Progress in Human Computer Interaction (2017)

ORIGINAL RESEARCH ARTICLE

Structural Design of Industrial Robot

Tongbo Jiang,Peiguo Zhao,Fan Ji

School of Electrical Engineering, Nanjing University of Mechanical and Electrical Engineering, Jiangsu, China

ABSTRACT

The robot is a planar joint robot composed of three degrees of freedom. Its main function is to carry out the handling and movement of precision instruments and objects. Because of the small size, simple transmission principle, is widely used in the electrical and electronic industry, household appliances, precision machinery industry and other fields. The whole system consists of robot, robot arm, joint, stepper motor drive system and so on. Through the degree of freedom of the stepper motor drive, complete the robot, the robot arm position changes. Specific design content: synchronous toothed belt drive design, screw nut design, the output shaft and shell design, stepper motor selection. On the basis of checking the strength of the structure, we optimize the structure of the robot.

KEYWORDS: robot, structural design, robot arm

1. Introduction

1.1. Preface

Industrial robot is a new technology in the field of modern automatic control, and has become an important part of modern machinery manufacturing production system, this new technology developed rapidly, and gradually become a new discipline - robot engineering. Robot involved in mechanics, mechanics, electrical hydraulic technology, automatic control technology, sensor technology and computer technology and other scientific fields, is a cross-disciplinary integrated technology.

The structure of the manipulator is relatively simple and the specificity is strong. With the development of industrial technology, made a separate program can be controlled by the repeated operation, the scope of application of a wide range of 'program control general manipulator', referred to as general manipulator. As the general manipulator can quickly change the working procedures, adaptability, so it is constantly changing the production of small and medium-volume production in a wide range of reference.

Modern industrial robot originated in the early 50s of the 20th century, is based on teaching reproduction and master-slave control, can adapt to changes in product categories, with multi-degree of freedom of the function of flexible automation products.

The robot was first developed from the United States. In 1958 the United States joint control company developed the first robot. His structure is: the body to install a rotary long arm, the end of the workpiece with a solenoid handling mechanism, the control system is teaching type.

In 1962, the United States Machinery Casting Company in the above-mentioned program on the basis of trial and production into a CNC teaching reproduction of the manipulator. Trade name Unimate (that is, universal). Sports system imitation tank turret, arm rotation, pitch, with hydraulic drive; control system with the drum storage device. A lot of ball coordinate general manipulator is developed on this basis. In the same year, the company merged with Prussian to set up Unimaton, which specializes in the production of industrial robots.

The United States also pay great attention to improve the reliability of the robot, improve the structure and reduce costs. Such as Unimate company established eight years of robot test bench, a variety of performance tests. Prepare the average time before the failure (Note: the average time before the failure is a measure of the reliability of a device. It gives the average run time before the first failure), from 400 hours to 1500 hours, the accuracy can be Increased to ± 0.1 mm.

2. The composition and development trend of manipulator

Industrial robots by the implementing agencies, drive agencies and control agencies composed of three parts.

2.1. Implementing agency

(1) Hand (2) Wrist (3) Arm (4) Body

2.2. Drive mechanism

The drive mechanism is an important part of an industrial robot. According to the different power sources, industrial robot drive mechanism can be divided into hydraulic, pneumatic, electric and mechanical drive four categories. The use of hydraulic mechanism to drive the robot, simple structure, compact size, light weight, easy to control.

2.3. Control system classification

In the control of the robot, a little dynamic control and continuous control in two ways. Most of the use of plug-pin control point control, but also the use of programmable logic controller control, microcomputer control, using cam, disk tape, punch card and other recording procedures. The main control is the coordinate position, and pay attention to its acceleration characteristics.

2.4. Trends in industrial robots

(1) Industrial robots continue to improve performance (high speed, high accuracy, high reliability, ease of operation and maintenance), while stand-alone prices continue to fall, the average stand-alone price from 91 million $ 103,000 to 97 million $ 65,000.

(2) Mechanical structure to the modular, reconfigurable development. For example, the joint module in the servo motor, reducer, detection system three integration: by the joint module, connecting rod module with the reorganization of the structure of the robot machine; foreign has been modular assembly robot products to the city.

(3) Industrial robot control system to PC-based open controller direction, easy to standardize, network; device integration increased, the control cabinet is small, and the use of modular structure: greatly improve the reliability of the system, Ease of handling and maintainability.

(4) The role of sensors in the robot is increasingly important, in addition to the traditional location, speed, acceleration and other sensors, the assembly, welding robot also applies the visual, force and other sensors, and remote control robot is visual, , Touch and other multi-sensor fusion technology to carry out environmental modeling and decision-making control Multi-sensor fusion configuration technology in the product system has mature application.

