Research on the Application of Computer Aided Technology in Mechanical Innovation Design

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Abstract—In this paper, Creo technology as a means to achieve innovative suspension design is described, for example, computer-aided 3D modeling technology in mechanical product design, kinematics analysis, application of intelligent control and other aspects. Through sample manufacturing verification, the shoe cabinet has stable performance and reliable operation, and summarizes the feasible application methods and advantages of computer-aided technology in the innovative design of mechanical products.

1. Introduction

The rapid development of science and technology, product life cycles continue to shorten, leading to constantly shorten product development cycles, in order to timely develop products to meet people's needs, CAD technology plays a very important role. Computer-aided technology is the use of computers and graphics technology to help designers perform design work, realize the intelligence and automation of product development, and improve the accuracy and efficiency of product design \cite{1}. Computer-aided technology is more of a single modular application in certain aspects such as product modeling, kinematic analysis, finite element analysis, product circuit design, and intelligent control. There is no systematic application for product development.

This article takes the product development of a suspended smart shoe cabinet as an example, from conceptual design-mechanical design-intelligent control, systematically expounds the application method of computer-aided technology in product innovation and development. This article solves the application problems of computer-aided technology in product design and development, and provides a feasible example for the innovative design and development of mechanical products.

2. Innovative concept design-hanging smart shoe cabinet

With the development of science and technology, automation and intelligent products continue to enter people's lives, but the degree of intelligence of shoe cabinets still cannot meet people's needs. Nowadays, shoe cabinets on the market mainly include ordinary shoe cabinets and smart care shoe cabinets. Ordinary shoe cabinets are simply placed horizontally or flipped horizontally, and their main function is storage; while smart care shoe cabinet products are more of an added care function on the basis of ordinary shoe cabinets, such as drying, deodorization, ozone disinfection, etc. When storing shoes in
these two types of shoe cabinets, people need to open the door, look for empty shoe spaces, and then put the shoes in. Whether it is an ordinary shoe cabinet or an intelligent care shoe cabinet, it has failed to solve the problem of automation when accessing shoes, especially when there are many types of shoes, it will bring troubles to people. Therefore, there is an urgent need to develop a smart shoe care cabinet that takes up less space, has a large storage capacity, and is easy to access shoes.

The innovative concept design of the hanging smart shoe cabinet will realize the hanging storage of shoes, which can realize automatic storage and disinfection care. All actions are intelligently controlled by single-chip microcomputers and use of the Internet of Things technology for Internet phone APP according to market demand.

3. Working Principle of Suspended Smart Shoe Cabinet

The shoe cabinet is divided into an access area and a storage area. The main function access area to achieve storage and retrieval shoes, hanging storage area using stored nursing shoes. Smart intelligent shoe is mainly reflected in the care process to achieve full access to the shoes of automatic identification, automatic positioning and automatic operation.

When storing shoes, the control system judges the shoe layer of the empty shoe position, and then the lower plate of the shoe box turned up 90°, the whole shoe box turned 60°, put in the shoes, the camera photographs are transmitted to the control system for storage and the LCD display, the shoe box overall rotation is 60°to reset. At this time, the hook enters the shoe mouth, the lower plate of the shoe box is turned down 90°, the gravity of the shoe is used to complete the shoe suspension action, the control system judges whether the shoe layer is full, and the suspension component rotates to the empty shoe position. The ball screw nut module drives the shoe box to switch between shoe layers, and finally reset.

When taking shoes, select the shoe picture or number through the LCD display. The ball screw nut module drives the shoe box to move down to the shoe layer access area. The suspension component rotates to select the shoes. The shoe stays in the shoe access area. The bottom plate of the box is turned over and drags the shoe to move away from the hook. Due to the shape of the shoe, the heel is heavy and the shoe is inclined to leave the hook first, its gravity falls back into the shoe box, and then the ball screw nut module drives the shoe box back Fixed access to the shoe area, the overall shoe box is turned 60°, the shoes are removed, the shoe box is rotated 60°, the lower plate of the shoe box is turned down and reset to complete the removal of the shoes, and finally reset.

