode to adjust the working situation of manipulator, only through the computer to change its program can. In actual production, in order to improve the production efficiency and increase the benefits of the company, the factory will generally install several manipulators between some production processes, which can not only ensure the effective production intensity, but also increase the safety and quality of products in the factory. Especially in some more dangerous occasions, if we use manpower to work, it will greatly increase the occurrence of dangerous accidents, but the manipulator can work normally. As a result, the manipulator is widely applied in heat treatment, electroplating, welding, stamping, forging, etc., and the structure of the manipulator is not complicated, their control is simple and their specific performance is particularly strong, such as the handling manipulator, loading and unloading manipulator, their handling device and loading and unloading device are all simple manipulators of the machine tool.

This design is mainly used in optical axis production line, for some light axis class of objects, which don't need too much manipulator claw force. Therefore, the pneumatic manipulator is designed as a pneumatic manipulator. Compared with the hydraulic manipulator, the pneumatic manipulator works faster, has higher production efficiency and is safer. As far as most of the factories in China are
concerned, the main mode of work is still manpower. If some simple pneumatic conveying manipulator can be introduced, it is very important for the development of domestic industry. Moreover, the production cost of this kind of manipulator is not high, the operation mode is simple, the operation is fast and the efficiency is high.

2. The working principle of manipulator
Manipulator is mainly composed of actuator, drive system, control system and position detection device. As shown in Figure 1:

![Figure 1. Working principle.](image1)

Control system: the manipulator receives the motion instruction from the control system, and completes a series of actions according to the instruction requirements. This part mainly selects and designs the manipulator control system [1].

Drive system: the driving device for the manipulator to complete the work.

Mechanical system: including manipulator claw, manipulator arm, wrist, frame and other parts, and also determine what kind of coordinate type it is and how many degrees of freedom are required.

Position detection device: detect the moving position of the manipulator.

The pneumatic conveying manipulator in this design mainly controls the gear movement by the motor, so as to control the rotation of the manipulator, as shown in Figure 2, the pneumatic cylinder is controlled by PLC and pneumatic transmission mode is adopted to realize the actions of specified requirements, sequence, motion track and certain speed and time for the corresponding parts of the actuator. At the same time, according to the information of its control system, it sends out instructions to the actuator. If necessary, it can monitor the action of the manipulator. When there is an error or a fault in the action, it will send out an alarm signal. The position detection device feeds back the actual position of the actuator to the control system at any time, compared it with the set position, and then adjusts it through the control system, so that the actuator can reach set position with certain accuracy.

![Figure 2. Manipulator assembly drawing.](image2)
3. Design of manipulator
Manipulator design includes manipulator material selection, the selection of basic parameters, motor parameters and mechanical structure design and so on.

3.1. Selection of manipulator basic parameters
The weight of the maximum grasping material of the manipulator is its main parameter, this design is pneumatic handling manipulator, according to the actual needs of the enterprise, after consulting the relevant mechanical design parameters, this set the weight of the manipulator to grasp objects is 10kg.

Manipulator at work is directly related to the stability and its movement speed, so set a proper motion parameter is the key to ensure the high-efficiency and work of the manipulator, if the speed is too low, manipulator slow movement will affect the efficiency of the whole work, it has violated the manipulator design goal, if the speed is too high, manipulator operation is easy to overload operation, which affects the precision of the manipulator and reduces the production efficiency. The maximum linear motion speed of the manipulator this time is set as 0.8m/s, the maximum rotation Angle is set as 70°/s, the average speed is set as 0.5m/s, and the average rotation Angle is set as 50°/s.

The main parameters of the manipulator also include the positioning accuracy of the manipulator. If the design accuracy is too high, the production cost of the manipulator will be greatly increased, but if the design accuracy is too low, the specified task cannot be completed. Considering the actual situation, the positioning accuracy of this pneumatic conveying manipulator is set to ± 1mm.

3.2. Motor selection
The motor parameters of the manipulator have a great influence on the operation of the manipulator. According to the actual calculation, n=810 RPM, the three-phase asynchronous motor of y90s-6 is selected, as shown in Table 1. The motor adopts b-level insulation, the shell protection grade is IP44, and the rated voltage is 380V.

| Model   | Rated power KW | Full load | Locked-rotor current | Locked-rotor torque | maximum torque |
|---------|----------------|-----------|----------------------|---------------------|---------------|
|         | Electricity A  | Speed r/min | Efficiency % | Power factor | Rated current | Rated torque | Rated torque |
| Y90S-6  | 0.75           | 2.3       | 910                 | 72.5               | 0.7           | 5.5          | 2.0          | 2.2          |

3.3. Lifting cylinder calculation
In order to meet the requirement of equal fast forward and backward speed of worktable, and reduce the flow of pneumatic pump, the equivalent area A1 and A2 of the cylinder without rod cavity and with rod cavity shall meet A1=2A2 (the cylinder inner diameter D and the piston rod diameter d shall meet the following requirements: d = 0.707D) .In order to prevent the workpiece from rushing forward suddenly after cutting, the cylinder should keep a certain back pressure and the mechanical efficiency of the cylinder should be 90%. Therefore, the effective area of the cylinder without rod cavity: F=P×A1(A1=15cm²).

