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Structure design of an omni-directional wheeled handling robot

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Structure design of an omni-directional wheeled handling robot

Binghui Wu*, Dezhao Qin*, Yuhan Chen, TianQi Cao, Maoliang Wu

Shanghai university of electric power, No.2588 Changyang Road, Yangpu District, Shanghai, China Zip Code: 200090

Email: wubinghui@shiep.edu.cn; tejchao.chin@shiep.edu.cn

Abstract. In response to the demand for automated item handling, this paper proposes an omnidirectional wheeled handling robot. Firstly, determine that its mobile platform is based on the design of the Mecanum wheel, which can move safely and efficiently. Secondly, according to the common object shapes, a single-side opening and closing insertion rack clamping mechanism is proposed. Thirdly, in order to meet the needs of transporting objects and avoid interference with the movement of the moving body, the mechanical arm is a four-degree-of-freedom joint structure. Finally, a decelerated AC servo motor with self-locking function is selected as the drive motor, and a low-speed motor with a reducer is used as the drive element of the moving body.

1. Introduction

With the overall development of industrial automation and continuous technological innovation, pure manual work can't meet people's requirements. Many industries have applied handling robots, which replace a lot of human labor and complete many tasks that people are unlikely to achieve. This technique can reduce the labor intensity and improve the efficiency of production [1-2]. The repeated consumption of manpower for handling items has led to the emergence of handling robots, which can complete the problem of handling items safely and efficiently. Some human tasks are replaced by handling robots, and handling robots can work non-stop, which greatly reduces human input [3]. The handling robot is a product of multidisciplinary integration.

The handling robot proposed in this article is a kind of new omni-directional handling robot, mainly for the smooth handling and stacking of common logistics boxes and rod-shaped materials. The robot has an omni-directional wheeled mobile system, and its mobile body mechanism provides the handling robot with the function of omni-directional rotation or flexible movement to a specified position, and flexible movement. The robot has a four-degree-of-freedom mechanical arm and a single-side open-close rack-mounted manipulator. Among them, the function of the grasping mechanism part is to realize the grasping and placing of items, and the function of the mechanical arm part is to better realize the grasping of the mechanism and provide multiple degrees of freedom of space.

2. Mobile platform design

The wheeled handling robot proposed in this article is required to achieve omni-directional turning. It requires accurate grasping, stable operation, and flexible movement to a specified position. Among these omni-directional wheels, universal wheels, omni wheels and Mecanum wheels are the most widely used[4-5]. The universal wheel can rotate in any direction, not easy to wear, and has a strong structure. However its weighing ability is poor, easy to slide, and the probability of accident is high; the omni wheel can move flexibly in all directions and is cheap. But the structure is more complicated, the lateral direction cannot be fixed, and the load-bearing capacity is relatively poor; the Mecanum wheels move flexibly in all directions, and the load-bearing capacity is better. Compared with omnidirectional wheels, the Mecanum wheels are not easy to slip and can change their speed. And it's installation method can generate force in any direction. However, the Mecanum wheel has a complicated structure and a high cost.

The handling robot generally works on ground, so the Mecanum wheel, which is more successful among the three omnidirectional wheels and the technology is relatively mature, is selected.

The combination of several Mecanum wheels can make the mobile platform form an omnidirectional movement with 3 degrees of freedom on the horizontal plane. The chassis structure of the four Mecanum wheels is shown in Figure 1. The small diagonal line in the wheel represents the axial direction of the ground contact roller, which is divided into left and right rotation. Each Mecanum wheel needs a motor to be drived separately by a reducer, and then the rotation speed and steering control of the 4 Mecanum wheels are properly matched, so that the mobile body can move in all directions. The movement scheme proposed in this paper can enable the omni-directional movement mechanism to move forward, move in an oblique direction, rotate in place or move laterally. This mobile platform can move flexibly in a limited work space.

