The Design and Verification of a New Light Distribution Curve Applied in Classroom

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Abstract: The visual health of teenagers has become the focus of social attention. Good classroom light environment plays an important role in the growth process of teenagers. Classroom lamps are the key factor to build a good classroom light environment. This article is based on the existing common lambert body light distribution curve based on the classroom light building light environment, to further improve the classroom space illumination uniformity, visual comfort, and improve the utilization efficiency of the light, put forward a new type of classroom lamp light distribution curve, and space environment simulation, light type and lambert with comparing the classroom light building light environment, from data analysis, the classroom space uniformity, visual comfort and a considerable improvement of utilization rate of light and verify the feasibility of this kind of light distribution curve, for the construction of high-quality classroom light environment has the reality significance.

Keywords: Classroom light environment, Visual comfort and health, Uniformity of illumination, Light efficiency

1 Introduction

The data show that the overall myopia rate of children and adolescents in China is 53.6% and showing an increasing trend.The prevalence of myopia generally presents a trend of younger age [1-2]. Studies have shown that a good classroom light environment is conducive to the protection of myopia among adolescents [3] and can improve their learning efficiency [4-6]. Classroom light plays an important role in classroom lighting. Proper light distribution curve can build a good light environment. Today's classroom lamps are basically Lambert shaped light distribution curves, and there is a certain distance between lamps and lanterns, resulting in low illumination evenness. The overall visual comfort of the classroom needs to be

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improved, and the light utilization is not high. In order to achieve the required illumination evenness, the number of lamps has to be increased and energy consumption has to be increased. Therefore, according to the characteristics of the classroom space environment, a new classroom light distribution curve is designed. Using DIALUX EVO built a typical spatial layout of the classroom, import IES of the original file, the designed light distribution curve and lambert light distribution curve for the actual data analysis and contrast of the lighting effect, discovered in this paper, design of light distribution curve, enhances the intensity of illumination uniformity of the classroom, reduces glare, so as to improve the overall visual comfort of the classroom, and improve the utilization rate of light energy, reduce the overall energy consumption of the space, proves the feasibility of the use of the light distribution curve, have the practical significance for the construction of high quality light environment of classroom.

2 Design idea and realization of new light distribution curve

Appropriate light distribution curve plays an important role in building a high-quality light environment, and can improve the utilization of light. In this paper, according to the particularity of classroom desk lighting, according to the scope of irradiation target, target illuminance, illuminance uniformity, the luminescence curve of luminaires in space should be derived in reverse. According to national standards, the average horizontal illumination of classroom desks should be above 300Lx, and the uniformity of illumination should be above 0.7. The height of lamp height from desk surface should be no less than 1.7m [8].

Therefore, this design idea is planned according to the above standards. The simulation classroom area is 62.1m^2 (6.9m×9m), the test range (the area where the desk surface is located) is 36m^2(6m×6m), and the test height (the high standard of the desk surface) is 0.75m. The luminescent points are arranged 2 m away from the target irradiation surface, and 4 classroom lights are used to illuminate the desk surface. Therefore, the irradiation range of the target surface of a single lamp is 9 m^2(3 m*3 m) square. In order to achieve better illuminance uniformity, the illuminance is the same everywhere in the range of the designed irradiation surface. In an ideal state, the uniformity is 1.

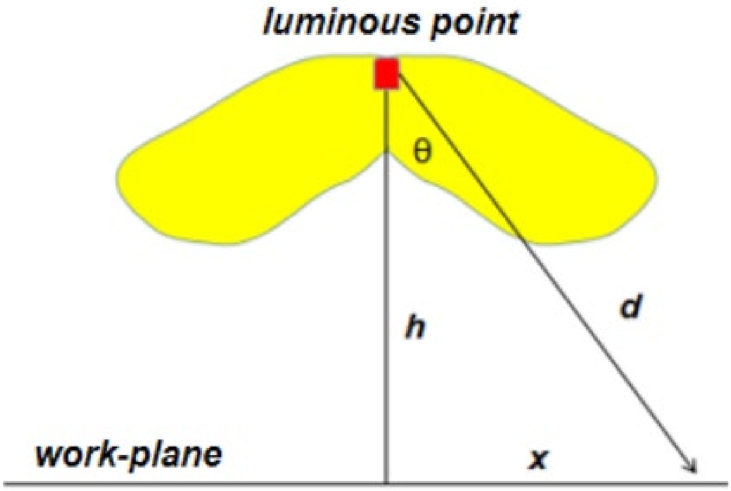

Fig. 1. Calculation diagram

$$I = I(\theta) \tag{1}$$

$$E = \frac{I(\theta)COS(\theta)}{d^2} = \frac{I(\theta)COS^3\theta}{h^2} \tag{2}$$

