Structure Design of a Loading and Unloading Manipulator

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Abstract

In the production of spade stamping, the manual loading and unloading work has been carried out in the past, and the efficiency is low and the risk is high. Therefore, a cylindrical coordinate automatic loading and unloading manipulator with four degrees of freedom is designed for the stamping stage of spade production. In this paper, the overall scheme of the spade stamping loading and unloading manipulator is first designed, and then the actuator is designed and selected. At the same time, the driving structure is designed, and the three-dimensional modeling design of the spade stamping automatic loading and unloading manipulator is completed by using three-dimensional design software.

Keywords

Spade; Manipulator; Automatic Loading and Unloading; Three-dimensional Modeling; Ram Pressure.

1. Introduction

The loading and unloading manipulator is a highly automated equipment that can automatically grab, transport and unload the workpiece according to the specified program [1]. In the actual production process, the loading and unloading manipulator not only improves the production efficiency, but also reduces the error rate of the product and the high cost of human labor. At the same time, it can effectively prevent the occurrence of personal disability accidents [2]. So loading and unloading manipulator in the safety of production with enterprises, improve product quality and reduce labor costs have great significance. They can complete some of our human difficult work. So research on loading and unloading manipulator is also very important [3].

2. The overall structure design of loading and unloading manipulator

As shown in Figure 1,Common industrial manipulators in industrial production can usually be divided into the following four categories : rectangular coordinate type, cylindrical coordinate type, spherical coordinate type and multi-joint type [4].
Because this is aimed at the production process of spade punch blank stamping forming process design loading and unloading manipulator. The function realized is to grab and transport the spade blank by the loading and unloading manipulator. In the actual process, the workspace is small and the required degree of freedom is less (4 degrees of freedom) [5]. At the same time, according to the process requirements, the cylindrical coordinate type is selected as the basic form of the loading and unloading manipulator.
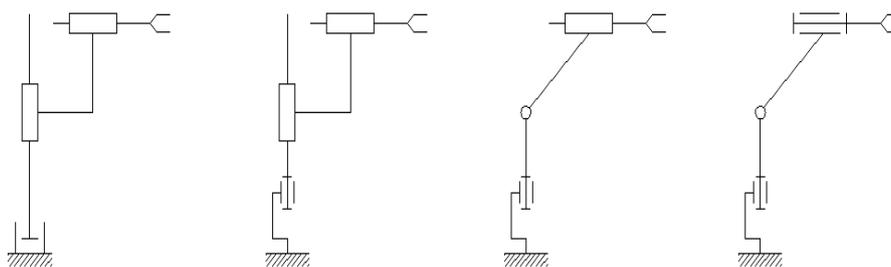
Figure 1. Basic form of industrial manipulator

In the process of spade stamping, due to the actual stamping workshop adjacent two punch space is relatively small, the loading and unloading manipulator also needs to be placed between the two stamping machines for loading and unloading the stamping machine. So you can know that the spade loading and unloading manipulator must be able to realize the left and right swing arm, can stretch and shrink in front and back, can realize the overall rise and fall, and includes the rotation movement of the grab spade blank. So this spade loading and unloading manipulator must have the following four spatial degrees of freedom :a wrist rotation, b arm stretching, c arm rise and fall, d arm left and right swing, The sketch of spade loading and unloading manipulator is shown in Figure 2 below.
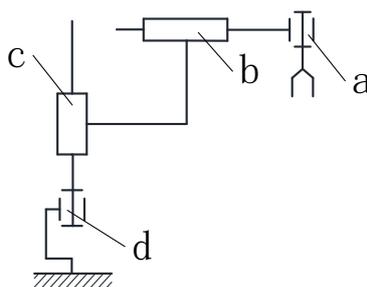

Figure 2. Brief drawing of loading and unloading manipulator

The main technical parameters of the spade loading and unloading manipulator are shown in Table 1.