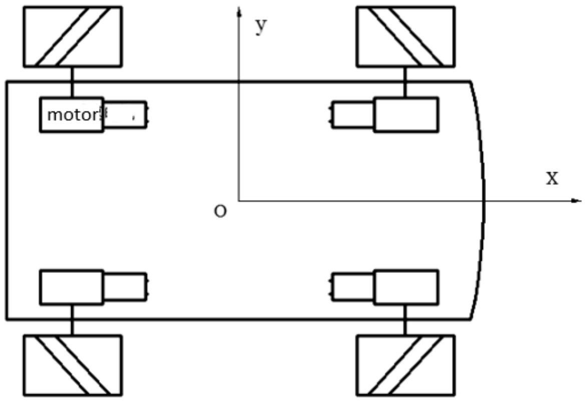


Fig. 1 structure of moving the platform

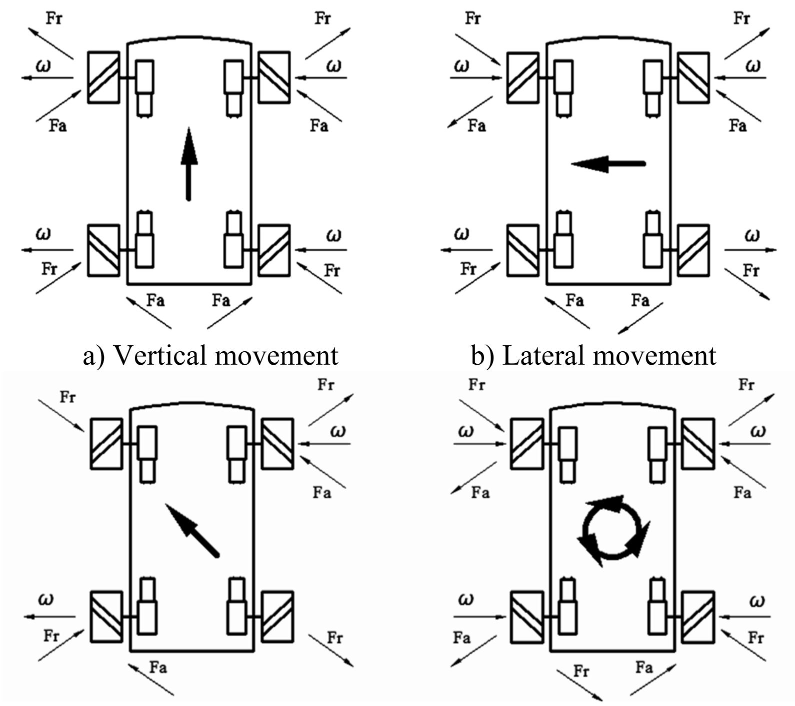
The force analysis of the moving body of the handling robot composed of four Mecanum wheels is shown in Figure 2, where Fa is the axial friction force received by the small roller when the wheel is rolling; Fr is the rolling friction force received when the roller is rotated; ω Is the angular velocity of rotation. Because each Mecanum wheel is driven independently, the motor is controlled to change the direction of its movement arbitrarily during its rotation, and the rotation direction and speed of each wheel are appropriately controlled to allow the moving body to move in any direction. If an ordinary wheel is used, this form can only move forward and backward. If you want to turn, you need to add auxiliary steering wheels need to be added if it rounded. But for the Mecanum wheel, it is characterized by the ability to generate axial force. After adjusting the rotation direction and rotation speed of each wheel, a force with a certain angle to the ground is generated, so that the entire platform can move in all directions.

For the placement plan of the 4 Mecanum wheels in the figure, when the platform moves forward and backward along the X axis, the steering and speed of the 4 Mecanum wheels are the same. When the platform moves left and right along the Y axis, the Mecanum on one side. The rotation direction of the wheels is opposite, and the rotation speeds of the 4 Mecanum wheels must be the same. When moving in other directions, the 4 Mecanum wheels can calculate the rotation direction and speed of each Mecanum wheel according to the conversion matrix of its motion model. The final combined speed of the 4 Mecanum wheels is the speed and direction of the moving body of the handling robot.

