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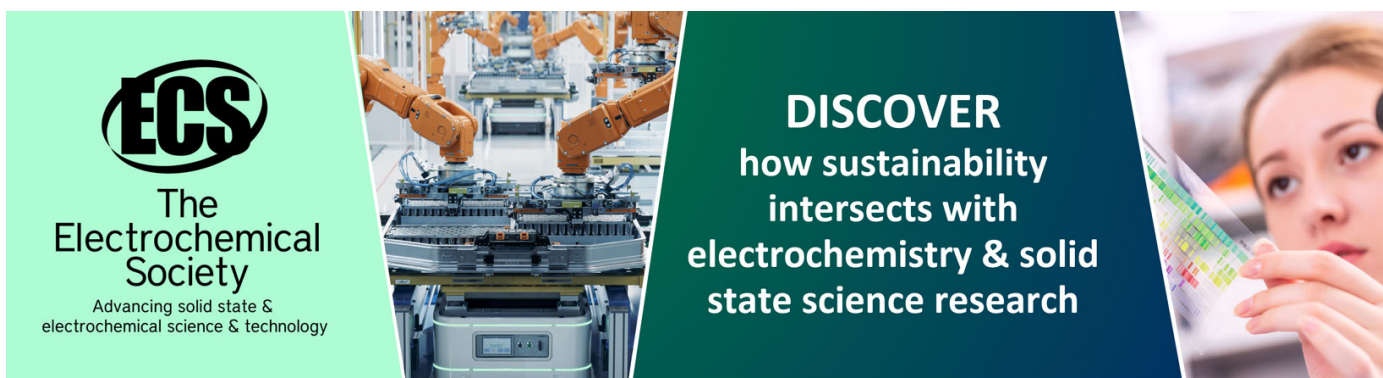
Study on the Performance of the Light Automatic Control Device

To cite this article: Zhiyong Li *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **237** 052064

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Study on the Performance of the Light Automatic Control Device

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Abstract. This paper presents a light automatic control device that can automatically adjust the sunlight indoors based on the solar radiation outdoors. This article researches the device's influence on indoor environment through experiments. Studies have shown that the illuminance of an experimental room with the device can be automatically adjusted according to solar radiation outdoors. When the solar radiation is strong, the illuminance of the experimental room about 30% lower than that of the comparison room which is not equipped with the device. When the solar radiation is weak, the illuminance of the experimental room is close to that of the comparison room. The difference between the indoor temperature of the experimental room and that of the comparison room also follows the similar rule. It is proved that the device can automatically regulate the sun light in room effectively, thereby achieving the control of indoor illumination and temperature so as to reduce the energy consumption in building.

1. Introduction

Large-area glass curtain walls of buildings occupy a large proportion of their external window area. Therefore, solar radiation would bring a lot of radiant heat if the weather has strong solar radiation, which can easily lead to excessive air conditioning load and light pollution in the room. In order to solve the problem, a light automatic control device is proposed in this paper. The device can automatically adjust the solar ray transmittance and the indoor and outdoor heat transfer in accordance with the outdoor temperature and the solar radiation intensity.

At present, the way to adjust the intensity and heat in room mainly relies on the respiratory glass curtain wall (or hot aisle glass curtain wall), adjustable venetian blind and some special glass that can automatically change color depending on solar radiation.

In terms of the study of glass curtain walls, the relevant researches made by scholars from various countries mainly have focused on the effect of glass curtain walls on the indoor optothermal environment ^[1]. At present, the adjustable venetian blind mainly contains two modes: automatic adjustment mode and manual adjustment mode. The research mainly focuses on the comparison of the two modes ^[2] and the simulation of the automatic control mode ^[3]. In addition, in terms of other dimming methods, some scholars conducted studies on the characteristics ^[4], energy efficiency, and application examples of photochromic glass ^[5].

This paper proposes a transparent device that can automatically adjust the indoor brightness and temperature as the solar radiation changes. The impact of this device on the indoor environment is studied.



