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Design and Development of Large Electric Curtain Control System for Time Controlled

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대형전동커튼 타임제어 시스템 설계 및 개발

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ABSTRACT

The purpose of this paper is to design a curtain control system for centralized management of large curtains, which includes curtain structure, electric curtain controller, communication system, user interface and remote control. Curtain structure is designed to avoid using limit switch. The system is based on microprocessor, determined the stop position and complete running time of electric curtain through time control, and achieved remote control of curtain opening and closing through wired and wireless communication modes. By establishment of a mathematical model to calculate the inertia compensation time of the electric curtain, the electric curtain can be stopped ahead of time, and the curtain can be completely closed by the inertia. The result of test experiment of 32 electric curtain controllers shows the communication success rate reached 100%.

Keywords : Electric Curtain(전동 커튼), Time Control(시간 제어), Inertia Compensation(관성 보정), Microprocessor (마이크로프로세서)

1. Introduction

Curtains have been inseparable from our living environment. The main purpose of curtains is to separate the indoor environment from the external environment, to play the role in shading and protecting privacy. At the same time, curtains play a certain role in interior design, which is essential for the combination of functionality and decoration in interior design. With the construction of large-scale infrastructure, indoor glass windows are large and locate in high place. A series of problems caused by indoor sunlight can be solved by curtain shielding. The traditional manual curtain system has been unable to meet the control requirements of large venues.[1] Electric curtain can be controlled by remote switch, which has the advantages of flexible operation and easy centralized management.[2] Therefore, it is ideal to install large electric curtain control systems in large venues.

Since the electric curtains entered the market, they

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have been favored by consumers. Electric curtain control systems have been developed to thousands of different types, and the market prospects are very impressive. Nowadays, the electric curtains in the market have become more and more comprehensive, and developed at low cost.

The electric curtains are generally driven by a motor, and the opening and closing control of the curtains is realized by changing the sense of rotation of the motor. The types of motors generally include: AC motors, DC motors, stepper motors, brushless motors, etc.[3-4] The working principle of the curtain is that the belt is installed in the closed curtain rod cavity, the belt is driven by gear, and the curtain is pulled through the belt to pull the lifting ring to realize the opening and closing of the curtain.[5] The AC motor can be directly driven by the mains, no need for an additional AC-DC converter, and its driving power is large, which can drive heavy-weight curtains to move.

Somfy is committed to researching smart home control systems, including electric roller blinds, electric blinds, and electric opening and closing curtains in the field of window coverings. The fabric opening and closing curtain developed and designed by the company has the characteristics of low running noise and stable running speed. It has the function of “hand touch”, that is, the hand-operated curtain can touch the motor to run, and with the function of sunset timing, it can be lowered or opened at night. The curtains are automatically pulled when the lamp is on. Combined with radio technology, the remote control can be used to control the opening and closing of the curtain. The TaHoma One control box can also be installed and operated from a tablet or mobile phone.

Korea YOUGUN company is committed to the development of curtain-type power system, its main products include electric projection screen, electric roller blinds, electric blinds, electric opening and closing curtains, etc., using Korean GGM motor, power 6W/15W/25W/45W, single motor work It can be controlled by switches and remote controls, and can be opened and stopped immediately.

The limit switch is more complicated when installed and the cost is higher. Therefore, we have designed a time control to replace the limit switch's electric curtain control. And designed a centralized curtain management system, the system can be controlled by the touch screen, remote control, the channel can choose wired channel, 2.4G or 433MHZ wireless channel.[6-8] By establishing a mathematical model to calculate the inertia compensation time of the electric curtain, the motor stops running ahead of time, and the complete closure of the curtain is realized by the inertia of the boom.

2. Design of System Structure

2.1 Track Design

The traditional electric curtains drive the belt to move the boom through gears, and controls the curtain opening and closing by changing the rotation direction of the motor. Two limit switches respectively located in one section and the middle part, which is used to judge when to stop the motor, where the curtain reaches open or close completely. Some electric curtains mount encoder sensor on the motor to determine where the boom is located. AS shown in Fig. 1, these type of methods have the problems of complicated installation, additional cost, and inconvenience in maintenance. This study can eliminate the additional positioning device and simplify the track structure by proposing a time-controlled method.