3. End effector design

The gripping mechanism (also called end effector) of the handling robot is the key part of the handling robot. Its design must have a certain degree of reliability, which is very important for the accurate handling and stacking of the objects. Therefore, when designing the manipulator claw, the manipulator claw must be considered to be compact. Moreover, the volume and quality are reduced.

Common objects to be transported are mostly logistics boxes and rod-shaped items. In order to ensure the integrity of the goods when handling heavy logistics boxes, it is not suitable to be grasped by direct clamping. This article proposes a unilateral opening and closing inserting rack clamping manipulator. The manipulator is mainly dragged by the insertion frame structure at the lower end, and then closed and grasped by the semi-circular arc claw at the upper end, which plays an auxiliary grasping role. The inner surface of the insert frame and the semi-circular arc gripper are glued with black rubber non-slip mats, which increase the friction and have a certain buffer effect when clamping the handling logistics box or rod-shaped materials, which are shown in Fig. 3.



a) Vertical movement b) Lateral movement

c) Move diagonally d) Rotate in place

Fig. 2 Force analysis of mobile body

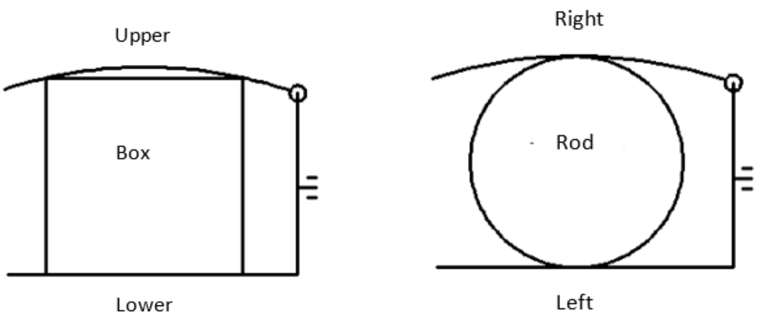


Fig. 3 Diagram of manipulator claw

According to the shape of the object to be transported and the relevant design technical parameters of the prototype, the SolidWorks software is used to perform 3D modeling of the robot grip, as shown in Figure 4. When carrying items in the box, the items placed on the bracket are lifted by the inserting frame structure. And then the semi-circular arc claw at the upper end rotates around the motor shaft within a certain angle range to achieve unilateral opening and closing movement. It can also realize the transportation of other rod-shaped objects by opening and closing one-sided by rotating the wrist 90°. Taking into account that the manipulator should have a self-locking function, the semi-circular arc gripper force transmission mechanism at the upper end is driven by an AC servo motor with self-locking.

4. The design of the robotic arm

The functions to be completed by the handling robot are positioning, grasping, handling and placing. This requires the cooperation within the mobile body and the manipulator. The mobile body provides all-round movement of the handling robot, and the manipulator needs to be responsible for the grasping of items. The manipulator includes the grasping mechanism and the mechanical arm. The grasping mechanism must ensure that the object can be grasped and kept still and cannot be damaged, the mechanical arm part requires the mechanical arm to be strong enough and flexible to operate.