(5) The role of virtual reality technology in robots has evolved from simulation, rehearsal to the use of process control such as the use of remote control robot operators in the remote operating environment to manipulate the robot.

(6) The development of contemporary remote control robot system is not the pursuit of full autonomy system, but is committed to the operator and the robot human-computer interaction control, that is, remote control plus local autonomous system constitutes a complete monitoring remote control operating system, intelligent robot out of the laboratory into the practical stage.

3. Overall design of the robot and the working principle

The main task of this design is to complete the structure of the robot design. In this chapter, the coordinates of the manipulator, the degree of freedom and the drive mechanism were determined.

3.1. Robot basic form of choice

Common industrial robots according to the arm of the action form, according to the coordinates of the form can be divided into the following four: (1) Cartesian coordinate manipulator;; (2) cylindrical coordinate manipulator (3) spherical coordinate (polar coordinate) type manipulator; (4) Multi-articulation machine manipulator. The cylindrical coordinate manipulator structure is simple and compact, high positioning accuracy, small footprint, so the design of cylindrical coordinate type.

3.2. The main parts of the robot and movement

According to the design task, in order to meet the design requirements, the design of the robot with four degrees of freedom both: hand rotation; arm stretching; arm rotation; arm lift 5 main movement.

The design of the robot mainly by the hand, wrist, arm, body and hydraulic system components:

(1) Hand, using a linear hydraulic cylinder drive, through the movement of the body to achieve the grip of the joint.

(2) The wrist, using a rotary hydraulic cylinder to achieve hand rotation

(3) Arm, the use of straight-line cylinder to achieve arm swing 1.2m. (4) the fuselage, using a straight cylinder and a rotary cylinder to achieve arm lift and rotation.

3.3. Selection of drive mechanism

Driving mechanism is an important part of industrial robots, industrial robot performance and price ratio depends largely on the drive program and its device. According to the different power sources, industrial robot drive mechanism can be divided into hydraulic, pneumatic, electric and mechanical drive four categories. The use of hydraulic mechanism to drive the robot, simple structure, compact size, light weight, easy control, driving force and other advantages. Therefore, the robot's drive scheme is selected for hydraulic drive.

3.4. List of technical parameters for the robot

First, use: for the workshop handling

Second, the design of technical parameters:

1. Pay attention: 1.25Kg (clamping hand)

2. The degree of freedom: 4 degrees of freedom, along the Z axis up and down, around the Z axis rotation, along the X axis telescopic, around the X axis

3. Coordinate type: cylindrical coordinates

4. The maximum working radius: 1800mm minimum working radius: 1350mm

5. The maximum center of the arm high: 1012mm

6. Arm movement parameters

Stretch travel: 450mm

Expansion speed: <250mm / s

Lifting stroke: 150mm

Lifting speed: <60mm / s

Rotation range:

Rotation speed: <70 / s

7. Wrist movement parameters

Rotation range:

Rotation speed: 90 / s

8. Arm grip: set by N = 0.5 / f * G

Here take f = 0.1 G = 1.25kg

N = 0.5 / f * G = 6.25 kg

The finger grip is 6.25kg

4. Manipulator hand design calculation

4.1. Basic requirements for hand design

(1) Should have the appropriate clamping force and driving force. It should be taken into account that the driving force required for different transmission mechanisms is different under certain clamping forces.

(2) The finger should have a certain opening range, the finger should have enough opening and closing angle (the finger from the open to close the fissure point of the turn), in order to grasp the work piece.

(3) Requires a compact structure, light weight, high efficiency, in ensuring their own stiffness, strength under the premise of the structure as compact, lightweight, in order to help reduce the load on the arm.

4.2. Typical hand structure

(1) Rotary type includes chute and lever type.

(2) Mobile type of movement that is the two fingers relative to the bearing for reciprocating motion.

(3) Plane translation type.

4.3. Design and calculation of manipulator hand grip

4.3.1 Select the type of grip and clamping device

The design is the design of translational handling robot design, taking into account the original parameters to be achieved: hand grip angle=, gripping weight of 1.25Kg. Commonly used industrial hand, according to the principle of holding the work piece, divided into two categories of clamping and adsorption. Adsorption is often used to grasp the work piece surface smooth, large area of the plate-like objects, not suitable for this program. The design of the manipulator with clamping fingers, clamping manipulator according to the form of movement can be divided into rotary and translational type. The fingers of the translating fingers are closed and closed by the fingers. The structure of the fingers is simple and suitable for clamping the flat material, and the change of the radial dimension of the work piece does not affect the position of the axial center. The theoretical clamping error is zero. If a typical translational finger is used, the driving force is added to the direction of the finger movement, which makes the structure complicated and bulky. Obviously inappropriate, so do not choose this type.

