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Computer Simulation Design of Joint Manipulator for Handling Pipeline

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Abstract. The joint manipulator is a transmission device suitable for operation close to the body, which can realize multiple degrees of freedom and move flexibly. In this paper, through the transmission analysis of the big arm, the small arm, the wrist and the other parts of the manipulator, a kind of joint manipulator used in the transportation pipeline is proposed, and a three-degree-of-freedom wrist transmission mechanism is designed. On this basis, the structure of the wrist transmission parts is analyzed and designed, and the mechanical analysis and strength check of the gear connecting shaft of the wrist part are carried out.

1. Introduction

Industrial robots are widely used in production because of their high automation and mechanization. Under the control of the program, industrial robots can complete some humanoid operations. Therefore, for some dangerous actions or repeated movements, industrial robots can be completed by manipulators to reduce the labour intensity of workers and improve production efficiency. At present, industrial robotics technology in China is developing rapidly, but there is still a long way to go compared with some developed countries. Especially for high precision manipulator parts which needs to be solved by import, our country cannot manufacture them independently. In view of this situation, we take the material handling manipulator which is most widely used in industrial production line as an example, and propose a design scheme of three-degree-of-freedom joint manipulator.

2. Site Requirements

According to the requirement of the production site, the industrial robots designed are installed in the middle of two production lines and controlled by motors, which are used to transfer workpieces between the two production lines. The workpieces are approximately a cube with a weight of 5Kg and a side length of 30cm. The two parallel production lines are 1 metre apart, and the maximum elongation of the manipulator is about 1.3 metres. The waist can rotate in space for a week. The bottom is fixed on the ground with bolts, as shown in Figure 1.

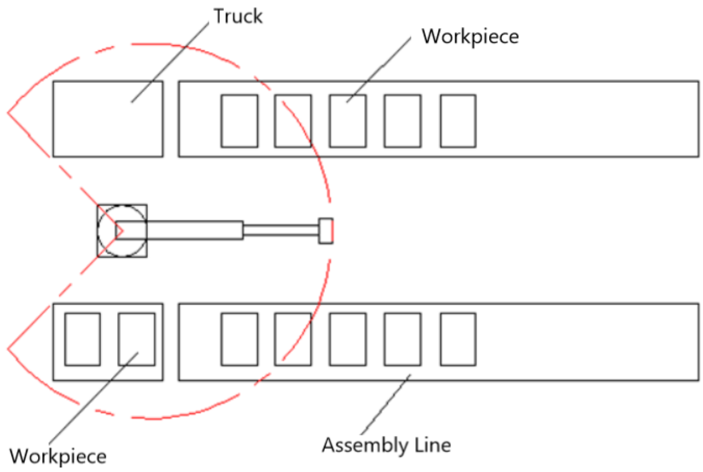

Figure 1. Site Layout

According to the requirement of the production site, the industrial robots designed are installed in the middle of two production lines and controlled by motors, which are used to transfer workpieces between the two production lines. The workpieces are approximately a cube with a weight of 5Kg and a side length of 30cm. The two parallel production lines are 1 metre apart, and the maximum elongation of the manipulator is about 1.3 metres. The waist can rotate in space for a week. The bottom is fixed on the ground with bolts, as shown in Figure 1.

Specific requirements of the industrial robot include:

(1) The workspace is large and the robot occupies a small area.

(2) Flexible handling of goods, faster speed and accuracy.

(3) It can be placed in the box body to facilitate the maintenance and maintenance.

(4) When driving each axis, the torque is small and the energy consumption is small.

3. Project Design

According to the requirements, we decided to adopt joint robots structure. The articulated robot arm consists of two parts: the dynamic joint and the connecting rod. The arm mechanism is a four-link mechanism, whose action can reach any point in the space range. Rotary frame is selected for the machine base. The wrist is located between the arm and the end effector, and its motion determines the action and posture of the end effector. Because of the high requirement for the motion of the end effector, a three-degree-of-freedom articulated manipulator is designed as shown in Figure 2.

