Numerical Simulation of Weak Parts of Main Components of Heavy-Duty Precision Brick Palletizing Robot

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Abstract. In order to improve the efficiency and quality of brick-making, a heavy-duty jointed brick-stacking robot is developed. According to the work requirements, the robot has a large number of grasping blanks at a time, which takes a large load and increases the deformation of work pieces. Through the analysis of the deformation of main parts, the weak parts were found and the deformation was further reduced, as a result, the whole structure is optimized to reduce scraping bricks gripper positioning deviation and improve the working accuracy.

1. Introduction

In recent years, the labor costs of operating workers have been rising and the impact of our country’s brick industry has been enormous. The higher the output of the brick production line, the more people are needed [1]. As a result, the factory has to carry out technical transformation, and build new automatic production line to solve this problem. In the past, most of the automatic pallet stacking operations were completed by Cartesian coordinate stacking machines or manual handling [2]. Because of the limitation of structure and other factors, Cartesian coordinate stacker has the disadvantages of large area and large power consumption. The joint type brick stowaway is a small, tight structure, which is good for the layout of the shop; the speed of handling is very fast and the production efficiency is greatly improved. It has an important contribution to the automation of brick production. In order to improve the efficiency and quality of brick-making, a heavy-duty jointed brick-stacking robot was designed [3]. Due to the large number of blank grabbing and large load, small deformation of the main parts will amplify the end of the claw, resulting in large deviation of grasping position. Therefore, the deformation of the main parts is analyzed to find the weak part for the further optimization and improve the working accuracy [4].

2. Structure of Palletizing Robot

Joint type adobe palletizing robot is mainly composed of base, the waist mechanism, balance cylinder body, arm, wrist and gripper. The base is the installation foundation of the whole robot body, and the waist is connected with the base by a rotating joint whose axis is perpendicular to the horizontal surface, providing support and overall rotation driving force for the arm mechanism, wrist mechanism and end gripper [5]. Arm mechanism mainly includes upper arm slewing support, forearm slewing...
support, upper arm, forearm, horizontal bar and vertical bar [6]. The upper arm slewing support includes a bearing seat, a reducer and a servo motor, which provides the upper arm with support and rotational driving torque [7]. Forearm slewing bearing slewing bearing and the upper arm has the similar structure, it provides support and drive moment of forearm [8, 9]. The upper arm and the forearm part constitute two parallelogram connecting rod mechanism, which increases the stiffness of the whole arm part and has the stroke amplification function, that is, to realize the larger work stroke at the end of the robot with a smaller driving stroke, so as to meet the performance requirement of the large work space for the brick stacking operation [10]. Wrist institutions for vertical installation of a reducer and ac servo motor, driving moment for the rotation of the gripper. The flange joint is reserved at the wrist to facilitate the installation and maintenance of the end gripper [11].

![Schematic diagram of mechanical structure of stacking robot](image)

**Fig. 1** Schematic diagram of mechanical structure of stacking robot

1-Wrist 2-Tie rod assembly 3-Forearm 4-Rocker arm 5-Upper arm 6-Vertical rod assembly 7-Balance cylinder 8-Waist joint 9-Support

3. **Finite Element Analysis of the Main Parts of the Robot**

The main components of the robot include the upper arm, the forearm, the wrist, and the tie rod.

3.1. **Upper Arm**

The software of Ansys was used for strength check and stress analysis of the upper arm. The cell type selects Solid entity model and uses the 20NODE186 node type to mesh the model. The boundary condition is that the load is applied to the upper end hole of the upper arm, and the applied load is as large as 1.2 times to the actual load, and the circumferential constraint is applied to the lower end of the upper arm. The analysis results are shown in figure 2.