Through the comprehensive consideration, the design of the choice of two fingers rotary gripper, the use of chute lever structure, clamping device selection normally open clamping device.

4.3.2 Calculation of clamping force and driving force

Gripper clamping force, is the main basis for the design of the hand. The size, direction and point of action must be analyzed and calculated. In general, it is necessary to overcome the load generated by the static load generated by the gravity of the work piece and the inertia force of the movement of the work piece so that the work piece can be kept in a reliable clamping state.

The clamping force can be calculated as follows: $F_N \geq K_1 K_2 K_3 G$

Where K_1 - The safety factor, usually 1.2-2.0;

k_2 - The working condition coefficient, mainly considering the influence of inertial force. Can be approximated by the following formula $K_2 = 1 + \frac{b}{a}$ a, the direction of gravity of the maximum increase in acceleration; $a = \frac{v_{\max}}{t_{响}}$

$v_{\max}$ - Maximum speed of movement of the work piece

$t_{响}$ - The system to achieve the highest speed of time, generally selected 0.03 ~ 0.5s

K_3 - The azimuth factor is selected according to the position of the finger and the work piece.

G - Grazed work piece received by gravity (N).

Calculate: set a = 100mm, b = 50mm, <<; robot to achieve the maximum response time of 0.5s, seeking clamping force F_N and driving force F and drive the size of the hydraulic cylinder.

(1) Set up $K_1 = 1.5$

$$K_2 = 1 + \frac{b}{a} = 1 + \frac{0.1/0.5}{9.8} = 1.02$$

$$K_3 = 0.5$$

According to the formula, bring the known condition into:

$$F_N = 1.5 \times 1.02 \times 0.5 \times 588N = 449.8N$$

(2) According to the driving force formula:

$$F_{\text{鋅}} = \frac{2 \times 100}{50}\left(\cos 30^0\right)^2 \times 449.8 = 1378\text{N}$$

(3) Take $\eta = 0.85$

$$F_{\text{隳}} = \frac{F_{\text{鋅}}}{\eta} = \frac{1378}{0.85} = 1621N$$

(4) To determine the diameter of the hydraulic cylinder D

$$\because F_{\text{隳}} = \frac{\pi}{4}\left(D^2 - d^2\right)p$$

Select the piston rod diameter d = 0.5D, select the hydraulic cylinder pressure oil working pressure P = 0.81MPa,

$$\sqrt{\frac{4F_{\text{隳}}}{\pi p\left(1-0.5^2\right)}} = \sqrt{\frac{4 \times 1621}{\pi \times 0.8 \times 10^5 \times 0.75}} = 0.587$$

According to Table 4.1 (JB826-66), select the cylinder diameter: D = 63mm

The inner diameter of the piston rod is:

D = 630.5 = 31.5 mm, d = 32 mm

4.3.4 Hand grip clamping range calculation

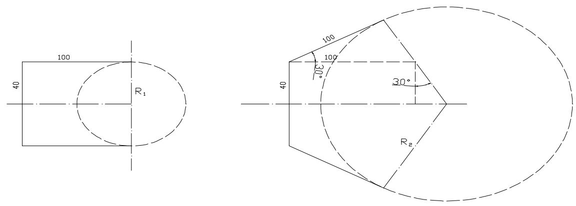
In order to ensure that the hand opening angle 60^0 , the piston rod movement length of 34mm.

Holding the grip range, fingers long 100mm, when the hand did not open the angle when the angle, according to the design of the body, its minimum clamping radius $R_1 = 40$, when opened 60^0 ,

The maximum clamping radius R_2 is calculated as follows:

$$R_2 = 100 \times tg30^0 + 40\cos 30^0 \approx 90$$

The clamping radius of the robot is from 40 to 90 mm



(a) (b)

Figure 4.2 Open hand

4.4. Analysis and calculation of clamping accuracy of manipulator hand grip

The accuracy of the manipulator requires accurate positioning of the work piece, high precision of gripping, repeated positioning accuracy and good motion stability, and sufficient crawling capability.

Whether the robot can accurately hold the work piece and send the work piece to the specified position depends not only on the positioning accuracy of the robot (determined by the moving parts such as the arm and the wrist), but also on the size of the manipulator clamping error. Especially in the multi-species,

Small batch production, in order to adapt to the work piece size within a certain range of changes, must be manipulator clamping error.

The design uses the bar to analyze the accuracy of the clamping error of the manipulator.

The clamping range of the manipulator is.

