Design of Intelligent Multi-layer Three-dimensional Bicycle Parking Garage

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Abstract. Along with the comprehensive construction of resource-saving, environment-friendly, low-carbon response to the call for green environmental protection. In view of the difficulties of bicycle parking, waste of public land resources and easy to lose, a new scheme of bicycle parking garage is designed. An automatic bicycle access system based on Arduino control chip is designed, including pneumatic and circuit control. Pneumatic control is used to grasp the bicycle manipulator; external circuit is used to process the input and output signals; AC and stepping motor are used to realize the lifting and horizontal movement of bicycle transportation. UG software is used to model, simulate and analyse the bicycle garage; Arduino software is used to write the control and management program of the automatic bicycle garage to realize the automatic access, record and safety protection functions of the bicycle. Through the establishment of the actual bicycle garage model, the feasibility of the design is verified; it has the advantages of convenient use, fast access to the car, high security, and high space utilization rate; it greatly saves the public land resources and facilitates people's travel. Foreword: in recent years, people's awareness of environmental protection has been strengthened, and the slogan of energy conservation and emission reduction has been put forward, and gradually a large number of shared bicycles have emerged. The use of bicycles is on the rise, which also leads to the difficulty of access to bicycles. The storage area covers a large area and is easy to be damaged and lost outdoors. In order to solve these problems and realize the concept of building an environment-friendly and smart city, the bicycle parking garage combines the intelligent system, and various intelligent parking garages emerge as the times require.

Keywords: Bicycle parking; Intelligent design; Bicycle garage; UG.

1. Introduction

At present, countries all over the world have developed mechanical stereo bicycle parking equipment with high parking density and small floor area. For example, some intelligent bicycle parking equipments have developed [1-3]. Most of the countries with limited land resources are developing vertical auto stereoscopic garage. Vertical auto stereoscopic garage is a kind of dense stereoscopic garage, which is only suitable for building in large shopping malls or hospitals and other public places. Because of its complex structure, high failure rate, high noise and slow access, this kind of equipment is not suitable for urban residential areas.

The domestic mechanical stereoscopic garage is mainly divided into lifting horizontal type, vertical circulation type, horizontal circulation type, multi-layer circulation type, plane movement type, vertical lifting type, simple lifting type and so on [4-8]. These types are mainly used in the parking of automobiles, among which the vertical lifting type, the horizontal lifting type and the simple lifting type are suitable for the parking of bicycle vehicles. Therefore, they are widely used in the design and
application of bicycle garage in the research at home and abroad. The design described in this paper can save capital construction investment, improve space utilization, and make the design more human-oriented, which not only ensures the safety of vehicles, but also improves the efficiency of vehicle collection.

2. The Overall Structure Design of Intelligent Multi-layer Three-dimensional Bicycle Parking Garage

2.1. Basic Principle of Intelligent Multi-layer Three-dimensional Bicycle Parking Garage

This intelligent multi-layer three-dimensional bicycle parking garage adopts the design concept of lifting and moving three-dimensional garage, and makes full use of three-dimensional space to design parking spaces to prevent collisions between vehicles. The intelligent multi-layer three-dimensional bicycle parking garage consists of two parts: mechanical control and electronic control. It is composed of the main frame, Arduino control system, bicycle lifting transmission system and parking space. The main body of the bicycle parking frame is built by square tube according to the shape of the field; the bicycle parking tray is installed at the intersection of square tube to improve the service life of the bicycle parking frame; the bicycle parking frame is fixed on the concrete ground as a whole; thus the bicycle parking frame is obtained. When the user needs to stop, put the car in the parking slot, click the touch screen, and select the corresponding storage location according to the vacancy fed back by the system. By pressing the function buttons of the touch screen and the position of the car, the system runs in turn according to the internal setting program after receiving the command, transmits the information to the Arduino controller, drives the AC motor and step driver, uses the AC motor to control the translation mechanism, and the frequency conversion and speed regulation of the step driver to control the lifting function of the lifting mechanism; and through the step The driver controls the forward and reverse rotation of the stepping motor to change the operation direction of the elevator. At the same time, the controller also controls the two position five way reversing valve in the pneumatic components to control the expansion and contraction of the transmission mechanism as well as the action of clamping and placing. After the intelligent parking garage senses the bicycle through the photoelectric sensor, the whole system will put the bicycle into the corresponding parking space according to the user's choice, the system will return the parking position to the LCD screen and display to inform the user after the car is parked; when the user clicks the touch screen, the system will take out the corresponding bicycle according to the user's identity identification.

2.2. Intelligent Multi-layer stereo Bicycle Parking Garage Translation Mechanism

The sliding mechanism of the screw rod is selected in the design of the translation mechanism, which is composed of an X-axis AC motor, a lead screw and a fixed optical axis. The AC motor is connected with the lead screw through the reducer; the lead screw and the optical shaft are respectively installed on the bottom plate through two bases. The y-axis base is installed on the slider of the lead screw and the optical axis through 8 nuts, so as to obtain the x-axis movement module, as shown in Figure 1.

