Development and Application of Simulation Control System of Logistics Palletizing Robot Manipulator

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Abstract. Loading and unloading and handling is one of the important parts of logistics. It often occurs in the logistics system, which connects all links in the production process and plays a very important role. The purpose of this paper is to discuss the development and application of the simulation control system of the logistics palletizing robot manipulator. According to the control requirements and functions of the control system, the control system is planned, the PLC control mode and PLC model are selected, the communication system is set, and the I / O interface is allocated. The arm parallel mechanism is selected to be in a relatively dangerous position. The control system of the small arm and the rear arm of the palletizing robot is designed. The function modules in the PLC program have achieved the expected purpose. On the premise that the strength and stiffness of the two key components meet the design requirements, the weight of the two key components is reduced by 50% and 10kg respectively. The optimization effect is obvious, which is conducive to improving the structural performance of the palletizing robot, saving materials and reducing production costs.

Keywords: Palletizing robot; manipulator simulation; control system; development and application

1. Introduction
The development of robot technology is an important symbol and implementation example of national industrial automation degree [1]. In fact, robot technology is an academic topic combining computer, telepathy and artificial intelligence, and it is also a hot spot in current scientific research [2-3]. With the rapid progress of related fields, the intelligence of robots is also higher and higher [4]. In the fields of ocean development, space exploration, social service and entertainment, robots have broad development space and application prospects [5].

In recent years, with the rapid development of the logistics industry, palletizing technology has made milestone progress in all aspects, but the early manual palletizing has low efficiency and requires high labor costs [6-7]. With the increase of labor intensity, the quality of work has also declined, which cannot meet the needs of automatic production [8]. The emergence of palletizing robot has the advantages of environmental protection, high efficiency, strong load capacity and operability, which realizes the automation of palletizing and makes the palletizing robot. It is very important to apply palletizing robot in production line, improve work efficiency, reduce labor cost, ensure product quality, and realize flexibility and automation of production line [9-10].

This paper takes the palletizing robot logistics system as the research object, and studies the control
method of the palletizing robot logistics system including the design and development of the hardware and software of the control system. Therefore, the design process of the robot palletizing logistics control system is formulated. According to the control requirements and functions of the control system, the control system is planned, the PLC control mode and PLC model are selected, the communication system and I/O interface are set, the reliability scale of the hardware system is formulated, and the kinematics solution of the 6-DOF manipulator is analyzed. The simulation experiment is carried out by simulating the moving parts of each logistics system with the LED on and off. The experimental results show that the touch screen can display the state of the system well.

2. Proposed Method

A. Kinematics Solution of 6-DOF Manipulator

A manipulator is a spatial multi degree of freedom mechanism composed of a series of links connected by a series of joints that can be moved or rotated. In order to get the motion relationship between the manipulator and its joints, and then complete the point motion in space, the motion trajectory planning and so on, the kinematics solution of the manipulator includes the forward solution and the inverse solution.

In this paper, the coordinate system \( \{0\} \) is defined as the reference coordinate and the joint variable

\[
T^6_0 = T^1_0(\theta_1)T^2_1(\theta_2)T^3_2(\theta_3)T^4_3(\theta_4)T^5_4(\theta_5)T^6_5(\theta_6) \tag{1}
\]

Finally, the product of the six link coordinate transformation matrix is obtained, which is the forward kinematics equation of the robot, as shown in formula (2)

\[
0^T = \begin{bmatrix}
  n_x & o_x & a_x & p_x \\
  n_y & o_y & a_y & p_y \\
  n_z & o_z & a_z & p_z \\
  0    & 0    & 0    & 1
\end{bmatrix} \tag{2}
\]

B. PLC System Design Process

Control requirements mainly refer to the basic control mode. According to the requirements of the control task to the PLC control system, the input and output signals required by the control system are counted and the appropriate PLC type is selected. Then I/O port of PLC are assigned and I/O terminal assignment table of PLC are compiled. According to the state flow chart and electric control principle diagram, the ladder diagram program is compiled as the core work of the whole software design. Then input the program to PLC. Through the self-diagnosis function of CPU, the syntax errors of input program can be found, and several logic errors can be checked carefully. After the program input is correct, the program can be debugged.