The general clamping error does not exceed 1mm, the analysis is as follows:

Average radius of work piece: $R_{cp} = \dfrac{90 + 40}{2} = 65mm$

Fingers long $l = 100mm$, take the V-angle $2\theta = 120^0$

The deflection angle β is determined by the optimum deflection angle:

$$\beta = \cos^{-1}\frac{R_{CP}}{l\sin\theta} = \cos^{-1}\frac{60}{100 \times \sin 60^0} = 46^0$$

Calculation $R_0 = l\sin\theta\cos\beta = 100\times\sin 60^0\cos 46^0$ =6.15

When S comes with: $R_0 \geq R_{MAX} \geq R_{MIN}$

Clamping error to meet the design requirements.

$$\text{å} = \left| \sqrt{l^2 + \left(\frac{R_{\max}}{2\sin\theta}\right)^2 - 2l\frac{R_{\max}}{\sin\theta}\cos\beta - \alpha^2} - \sqrt{l^2 + \left(\frac{R_{\max}}{\sin\theta}\right)^2 - 2l\frac{R_{\min}}{\sin\theta}\cos\beta} \right. = 0.678$$

5. Wrist design calculation

5.1. The basic requirements of the wrist design

(1) Strive to compact structure, light weight

The wrist in the forefront of the arm, it together with the hand of the static, dynamic load by the arm bear. Obviously, the wrist structure, weight and power load, directly affect the arm structure, weight and operating performance. Therefore, in the wrist design, we must strive to compact structure, light weight.

(2) Structural considerations, reasonable layout

Wrist as the executive body of the robot, but also bear the role of connection and support, in addition to guarantee the strength and movement requirements, there must be sufficient strength, stiffness, but also should be considered, reasonable layout, to solve the wrist and arm and hand Part of the connection.

(3) Must consider the working conditions

For this design, the working conditions of the manipulator are the handling of the bar in the workplace, so it is not affected by the environment, not in the high temperature and corrosive working medium, so the arm of the manipulator is not too many unfavorable factors.

5.2. Wrist structure and choice

5.2.1 Typical wrist structure

(1) A wrist structure with a degree of freedom of rotation. It has a compact structure, flexibility and other advantages of the wide wrist rotation, the total torque M, the need to overcome the following resistance: to overcome the use of inertia used to overcome. The angle of rotation is determined by the angle of rotation between the moving piece and the static sheet (usually less than).

(2) Rack piston driven wrist structure. In the case where the required turning angle is greater than that, the wrist structure driven by the rack piston can be used. This structure is larger in size, generally suitable for hanging arm.

(3) A wrist structure with two degrees of freedom. It gives the wrist with two degrees of freedom of horizontal and vertical rotation.

(4) Machine-liquid combination of the wrist structure

5.2.2 Wrist structure and the choice of drive mechanism

The design requires wrist to turn, taking into account the above analysis taking into account various factors, the wrist structure is chosen to have a degree of freedom to drive the wrist structure, using a hydraulic drive.

5.3. Design of the wrist

5.3.1 Parameters for wrist design considerations

Grip the work piece weight 1.25Kg, turn 180^0 .

5.3.2 Calculate the driving torque of the wrist

(1) Torque required for the drive torque of the wrist $M_{惯}$.

(2) Frictional torque at the wrist support $M_{惯}$.

Gripping bar material diameter 100mm, length 1000mm, weight 60Kg, when the hand rotation, the calculation of torque:

(1) Hand grip, hand drive hydraulic cylinder and rotary cylinder rotary parts equivalent to a cylinder, height 220mm, diameter 120mm, the gravity estimate G = 3.14

$$G = \pi \times 0.06^2 \times 0.22 \times 7800Kg/m^3 \times 9.8N/Kg = 190N$$

(2) Rub the moment $M_{摩} = 0.1m$.

(3) The angle of rotation of the start process $\phi_{启} = 18^0 = 0.314rad$, constant speed angular velocity= $\omega = 2.616s^{-2}$.

$$M_{惯} = \left(J + J\right)\frac{\omega^2}{2\phi_{启}}$$

Find the moment of inertia formula:

$$J = \frac{1}{2}MR^2 = \frac{1}{2}\frac{190N}{9.8N/Kg} \times 0.06^2 N \cdot m \cdot s^2 = 0.0342N \cdot m \cdot s^2$$

$$J_{工件} = \frac{1}{12}\frac{G}{g}\left(l^2 + 3R^2\right) = \frac{1}{12}\frac{1.25 \times 9.8\left(1^2 + 3 \times 0.05^2\right)}{9.8} = 0.105N \cdot m \cdot s^2$$

Substitute:

$$M_{惯} = (0.0342 + 0.1049)\frac{2.616^2}{2 \times 0.314} = 1.5158N \cdot m$$

$$M = M_{惯} + M = M + 0.1M$$

$$M = \frac{1.5158}{0.9} = 1.3642N \cdot m$$

5.3.3 Calculation of wrist driving force

Table 5-1 Diameter series of hydraulic cylinders (JB826-66) (mm)