$$I(\theta) = \frac{h^2 E(\theta)}{COS^3\theta} \tag{3}$$

Where h represents the vertical height of the luminous point from the illuminated surface, and D represents the spatial distance from the luminous point to each irradiated point. From the above equation, we get the computational relationship between luminescence intensity I and illumination, the vertical height of the luminescence point from the irradiation surface h, and the Angle between the luminescence point and the irradiated point. In this calculation, in order to ensure the illumination is equal everywhere, E is determined as a constant value, and H has also been determined as 2m. Therefore, the relationship between light intensity and Angle can be obtained.

Through this formula, the distribution curve of the same circular area with illumination can be calculated, but the design needs to realize the illumination distribution within the rectangular area. Therefore, on this basis, horizontal Angle C is introduced to construct a cartesian coordinate system along with vertical Angle, as shown in the figure below:

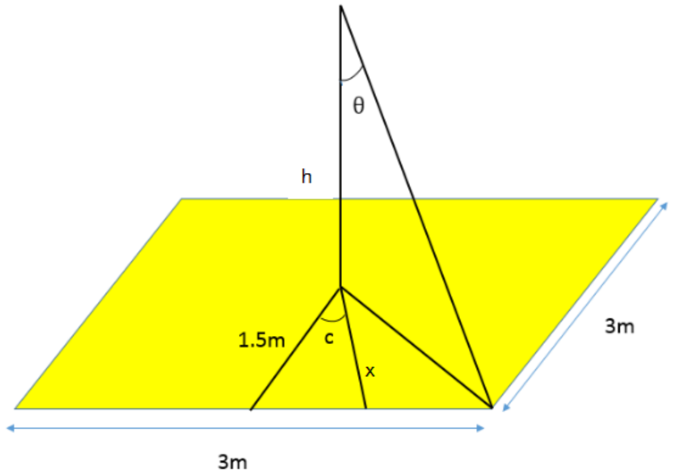

Fig. 2. Schematic diagram of exposure condition

The irradiation area in this design is symmetrical in accordance with quadrant, so only 1/4 area needs to be calculated and designed. Therefore, c=0,3,6... At 90 degrees, according to different c angles, the maximum amount of can be cut off at different c angles. In order to ensure the accuracy of calculation, a smaller interval is taken when calculating, =0,0.5,1.0...... The delta theta is computed as follows:

$$\frac{1.5}{x} = \cos c \tag{4}$$

$$\tan\theta = \frac{\mathrm{x}}{\mathrm{h}} \tag{5}$$

$$h = 2 \tag{6}$$

From (4), (5) and (6), get (7) $$x = 2\tan\theta = \frac{1.5}{\mathrm{cosc}} \tag{7}$$

$$\frac{0.75}{\cos c} = \tan\theta \tag{8}$$

$$\theta \text{ truncatio n} = arc\frac{0.75}{\cos c} \tag{9}$$

Then the relation (3) of spatial light intensity I is calculated from above. The light intensity of each small element is calculated, and the light intensity distribution data of the whole space is obtained. As shown in the following table, the spatial strength distribution corresponding to some micro-elements calculated by software is obtained. In the figure, horizontal Angle C and vertical Angle jointly determine a micro element, form a matrix, calculate the light intensity of each micro element, and jointly constitute the spatial light intensity distribution.