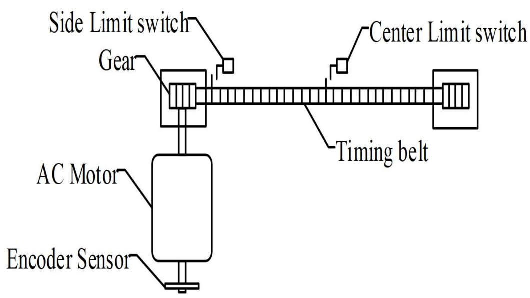

Fig. 1 Traditional electric curtain drive mode

The track is made of high-quality aluminum alloy material track. The track surface adopts ultra-quiet electrophoresis technology instead of spray paint. The electrophoresis process makes the track smoother, the track opening and closing operation sound is smaller, and it can be more resistant to friction and humidity. The track is corroded and has an extremely longer lifetime. In addition, the aluminum alloy body has good heat dissipation, preventing the rail from overheating and affecting the service life of the fuselage. The control mode can be combined manually and electrically, and can be switched freely. In the power-off state, the curtain can be manually pulled, and the operation can be automatically stopped when the track is blocked to prevent damage. The electric curtain track is easy to install, and is basically similar to the ordinary track installation method and is convenient to use. The control mode can be manually, switched, remotely controlled, touch screen, etc., and can be controlled by single or group, which is convenient and flexible to use. The electric curtain track has a beautiful overall appearance and a wide range of applications, and is suitable for gymnasiums, offices, leisure, entertainment and other places.

2.2 Design of Control Mode

In order to meet different control requirements, this study designed a variety of different control methods, including touch screen control, remote control and switch control. As shown in Fig. 2, Each controller is equipped with a manual switch for manual control of each electric window shade. Each controller can be connected via RS485 bus and controlled centrally or separately via touch screen or remote control. At the same time, each controller also has a wireless transceiver module, which enables wireless control in the case of inconvenient wiring. The wireless frequency band is set on the 433MHZ or 2.4GHZ free frequency band, and the interference is prevented by setting different frequency bands.

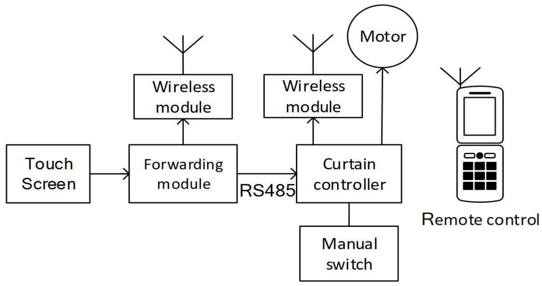

Fig. 2 System communication structure

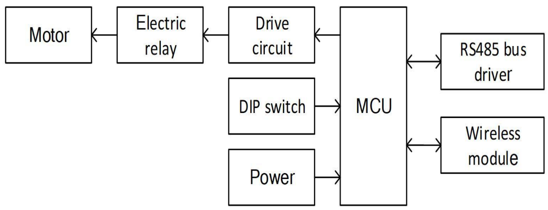

Fig. 3 Controller composition block diagram

Each system is equipped with a unique forwarding module, which is the transit hub for the entire system communication. The function of this module is to receive the instructions from the touch screen or remote control then forward the instructions to all control modules according to the communication mode set by the user. The forwarding module is also capable of receiving instructions from the controller and displaying them on the screen for verifying that the communication is functioning properly.

2.3 Controller Composition

As shown in Fig. 3, the MCU is the core of the controller. The serial number, curtain type and other parameters are set by the DIP switch. The MCU receives data through the RS485 bus or the wireless module. Two electronic relays are controlled by the driving circuit to make the motor forward or reverse to achieve the purpose of opening or closing the curtain.