20	25	32	40	50	55	63	65
70	75	80	85	90	95	100	105
110	125	130	140	160	180	200	250

Set the wrist part of the size: according to Table 5-1 set the cylinder radius of the air R = 110mm, diameter according to Table 4-2 select 121mm, this is the minimum thickness of the hydraulic cylinder wall, taking into account the actual assembly problems Diameter of 226mm; moving piece width b = 66mm, the output shaft r = 22.5mm. The basic size shown in Figure 5.1. Then the rotary cylinder working pressure, $P \geq \frac{2M}{b\left(R^2 - r^2\right)} = \frac{2 \times 61.11}{0.066 \times \left(0.055^2 - 0.0225^2\right)} = 7.35Mpa$ select 8Mpa

Table 5.2 Standard cylinder diameter (JB1068-67) (mm)

Hydraulic cylinder inner diameter	40	50	63	80	90	100	110	125	140	150	160	180	200
20 steel P	50	60	76	95	108	121	133	168	146	180	194	219	245
45 steel	50	60	76	95	108	121	133	168	146	180	194	219	245

6. Arm design and related calculations

The arm component is the main holding part of the manipulator. Its role is to support the wrist and hand (including the work piece or tool), and drive them for space movement. Arm movement should include 3 movements: telescopic, swivel and lift. This chapter describes the telescopic movement of the arm, the arm of the rotation and lifting movement set in the fuselage, will be described in the next chapter.

The purpose of the arm movement: the hand to the space within the scope of any movement. If you change the posture of the hand (position), with the degree of freedom of the wrist to be achieved. Therefore, in general, the arm should have three degrees of freedom to meet the basic requirements, both arm stretching, left and right rotation, and movements. The various movements of the arm are usually carried out by means of a drive mechanism and various transmission mechanisms. From the analysis of the force of the arm, it is directly subjected to the static and dynamic loads of the wrist, the hand, and the work, more. Therefore, its structure, scope of work, flexibility and other direct impact on the performance of the robot.

6.1. Basic requirements for arm design

6.1.1 Arm should be carrying capacity, good stiffness and light weight

(1) According to the force situation, a reasonable choice of cross-sectional shape and contour size.

(2) To improve the support stiffness and reasonable choice of support distance.

(3) The rational placement of the force of the location and direction.

(4) Pay attention to simplify the structure.

(5) To improve the accuracy of cooperation.

6.1.2 Arm movement speed should be high, inertia to be small

The movement speed of the hand of the manipulator is one of the main parameters of the manipulator, which reflects the level of production of the manipulator. For high-speed motion of the robot, the maximum speed of movement in the design of 1000 ~ 1500mm / s, the maximum slewing angular velocity design $180^0/s$, the majority of the average moving speed $1000mm/s$, the average speed of rotation in the speed $90^0/s$. In the case of constant speed and rotational angular velocity, reducing the weight of the body is the most effective and direct way to reduce the inertia, so the arm of the arm should be as light as possible. There are three ways to reduce inertia:

(1) To reduce the weight of arm moving parts, the use of aluminum alloy material.

(2) To reduce the contours of the arm movement.

(3) To reduce the radius of rotation, and then arrange the robot action sequence, the first shrink after the rotation (or first turn after the expansion), as far as possible in a smaller extension position under the rotation action.

(4) The drive system is provided with a cushioning device.

6.1.3 Arm movements should be flexible

To reduce the friction between the arm movement resistance, as far as possible with rolling friction instead of sliding friction. For cantilevered robots, the drive parts, guides and locators are arranged so that the arm movement is as balanced as possible to reduce the eccentricity of the lift support axis, in particular to prevent the occurrence of the mechanism stuck (self-locking phenomenon). To this end, it must be calculated so that it does not meet the conditions of self-locking.

6.2. The typical mechanism of the arm and the choice of structure

6.2.1 Typical movement of the arm

Common arm stretching mechanism has the following:

1 Double guide arm telescopic mechanism.

2 Arm of the typical form of movement are: linear motion, such as arm stretching, lifting and lateral movement; rotary motion, such as the arm of the left and right swing, up and down swing; meet the movement, such as linear motion and rotary motion combination, Hydraulic cylinder hollow structure.

3 Double piston rod hydraulic post structure.

4 Piston rod and gear rack mechanism.

6.2.2 Selection of arm movement mechanism

Through the above, considering the design of the choice of double guide rod telescopic mechanism, the use of hydraulic drive and hydraulic cylinder selection of double acting hydraulic cylinder.

6.3. Calculation of driving force of arm linear motion

The first to make a rough estimate, or analog similar structure, according to the initial parameters of the movement to determine the main body size, and then check the calculation, modify the design. So repeatedly, draw the final structure.