2. Structure of light transmittance device

The light automatic control device proposed in this paper (Figure 1) uses bimetal as an important element for adjusting illumination and temperature. When sunlight streams into the room from the outside, the bimetal fixed on the support frame 8 will be bent due to the solar radiant heat. The stronger the solar radiation is, the greater the bending curvature of the bimetal will be. After the bimetal is bent, it can block some direct sunlight. When the solar radiation is strong (at noon), the bimetallic strip with a large curvature can prevent most of the sun rays to enter the room. When the solar radiation is weak (at early morning or late afternoon), the bimetallic strip with less bending curvature can prevent less sunlight. When sunlight enters the room, the device can automatically adjust the solar radiant heat entering. In addition, due to the formation of air passages between glasses, natural convection of the air can be formed inside the air passage, so that the excess heat absorbed by the bimetal can be brought out in time. The device can automatically adjust the indoor temperature and brightness, thus reducing the energy consumption in building.

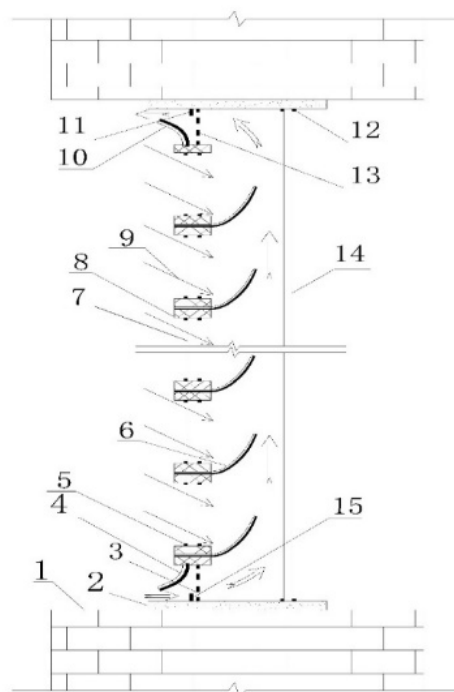


Figure 1. Schematic diagram of self-regulating glass curtain wall with bimetallic strip

1—walls; 2—pedestals; 3—air holes; 4—bimetallic strip; 5—slots; 6—bimetals; 7—glasses; 8—supports; 9—direct sunlight; 10—double Metal sheet; 11 - positioning bar; 12 - card slot; 13 - vent; 14 - glass; 15 - positioning bar.

3. Experiment setup

The experimental research regarding the device's temperature regulation and dimming performance was conducted respectively. For the test and analysis on the performance of adjusting the illuminance and temperature, an experimental room and its contrast room were built respectively. In the temperature adjustment experiment, the experimental room was provided with a light automatic control device, while the comparison room was only equipped with double glasses. In the dimming experiment, the experimental room was provided with a light automatic control device, while the comparison room was provided with a glass or louver shade facility.

3.1. Experiment settings for temperature adjustment

The experiment bench parameters of the temperature regulation experiment in this article are as follows: This article sets up two rooms to test and analyze the temperature regulation performance of the device, namely the experimental room E equipped with self-regulating light transmittance device with bimetallic strip (Figure 2) and its contrasting room F with double glasses (Figure 3). The setting positions of the illuminance measurement points (3, 4, 7, 8) and the temperature measurement points (A1, B1, C1, A2, B2, C2, C3, A4, B4, C4) of rooms E and F are shown.

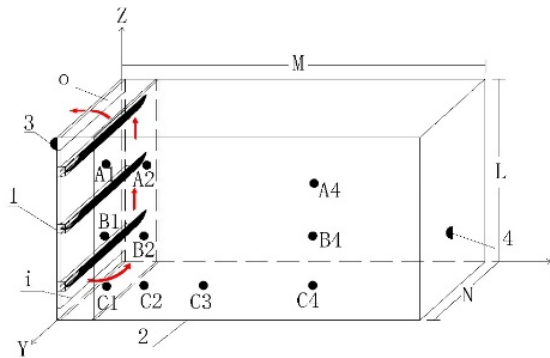


Figure 2. The layout of the test point of the experimental room E.