2.4 Controller Workflow

When the system is powered on, the controller start initializes first, the initialization includes the communication mode setting and module initialization, reads the saving parameters of position and operation information last time, and calculates the inertia compensation time according to the type of the curtain set by the dial switch. The controller enters the wait instruction mode after the initialization is completed. When the controller receives data, the microprocessor will arrange the received data, verify the data frame header and footer then intercept the intermediate data, and perform a CRC check to ensure that the received data has not been tampered. After the data verification, the microprocessor will parse the instruction in the data packet, and determine whether the instruction is valid for itself according to the number. After the verification number is the same, the microprocessor will start or stop the motor according to the type of the instruction, according to the position and time information recorded, microprocessor calculates the time to stop the motor running. When the stop time is reached, the microprocessor stops the motor running. During the operation of the motor, the micro-control can still receive and verify the data through the interrupt, ensuring that the instruction will not be missed.

3. Inertia Compensation Time Calculation

Since the AC motor continues to rotate due to inertia when it stops, in order to completely close the curtain, the motor must be stopped beforehand. This time we call this inertia compensation time. As long as the inertia compensation time is known, the microprocessor can grasp the position of the boom whenever the motor is stopped.

Through several experiments, the mathematical model is established under the conditions of different power motors, different track lengths, different curtain heights and different suspension angles.

$$T = K_w \times W + K_h \times H + K_f \times K_\theta \times \tan\theta \quad (1)$$

Where W is the motor power; H is the height of the curtain, θ is the angle of inclination relative to the horizontal curtain, and K_w, K_h, K_f, and K_θ represent the corresponding parameters. Different motor power, track length, track height, and suspension tilt angle are selected. After a large number of experiments, a large amount of experimental data is obtained to determine the coefficient of the mathematical model and the calculation formula of the inertia compensation time T is obtained. When the curtain is in an open state, the inertia time parameter T is:

$$T = 11.2364W + 4.218H + 0.968 \times \tan\theta \quad (2)$$

When the curtain is closed, the inertia time parameter T is:

$$T = 11.2364W + 4.218H - 0.968 \times \tan\theta \quad (3)$$

The pre-stop time calculated by the mathematical model is compared with the time determined by the actual experiment to determine that the model is consistent with the actual situation, and the effect of complete closure is achieved in the actual control process. Fig. 4 to Fig. 7 are the comparison between the calculated value of the inertia time and the actual value of the curtain with a motor length of 15W and 25W, a track length of 5 meters and a curtain length of 10 meters at a tilt angle of -30 to 30 degrees. The error range is 1~3 milliseconds. Fig. 8 shows the comparison between the theoretical calculation value and the actual value of the inertia compensation time as the length of the curtain track is 5 meters, the length of the curtain is 10 meters, and the inclination angle of the track is 0 degrees. The error range is 1 to 10 millisecond. Fig. 9 and Fig. 10 show the theoretical calculation of the inertia time and the actual value of the motor power of 12W and 25W, the track length is 5 meters, the inclination angle is 10 degrees, and the curtain length varies from 5 meters to 15 meters. The error range is 1 to 4 milliseconds.