3. Experiments

A. Experimental Equipment

This experiment mainly simulates the start/stop of the moving parts of each logistics system by the light-emitting diode on and off, simulates the photoelectric sensor by manual switch, and presses/releases the switch to replace the arrival and departure of finished product boxes and pallets. In order to detect the PLC program, touch screen program and the communication between them, the LED is controlled on the PLC hardware system experimental board. Since the FP2 PLC has not arrived yet, fp-x will be used instead of FP2 in this experiment. The touch screen and manual switch will be pressed to detect whether the LED can be on or off as expected.

B. Data Acquisition

After entering the optimization design module, the system automatically generates 9 groups of design points in DX module according to the input parameter variables and parameter ranges. The corresponding solution results of each design point can be obtained by updating and solving the design
4. Discussion

A. Design of Forearm

The PLC system can run normally, and each function module in PLC program has achieved the expected purpose. The touch screen can display the status of the system well, and the operation of the system can also be controlled by the touch screen.

The influence degree of each design variable on the maximum deformation, maximum equivalent stress and total mass: the influence of the jib thickness on the mass is relatively large; the influence of the jib thickness on the maximum equivalent stress is much greater than that of the welding angle; the influence of the boom thickness and welding angle on the maximum deformation is basically the same, and the overall trend is opposite.

After the response diagrams of design variables, constraints and objective functions are obtained, the objective driven optimization method provided in awe environment can be used to quickly obtain ideal optimization results. Before getting the optimization results, it is necessary to set the priority of constraint conditions and objective functions, and set the priority of mass and maximum deformation as higher. Other parameters are set according to the default state of the system. After the above settings are completed, the system will automatically select three groups of better candidate optimization results according to the priority of each parameter and response surface graph, as shown in Table 2.

| Parameter                          | Option A | Option B | Option C |
|------------------------------------|----------|----------|----------|
| Maximum deformation (mm)           | 0.84     | 0.81     | 0.93     |
| Maximum stress (MPa)               | 86       | 88       | 90       |

It can be seen from table 2 that in order to facilitate the selection of materials, it is necessary to round off the decimal part of the design variables. The thickness of the forearm is 4mm and the welding angle is 210 °. After optimization, the weight of the forearm is 41kg, which is 50% less than
that before optimization. The optimization effect is obvious, as shown in Figure 1.

B. Design of Rear Boom

After obtaining the response diagram of design variables, maximum stress and maximum deformation, the objective driven optimization method provided by awe environment can be used to quickly obtain ideal optimization results. Before getting the optimization results, it is necessary to set the priority of constraint conditions and objective functions, and set the priority of mass and maximum deformation as higher. Other parameters are set according to the default state of the system. After the above settings are completed, the system will automatically select three groups of better candidate optimization results according to the priority of each parameter and response surface graph. The maximum deformation of the three groups of optimal optimization results are all less than 0.5mm, and the maximum stress is within the allowable range. According to the comprehensive consideration of various factors such as structural safety, reliability and lightweight, scheme C is finally selected as the optimal scheme. However, in order to facilitate the selection of materials, it is necessary to round off the decimal part of the design variables. After optimization, the overall maximum stress and maximum deformation of the rear boom are within the required range, which can meet the requirements of strength and stiffness. The weight of the optimized boom is 91kg, which is 10kg less than that before optimization. The optimization effect is obvious, as shown in Figure 2.

Fig.2. Comparison of parameters before and after optimization of rear boom

5. Conclusions

With the rapid development of industrial automation, more and more robot technology has been applied to industrial operation. The traditional sorting technology mostly adopts sports teaching mode, which requires fixed target position and low efficiency. This paper analyzes the kinematics solution of 6-DOF manipulator from the perspective of mechanism, and makes relevant theoretical derivation; obtains the relationship expression of robot forward kinematics equation, which lays the foundation for the follow-up analysis; expounds the research and development of software part of palletizing robot logistics control system. This paper introduces the working principle of PLC, carries on the simple PLC programming, compiles the practical control program. In this paper, the static strength and stiffness of the palette robot arm are analyzed and calculated based on the four representative working limit positions under the maximum working load.

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