1—Light automatic control device; 2,6—Experimental body; 3, 7—Outdoor illuminance probe; 4, 8—Indoor illuminance probe; 5—Double-layer vitreous body;

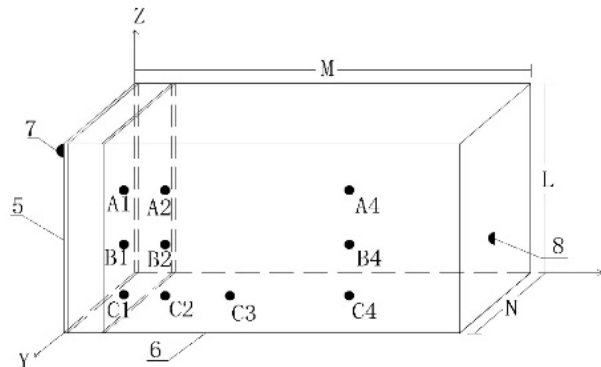


Figure 3. The layout of the test point of the ordinary room F.

Table 1 shows the nine experiment conditions of the temperature regulation experiment.

Table 1. Experiment Conditions

Conditions	Vent width /m	Vent length/m	Average illumination /lux
Case 1	0.10	0.01	12370
Case 2	0.15	0.01	12120.6
Case 3	0.20	0.01	11088.3
Case 4	0.10	0.03	11396.1
Case 5	0.15	0.03	13276
Case 6	0.20	0.03	12184.9
Case 7	0.10	0.05	16216.1
Case 8	0.15	0.05	11436.7
Case 9	0.20	0.05	7983.9

3.2. Experiment settings for illumination adjustment

In the experiment of illumination adjustment, the dimming effect under different parameters, such as the angle between the sun rays and the room floor, different aspect ratios, and the presence or absence of shielding was analysed .

Table 2 shows the experimental conditions of illuminance adjustment performance.

Table 2. Light adjustment experiment conditions

Conditions	Solar elevation angle	Room inclination	The angle between the sun and room	Room direction	Aspect ratio
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Nothing	case A	69.9	0	70	south	1
	case B	70.12	30	40	south	1
	case C	68.13	70	0	south	1
	case D	70.34	0	70	south	2
	case E	71.95	30	40	south	2
	case F	68.66	70	0	south	2
Venetian blind	case G	73.23	0	70	south	1
	case H	73.59	30	40	south	1
	case I	74.39	70	0	south	1
	case J	73.10	0	70	south	2
	case K	73.69	30	40	south	2
	case L	74.32	70	0	south	2

4. Illumination adjustment characteristic analysis

4.1. Non-shade contrast experiment

The following figures show the experimental data when the comparison room is not blocked.

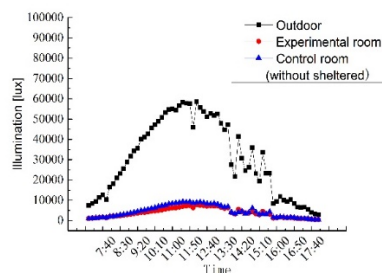


Figure 4. The inclination of the room is 0° and the aspect ratio is 1 Illumination variation with time.

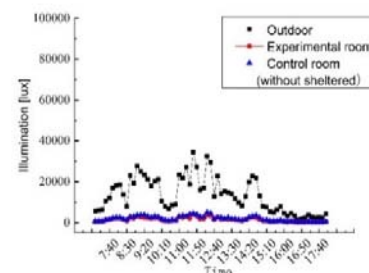


Figure 5. The inclination of the room is 0° and the aspect ratio is 2 Illumination variation with time.

When the room tilt angle is 30° and 70° , the experimental results are similar to the above.

From the above data, it can be seen that light automatic control device plays a role in reducing the shielding of light in the early morning and early evening, and increases the shielding effect of light at noon. When the outdoor illuminance is low and the fluctuation is large, the light automatic control device does not cover the light excessively, which is beneficial to practical use.

4.2. Venetian blind-shaded comparison experiment

Figure 6 and 7 show the experimental data when the comparison room is shaded by the venetian blind.