Table 1 Main technical parameters

project	parameters
End Grab Weight of Manipulator	Less than or equal to 6KG
Freedom of manipulator	4
Coordinate Type of Manipulator	Cylindrical coordinate type
Maximum working radius	1200mm
Wrist motion parameters	Rotation angle: 360°
Telescopic parameters of arm	Telescopic travel:450mm; Extending-retracting speed of boom:500mm/s
Arm lifting parameters	Lifting stroke:350mm; Lifting speed:25000mm/s
Arm rotation parameters	Rotation range:±120°; Rotational speed:360°/s

3. Design of loading and unloading manipulator actuator

The actuator is composed of arm, hand, wrist, column and seat.

3.1. Hand design of loading and unloading manipulator

For the handling of workpieces, the most widely used hand of manipulator is clamping type and adsorption type [6]. Clamping type, can be used for some relatively complex shape, high hardness workpiece. Adsorption type is mostly used for smooth, relatively light workpiece [7]. The design of the loading and unloading manipulator is applied to stamping the loading and unloading in the production process of the spade. The spade blank is lighting and the surface is smooth, so we choose the adsorption type as the hand of the loading and unloading manipulator. The adsorption type includes air sucker and electromagnetic sucker, we choose the air suction sucker. Since the contact between the air sucker and the workpiece is flexible and can also prevent the surface of the workpiece from being scratched. Therefore, the negative pressure air suction cup is selected here as the hand of the loading and unloading manipulator to carry out the grasping and handling of the workpiece.

Design of mechanical interface model between manipulator sucker and wrist by SolidWorks software. Figure 3 below shows [8].
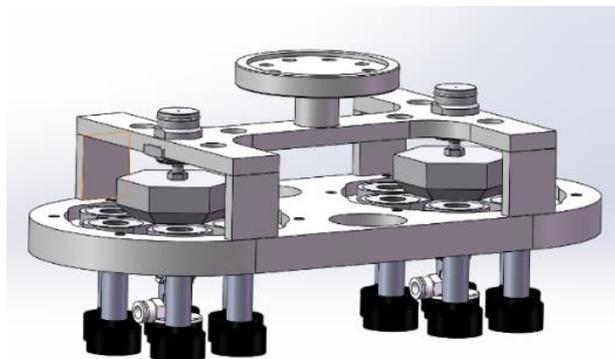

Figure 3. Plum blossom negative pressure air sucker at the end of manipulator

3.2. Design of loading and unloading mechanical wrist

The wrist of the loading and unloading manipulator is the hand and arm connecting the manipulator, which can complete the purpose of rotary grasping and dropping the workpiece. Because of the constraints of the overall structure of the loading and unloading manipulator, and in order to make the overall structure more simple, and save space as much as possible makes the manipulator more simple and practical. So you can choose a smaller volume, and relatively large torque DD motor, used as loading and unloading manipulator wrist. Rotating the end sucker of the manipulator by rotating the DD motor. The wrist structure of the manipulator is shown in Figure 4.
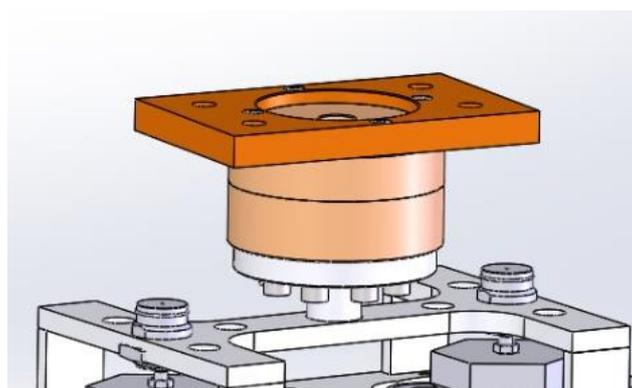