4. Mechanical innovation design of the main mechanism of the smart shoe cabinet

In order to make the model of the smart shoe cabinet easier, it is advisable to use a two-layer shoe cabinet, and the innovative design of the mechanical structure uses computer-aided software to design the bottom-up method. Firstly use visualization methods to calculate and analyze the main structural components, determine the size of the components, and then use computer-aided software to draw a three-dimensional model, optimize the design plan through assembly, motion simulation, finite element analysis, etc. Finally, a virtual model that meets functional requirements and customer requirements is formed.

4.1. Innovative structure design

4.1.1. Scheme design of shoebox turnover mechanism.

The turning of the shoe box is divided into two parts: the whole turning mechanism of the shoe box and the turning mechanism of the lower plate of the shoe box. The shoe box integral turnover mechanism realizes the automatic storage and retrieval function of the shoes. The mechanism turns outwards to open the shoe box, puts in or takes away the shoes; resets and hangs the shoes. The valgus angle of the shoebox is designed to be 60° and can be reset. This function is planned to be realized by a plane linkage mechanism, as shown in Figures 1 and 2.
The active part is an electric push rod with a stroke of 750mm. When the push rod is extended at the limit position, the shoe box is in a vertical state; when the push rod is retracted, the connecting rod is pushed to drive the shoe box to turn out by 60°. Therefore, it is necessary to determine the retracted position of the push rod, the length of the connecting rod, and the distance between the turning center of the shoe box and the positioning hole of the connecting rod. Designed by drawing method, the two limits of the shoe box are drawn proportionally in AutoCAD software, so as to directly obtain the length of other rods. As shown in Figure 1. The distance between the shoe box turning center and the bottom of the shoe box and the bottom plate is 50mm and 15mm respectively; the shoe box and the connecting rod are located 70mm above the turning center; the connecting rod length is 143mm.

4.1.2. Scheme design of shoe box up and down movement mechanism

In order to realize the switching of the smart shoe cabinet between shoe layers, the shoe box needs to reciprocate up and down, and this part is realized by a ball screw nut mechanism. The shoe box and the electric push rod of the turning mechanism are installed above the ball screw and nut mechanism, and the movement stroke is 750mm.
4.1.3. Design of sprocket and chain mechanism

The storage area of the shoe cabinet is preliminarily designed with two layers. The shoes are accessed in a hanging mode. The selection of shoes is realized by rotation when the shoes are accessed. Therefore, a sprocket and chain mechanism is adopted. The sprocket chain mechanism is proposed to adopt the standard GB/T 1243-1997 roller chain 08A with a pitch of 12.7mm. The sprocket adopts an integral structure, drills a hole with a diameter of 16 and a keyway, and connects to the shaft to achieve rotational movement, as shown in Figure 4.

According to the overall design, the chain length is set to 1000mm, the chain pitch is 12.7mm, the number of chain links is 80, and the number of teeth of the sprocket is 24. Each time the shoe is stored (or retrieved), the sprocket rotates 0.7 times. The distance between the two pairs of shoes after suspension is $17 \times 12.7 = 215.9$mm, which is 216mm. The shoe taking time is 5s, the motor speed is set to 85r/min, then the chain speed is

$$v = \frac{24 \times 12.7 \times 85}{60 \times 1000} \approx 0.43 \text{ m/s} \leq 0.6 \text{ m/s}$$

This chain drive is a low-speed chain drive. Therefore, the main failure form of the chain drive is the overload of the chain, so the static strength calculation should be carried out, and the static strength safety factor should be checked.

$$S = \frac{F_{W} \cdot m}{K_{a} \cdot F} = \frac{1163 \times 1}{1 \times 1000 \times 0.1} = 5 \geq 4 \sim 8$$

Meet the safety factor requirements.

Figure 4 Sprocket chain

The motor and the sprocket need to be connected by a shaft. The sprocket shaft is divided into a driving shaft and a driven shaft, and the structure of the shaft is designed according to the height of the shoe layer (290mm). One end of the driving shaft is connected with the coupling and the motor, and the other end is connected with the sprocket through a key, and is fixed by a bearing seat. The driven shaft is also connected with the sprocket through the key, and the two sides of the shaft are fixed on the upper and middle layers of the shoe cabinet through the bearing seat. According to the diameter of the sprocket $\Phi 16$mm and the thickness of the sprocket $25$mm, the model of the selection key is A5, the national standard GB/T1096-2003, and the length is 18mm.