The driving force of the hydraulic cylinder which is horizontally telescopic linear motion is determined to determine the driving force required for the hydraulic cylinder according to the resistance of the hydraulic cylinder to overcome the friction and inertia. Calculation of Driving Force of Hydraulic Cylinder Piston.

$$F = F_{摩} + F \quad + F_{回} + F$$

6.3.1 Arm friction analysis and calculation

Analysis:

Friction calculation of different configurations and different guide cross-sectional shape, the friction resistance is different, according to the specific circumstances of the estimate. The design is a double guide bar, the guide rod symmetrical configuration on both sides of the telescopic Kong.

Calculated as follows:

As the guide rod symmetrical configuration, the two guide rods force balance, according to a guide rod calculation.

$$\sum M_A = 0$$

$$G_{总} L = aF_b$$

Get it $F_b = \dfrac{G_{总} L}{a}$

$$\sum Y = 0$$

$$G_{总} + F_b = F_a$$

Get it $F_a = G_{总}\left(\frac{L+a}{a}\right)$

$$F_{摩} = F_{a_{摩}} + F_b \quad = \mu' F_a + \mu' F_b$$

$$\therefore F_{摩} = \mu' G_{总}\left[\frac{2L+a}{a}\right]$$

The total gravity $G_{总}$ (including the work piece) (N) of the parts involved in the movement;

L - The distance between the center of gravity of the total weight of the arm and the moving part to the front end of the guide support (m), refer to the calculation of the previous section;

a - The length of the guide support (m);

- Equivalent friction coefficient, which is related to the cross section of the guide support.

For cylindrical surfaces: $\mu' = \left(\frac{4}{\pi} \sim \frac{\pi}{2}\right) \times \mu = (1.27 \sim 1.57)\pi$

μ - Friction coefficient, for static friction and no lubrication:

Steel on bronze: take μ = 0.1 ~ 0.15

Steel on the cast iron: take μ = 0.18 ~ 0.3

Calculate:

Guide rod material selection steel, guide support selection cast iron $\mu' = 0.20 \times 1.5 = 0.3$, $G_{总} = 1070N$, L = 1.69-0.028 = 1.41m, guide support a design for 0.016m

The relevant data into the calculation

$$F_{摩} = G_{总}\mu'\left(\frac{2L}{a}\right) = 1070 \times 0.3 \times \left(\frac{2 \times 1.41 + 0.16}{0.16}\right) = 5978.6N$$

6.3.2 Calculation of arm inertia force

This design requires arm translation is V = $5m/\min$, in the calculation of inertia force, set the start time $\Delta t = 0.2s$, start speed Δ V = V = $0.083m/S$

$$F_{惯} = \frac{G_{总}\Delta v}{g\Delta t}$$

$$F_{惯} = \frac{G_{总}\Delta v}{g\Delta t} = \frac{1070N \times 0.083S}{9.8N/Kg \times 0.02S} = 45.5N$$

6.3.3 Friction resistance of the sealing device

Different seals have different frictional resistance, in the arm design, the use of O-type seal, when the hydraulic cylinder working pressure is less than 10Mpa. The total frictional resistance of the seal at the hydraulic cylinder can be approximated as: . $F_{封} = 0.03F$

After the above analysis and calculation of the final calculation of the driving force of the hydraulic cylinder:

$F = 0.03F + F_{惯} + F$ =6210N

6.4. Determination of working pressure and structure of hydraulic cylinders

After the above calculation, the driving force of the hydraulic cylinder F = 6210N was determined, and the working pressure of the hydraulic cylinder was selected according to Table 3.1 P = 2MPa

1 To determine the structure of the hydraulic cylinder size:

The calculation of the cylinder bore diameter is shown in Figure 6.2

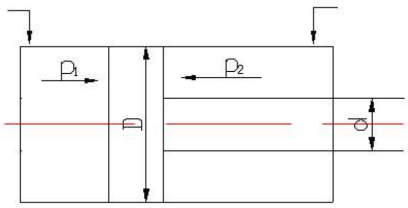


Figure 6.2 Schematic diagram of double acting hydraulic cylinders

When the oil enters the rodless cavity,

$$F = F_1\eta = p\frac{\pi D^2}{4}\eta$$

When the oil into the rod cavity,

$$F = F_2\eta = p\frac{\pi\left(D^2 - d^2\right)}{4}\eta$$

Effective area of hydraulic cylinder:

So there is no rod cavity

$$S = \frac{F}{p_1}$$

$$S = \frac{F}{p_1} \text{ (Without stem)}$$

$$D = \sqrt{\frac{4F}{\pi p_1 \eta} + d^2} \text{ (With stem)}$$

F = 6210N, $p_1 = 2\times10^6 pa$, select mechanical efficiency $\eta = 0.95$

Replace the relevant data: $D=\sqrt{\frac{4F}{\pi p_1}\eta}=1.13\sqrt{\frac{F}{\eta p_1}}=1.13\sqrt{\frac{6210}{0.95\times2\times10^6}}=0.06460m$

According to Table 6-1 (JB826-66), select the standard hydraulic cylinder diameter series, select D = 65mm.