Figure 4. Wrist part of manipulator

3.3.   Design of loading and unloading manipulator arm

The arm of the loading and unloading manipulator should realize three degrees of freedom, including the expansion of the arm, the left and right swing of the arm and the rise and fall of the arm. The arm of the loading and unloading manipulator can not only support the wrist and the hand of the manipulator, but also realize spatial motion. After the above analysis, considering the cost of processing and manufacturing, as well as the further simplification of the mechanical mechanism, the linear module is selected to realize the function of the manipulator stretching, swinging arm and rising and falling. And loading and unloading manipulator speed and accuracy can be guaranteed. The structure of the arm part of the manipulator is shown in Figure 5.
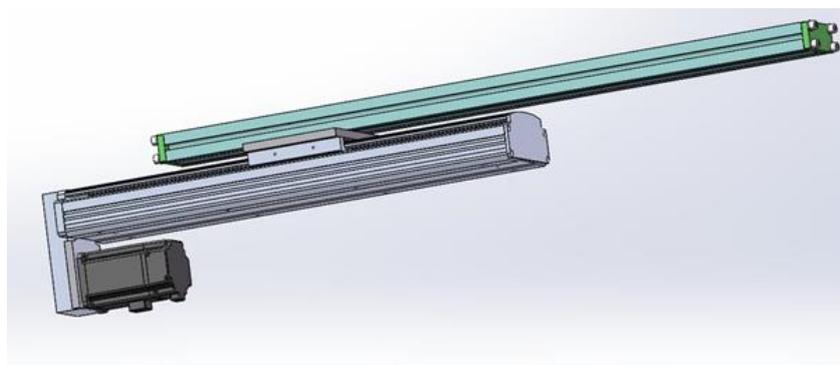

Figure 5. Arm part of manipulator

3.4.   Design of fuselage seat for loading and unloading manipulator

The mechanical mobile phone seat consists of two parts base and waist. In the design process, the base section of the manipulator base needs to be large enough, and the base needs to have a certain bearing capacity to ensure that it can withstand the overall weight of the manipulator, otherwise it will directly affect the working performance and progress of the manipulator. The driving form of this design is directly realized by the motor driving the deceleration mechanism, rather than directly driven by the motor, which can make the overall structure of the loading and unloading manipulator compact. Combined with the actual work needs, the gear transmission deceleration mechanism with large transmission ratio is selected to ensure the working condition requirements. Since the motor speed under the base is not high, the four-point angular contact ball slewing bearing is selected. The structure of the body part of the manipulator is shown in Figure 6.
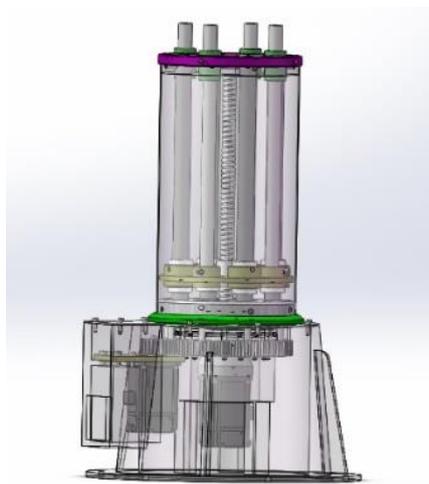

Figure 6. Body part of manipulator

4. Design of driving mechanism of loading and unloading manipulator

The drive of the loading and unloading manipulator can be divided into the following four types according to different power sources: pneumatic drive, hydraulic drive, mechanical drive and electric drive[9].

Because the loading and unloading manipulator should have enough response speed and high positioning accuracy in the process of grasping and handling spade blank, the mechanical drive is selected as the driving part of the loading and unloading manipulator[10].

According to the characteristics of each drive and further analysis of the working environment, the suction plate of the hand of the loading and unloading manipulator is controlled by compressed air, and other power sources are driven by servo motors.

5. Calculation and selection of main parts of loading and unloading manipulator

5.1. Calculation and selection of hand sucker

In the process of grabbing the spade blank workpiece the manipulator, it is known that the spade blank is about 1.2 kg, and the pressure of the vacuum generator in the whole system is about −0.08 MPa.

