An Indoor Lighting Facility without Power Supply Based on Fiber-optic Guided Natural Light

Zikai Zong1, Licai Cao2 and Xinhong Xiong1*

1Department of Mechanical Engineering and Automation, Wuhan University of Technology, Wuhan, Hubei, 430070, China
2Department of Mechanical Engineering and Automation, Wuhan University of Technology, Wuhan, Hubei, 430070, China
*Corresponding author’s e-mail: 10691907@qq.com

Abstract. In underground parking lots and the like, lighting devices are required during the day because there is no medium such as windows that allow sunlight to enter. In addition, in many buildings, due to lack of lighting, lighting is also required during the day, which causes a great waste of energy. In view of the above situation, an indoor lighting facility based on fiber-optic natural light-based power supply is designed. This design is mainly divided into three parts: mechanical concentrating platform, optical fiber transmission part and light diffuse reflector. By arranging a mechanical concentrating platform that can receive sunlight and install solar panels and concave mirrors in a place where the light source is received, the received natural light is transmitted to the room through the optical fiber with extremely high transmittance, and passes through the room. The astigmatism device distributes the natural light transmitted into every corner of the room as much as possible. This design can greatly save the use of electrical energy.

1. Research background and significance

1.1. Research background
After the human society entered the 21st century, both in China and in the world, in order to adapt to the needs of the development of productive forces and promoted by science and technology, all the building facilities are almost in the direction of large-scale and high-level development, and large Some of the public buildings have space in the ground, such as public parking. In the process of development, humans have made every effort to develop the space available to accommodate more and more people, but more and more problems have also been exposed. Among them, how to solve the lighting problem in the building interior has become a point of widespread concern.

Like in an underground parking lot, there is no medium such as a window that allows sunlight to enter, so we have to install lighting lights in the underground parking lot, and people in such places do not stay all the time, but the lights remain illuminated. The state, which caused a lot of energy waste. In addition, due to the large-scale and high-rise buildings, it is difficult to ensure that even if any part of the space above the surface of the building can receive sufficient sunlight during the day, there is still a need to turn on the lights during the day. And in places like office buildings and office buildings, sometimes the angle of sunlight is not ideal, which makes people feel glaring, so many people choose to use curtains to block the sun and use electric lights to illuminate. Based on the above background, I have designed the relevant institutions and devices for the current problem of power waste. Based on
the theory that optical fibers have very high transmittance of natural light, an indoor lighting facility without power supply is designed, which integrates collection, transmission and release of natural light guided by optical fibers.

1.2. Research significance
(1) Reduce lighting power consumption in public places and avoid energy waste. The use of new energy is in line with social development trends, ensuring energy security and promoting sustainable economic and social development.
(2) Lighting is guided by natural light to guide the natural light, which is of great benefit to the human body and meets the current social needs.
(3) At present, solar panels are mainly used to supply indoor lighting, but solar panels are expensive and difficult to maintain, and are not suitable for areas with more rainy days. Compared with solar panels, optical fibers are inexpensive and easy to use, enabling efficient collection and efficient transmission of natural light.

2. Design

2.1. Overall design ideas
This design is mainly divided into three parts: mechanical concentrating platform, optical fiber transmission part and light diffuse reflector. Set up a mechanical concentrating platform which can accept sunlight in the place with better light source. The device is equipped with solar panels and concave mirrors to collect outdoor sunlight. The mechanical concentrating platform can follow the direction of the sun movement under the control of single chip computer to achieve the effect of fully concentrating sunlight. Finally, the natural light transmitted into the room is dispersed to every corner of the room as much as possible through the indoor astigmatism device. At the end of the diffuse reflectance astigmatism device, there is also a LED supplementary lamp. The power supply of the LED supplementary lamp comes from the solar panels on the mechanical concentrating platform. The existence of LED supplementary light ensures the stability of indoor lighting and is not affected by the change of outdoor lighting.

2.2. Research content and key technologies
(1) The mechanical concentrating platform of this design can track daylight.
(2) Solar optical fiber coupling technology is used at the junction of optical fibers to avoid refraction and reflection due to the discontinuity of propagation medium, so that natural light is introduced from outdoor to indoor as far as possible through optical fiber medium;
(3) In order to distribute the light as much as possible to every corner of the interior space, a specular diffuse reflector is added to the design. Natural light is dispersed into the interior of the room through a specular diffuse reflector after entering the room;
(4) When the external light is weak, the LED fill light will add an additional light source to the fiber to ensure the stability of the light.

3. Overall design

3.1. Functional design
1) This design has the function of automatically following the sun's rotation and receiving the sunlight to the maximum extent.
2) It has the function of conducting natural light. Using the solar optical fiber coupling technology, natural light can pass through the optical fiber medium to the maximum extent.
3) It has automatic light compensation function, and LED light compensation lamp can ensure the stability of light.
4) It has the function of self-supplying electric energy and does not need external power supply. The solar panel is used as the power supply of the device.

5) It has the function of utilizing outdoor natural light to illuminate.