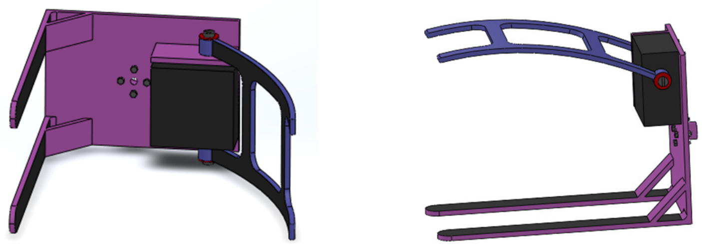


Fig. 4 3D model of the gripping mechanism

The arm mainly determines the movement space on the vertical plane of the handling robot. The structure of the arm directly affects the space limitations of the handling items when carrying items. If the structure design is unreasonable, the grasping mechanism will not be able to achieve what it should achieve. The grab function, in serious cases, can cause interference and damage to the entire organization. Through the analysis of the characteristics and application places of Cartesian coordinate manipulator, articulated manipulator, SCARA manipulator, spherical coordinate manipulator and cylindrical coordinate manipulator, the handling robot in this article finally adopts the form of articulated manipulator. The mechanical arm is not only superior in the motion space, but also in the realization of complex motion postures, better than other structural forms of machines. According to the size of the mobile body model prototype of the handling robot, the final study is designed as an articulated mechanical arm with 4 degrees of freedom (excluding the grasping mechanism part). In order to avoid the interference between the robot arm and the mobile body, the virtual prototype is optimized, and the joint angle and the length of each arm can be obtained.

According to the size of the related design technical parameters of the prototype, the specific structure of the mechanical arm is designed. It is composed of three joints, four deceleration AC servo motors and a base structure, with a total of four degrees of freedom. They are one degree of freedom at the connection between the arm joint and the base, two degrees of freedom at the connection between these three joints, and one degree of freedom at the connection between the wrist joint and the grasping mechanism. As the intermediate structure connected with the grasping mechanism and the moving body, the mechanical arm requires reliable connection between them, especially the base part with the greatest force. Therefore, the strength of the base structure can be determined by the force at the farthest limit position of each joint arm.

The three-dimensional model of the handling robot model prototype is shown in Figure 4.

5. Conclusion

This paper proposes an omni-directional wheeled mobile handling robot, which uses a moving body with Mecanum wheels, a four-degree-of-freedom articulated manipulator (excluding the gripping mechanism) and a unilateral opening and closing fork-type gripping manipulator. The robot can ensure that the objects can be accurately grasped without damaging the objects when transporting. Moreover, the robot is flexible in movement and can freely turn and move in a small space.

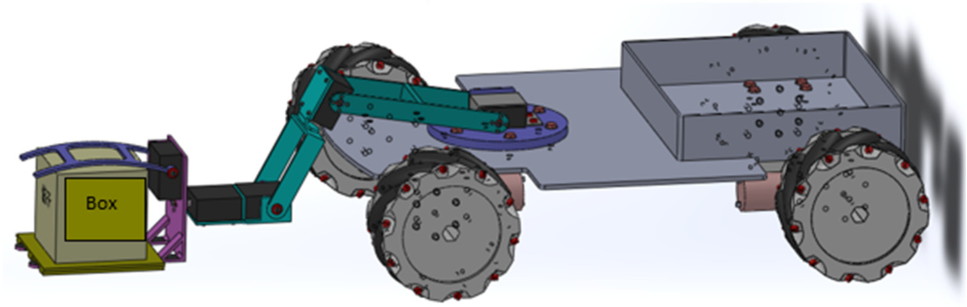


Fig.5 The handling robot grabs the three-dimensional model of the box

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References

[1] Dengyu Miao. Structure Design and Dynamic Performance Analysis and Optimization of Heavy-load Transfer Robot [D].Hefei University of Technology, 2014.

[2] Zhengyi Hu. Optimization Design and Simulation On Truss Transportational Manipulator [D]. Wuhan University of Technology, 2007.

[3] Canfeng He. Dynamic Simulation and Structural Optimization of Transporting Manipulator Based on Rigid-Flex Multibody Dynamics [D].South China University of Technology，2011.

[4] Hangyu Xu. Design and Realization of the Control System of Warehouse Handling Robot [D]. Nanjing University of Science and Technology，2017.

[5] Wei Li. Control System design of 6 DOF Industrial Robot. [D]. East China University of Science and Technology，2014.

[6] Yang Hu. The Design of the Hub Carrying Robot and Research on Control System [D].AnHui University of Science and Technology,2016.

[7] Chung Jae Heon,Yi Byung Ju, Kim Whee Kuk,Lee Hogil.The dynamic modeling and analysis for an om-nidirectional mobile robot with three caster wheels[J].Mobile Robot, IEEE, 1994,(3):3091 -3096.