![Figure 1. Lifting mechanism and bicycle parking frame](image)
2.3. Intelligent Lifting Mechanism of Multi-layer Three-dimensional Bicycle Parking Garage
The lifting mechanism adopts chain drive, which is composed of y-axis stepping motor, chain, aluminum profile and fixed optical shaft. The stepper motor is connected with the chain through gears, the aluminum profile is fixed on the y-axis base through the lower hole and angle steel, and the stepper motor is fixed on the top of the aluminum profile. The chain movement is driven by the motor, so as to control the lifting movement of the bicycle tray and complete the lifting requirements. Meanwhile, in order to deal with the emergency situation, a self-locking mechanism shall be set, so that the lifting mechanism can remain in place in the emergency situation, and the mechanism will not be damaged due to sudden falling, as shown in Figure 2.

![Figure 2. Lifting mechanism and bicycle parking frame](image)

2.4. The Transmission Mechanism of Intelligent Multi-layer Three-dimensional Bicycle Parking Garage
The transmission mechanism adopts the design of a new type of mechanical rodless cylinder and a mechanical clamping claw. During transmission, the extension of the rodless cylinder controls the forward and backward movement of the mechanical gripper, and then the mechanical gripper performs the action of clamping and placing. Two clamping claws of the manipulator are pneumatically controlled and fixed on the main body of the manipulator through two fixing pins. The manipulator is positioned at the end of the cylinder extension rod through screws. A small straight cylinder is installed in the main body of the manipulator. When high-pressure gas is introduced, the cylinder extends and ejects the auxiliary movement device of the clamping claw to clamp the bicycle. The position sensor is used to control the moving position of the pneumatic gripper actuator, and the actual position of the actuator is fed back to the control system at any time, and compared with the set position, and then adjusted through the control system, so that the actuator reaches the set position with appropriate accuracy, so as to complete the transmission task.

3. Structure Analysis of Intelligent Multi-layer Three-dimensional Bicycle Parking Garage
According to the UG finite element analysis of the maximum deformation and the maximum principal stress of the bicycle parking frame under the maximum bicycle load, the cloud chart is as shown in the figure below:
Summary of car parking results
Results summary Structural Results:
Coordinate system: absolute rectangular coordinate system
Load working number: 1

Table 1. Results of maximum displacement and main stress of parking frame

| Subcase – Static Loads 1 : Number of Iterations = 1 |
|-----------------------------------------------|
| Static step size 1 | Displacement (mm) | Stress(mN/mm^2(kPa)) |
|                   | X     | Y    | Z    | Magnitude | Von- | Min Principal | Max Principal | Max Shear |
| Max               | 003 6.098e+003 | 5.572e+005 | 1.540e+001 | 9.167e+000 | 4.082e+005 | 5.986e+000 | 2.447e+005 | 2.163e+005 |
| Min               | 003-6.271e+003 | -6.166e+000 | -4.209e+000 | 0.000e+000 | 2.367e+000 | -1.076e+000 | 1.076e+000 | 1.364e+000 |

The results of the maximum displacement and the maximum principal stress of the parking frame can be obtained from formula 1. Therefore, from the fourth strength theory formula
Therefore, the bicycle parking frame conforms to the use strength condition of the fourth strength theory. Based on the results of finite element analysis, the topological optimization of UG is carried out, and the three-dimensional dimensions of bicycle parking tray and bicycle frame are input respectively, and the solution results can be obtained:

The bicycle tray shall be designed with an upward inclination of 15 degrees to prevent the bicycle from falling due to plastic deformation, while the vertical support bar of the bicycle parking frame shall be designed with a small shape of the upper part and the lower part, so as to resist the bending deformation and the instability of the overall structure of the bicycle frame.

4. Conclusions

This paper summarizes the advantages and disadvantages of various garages by studying the current situation of bicycle parking at home and abroad, and designs the intelligent three-dimensional multi-layer bicycle parking garage based on the current situation of domestic bicycle parking. The garage can make full use of the above ground and underground space, with three times of the space utilization rate of the general ground garage; solve the problem of insufficient bicycle parking space, through calculation and finite element analysis and design, get the final structure of the garage, which runs well in the actual application of the validation process, and has a strong market application value.

Acknowledgments

This project was supported by the General Program of Chongqing Natural Science Foundation (Grant No. cstc2019jcyj-maxmX0812), Science and Technology Research Program of Chongqing Municipal Education Commission (Grant No. KJQN201901308, KJQN201901313), Chongqing University of Arts and science talent introduction project (Grant No. R2018SJD17, R2019FJ005), and Yongchuan Natural Science Foundation Project (Grant No. Ycstc, 2019nb0802).

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