3.2. Structural design
1) Mechanical Concentrating Platform
   Concave mirror
   Gear mechanism
   Light-guide fiber
   Solar panels
   Push rod motor
   Gear motor
   Floor platform
   Supporting truss

   Figure 1 Mechanical Concentrating Platform

   The mechanical concentrating platform rotates itself through the engagement of gear mechanism. The inspiration for designing this mechanism comes from the positive of sunflower. The data measured by photosensitive sensor and gyroscope are transmitted to single chip computer. The single chip computer controls the push rod motor to rotate the concentrating platform vertically and the decelerating motor to rotate the concentrating platform horizontally. Ensure that the concentrating platform keeps track of the sun's trajectory to ensure that sufficient sunlight can be collected. The mechanical concentrating platform uses the concentrating principle of concave mirror to concentrate the collected sunlight in the middle of the optical fibers. As shown in Fig.1, the light intensity of the collected sunlight is enhanced. The power source of single-chip computer, sensor and motor driving the mechanism is the solar panels on the mechanism. In this way, no additional power supply is needed for the whole machine to work.

2) Optical fibre transmission part

   The sunlight collected by the mechanical concentrating platform is transmitted through the optical fibers. Now the transmittance of the optical fibers on the market can reach more than 90%. At the joint where the two optical fibers are connected, a gap is often generated, which causes natural light to be refracted and reflected by the discontinuity of the propagation medium, so that the transmission
efficiency of natural light is greatly reduced. Therefore, at the fiber link, the design uses solar coupling technology to link to avoid the above situation, so that the natural light transmission efficiency is maximized. A plurality of optical fiber wires are distributed and integrated with a soft sheath outside to form a fiber bundle. A detachable fiber coupler is used between the fiber and the fiber. The fiber coupler is a Y-branch component, and the optical signal input by one fiber can be equally divided.

Plastic material is selected for optical fiber transmission part. Plastic fibers have high light transmittance, soft, flexible but not fragile, relatively low cost, easy access to all corners of the building, without too much limitation. Compared with quartz optical fibers, plastic optical fibers have the disadvantage of high temperature resistance. The solar-collecting fiber on an outdoor mechanical concentrating platform will be subjected to extreme heat, so at the input end of the fiber, the design uses quartz fiber to prevent the fiber from melting due to high heat.

3) Mechanical Concentrating Platform

The light diffuse reflector consists of a relatively rough acrylic material and is coated with a diffuse coating on the surface to diffuse the light on the surface of the material to achieve the best possible distribution of light to all corners of the interior space. The diffuse reflective coating is coated on the reflective surface of the lamp source to form a diffuse reflective coating. The point light source is changed into a surface light source, and the light is homogenized to improve the light efficiency. At the same time, the diffuse reflective coating can eliminate glare or spot and improve the reflective effect.

This design uses LED fill light. After the sensor senses the change of light, the MCU will control the LED fill light to adjust its brightness to ensure the stability of the indoor light. In the absence of daylight at night, the LED fill light can play a role in lighting. The LED fill light is powered by a solar panel and does not require an external power supply.

4. Feasibility analysis

4.1. Structural feasibility

The structural design is carried out by using SolidWorks, and the feasibility is analyzed by simulation software. After analysis and calculation, accurate technical indicators are obtained to verify the structural feasibility of the design.

4.2. Economic feasibility

The price of optical fiber using plastic and quartz in this design is relatively low, and the cost of the whole machine is lower than that of similar products on the market, and the prospect is broad.

5. Innovation

(1) Natural light is collected efficiently by the principle of concave mirror concentrating, and sufficient natural light is collected;

(2) With the application of solar optical fiber coupling technology, natural light is introduced from outdoor to indoor through optical fiber media to the maximum extent;

(3) The mechanical concentrating platform can rotate vertically and horizontally to better collect sunlight;

(4) Using single-chip computer to control LED light supplement lamp to ensure adequate light

6. Conclusion

Through market research, this paper analyzes the problems of low efficiency and high cost of existing fiber-optic transmission devices. In order to improve the collection efficiency and conduction efficiency of sunlight, the actual functions and structures are designed. It is suitable for a wide range of public places and family homes, so it has a wider range of applications.

By collecting and conducting sunlight for indoor lighting, a new way of using energy has been developed to achieve energy saving and emission reduction. Its promotion can reduce the dependence
on electric energy to a certain extent, thus achieving a more harmonious integration between man and nature.

Acknowledgments
First and foremost, I would like to show my sincere gratitude to my partner and teachers, who give me support during the research. Instead, I am extremely grateful for my parents for their constant encouragement.

References
[1] Zhang Jianchao, De Xuehong, Ge Yan, Yu Zhihong. (2018) Development of energy-saving solar tracking functional optical fiber guiding lighting equipment [J]. Mechanical design and manufacture, 12: 172-176.
[2] Si Wenyue, Zhiyong Jun, Lu Jie, Hao Mingyu. (2018) Fire-proof, explosion-proof and shock-proof lighting system based on optical fiber lamp technology [J]. Electromechanical information, 30: 26-27.
[3] Wang Cong, He Bing, Jiang Yan. (2017) New Progress and Prospect Analysis of Optical Fiber Lighting Technology Application [J]. Urban Construction Theory Research, 18: 107-109.
[4] Wang Congke, Zhou Dinghua, Yi Wei, Zhu Xiangbing. (2017) Microscopic illumination path design with built-in light guide fiber [J]. China Lighting Electrical Appliances, 01: 24-26.