As shown in FIG. 2(a), the stress value increases successively from left to right. The maximum stress is located at the contact position between the arc at the lower end of the upper arm and the plate, and the maximum value is 49.8Mpa. Correspondingly. By FIG. 2 (b), the maximum deformation also occurs at the contact positions of the lower end circular arc and the flat plate of the upper arm with a maximum deformation of 1.99 mm. This is mainly because the large load bears capacity of the upper arm at work, and the stress concentration is easy to occur at the contact position of the arc at the lower end of the upper arm and the flat plate. Therefore, the transition rounded angle can be appropriately increased at the maximum deformation to reduce the stress value, increase the stability and safety of the robot operation, and improve the grasping accuracy of the claw.
3.2. Forearm

The forearm is connected with the wrist, and the wrist is connected with the claw under working conditions, so it bears the direct load given by the blank, which has a great impact on deformation. As for the analysis, firstly, the forearm solid model is established and meshed. The second is to load and constraints, in the forearm top hole applied load, load is calculated at 1.2 times, on the lower end of the forearm surface constraints on the circumference of a circle, the result is shown in FIG. 3.

Fig. 2 Big arm deformation cloud map
As shown in FIG. 3 (a), the stress value increases successively from left to right. At the position of maximum stress, it appears at the contact point between the arc at the lower end of the forearm and the plate, with a maximum value of 50.6Mpa, while at other positions of the forearm, the stress is relatively small. Correspondingly, according to FIG.3 (b), the maximum deformation also occurs at the contact position between the arc at the lower end of the forearm and the plate, and the maximum deformation is 3.44mm. This is mainly because the heavy load bears capacity of the upper arm at work. Under the condition that the overall operation is not affected, the maximum stress can be reduced by increasing the transition angle to improve the stability of the overall operation of the mechanical arm and the position accuracy.
3.3. Front Connecting Rod

Under working condition, the connecting rod is connected with the wrist to ensure that the wrist is in a vertical posture. The gravity of the blank makes the wrist bear a larger load, so it bears the direct load given by the blank and has a greater impact on deformation. As for the first step in the analysis process, the solid model of the front link is established, and the grid is divided. The second step is the application of load and restraint, the load is applied at the end of the connecting rod, the load value is calculated as 1.2 times of the hole on the other end of the front connecting rod, and the result of the analysis is shown in FIG. 4.

Fig. 4 Front connecting rod stress deformation cloud map
It can be seen from FIG. 4 (a) that the stress value is distributed evenly except for both ends. The maximum stress in the figure is located in the hole at both ends of the link, and the maximum stress value is 12.9mpa. Correspondingly, it can be obtained from FIG. 4 (b) that the maximum deformation occurs at the end of the applied load, and the maximum deformation is 1.53mm, which is to bear a large load when the connecting rod is connected with the wrist and is prone to deformation. However, the overall structure is relatively reasonable, so there is no need to make a further optimization.

### 3.4. Wrist

Also under working condition, the wrist is connected with the grasping claw, directly bearing the load, which has a great impact on the deformation. The solid model of draw bar is established for mesh division. Load and constraint mode are applied. The load is applied on the end face of the flange plate. The load is calculated as 1.2 times, and the result is shown in FIG. 5.

![Wrist deformation cloud map](image)

**Fig. 5** Wrist deformation cloud map
As can be seen from FIG. 5 (a), the overall stress value is uniformly distributed. The maximum stress value occurs at the contact position between the vertical reinforcement plate and the motor mounting surface, and the maximum value is 31.8mpa. The stress at other positions is uniformly distributed and relatively small, which has little influence on the normal operation of the wrist. Correspondingly, by FIG. 5 (b), the largest deformation occurs at the flange surfaces of the applied load, maximum deformation is 6.79 mm. It is because that wrist is connective with the grab hand when the wrist is in the condition of motion, the negative load force is great. The stress concentration phenomenon is easy to occur in the position of the vertical reinforcement plate and the motor mounting surface. Therefore, the maximum stress can be reduced by increasing the thickness of the vertical reinforcement plate and the transition angle.

4. Conclusion
By means of the finite element method, the deformation stress distribution of the main parts of joint stacking is analyzed, and the weak parts of upper arm, forearm, wrist and connecting rod are found. Through the improvement of the local structure, the deviation of grab position or material fracture can be improved to cope with the deformation caused by large load, so as to improve the precision and stability of the piling work of the brick, as well as the efficiency and quality of the brick.

Acknowledgments
This work is financially supported by Integration Project of Zibo (2016ZBXC128).

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