Calculation of Vertical Lifting Force of Absorber in Theory

$$F = m(g + a)s$$

Among them:

F -maximum suction.

m -Weight of spade blanks.

g -Gravity acceleration, we take 10 m/s² here.

a -Absorb the acceleration value of spade blanks and select the acceleration value here as a=5 m/s².

s -Safety factor. Here suction spade blank way for horizontal suction, the safety factor is s=4.

We calculate that the suction is 72N.

Through the following suction calculation formula, the required suction plate area can be obtained:

$$F = \frac{P \times C}{101} \times 10.13 = \frac{80 \times C}{101} \times 10.13 = 72$$

Among them:

F-suction (N) was 72 N.

C -Area of sucker (cm²).

P-vacuum degree (-KPa) is -80 KPa.

Through the above calculation formula, the suction cup area can be obtained as C = 8.9cm².

Based on the above calculation results, J-WET06-d25 vacuum sucker from Jetta can be selected.

5.2. Calculation and Selection of Servo Motor on Manipulator Arm

According to the design requirements, the mass of the slider moving on the guide rail is about, The specific parameters of the selected linear module are calculated as follows:

(1) Motor rotational inertia J_M :

According to the principle that the required load inertia is less than three times the inertia of the motor rotor: $J_M > J_L / 3 = 2.986$

(2) The torque required by the motor T:

Rated torque of motor $T > T_f = 0.219N$, torque $T > T_f + T_a = 5.819N \cdot m$

(3) Motor speed n:

$n = v \cdot 60/(\pi D) \cdot R_1 = 1 \times 60 \div (3.14 \times 0.048) \times 3 = 1194 r/\min$

After the above calculation and analysis, we choose Delta 750W AC servo motor of ECMA-C20807ES .

6. Design of 3D Model of Loading and Unloading Manipulator

After the calculation and selection theory of the main parts of the loading and unloading manipulator of the spade stamping forming in the early stage, the three-dimensional model of the loading and unloading manipulator is drawn by using the three-dimensional modeling software SolidWorks 2018, and the three-dimensional assembly drawing of the loading and unloading manipulator is obtained by continuous and detailed optimization. Figure 7 below shows.
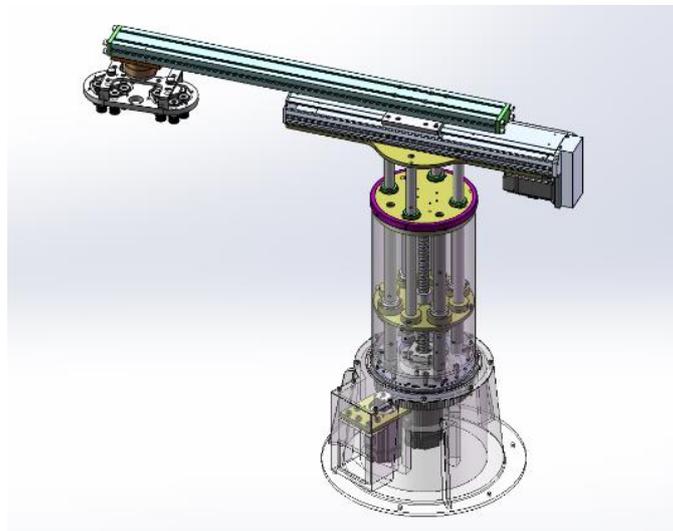

Figure 7. 3D assembly drawing of loading and unloading manipulator

7. Conclusion

According to the requirements of the function, the overall structure of the manipulator is designed firstly, and then the actuator of the loading and unloading manipulator is designed and selected. At the same time, the driving mechanism is designed. Finally, the three-dimensional model of the spade stamping automatic loading and unloading manipulator is drawn by three-dimensional design software and its motion simulation can realize the original intention of the design. The design results are transformed into physical objects, which is beneficial to improve production efficiency and reduce the risk rate of accidents.

Acknowledgements

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