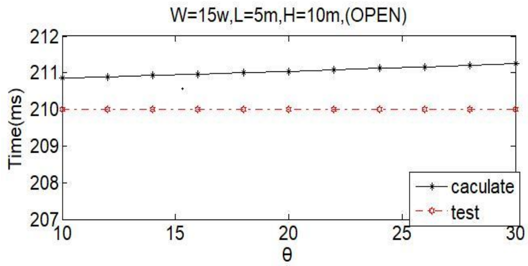

Fig. 4 Theoretical calculation and actual value comparison

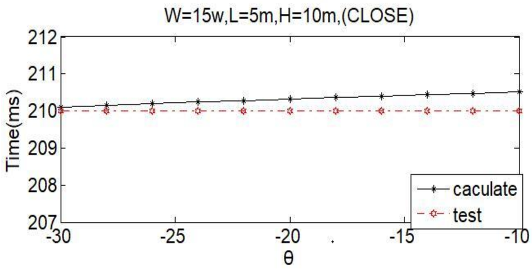

Fig. 5 Theoretical calculation and test value comparison

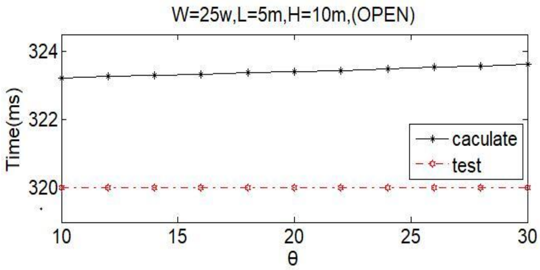

Fig. 6 Theoretical calculation and test value comparison

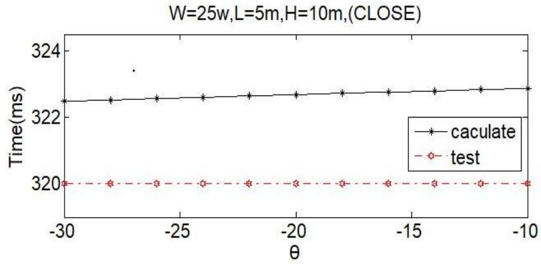

Fig. 7 Theoretical calculation and test value comparison

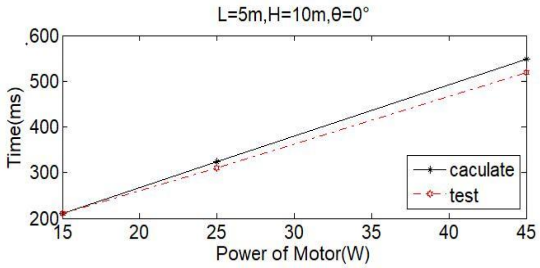

Fig. 8 Theoretical calculation and test value comparison

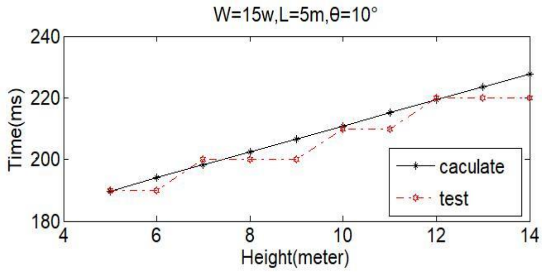

Fig. 9 Theoretical calculation and test value comparison

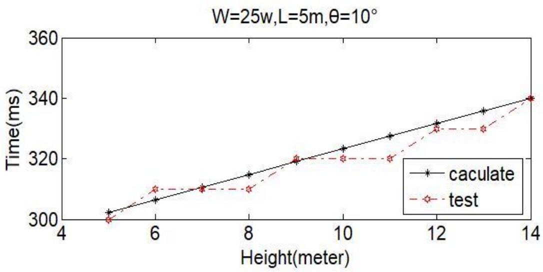

Fig. 10 Theoretical calculation and test value comparison

4. Conclusion

In this paper, we designed a time-mode-controlled operation of the electric curtains. The micro-controller records the time the curtains are running to determine the position of the boom on the track and determines when to stop the motor when the curtains are fully open or closed. Since the boom still has inertia after the motor stops running, the relationship between the inertia compensation time and the motor power, track length, curtain height, and track tilt angle is found experimentally. The accuracy of the theoretical calculation is determined by comparing the theoretical calculation with the actual inertia time value.

We also designed remote centralized control of systems with multiple electric curtains via screen or remote control. According to different usage scenarios, RS485 bus communication mode, 2.4GHZ or 433MHZ free frequency band communication mode can be adopted to meet different interference environments and installation requirements. At the same time, each curtain is also equipped with a manual switch for individual control in a specific scene. The electric curtain designed in this paper has the following advantages:

1) The limit switch or encoder sensor is eliminated on the electric curtain structure, which makes the installation easier and requires no additional wiring, which reduces the cost and is easy to maintain.
2) By setting a variety of different communication methods, it can meet different user needs, and can achieve centralized control and management in large venues.

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