4.2. Computer Aided Design and Kinematics Analysis

4.2.1. Computer Aided Design Application

Through the above calculation of the main components, determine the size of non-standard parts and the selection of standard parts. In order to quickly realize the design and manufacture of products, standard parts are selected as much as possible. The advantage is that they can be purchased directly, saving design and manufacturing time, and it is very convenient to purchase, such as the ball screw nut pair in the smart shoe cabinet. For non-standard parts that need to be designed and manufactured, the computer-aided three-dimensional design software creo is used to draw the part model and assemble according to the design requirements. Computer-aided design technology can make graphics quickly and intuitively, and designers can make judgments and modifications to the design in time; the computer can be used to process graphics data related to graphics editing, enlargement, reduction, translation, and
rotation. CAD can reduce the labor of designers, shorten the design cycle and improve design quality. The assembly drawing is shown in Figure 5. [5-6]

![Assembly drawing of smart shoe cabinet](image)

**Figure 5 Assembly drawing of smart shoe cabinet**

In the figure, 1 is the upper plate, 2 is the turning mechanism, 3 is the ball screw nut, 4 is the electric push rod, 5 is the frame, 6 is the sprocket chain, 7 is the shoe box, 8 is the motor, and 9 is the shaft.

### 4.2.2. Kinematics analysis of smart shoe cabinet

The design and modeling of the product only complete the hardware setting of the product. Whether the hardware setting can realize the corresponding functional actions is still uncertain. Computer-aided technology can help designers achieve motion simulation products, in order to verify the established conditions, product design meets functional requirements, improve product development efficiency and cost savings.

After completing the assembly and constraints of the smart shoe cabinet, enter the Creo mechanism simulation module to simulate the corresponding motion mechanism, as shown in Figure 6.

To define the sprocket chain, you can use manual drag to test the operation of each movement mechanism. Then set the rotation speed of the driving sprocket motor, the rotation speed of the ball screw motor, and the rotation speed of the electric push rod motor to perform the motion simulation. During the simulation, Should interference occur, the product will stop the motion and interference prompted an error message, the designer of the product after further modification motion simulation again. By observing the movement process of the product, it can be designed to meet the functional requirements of the product, and the later work can be continued. [7-8]

![Motion simulation of smart shoe cabinet](image)

**Figure 6 Motion simulation of smart shoe cabinet**

### 5. Intelligent control circuit design

The intelligent shoe cabinet control system adopts single-chip microcomputer to control operation. The control system consists of hardware and software. The circuit hardware of the whole machine is composed of STC12C5A60S2 single-chip microcomputer, touch color screen, stepping motor, L9110 drive module, electric push rod, limit switch, etc. The software part uses computer-aided technology Keil uVision4 software to write and modulate the program. Finally, after the joint debugging of the software and hardware in the Proteus software is correct, PCB technology can be used to design the
hardware circuit of the smart shoe cabinet control system and make a plate, and the software program is loaded into the single-chip microcomputer.

![Figure 7 Keil uVision4 program debugging](image7)

![Figure 8 Control system hardware structure](image8)

6. **Experimental performance and results of the smart shoe cabinet**

According to the design requirements of the smart shoe cabinet, complete the installation and commissioning of the product. And carry out the functional test of the smart shoe cabinet, which can successfully complete the automatic access and ozone disinfection functions of the shoes. The disadvantage is that the smart shoe cabinet can only access shoes with heels and store shoe sizes and sizes, but not all of them. The product will be optimized and modified later.

![Figure 9 Physical map of the smart shoe cabinet](image9)

7. **In conclusion**

Hanging intelligent shoe production control from design and development, to production and development of intelligent computer-aided technology, the whole process has involved and play a very important role. The design provides a visual modeling motion simulation process. The development of the intelligent control system system also improves the efficient and feasible simulation process.
Through the innovative design case of the suspended smart shoe cabinet, it is found that the product design and development have been closely integrated with computer-aided technology. It is an indispensable technical means to achieve efficient and feasible product development.

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