The horizontal Angle distribution C

The vertical Angle distribution is θ

	0	3	6	9	12	15	18	21	24	27	30
0	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
0.5	2400.274	2400.274	2400.274	2400.274	2400.274	2400.274	2400.274	2400.274	2400.274	2400.274	2400.274
1	2401.097	2401.097	2401.097	2401.097	2401.097	2401.097	2401.097	2401.097	2401.097	2401.097	2401.097
1.5	2402.469	2402.469	2402.469	2402.469	2402.469	2402.469	2402.469	2402.469	2402.469	2402.469	2402.469
2	2404.391	2404.391	2404.391	2404.391	2404.391	2404.391	2404.391	2404.391	2404.391	2404.391	2404.391
2.5	2406.866	2406.866	2406.866	2406.866	2406.866	2406.866	2406.866	2406.866	2406.866	2406.866	2406.866
3	2409.894	2409.894	2409.894	2409.894	2409.894	2409.894	2409.894	2409.894	2409.894	2409.894	2409.894
3.5	2413.48	2413.48	2413.48	2413.48	2413.48	2413.48	2413.48	2413.48	2413.48	2413.48	2413.48
4	2417.625	2417.625	2417.625	2417.625	2417.625	2417.625	2417.625	2417.625	2417.625	2417.625	2417.625
4.5	2422.333	2422.333	2422.333	2422.333	2422.333	2422.333	2422.333	2422.333	2422.333	2422.333	2422.333
5	2427.608	2427.608	2427.608	2427.608	2427.608	2427.608	2427.608	2427.608	2427.608	2427.608	2427.608
5.5	2433.455	2433.455	2433.455	2433.455	2433.455	2433.455	2433.455	2433.455	2433.455	2433.455	2433.455
6	2439.878	2439.878	2439.878	2439.878	2439.878	2439.878	2439.878	2439.878	2439.878	2439.878	2439.878
6.5	2446.884	2446.884	2446.884	2446.884	2446.884	2446.884	2446.884	2446.884	2446.884	2446.884	2446.884
7	2454.478	2454.478	2454.478	2454.478	2454.478	2454.478	2454.478	2454.478	2454.478	2454.478	2454.478
7.5	2462.666	2462.666	2462.666	2462.666	2462.666	2462.666	2462.666	2462.666	2462.666	2462.666	2462.666
8	2471.456	2471.456	2471.456	2471.456	2471.456	2471.456	2471.456	2471.456	2471.456	2471.456	2471.456
8.5	2480.856	2480.856	2480.856	2480.856	2480.856	2480.856	2480.856	2480.856	2480.856	2480.856	2480.856
9	2490.872	2490.872	2490.872	2490.872	2490.872	2490.872	2490.872	2490.872	2490.872	2490.872	2490.872
9.5	2501.515	2501.515	2501.515	2501.515	2501.515	2501.515	2501.515	2501.515	2501.515	2501.515	2501.515
10	2512.794	2512.794	2512.794	2512.794	2512.794	2512.794	2512.794	2512.794	2512.794	2512.794	2512.794
10.5	2524.718	2524.718	2524.718	2524.718	2524.718	2524.718	2524.718	2524.718	2524.718	2524.718	2524.718
11	2537.298	2537.298	2537.298	2537.298	2537.298	2537.298	2537.298	2537.298	2537.298	2537.298	2537.298
11.5	2550.546	2550.546	2550.546	2550.546	2550.546	2550.546	2550.546	2550.546	2550.546	2550.546	2550.546
12	2564.473	2564.473	2564.473	2564.473	2564.473	2564.473	2564.473	2564.473	2564.473	2564.473	2564.473

Fig. 3. Light intensity distribution corresponding to partial micro-elements

The above light intensity distribution data will be compiled in the format of IES file. Classroom lights are designed in this paper, so the data will be integrated in the format of class C indoor lamps. [9]Take a 0.5 degree interval between the angles on the vertical axis θ ,The range of points is 0-90 degrees, and the number of points is 181 times. The horizontal axis Angle is taken at intervals of 3 degrees. The range of points is 0-90 degrees, and the number of points is 31 times. The two forms a matrix, divides the irradiated surface into 5611 small elements, and the light intensity of each part forms the light intensity distribution curve.

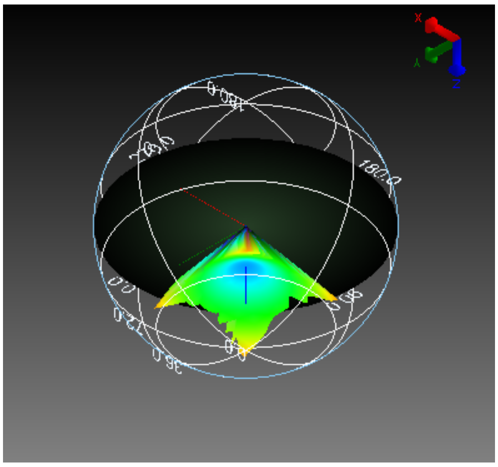

Fig. 4. 3D distribution of the designed light distribution curve

3 Simulate the effect of classroom environment

After get the light distribution curve, according to the current common classroom layout model, import the design files of the IES of light distribution curve and the market is more popular nowadays lambert shape light distribution curve of the classroom light, to build two kinds of light distribution curve of the indicators of the classroom light environment carries on the analysis comparison, in addition to energy consumption are compared.