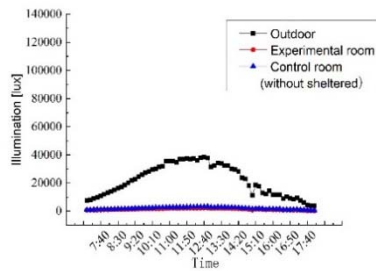


Figure 6. The inclination of the room is 0° and the aspect ratio is 1 Illumination variation with time

The illuminance of the experimental room and the comparison room is closer than that showed in the experimental data when the room is no-shade. The illuminance of the experimental room is still lower than that of the comparison room, when the outdoor illuminance is relatively large, the sun shading effect of the device is more obvious (as shown in Figure 7). When the illuminance is small, the sun shading effect of the device is weakened (Figure 6)

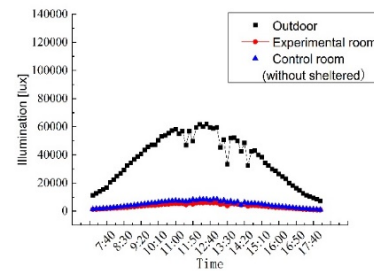


Figure 7. The inclination of the room is 30° and the aspect ratio is 1 Illumination variation with time.

5. Temperature regulation characteristic analysis

5.1. Temperature distribution

5.1.1. Horizontal temperature distribution

Figure 8 shows the horizontal temperature distribution of the experiment room and the comparison room. As we can see in the figure, the temperature of each experimental room was lower than that of the comparison room. In the early morning and early evening, the temperature at the measuring point in the same location of the experimental room and the comparison room was similar. In the late morning, the temperature in the same location of the measuring point of the comparison room was significantly higher than that of the experimental room. It proves that the device played a role in reducing solar radiant heat during solar energy excess period.

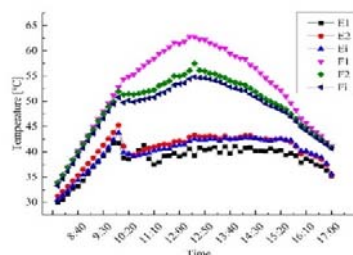


Figure 8. The average temperature comparison between the room E and the ordinary room F (Case 7)

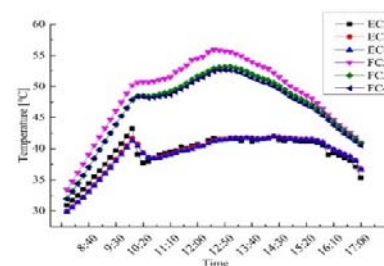


Figure 9. The indoor temperature comparison between the room E and the room F

Figure 9 shows the horizontal temperature distribution near the ground in the experiment room and the comparison room. The temperature of each experimental room was significantly lower than that of the comparison room. It proves that the device reduced the solar radiant heat during the solar energy excess period and reduced the indoor temperature.

5.1.2. Vertical temperature distribution.

Figure 10. shows the temperature distribution of interlayer and inner surface of inner glass in the room E in the vertical direction. It can be seen from the figure that the temperature distribution of the glass

interlayer from bottom to top exhibited a low-high-low characteristic. The temperature distribution of the inner surface gradually increased from the bottom to the top.

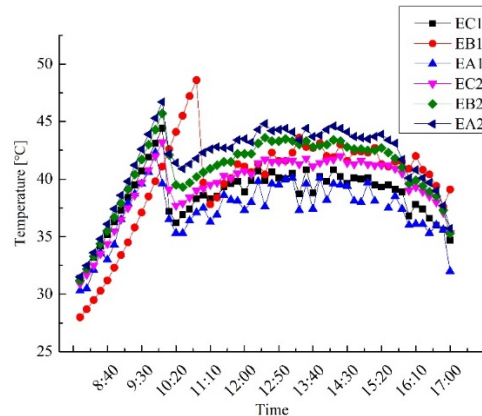


Figure 10. Temperature distribution of interlayer and inner surface of inner glass in room E in the vertical direction.