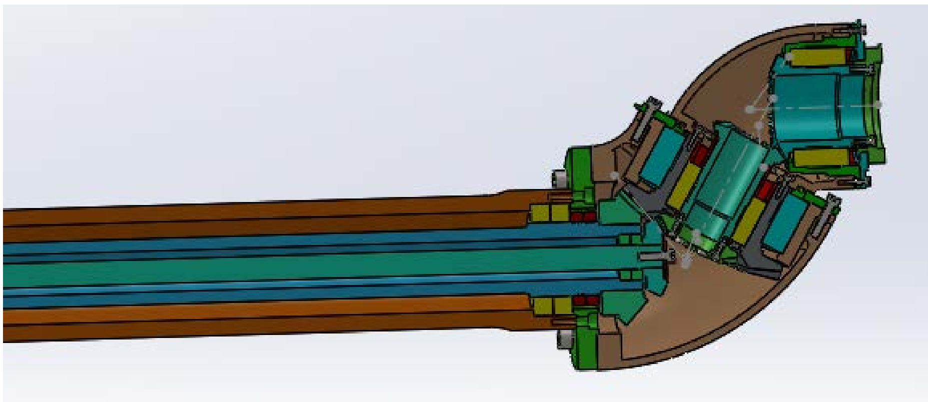

Figure 2. Three-degree-of-freedom Articulated Manipulator

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The end of the three-degree-of-freedom robot wrist is connected with the arm of a four-bar mechanism. The control motor is installed on the arm, which can reduce the wrist's weight and facilitate the wrist's flexible rotation. The transmission structure of the small arm joint is shown in Figure 3. The arm can pitch in three-dimensional space, and then determine the position of the wrist. The range of action is from + 130 degree to – 90 degree. The servo motor is mounted on the driving arm, that is, the joint of the big arm. Through the through hole at the bottom of the arm, two connecting rods are used to connect the small arm seat. Through the action of the connecting rod, the pitching action of the small arm seat is realized. The bottom is connected by a flat key, while the upper arm and the bottom pole are connected by a tension sleeve. There are through holes at the bottom of the arm. The arm is connected with the reducer through the through holes. The motor is installed side by side with the reducer. The position of wrist in the plane is determined by the pitching motion of the upper arm and the lower arm. The position of the manipulator in the workspace is realized by the waist rotation and the pitching motion of the arm and the arm. The shaft at the waist has a central shaft hole, which matches the shaft of the motor and transfers the torque of the motor to the shaft by means of keys. The waist transmission structure is worm wheel and worm drive mode. The rotation of the motor drives the turbine to rotate and makes the waist rotate.

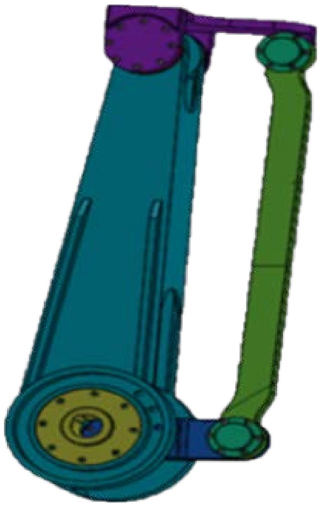

Figure 3. Robot Arm

4. Computational Analysis

According to the requirements of production, it is known that the arm inertia of the workpiece is:

$$J = ms^2/6 = 7.5 \times 10^{-4} kg.m^2 \quad (1)$$

The rotational speed is:

$$w = 330^{\circ}/s$$

The rotational angular acceleration is:

$$\beta = 3300^{\circ}/s^{2}$$

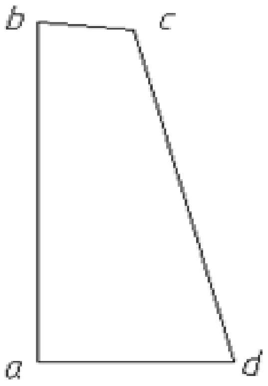

Figure 4. Four-bar Linkage

The crank-rocker mechanism is selected for the four-bar linkage. Among them, in Figure 4, L arm = 1000mm, represented by a-b; L base bar = 400mm, represented by a-d; L rear bar = 1000mm, represented by d-c; L arm = 200mm, represented by b-c. The frame, rocker and crank of four-bar linkage are a-b bar, a-d bar and b-c bar respectively.

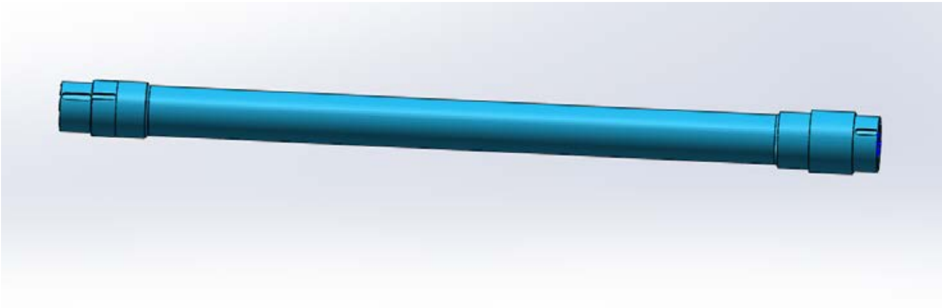

Figure 5. Connecting axle

Because the gear and key are installed at the connecting axle of wrist gear, the force of wrist gear is complex. Therefore, it is necessary to analyze the force of wrist gear axle. As shown in Figure 5, according to the above analysis, it is known that the upper torque of the gear is:

$$T_1 = 9.55 \times 10^6 \times \left(\frac{P_1}{n_1}\right)\eta \tag{2}$$

Then the circumferential force is:

$$F_t = \frac{2T_1}{d_1} = 1260 \tag{3}$$

After checking, the strength of the wrist gear connecting shaft meets the requirements.

5. Conclusions

The structural design of articulated robot wrist is the key and difficult point in the design of the whole structure of robot. In this paper, a mechanical system of robot used in handling assembly line is analyzed, including waist rotation structure, large lower arm rotation mechanism and three-degree-of-freedom wrist structure. On this basis, the structure of the wrist transmission parts is analyzed and designed, and the mechanical analysis and strength check of the gear connecting shaft of the wrist part are carried out. After analysis, the range of motion of the designed robot wrist can meet the requirements of the field. The design scheme also provides a useful reference for similar joint manipulator design.

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6. References

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