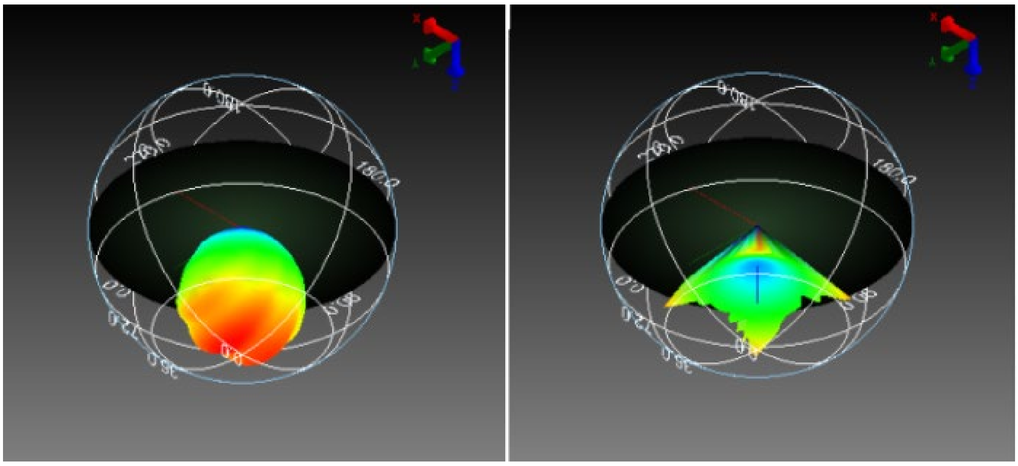

Fig. 5. Lambert type distribution for comparison (left) and design light distribution curve (right)

The simulation classroom covers an area of 62.1m^2 (6.9m×9m). According to national standards, the reflection ratio of each area is set. The reflection ratio of side wall and back wall is 0.77, the reflection ratio of front wall is 0.6, the ground is 0.35, and the desktop is 0.26. The test area (desk surface area) is 36m^2 (6m×6m), and the test height (desk surface height) is 0.75m. UGR calculation point is set in the middle chair of the last row, with a height of 1.2m, where the glare of the whole classroom is the most severe, simulating the overall glare received by the students in the last row. Since there is no clear height regulation for the installation of classroom lights, it is only required to be no less than 1.7m from the desk surface. In combination with the design requirements, the height of both lamps is set to 2m to illuminate the desk surface where the students are. The layout is perpendicular to the blackboard surface and uniformly distributed in the space. The specific parameters and lighting effect parameters are shown in Table 1.

Table 1. Comparison of classroom parameters and effects of two kinds of light distribution

Classroom parameters and lighting effects of two types of light distribution		
	Lambert's light distribution	This design distributes light
Overall classroom area	6.9m*9m=62.1m^2	
Target test area	6m*6m=36m^2	
Number of classroom lights	9 lamps	4 lamps
Luminance flux (lm)/power (w)	2000lm/30w	4000lm/60w
horizontal illumination（lx）	307lx	383lx
Uniformity of horizontal illumination	0.73	0.86
UGR	19	15

Fig. 6. Renderings of simulated classroom space(reading area)

By analyzing the data obtained from the simulation, it is found that the light distribution curve is precisely designed according to the environment used in this paper, so that the light environment of the whole classroom is improved. Compared with the traditional Lambert-type curving classroom lamps, the illuminance and uniformity of the desks in the classroom are improved under the premise of the same height of the lamps. The average illuminance of the desks in the classroom is 383lx and the uniformity is 0.86. UGR glare has also been reduced from 19 to 15, with some improvement in glare. In addition, the design of light distribution curve, improve the utilization of light energy, on the premise of reducing the space total light flux, improve the target surface illuminance. The luminous flux of the whole classroom was saved by 2000LM and energy consumption was nearly 11%, but the illumination of the target surface and the uniformity of illumination were increased by 24% and 18%, respectively. The data analysis shows that the light distribution curve of this design can be well applied to classroom lighting and play a role in improving the quality of light environment.

Fig. 7. Classroom lighting environment rendering using the light distribution curve lamps

4 Summary

According to the present classroom space environment and actual lighting requirements, this paper designs a new light distribution curve suitable for classroom lamps. This light distribution curve was introduced into a typical classroom space, DILUX EVO was used for simulation, and the average illumination and illuminance uniformity of the target exposed surface (desk surface) were considered. It was found that the illuminance uniformity of the target surface was increased by 18% compared with the traditional Lambert-type light distribution classroom lamp under the premise of the same light distribution height. The overall UGR of the space is also controlled, and the classroom glare value using this light distribution curve is 15. In addition, the utilization rate of light energy was improved, the overall luminous flux consumption was reduced by nearly 11%, and the illumination was increased by 24%, which verified the feasibility of using the distribution curve. It is of practical significance to construct high quality classroom lighting environment.

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