1 Design of the outer diameter of hydraulic cylinder

According to the assembly and other factors, taking into account the arm of the hydraulic cylinder at 7mm, so the outer diameter of the hydraulic cylinder is 79mm.

2 Calculation of piston rods

The size of the piston rod to meet the piston (or hydraulic cylinder) movement requirements and strength requirements. For the length L is greater than the diameter d of more than 15 times, according to pull, pressure strength calculation:

$$\sigma=\frac{F}{\frac{\pi}{4}d^2}\le[\sigma]$$

Design of the piston rod to take the material for the carbon just $[\sigma] = 100 \sim 120Mpa$, so the piston diameter d = 20mm, L = 1360mm, now check.

$$\sigma=\frac{F}{\frac{\pi}{4}d^2}=\frac{6210}{\frac{\pi}{4}\times0.02^2}=19.8\times10^6 Mpa\le100\times10^6$$

Conclusion: The strength of the piston rod is sufficient.

7. Body design calculations

The fuselage is a component that directly supports and drives the arm. The general realization of the arm of the rotation and movements, the movement of the transmission mechanism are installed in the fuselage, or directly constitute the fuselage of the trunk connected with the base. Therefore, the more the arm movement, the body of the body and the more complex the situation. The fuselage can be fixed, it can also be walking, both along the ground or overhead orbit movement.

7.1. Overall design of the fuselage

In accordance with the design requirements, the robot to achieve the rotation of the arm 1800, to achieve the arm of the rotary motion mechanism is generally designed in the fuselage. In order to design a reasonable sports institutions, we must consider, analysis.

The body carries the arm, do the rotation, lift movement, is an important part of the robot. Commonly used body structure has the following:

1 Turn cylinder placed under the structure of the lift. This structural advantage is able to withstand greater emphasis on torque. The shortcomings of the rotary motion transmission path is long, the spline shaft deformation on the rotation accuracy of a greater impact.

2 Turn cylinder placed above the lifting structure. This structure uses a single cylinder piston rod, internal guide, compact structure. But the rotary cylinder and arm with the lift, moving parts larger.

3 Piston cylinder and rack gear mechanism. Rotary arm movement is through the rack and pinion mechanism to achieve: the reciprocating movement of the rack and arm connected to the gear for reciprocating rotation, so that the arm swing around.

Analysis:

After a comprehensive consideration, the design of the rotary cylinder placed on the lift above the structure. The design of the fuselage includes two movements, the body of the rotation and lift. As shown in the figure above, the rotary mechanism is placed on the body structure above the lift cylinder. The arm member is connected with the upper end cover of the rotary cylinder, and the movable piece of the rotary cylinder is connected with the cylinder body, and the arm is driven by the arm movement. The rotary shaft of the rotary cylinder is integral with the piston rod of the lift cylinder. Piston rod with hollow, built a spline sleeve with the spline shaft with the piston lift from the spline shaft guide. The spline shaft and the lower end cap of the lift cylinder are fixed with a key, and the lower cover is fixed to the base connected to the ground. This fixed the spline shaft, also through the spline shaft fixed piston rod. This structure is a guide rod in the interior, compact structure.

The drive mechanism is a hydraulic drive, the rotary cylinder through the two oil holes, an inlet hole, an oil drain hole, respectively, to both sides of the rotary blade to achieve blade rotation. Rotation angle is generally determined by the mechanical stop, for the design is to consider the two blades can be rotated between the angle, in order to meet the design requirements, the design of moving film and static film can be rotated between 1800.

7.2. Design and calculation of body rotation mechanism

(1) Calculation of driving torque of rotary cylinder

The rotational drive torque of the arm swing cylinder $M_{驱}$ should be balanced with the moment of inertia generated during arm movement $M_{惯}$ and the frictional resistance moment $M_{阻}$ at each seal.

$$M_{驱} = M_{惯} + M_{阻} + M_{回}$$

Calculation of inertia moment

$$M_{惯} = J_0 \varepsilon = J_0 \frac{\Delta\omega}{\Delta t}$$

Where - $\Delta\omega$ the speed of the rotary cylinder moving speed (rad/s) during the start-up process $\Delta\ \omega = \omega$

Δ t - the time of the start-up process (s);

J_0 - Moment of inertia ($N \cdot m \cdot s^2$) of the arm rotating parts (including the work piece) to the rotary axis.