As shown in Table 2, according to GB/ T2348-1980, take the standard value D=43mm; It could have taken 40, taking into account factors such as unpredictable overloading, so it took a slightly larger one here [2].

According to the pneumatic control manual, the diameter of piston rod is selected according to the rod diameter ratio d/ D, according to the selection rules, d/ D =0.3-0.6, indicating that the piston rod is under tension, and d/ D =0.5-0.8, indicating that the piston rod is under pressure.
Table 2. Cylinder bore series GB/T2348-1980.

| Bore series/mm | 8  | 10 | 12 | 16 | 20 | 25 | 32 | 40 | 50 | 63 |
|----------------|----|----|----|----|----|----|----|----|----|----|
| 80            | 80 | 100| 125| 160| 200| 250| 320| 400| 500| 630|

Since $A_1=2A_2$, diameter of piston rod $d=0.5$, $D=31.5\text{mm}$ select $d=32$ (standard diameter) is shown in Table 3:

Table 3. Piston rod diameter series.

| Rod diameters/mm | 4   | 5   | 6   | 8   | 10  | 12  | 14  | 16  | 18  | 20  |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 22               | 22  | 25  | 28  | 32  | 36  | 40  | 45  | 50  | 56  | 63  |
| 70               | 70  | 80  | 90  | 100 | 110 | 125 | 140 | 160 | 180 | 200 |
| 220              | 220 | 250 | 280 | 320 | 360 | 400 |

Cylinder body is an essential part of cylinder parts, the cylinder block material generally requires sufficient strength, and the commonly used materials are cast iron, alloy cast iron, steel, alloy steel, etc. Because when working, when the air pressure of the air cylinder is too large, it is necessary to check its strength. Among these materials, alloy steel has the best performance, so seamless alloy steel pipe is selected as the cylinder material.

4. Pneumatic manipulator positioning and stability to determine

Whether the pneumatic manipulator can work accurately or not is actually a three-dimensional positioning problem, which is a combination of several linear and angular positioning. In many simpler cases, a single quantum value may be primary [3]. The factors affecting the positioning error of a single line or angle are as follows:

1) positioning of the manipulator movement error is very large, the positioning of the manipulator there are a lot of ways, such as mechanical block positioning, pneumatic positioning, hydraulic positioning, etc., each positioning method has its unique characteristics, according to the actual production of different conditions to choose different positioning.

2) positioning speed has a great influence on positioning accuracy, because the energy of moving parts must be different when positioning speed is different. Generally, in order to reduce the positioning error, the positioning speed should be reasonably controlled, such as improving the buffer performance and buffer efficiency of the buffer device, and controlling the drive system to slow down the moving parts in time.

3) the manufacturing accuracy and installation speed regulation accuracy of pneumatic manipulator have a direct impact on the positioning accuracy.

4) the stiffness of mechanical parts of the manipulator is very important for the manipulator to work normally, if the stiffness of the mechanical parts is too low, the manipulator operation is not stable, affecting the production efficiency, so the stiffness index of the parts must be strictly selected.

5) pneumatic pressure fluctuations and voltage, temperature fluctuations will affect the repeated positioning accuracy of pneumatic manipulator. Therefore, the necessary pressure regulation and pneumatic measures are adopted [4].

6) the control system has a great impact on the precision of manipulator operation, switch control, electrical proportional control and servo control position control precision is not the same. This is not only due to the different accuracy and sensitivity of various control elements, but also related to the presence or absence of position feedback devices.

This topic combines the actual comprehensive consideration to select the mechanical block positioning, mechanical block positioning is set at the end of the stroke of the mechanical block. When the pneumatic carrying manipulator through deceleration to the end, close to block and positioning. If the positioning has been slowed down before, the driving pressure is not removed during the
positioning. In this case, the positioning of the mechanical block can achieve a higher repetition accuracy [5]. Generally, it can be higher than ±0.5mm. If the driving road is closed during positioning and the working pressure is removed, then the pneumatic manipulator may be touched back to a small distance by the block, thus the positioning accuracy becomes lower.

5. Conclusions
This design is based on the air pressure handling manipulator of the optical shaft production line, which is suitable for light shaft products production line, and can quickly carry the products produced to the next process, it not only moves fast, but also has little resistance loss and low cost, which greatly improves work efficiency.

References
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