Figure.11 shows a comparison of the temperature distribution between the glass interlayer of the room and the inner surface of the inner glass. As we can see from the figure, it shows a low-high-low temperature distribution of the glass interlayer from bottom to top. It is the same as the experimental room. the temperature distribution of the inner glass of the comparison room gradually increases from the bottom to the top, which is the same as that of the experimental room. In the room E and F, there is a problem that the temperature between the glass interlayers was too high, but the temperature between the glass interlayers in room E was significantly lower than that between the glass interlayer in the room F. This is the reason why the device can effectively reduce the temperature in room.

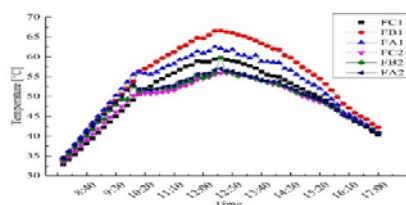


Figure 11. Temperature distribution of interlayer and inner surface of inner glass in the room F in the vertical direction

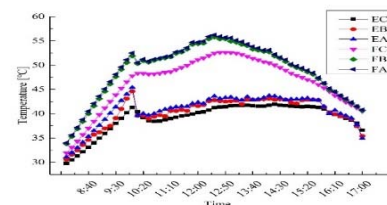


Figure 12. The indoor temperature comparison between the room E and the room F in the vertical direction

Figure.12 shows the vertical temperature distribution of the experiment room and the comparison room. The temperature of each experimental room was significantly lower than that of the comparison room. It proves that the device can effectively reduce the energy consumption of air conditioner.

5.2. The change of quantity

Based on the measured data concerning temperature and air flow rate, the natural convection heat in the experimental room was calculated. Figure 13 shows a graph of the heat taken away by the natural convection of the device over time.

It can be seen from Figure 13 that the case 2, case 3, and case 5 had the highest heat, the case 1, case 4, case 6, case 8, and case 9 had less heat and tend to be consistent, while the case 7 had the smallest amount of heat. It proves that the device has the best effect of reducing heat transfer when the width of the air passage is 0.2m and the width of the vent is 0.01m (as shown in the case 7).

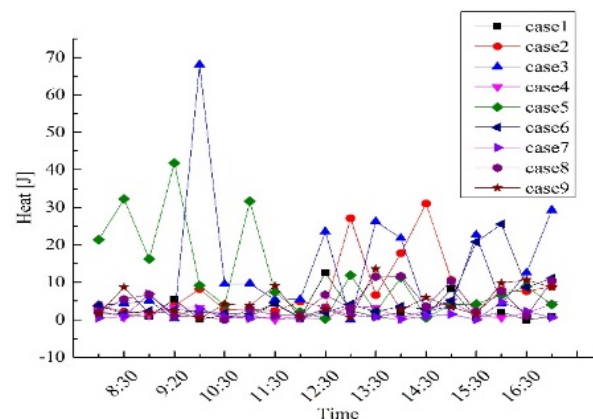


Figure 13. Heat change over time

Due to the air flow in ventilation passages, the solar radiation absorbed by the bimetal strips would be brought out, significantly reducing the heat build-up and the heat transfer indoors. It lowered the temperature of the inner surface of the inner glass, which can reduce the heat loss and the energy consumption of the building.

6. Conclusion

This paper studies the performance of light automatic control device concerning illumination adjustment and temperature adjustment, and mainly analyzes the influence rule of the device on the indoor illumination distribution and temperature distribution through comparative experiments.

In terms of the illuminance adjustment, the device initially achieved to reduce the light entering the room during noon hours, and increase light entering the room in the early morning and early evening and in the weather with low solar radiation. In outdoor condition where solar radiation fluctuates, the effect of regulation was not very obvious.

In terms of the temperature regulation, the temperature in the ventilation channel and in the experimental room equipped with the device was significantly lower than that of the comparison room exposed to the solar radiation, which proves that the device achieves the purpose of automatic temperature adjustment.

Acknowledgements

This study was supported by the National Natural Science Foundation of China (Project No. 51508005) and the National Natural Science Foundation of China (Project No. 51568060).

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