If the distance between the center of gravity of the arm turning part and the rotary axis is ρ ,

$$J_0 = J_c + \frac{G}{g}\rho^2$$

Where - J_c the moment of inertia of the center of gravity of the rotary part.

$$J_{c_z} = m\left(l^2 + 3R^2\right)/12$$

The rotating part can be equivalent to a length of 1800mm, diameter of 60mm cylinder, the quality of 159.2Kg. Set the starting angle ω = 180, the starting angular velocity $\triangle\omega$ =0.314 rad/s , starting time is designed to 0.1s.

$$J_{c_z} = m\left(l^2 + 3R^2\right)/12 = 43N \cdot m \cdot s^2$$

$$J_0 = J_c + \frac{G}{g}\rho^2 = 1495N \cdot m \cdot s^2$$

$$M_{惯} = J_0\varepsilon = J_0\frac{\Delta\omega}{\Delta t} = 1495 \times \frac{0.314}{0.1} = \ =4694.3 \quad M_{惯} = J_0\varepsilon = J_0\frac{\Delta\omega}{\Delta t} = 1495 \times \frac{0.314}{0.1} =$$

The frictional resistance moment at the seal can be roughly estimated $M_{阻}$ = 0.03 $M_{驱}$, since the oil return is generally very small, so it is ignored here.

After the above calculation $M_{驱}$ = 4839.5 $N \cdot m \cdot s^2$

(1) The initial determination of the size of the rotary cylinder

Design the rotary cylinder of the static film and moving piece width b = 60mm, select the working pressure of the hydraulic cylinder 8Mpa. D is the diameter of the connection between the output shaft and the movable piece, d = 50mm, the inner diameter of the rotary cylinder is calculated as follows:

$$D = \sqrt{\frac{8M_{驱}}{\text{bp}} + d^2}$$

D = 151mm

(2) The inner diameter of the hydraulic cylinder is 150mm, and the basic outer diameter of the hydraulic cylinder is 180mm (not the final size) according to Table 4.2, and then the condition is considered.

8. Conclusions

China's robot research and application started late, but with the rapid development of domestic and foreign robot, social demand and technological progress, assembly robot has been rapid development, multi-species, less mass production methods and to improve product quality and Production efficiency of the production process needs, is to promote the development of the robot direct power. SCARA robots in the light, relatively simple and requires low cost of the assembly work in the robot show great skill. This topic is put forward in this context, this is an important issue. This paper mainly completed the following work:

1. Carried out the design of the robot body

The robot should have the characteristics of beautiful appearance, small size, light weight, low cost and simple driving principle. The robot is designed with four degrees of freedom structure, which consists of fuselage, arm, arm and wrist. Where the third degree of freedom is the moving joint; the other three degrees of freedom are rotary joints. SCARA robot four joints are selected low-cost stepper motor drive. The first and second joints adopt the transmission structure of the synchronous toothed belt, make full use of the arm space, compact structure; the third joint adopts the screw nut drive, the screw itself has the self-locking function, the transmission precision is higher : The fourth joint uses a stepper motor to drive directly.

2. Carried out kinematic analysis

In the case of static mechanics calculation, the coordinate system of the rod is established by D-H method, and the kinematics analysis of the robot is completed, including the derivation of the positive kinematics equation and the solution of the inverse kinematics. 3. Robot Stepping Motor Control

As the robot uses stepper motor drive. Through this example, the SCARA robot body, the kinematics analysis and the control of the stepping motor are designed in this paper. In this paper, the robot is required to complete the task, carried out three aspects of the basic research in line with the requirements of the robot. In the future research work, mainly to further in-depth robot structure design, so that its structure tends to perfect.

References

1. Liu Jin Chang, Xin Jiancheng. Robot World [M]. Zhengzhou: Henan Science and Technology Press, 2000
2. Zhu Jing. Robot and Control Technology [M]. Hangzhou: Zhejiang University Press, 1991
3. Wu Guangyu, Jiang Fuxing. Introduction to Robotics Engineering [M]. Harbin: Harbin Institute of Technology Press, 1988
4. Zhou Yuanqing, Zhang Zengxing. Intelligent Robot System [M]. Beijing: Tsinghua University Press, 1989
5. Fu Jing Sun. Robotics [M]. Hefei: China Science and Technology Press, 1992
6. Bai Min, Liu Yuanjiang. From 2004 China International Robot Exhibition to see China's robot industry status and future [J]: machine
7. Chinese Journal of Sensors and Actuators .2005. (1): 20-24
8. Liu Mingbao, Lu Chunhong, et al. The composition of the manipulator and the determination of technical indicators. Journal of Henan Polytechnic College, 2004.